Defining key performance indicators to manage the value chain in virtual enterprises

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Declaration

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

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Summary

This thesis is about the principles and practices of the emerging discipline of virtual enterprising within the context of supply chain management. This type of enterprise makes it possible for Southern African companies to compete in the global marketplace against global players.

Value chain analysis is firstly discussed to help the business units, within the virtual enterprise, identify their competitive advantage. This competitive advantage will secure the position of these business units within the virtual enterprise. Electronic commerce is described as the vehicle for data communication within the virtual enterprise, and the supported enterprise resource planning (ERP) software as the transaction capturing software.

A performance measurement system is proposed that will assist with the management of virtual enterprises at a macro level. Some conclusions and recommendations are made as to how the management of performance can assist the business units, within the virtual enterprise, to grow financially and obtain sustainability. Recommendations are also made for the implementation of the proposed structure within the 3-D Business Simulator.

Opsomming

Hierdie tesis handel oor die beginsels en gebruike van die ontluikende dissipline van virtuële ondernemend binne die konteks van toevoerkettingbestuur. Hierdie tipe ondernemings maak dit moontlik vir Suid-Afrikaanse ondernemings om in die globale mark teen globale, multinasionale spelers te kan meeding.

Waardekettinganalise is eerstens gedefinieer, om die besigheidseenhede, wat deel vorm van die virtuële onderneming, te help om hul kompeterende voordeel te identifiseer, en sodoende te kan aanwend om hul posisie binne die virtuële onderneming te verseker. Elektroniese handel word bespreek as die middel van data-kommunikasie binne die virtuële onderneming, en ondernemingshulpbronbeplanning (ERP) sagteware as die sagteware wat verantwoordelik is vir die vasvang van alle transaksies.

‘n Prestasiemetings-struktuur word voorgestel wat met die bestuur van die virtuële onderneming op makro-vlak sal help. Gevolgtrekkings en aanbevelings word gemaak vir die aanwending van prestasiemeting om met die bestuur van die besigheidseenhede binne die virtuële onderneming van hulp te wees, en sodoende hierdie besigheidseenhede te help om finansieël te groei en volhoubaar te ontwikkel. Aanbvelings word ook gemaak vir die toepassing van die voorgestelde struktuur binne die konteks van die 3-D Besigheidsimulator.

Acknowledgements

Soli Deo Gloria

"Whatever you do ... do it all for God's glory!"

I Corinthians 10:31

I would like to express my gratitude towards the following individuals, groups, and institutions for their generous support, encouragement, and other means of contributing to this thesis:

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- To my parents, whose love, guidance and support mean everything to me.
- My brother, sister and brother-in-law, always willing to help and support me.
- To my friends, Hannes, Derik and Morné, always wondering when my thesis will be finished.

Terms of reference

This thesis was done under the auspices of the Efficient Operations Management Division of the Global Competitiveness Centre (GCC) at the University of Stellenbosch. The GCC was officially started in 1997, with the objective to promote and facilitate global competitiveness in the South African industry. The EOM Division of the GCC promotes objective leadership in the field of operations management. Activities in this field include the following:

- Manufacturing Logistics
- Enterprise Resource Planning (ERP) Logistics
- E-Commerce
- Supply Chain Management (SCM)
- Customer Relationship Management (CRM)

The author did not receive a specific assignment, but was given the responsibility to identify and plan a suitable project within the scope of the EOM's activities. The requirements laid out for the thesis were the following:

- The theme had to be chosen from the field of operations management;
- The project scope should not be too wide;
- The theme should further the research of the EOM, and ultimately the research of the Department of Industrial Engineering;
- The project should have value for the EOM Division.

Within the scope of these requirements and the personal interest of the student, the resulting project was **Defining key performance indicators to manage the value chain in virtual enterprises**.

Executive summary

The manufacturing company of the future will need specific entities to stay globally competitive. The company will need to be able to change drastically, and should adopt a "New Economy" philosophy, where rapid change will be introduced when needed.

This rapid change can only be incorporated if companies know what their competitive advantage is. This again can only be achieved if value chain analysis is completed, where the company determines the smallest business units that add value. Each of these business units can present the virtual enterprise with a competitive advantage; either a cost advantage, a differentiation advantage or a focus in one of the previous two categories. Without this analysis, companies do not really know or understand their own specific expertise. This analysis is also needed for companies in order to know what competitive advantage they can introduce to a virtual enterprise, otherwise another company that knows its competitive advantages will replace them. A clear understanding of the capabilities each partner brings into the organisation as well as each partner's expectations and mutual trust will limit the extent of co-ordination required for success within this type of venture.

On the highest level, the company must be flexible enough to form part of a virtual enterprise, where its expertise can be used in a productive way. Through virtual enterprises, it becomes easier for SMEs to compete in the global arena, something up to now largely the domain of larger organisations. This is because virtual enterprises will offer the partner companies the infrastructure, knowledge and customer and supplier base traditionally largely reserved for multi-national companies.

On a lower level, companies will need systems and philosophies to be able to form part of these virtual enterprises. The first, and most important philosophy needed, is value chain analysis. Value chain analysis helps companies to identify their competitive advantage. This

process can be seen through Porter's Value System, which introduces a method for describing a virtual enterprise. Although Porter did not develop the value system to describe VEs specifically, the model fits in perfectly with the discussions in this thesis on the subject. The following figure represents a virtual enterprise from a value system perspective.

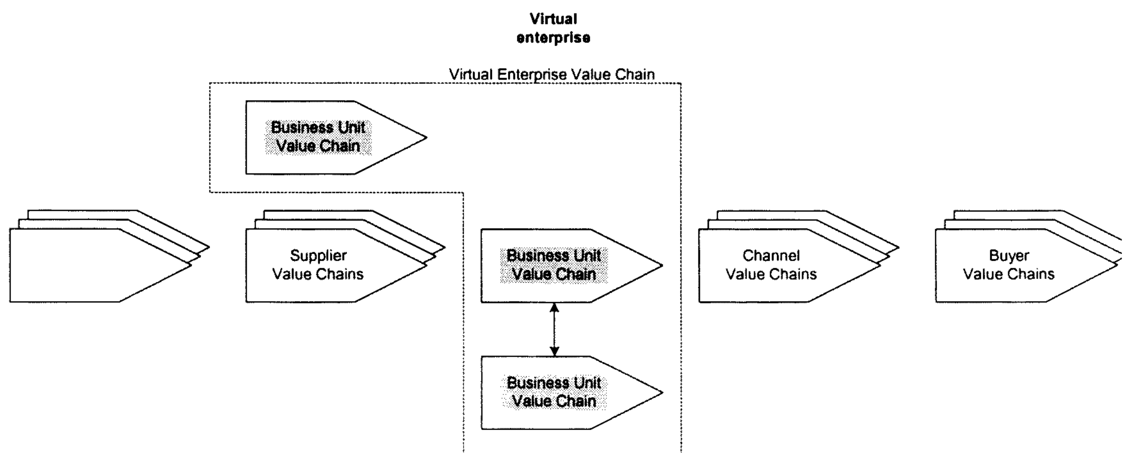

Figure ES.1: Virtual enterprise from a value system perspective

In this model, the business unit can represent a partner company of the VE. Figure ES.1 also shows that it is possible that more than one partner can perform the same function, it all depends on the market opportunity that the virtual enterprise needs to satisfy.

After the necessary value chain analysis has been completed, the company should concentrate on the technology that is needed to support its integration with other companies within the virtual enterprise. Manufacturing and any other transformation today are concerned with visibility in all business processes. This can be achieved, for instance, through the use of an ERP package, a company-wide software application that can be integrated with applications from vendors, customers and partners.

Integration of different ERP suites should be made possible through the use of e-commerce. B2B e-commerce will form an integral part of the virtual enterprise, where the partners will share production schedules, product information, customer orders and all other process and product-related data. The integration of these data is described through the use of a **Supply Chain Management model**, presented in Figure ES.2.

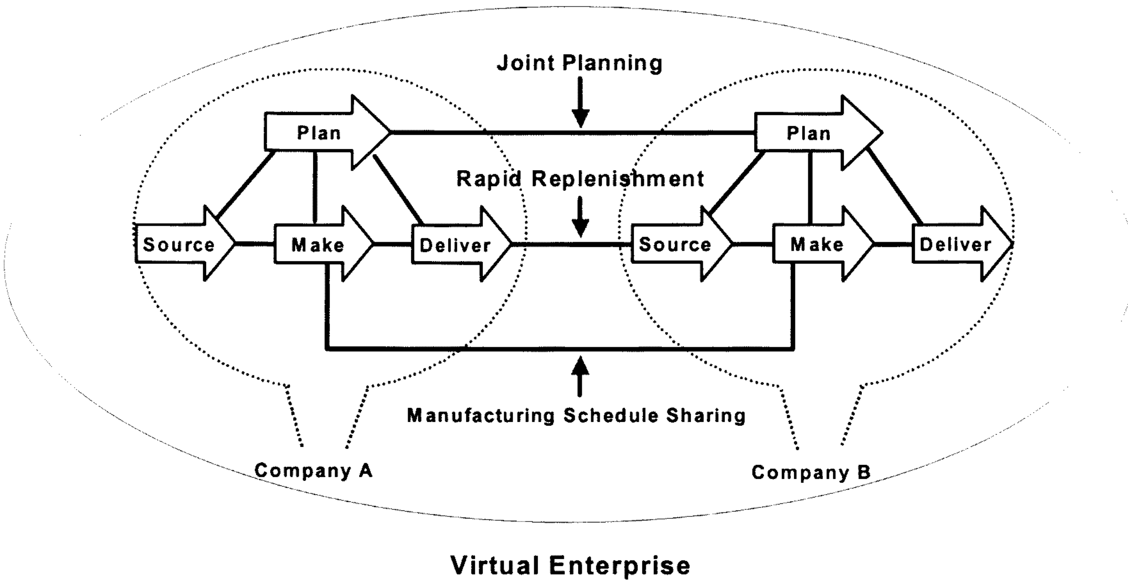

Figure ES.2: Integration of IT systems in a virtual enterprise

In this example, the joint planning and manufacturing schedule sharing will be performed by an ERP solution. The functionality for these operations already exists as a standard module within ERP solutions; difficulties might however be experienced when the partners in the VE use different ERP solutions. The communication of these solutions will be accomplished through B2B e-commerce.

The process of this thesis is described in Figure ES.3. Companies aim to be more competitive to stay in business, but can only achieve this if they are aware of their competitive advantage. Therefore it is necessary to do value chain analysis. But value chain analysis alone is not sufficient, and the correct technologies must be in place. Within the South African context this can only be fully realised through the use of virtual enterprises. The elements described above will serve as the necessary inputs for the formation of virtual enterprises, leading companies to greater competitiveness.

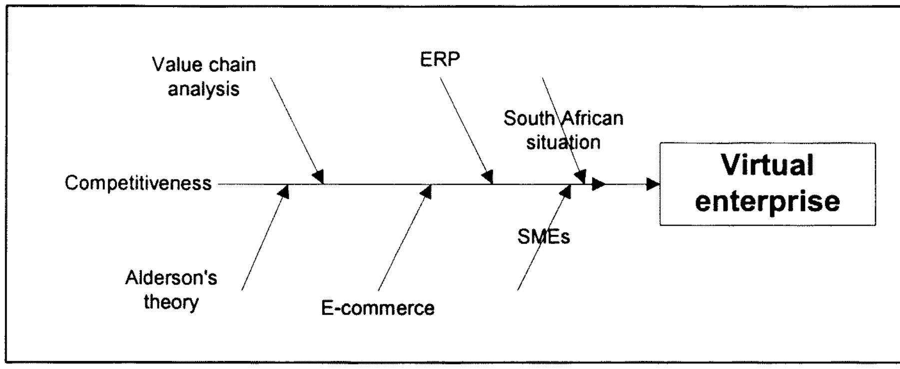

Figure ES.3: The process from competitiveness to the virtual enterprise

Throughout this whole process of establishing and managing a virtual enterprise, key performance indicators (KPIs) must be used. Processes cannot be managed if they are not measured. This thesis will introduce different KPIs to track internal performance, supplier performance, as well as indicators of performance as perceived by the customer. During the development of the KPI framework, the basic structures and philosophies of the Balanced Scorecard and the SMART system were used. It was found that these systems could not be applied as-is, because they do not address all the relevant aspects necessary to manage these enterprises. The structure can then be implemented in a "dashboard"-manner, raising flags when indicators move outside their pre-defined tolerances. This will result in rapid intervention by the person(s) responsible for that specific process. Figure ES.4 presents the reader with an overview of this "dashboard", where the different colours indicate whether a specific area is totally in control (green), whether one of the underlying KPIs is getting close to its limits (orange), or whether a KPI is out of control (red).

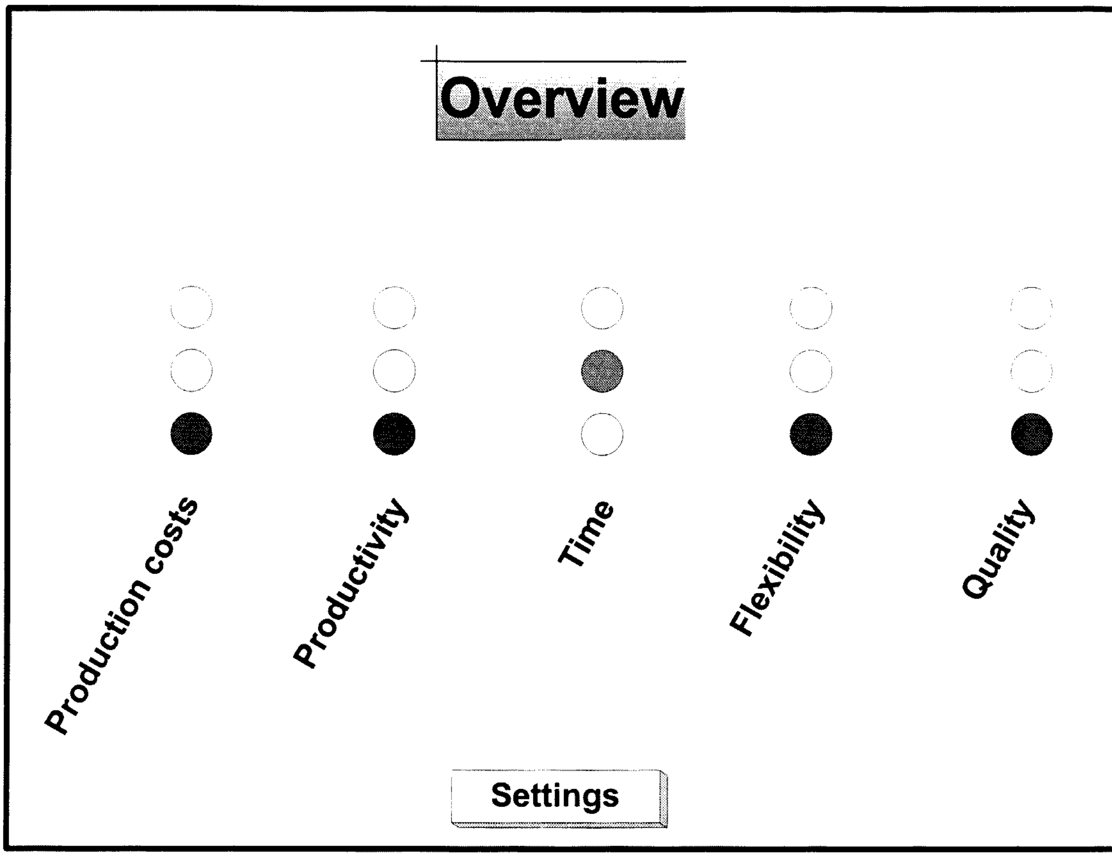

Figure ES.4: Overview of executive dashboard

In closing, the rationale for the final part of this thesis is given:

> *When you can measure what you are speaking about, and express that in numbers, you know something about it ... otherwise your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in thought advanced to the stage of science* (Lord Kelvin, 1824 – 1907).

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Glossary

3DBS	–	3-Dimensional Business Simulator
ASP	–	Application service provider
B2B	–	Business-to-business
BPR	–	Business process re-engineering
BSC	–	Balanced Scorecard
CRM	–	Customer relationship management
ECA	–	Electronic commerce application
EDI	–	Electronic data interchange
EE	–	Enterprise engineering
EOM	–	Efficient operations management
ERP	–	Enterprise resource planning
GCC	–	Global Competitiveness Centre
HTML	–	Hypertext markup language
IOS	–	Interorganisational systems
ISP	–	Internet service provider
IT	–	Information technology

IVAN	–	Internet value added networks
JIT	–	Just-in-time
KPI	–	Key performance indicators
MES	–	Manufacturing execution system
MPS	–	Master production schedule
MRP	–	Materials requirement planning
MRP II	–	Manufacturing resource planning
NII	–	National information infrastructure
NIIIP	–	National industrial information infrastructure protocol
ODBC	–	Open database connectivity
OPT	–	Optimised product technology
PLC	–	Programmable logic controllers
ROI	–	Return on investment
SCADA	–	Supervisory control and data acquisition
SCM	–	Supply chain management
SMART	–	Strategic Measurement Analysis and Reporting Technique
SMEs -	–	Small or medium enterprises
TCP/IP	–	Transmission Control Protocol/Internet Protocol
UPS	–	United Parcels Service
URL	–	Uniform resource locator
US	–	University of Stellenbosch

VAN – Value-added networks

VE – Virtual enterprise

XRP – Extended resource planning

Chapter 1

Introduction

1.1 Introduction

Global competitiveness depends on embracing e-commerce as a vehicle for companies in a changing market. E-commerce offers the opportunity for companies to be more competitive in foreign markets. It is also common practice to use e-commerce for transactions outside the boundaries of the country consumers are living in. With businesses no longer effectively shielded from external competition, they have to learn to adapt quickly to remain competitive. This can only be achieved if the value chain, and the whole supply chain, is considered.

Porter (1985:4-10) identified five competitive forces that are present in all industries. The strength of each of these five forces depends on the specific industry the company is competing in. The five-force structure allows a firm to see through the complexity and to pinpoint those factors that are critical to competition in its industry, as well as to identify those strategic innovations that would most improve the organisation's profitability. These five forces are important because they contribute to an understanding of the industry structure, which determines who captures the value. Profitability is determined by whether an organisation can capture the value they create, or whether the value is competed away from them. Figure 1.1 shows these five forces, and the elements that drive them.

The five forces that drive competition are:

- bargaining power of suppliers;
- threat of new entrants;
- bargaining power of buyers;
- threat of substitute products or services; and
- rivalry among existing firms.

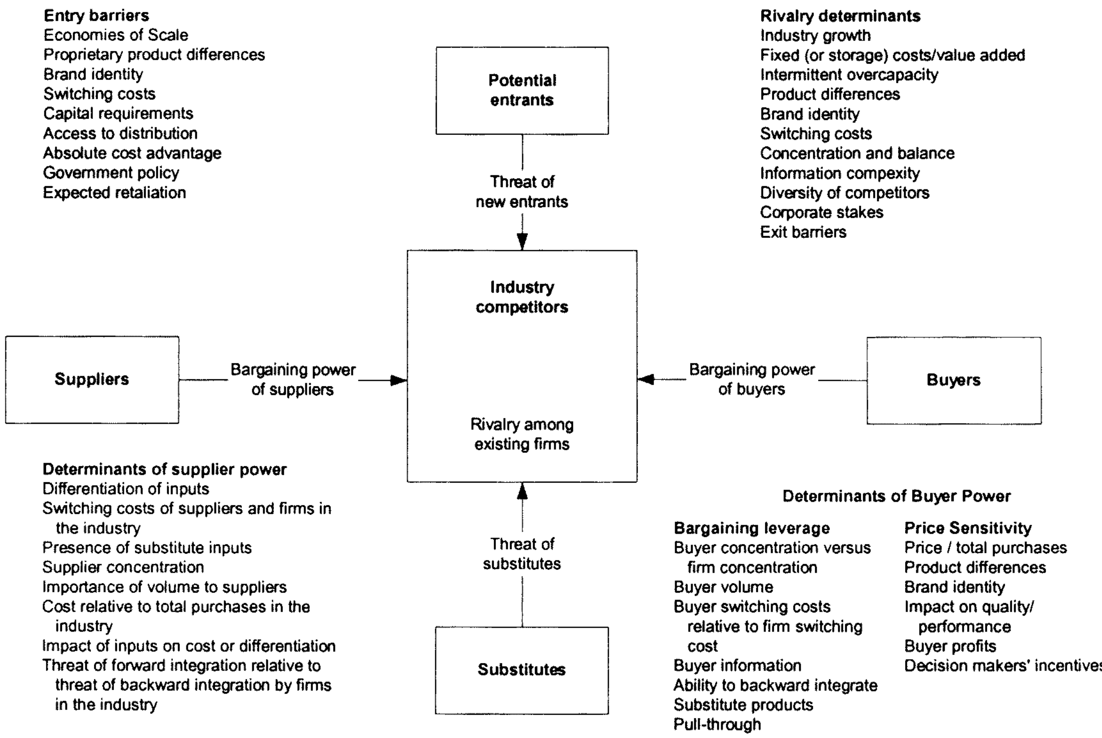

Figure 1.1: Elements of industry structure

Source: Porter (1985: 6)

Each of these five forces can either capture value for a company or compete it away from the company. The forces are explained below.

1.1.1 Bargaining power of suppliers

Porter (1980:27-28) identified six conditions that make suppliers powerful, namely:

- The industry is dominated by a few companies, and the suppliers are more concentrated than the industry they sell to.
- A supplier is not obliged to contend with other substitute products for sale to the industry.
- The industry is not an important customer of the supplier. This will happen when the sales to an industry are a fraction of the total sales of the supplier.

- The supplier's product is an important input to the buyer's business. The supplier's power is raised when an input is important to the success of the buyer's product, especially if the input is not storable.

- The supplier's products are differentiated or the products have built up switching costs. If there are switching costs, or the products are differentiated, the buyer is cut off from the option to play one supplier off against another.

- The supplier poses a credible threat of forward integration, providing a check against the industry's ability to improve the terms on which it purchases.

Porter (1980) mentions that suppliers should not only be seen as other organisations, but can also be labour. Labour can exert all the above-mentioned conditions, especially when the labour force is tightly organised or the supply of labour is scarce.

1.1.2 Threat of new entrants

Porter (1980:7-12) identifies the following six sources of barriers to entry:

- **Economies of scale.** This refers to the decline in unit cost of a product as the volume per period increases. There are two possible options here: the entrant can come in on a large scale and risk reaction from existing organisations, or he/she can come in on a small scale and accept a cost disadvantage. Both options are undesirable.

- **Product differentiation.** This means that existing firms have brand identification and customer loyalties. A barrier is created for new entrants since they need to spend heavily to overcome exsisting customer loyalties.

- **Capital requirements.** A barrier is created by the need to invest large financial resources to enter an industry, especially if the capital is required for risky or unrecoverable expenses.

- **Switching costs.** Switching costs is a one-time cost incurred when a buyer switches from one supplier's product to another. It can include employee retraining costs, costs incurred due to product redesign, and cost in qualifying and testing a new source.

- **Access to distribution channels.** A new entrant must persuade the distribution channel to accept its product, through price breaks and cooperative advertising allowances. This creates an entry barrier since profits are reduced.

- **Cost disadvantage independent of scale.** Established organisations may have cost advantages, such as proprietary product technology, favourable locations, government subsidies, and learning or experience curves that cannot be replicated by potential entrants, irrespective of their size and attained economies of scale.

The reaction from existing competitors can play an equally important role as the barriers to entry that a new organisation faces. It is important that these two factors are both looked at.

1.1.3 Bargaining power of buyers

Porter (1980:24-26) identifies eight circumstances that make a buyer group powerful:

- The buyers are concentrated or purchase large volumes relative to seller sales. If the buyer purchases a large portion of the total sales, it raises the buyer's business in the specific market, and his/her bargaining power.

- The products purchased from industry presents a significant fraction of the buyer's cost of purchase. In circumstance like these, buyers tend to shop for a favourable price and purchase selectively.

- The products purchased from industry are standard or indifferent. In circumstances like these, buyers can find alternative suppliers easily, and play suppliers off against each other for better value.

- The buyer faces few switching costs. The buyer's power is enhanced if the seller faces switching costs.

- The buyer earns low profits. Low profits enhance the power of the buyers since it offer great incentives to lower purchase costs.

- Buyers pose a credible threat of backward integration. Producers engage in manufacturing components in-house and purchasing the rest of the components from outside suppliers. This gives the buyers the power of negotiation, since the threat of further in-house manufacturing can be used, and a more detailed knowledge is available on the costs of the materials.

- The industry's product is unimportant to the quality of the buyer's products or services. Buyers are generally less price sensitive if the quality is very much affected by the industry's product.

- The buyer has full information. If the buyer has full information, he/she is in a greater position to ensure that he/she receives the most favourable prices offered to others and can counter supplier's claims that their viability is threatened.

These sources of buyer power can also be attributed to consumers in general; all that is needed is a modification of the frame of reference.

1.1.4 Threat of substitute products or services

The threat of substitute products can be identified by looking for other products that can perform the same function within the specific industry. The result is a ceiling on prices that can be charged for a product.

1.1.5 Rivalry among existing firms

Rivalry occurs when one or more competitors either feel the pressure or see the opportunity to improve their competitive position. Porter (1980:18-21) identified the following factors that determine the rivalry among firms:

- Numerous or equally balanced competitors. If organisations are relatively balanced in terms of resources and size, or if there are a number of organisations, it creates instability in the market since they may be prone to fight each other, and they could have the resources for retained and vigorous retaliation.

- Slow industry growth. If there is slow growth in an industry, competition turns into a market share game for firms seeking expansion.

- High fixed or storage costs. High fixed costs create pressure for firms to fill capacity, which often leads to rapidly escalating price cutting when excess capacity is present. The same situation arises when storage costs are high.

- Lack of differentiation or switching costs. When a product is perceived as a commodity, choice by the buyer is largely based on price and service, resulting in intense price and service competition. In the case of product differentiation, buyers have preferences and loyalties to particular sellers. The same effect is experienced as regard switching costs.

- Capacity augmented in large increments. Where capacity must be added in large increments, capacity additions can be disruptive to the supply/demand balance in the industry, especially where there is a risk of bunching capacity additions.

- Diverse competitors. Companies can be diverse in strategies, personalities, origins, and relationships, resulting in differing goals and differing strategies in order to compete. This may result in these companies running head-on to each other in the process.

- High strategic stakes. The rivalry in an industry becomes even more fierce and volatile if a number of organisations have high stakes in achieving success.

- High exit barriers. These barriers are the economic, strategic and emotional factors that keep companies competing in businesses even though they may be earning low returns on their investments. Examples of these barriers include specialised assets, fixed cost of exit, strategic interrelationships, emotional barriers, and government and social restrictions.

It is important to note that the industry structure determines who keeps what proportion of the value a product creates for buyers. If a product does not create much value for its buyers, there is little value in it being captured by firms, regardless of the other elements of structure.

Porter (1985:5) further notes that the profitability of the industry is not a function of what the product looks like or whether it embodies high or low technology, but of industry structure. This is because the five competitive forces determine industry profitability through price, costs and required investments of firms in an industry – the elements of return on investment.

It can be seen in Figure 1.1, and the above explanations, how each of the five forces influences the price, costs and investments of firms.

Successful companies no longer just add value to their products – they invent it. This means that a shift must occur in the traditional value chain. Traditionally, the focus of organisations was on well understood products, but lately the focus has shifted to the customer. This is explained in Figure 1.2.

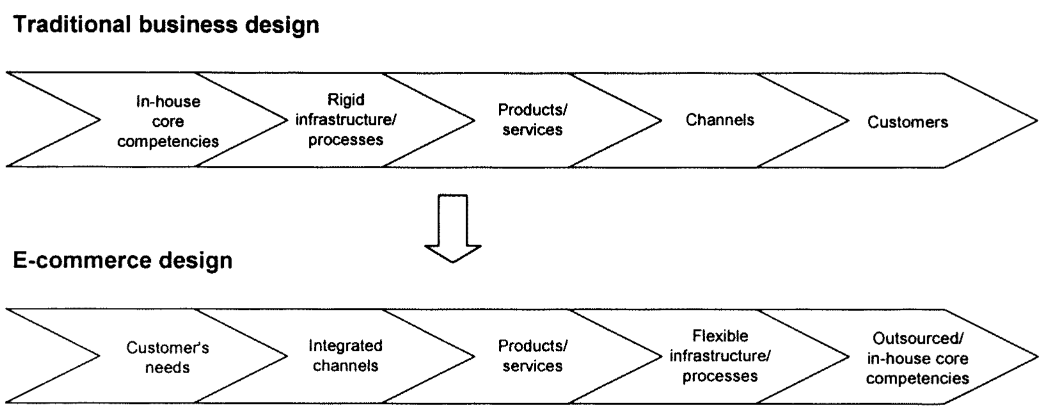

Figure 1.2: The changing face of business

Source: Kalakota and Robinson (1999:60)

E-commerce creates new processes to build better customer relations and to create new value propositions. Products can easily be replicated through many different processes. Companies must differentiate themselves as regards value to the customer. This value can be seen as the convenience of purchasing a high quality product at a low cost. According to Walters and Lancaster (1999) opportunities can easily become threats. These opportunities are achieved through the elimination of layers of costs that are built into the value chain, simply by consolidating parts of the chain, eliminating transaction participants, developing exclusive skills, and pre-empting other companies' competitive views.

Janssen and Sol (2000) note that e-commerce enables new kinds of business models to coordinate a value chain. This coordination can be accomplished using direct communication or with the help of intermediaries such as brokers, dealers and auctions. The role of electronic intermediaries is becoming increasingly more important, since traditional, physical intermediaries are threatened by direct communication between sellers and buyers. The added value of these traditional intermediaries may be very limited, and in their continuing search for adding value they try to transform their existing business into an electronic intermediary business.

Each company has a value chain, and the end of one company's value chain links to the beginning of another's. This gives rise to the notion of *supply chains*. Supply chains refer to the complex network of relationships that organisations maintain with trading partners to source, manufacture and deliver products. The supply chain consists of multiple companies that function as efficiently and effectively as a single company, with full information visibility and accountability.

The supply chains gives rise to the notion of *virtual enterprises* (VE). A VE is another way to add value without the normal cost associated with traditional supply chains. A VE is formed to exploit fast changing market opportunities, where traditional organisations will react too slowly or where they cannot react fast enough to satisfy the customer's need in a cost effective manner. A VE is an alliance of companies formed to share costs, skills and access to global markets through the core competencies of each partner. The size of the partner is irrelevant, since the partners in a VE bring only their core competencies, what is specifically needed at a certain moment, to the VE.

Since the size of the partners in the VE is irrelevant, the VE is a perfect vehicle for small and medium enterprises to create an international presence. Small and medium enterprises (SMEs) in the South African environment should consider their traditional business model in the supply chain environment, and should also consider the advantages of becoming part of a VE. VEs are the appropriate co-operation alternative to the global market that seems to be exploitable only for large organisations. A VE will be a well functioning business process that is supported by communication platforms, management co-ordination tools, and capacity and competence planning for the whole life cycle of the product.

South African companies are in an ever-increasing dangerous position as a result of disintermediation. South Africa's geographical location is already considered a burden in a global supply chain. The cost of moving a product to a customer in a foreign country is substantially higher than for companies competing from a location situated within their market. The cost of information transfer, without a vehicle such as the Internet, is also much higher than it would be for companies located in near proximity of their customers. These are only two of the more obvious aspects for joining a global supply chain.

Figure 1.3 shows a simple flow diagram that depicts the structure of this thesis. E-commerce, the value chain, and ERP are used as background to describe the technology needed to support the virtual enterprise, and to identify the requirements for the possible partners. The concepts of virtual enterprises are placed in context with the development of a model of a VE, namely the 3-D Business Simulator. Key performance indicators for the virtual enterprise are identified, and this structure is demonstrated in a case study with the aid of the 3-D Business Simulator.

A detailed description of how the different chapters fit in with this flow diagram, is presented to the reader in the remaining paragraphs of this chapter.

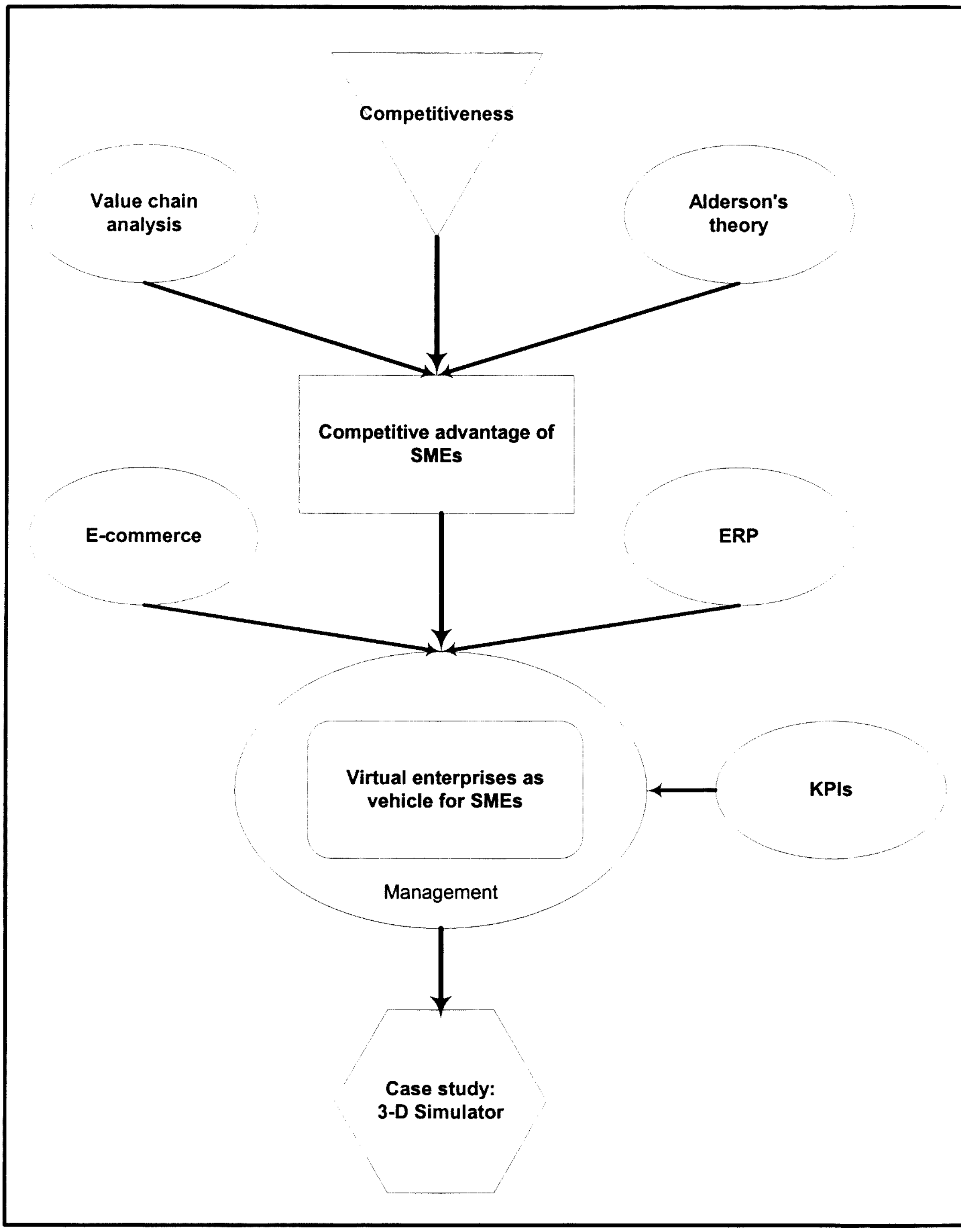

Figure 1.3: Thesis structure

The purpose of this thesis is to consider the position of SMEs, within South Africa, in the global environment. The focus will be on virtual enterprises. The commerce relationship between organisations will be considered, thus the thesis will concentrate on the B2B aspects of e-commerce. To gain an understanding of the potential for SMEs, it is necessary to understand the possibilities for these enterprises. Chapter 2 describes the problem statement and objectives, and the working method followed to reach the objectives that were identified.

Chapter 3 introduces the reader to the concept of virtual enterprises, and the possibilities that this form of enterprise hold for small and medium enterprises (SMEs). The Internet has made it possible for organisations to exploit fast changing conditions, and the only way to use this opportunity effectively is through the establishment of virtual enterprises. The position of virtual enterprises within the broader context of supply chain management is also discussed.

A detailed understanding of the value chain is necessary for any organisation that wishes to participate in a virtual enterprise. It is necessary to know exactly what competitive advantage an organisation can bring to the virtual enterprise. For this reason, the value chain is discussed in detail in Chapter 4. Chapter 4 also compares the value chain with Alderson's General Theory of Marketing, developed in 1965, to show the reader that the train of thoughts used today originated from very different fields of study, many years ago.

In Chapter 5 e-commerce is discussed, and the necessity of this technology as a vehicle for information transfer for the virtual Enterprise. This chapter also deals with the concepts of e-commerce, and the technology that supports it, at a strategic level. This is to present the reader with an overview of how this technology works, and the possibilities that it offers.

Different e-commerce business models are discussed in Chapter 6. The virtual enterprise will make extensive use of business-to-business (B2B) e-commerce in their day-to-day operations. The different models are therefore discussed in detail. Some of the business-to-consumer (B2C) models are also discussed within this chapter for the sake of completeness, and because many of the characteristics of B2C e-commerce are shared with B2B e-commerce. It is important for the partner companies within the virtual enterprise to consider these different models, and to decide whether there exists a particular model that can be used in conjunction with their current competitive advantage to offer partner companies an even bigger edge for competing within the VE.

Chapter 7 deals with the second important building block of virtual enterprises, namely enterprise resource planning (ERP). It is nearly impossible for the virtual enterprise to operate without the effective integration of ERP between the partners.

The last two chapters, Chapter 8 and Chapter 9, complete this study with the development of a performance measurement structure, the Performance Tree, to manage the different business units within the virtual enterprise. Key performance indicators (KPIs) will be used to indicate when elements within the virtual enterprise need attention. This will help to drive improvement within the enterprise, since the KPIs will only return to normal when the problem areas are addressed. The KPIs will use the ERP and MES databases as its sources of data.

The appendices of this thesis deal with the Training Centre, and a specific project within the centre, the 3-D Business Simulator. Appendix B gives a brief overview of the Training Centre, followed by an in-depth discussion of the 3-D Business Simulator in Appendix C. The 3-D Business Simulator can be seen as a model of a virtual enterprise, and makes use of all the technology that is presented in the literature study of this thesis. The current model, developed by TracIT for the GCC, is only a demonstrator, and the necessary integration between all the components does not exist. The next model being developed will be completed by the end of 2002, and will be completely integrated. Within the scope of this bigger project, the Performance Tree will be implemented.

Chapter 2

Problem statement and objectives

2.1 Problem statement

It is universally accepted that a well functioning small business sector contributes to the economic and social growth of a country (Bankseta 2002). The small business sector exerts a strong influence on the economies of all countries, particularly in the fast changing and increasingly competitive global market. SMEs are recognised as playing a pivotal role in the advancement of prosperity in communities. To ensure economic prosperity in South Africa, the number of entrepreneurs who successfully found and develop small and micro-enterprises need to increase significantly. According to the World Competitiveness Report, South Africa found itself in the 34^{th} position this year, and will need to increase its position drastically to compete with the global players.

However, an unacceptable and disappointingly high number of small and micro-enterprises in South Africa fail during their early years of operation (Bankseta 2002). They face a myriad of challenges. Taking into account the high failure rate of new small enterprises and their importance to the national economy, it is critical to look at how challenges facing SMEs could be overcome.

Virtual enterprises are seen as an option for SMEs within South Africa in order to establish themselves in the global market. Operating in a global marketplace requires companies to become super-efficient, if they want to meet the best competition the world can present them. This has given rise to the range of fashionable strategies of corporate transformation, downsizing and re-engineering, and in turn, to the concept of virtual enterprises.

The component companies in the virtual enterprise are built around expertise and specialised knowledge. It is this knowledge that is becoming the true leverage of the organisation. Without knowledge, it will be impossible to operate these organisations. One of the most simplistic methods of sharing knowledge, is outsourcing. Outsourcing will enlarge and enhance the pool of available knowledge, but traditional organisations attempt to complete all processes in-house.

The only organisation that is geared for harnessing this type of knowledge, is the virtual enterprise. The virtual enterprise will bring the necessary competitive advantage of each of the partner companies together, sharing only the expertise that is needed to operate them. The first requirement, however, is value chain analysis, otherwise companies will not know what their competitive advantages are. The next step is to consider the different vehicles for this transfer of knowledge.

2.2 Objectives

This project has three objectives. The first objective is the creation of a literature study to review the possibilities that virtual enterprises offer, in conjunction with the use of ERP and e-commerce. This review will introduce the reader to the concept of virtual enterprises, and will also discuss how an e-commerce link between ERP packages can be used to facilitate these virtual enterprises.

The second objective is the development of a framework to manage the performance of the virtual enterprise. A structure will be developed that utilise key performance indicators (KPIs) to manage and improve performance. These KPIs will indicate when operations are out of tolerance, and need attention. The KPIs can then be used at the highest level to identify the specific areas where attention may be focused, and unnecessary time is not spent on improving operations that are within acceptable tolerance.

The third objective is to use the performance measurement framework as a starting point for other projects and for training courses on the 3-D Business Simulator. The current model is only used to demonstrate the possibilities of the integrated system, without complete integration between all the different types and layers of software. One of the secondary purposes of this thesis is to develop the KPI structure in such a manner that it will be possible to use it effectively on the next version of the 3-D Business Simulator. The KPIs will be demonstrated on a production Qmuzik ERP base, to show that operations will influence the indicators. The structure can be transferred to the 3DBS base by altering the ODBC. The structure can then be used to by the Training Centre to demonstrate many of the operations management principles. The EOM division of the GCC established the Training Centre during 2001. The purpose of the Training Centre is to expose students, as well as industrial partners, to the concepts of ERP and ERP-related subjects. The courses presented by the Training Centre should also include topics related to operational management that are complementary to ERP and beyond (i.e. e-commerce, CRM, EE, etc.).

It is the opinion of the author that in future the use of business-to-business e-commerce and the effective structuring of the enterprise within a VE will determine the survival and financial growth of SMEs competing in the global environment.

2.3 Work method

The work method employed in this thesis corresponds to the 5-step model of the GCC. The five steps are to *identify*, to *acquire*, to *master*, to *multiply* and to *transfer* leading-edge technologies and knowledge to students and industry. Each of these five steps is explained briefly.

- **Identify.** The first step of this model identifies new technologies and knowledge that are applicable to the industry within South Africa. The GCC identified e-commerce as a technology that can promote the competitiveness of South African companies. The vehicle for this technology is an ERP system.

- **Acquire.** Once a technology has been identified, the GCC plans the acquisition of the technology. In this instance, Qmuzik was identified as an Industrial Partner on the grounds of the ERP package they designed. TracIt solutions were identified for their manufacturing execution software, and skills in developing e-commerce links to their software. The knowledge that accompanies these technologies is also acquired.

- **Master.** The technologies and knowledge that were acquired in the previous step, need to be mastered. This step can be achieved through in-house competencies, and/or through the involvement of industrial partners.

- **Multiply.** Success for these new technologies and knowledge can only be achieved if as many people as possible are introduced to them, understand them and can teach them.

- **Transfer.** The final step of this model is the transfer of this mastered technologies and the accompanying knowledge to industry. Many different vehicles are available for these transfers (training, seminars, conferences, workshops, etc.). In the case of this thesis, the 3-D Business Simulator is used to transfer the gained technology.

Chapter 3

Virtual enterprises and SMEs

3.1 Introduction

This chapter deals with enterprises within South Africa. The first section describes what is understood by *small and medium enterprises* (SMEs). Section 3.3 introduces the reader to virtual enterprises (VEs), and the possibilities that these structures hold for SMEs. In the final section the position of VEs in the bigger picture, namely the supply chain is considered.

3.2 Small and medium enterprises (SMEs)

3.2.1 Introduction

Small and medium enterprises (SMEs) are the cornerstone of South Africa's competitive position and job creation. South Africa is still seen as an emerging market, resulting in a lack of large direct investment. This, in conjunction with the lack of technical and organisational competencies, can only be exploited by SMEs willing to operate in the global market. SMEs are significant providers of employment and a major source of important innovations regarding commerce (Barnes & Hunt 2001:104).

SMEs form a dynamic and heterogeneous community, which is confronted by many challenges. These include increased competition resulting from the South African internal market and the growing demands of larger companies for which SMEs often work as sub-contractors. SMEs need to innovate constantly in order to meet these challenges and to remain competitive. Among other things, this means developing new technologies in-house or gaining access to them. Besides this, many SMEs both need and want to internationalise in search of new markets and business opportunities.

3.2.2 Definitions

There is currently no single definition of a small or medium firm in South Africa, mainly because of a lack of criteria for defining the boundaries of these businesses. As a starting point, definitions from other countries are considered. Two criteria are available for determining the size of the enterprise, namely *turnover* and the *number of employees*.

The Department of Trade and Industry of the European Commission states that a company is defined as *small* if it satisfies at least two of the following criteria:

- a turnover of less than £2.8 million;
- a balance sheet total of less than £1.4 million;
- less than 50 employees.

The criteria for companies to be classified as *medium*, include that they must satisfy at least two of the following three criteria:

- a turnover of less than £11.2 million;
- a balance sheet total of less than £5.6 million;
- less than 250 employees.

Wright and Burns (1998) defines the concepts solely with regard to the number of employees. They define a *micro-organisation* as one that has 0-9 employees, a *small* organisation as having 10-99 employees, a *medium* organisation as having 100-499 employees, and a *large* organisation as having more than 500 employees.

The definition for micro- and small enterprises, supplied by Wright and Burns, corresponds with the definitions used by the Philippines government. The only difference is that they describe a *medium* organisation as one that has 100-199 employees.

As can be seen from the definitions above, there is not a single criterion for describing SMEs . The author is of the opinion that it is not important to set exact boundaries to each of these organisational sizes, but it is important to be consistent regarding the definition that is used. The importance of SMEs must never be underestimated, since these organisations form the building blocks for the virtual enterprise.

3.2.3 SMEs and the Internet

The Internet is a possible mechanism for SMEs to enter the global market. SMEs will be likely to use a new technology if it is widely available to ordinary people (Barnes & Hunt 2001:106). It is, however, important for SMEs to be prepared to change their business processes in order to succeed in using the Internet. There is a greatly increased level of interactivity on the Internet, and the changed nature of communication with and among customers, suppliers, and within the organisation itself, should be taken into consideration.

3.3 Virtual enterprises (VEs)

3.3.1 Introduction

Nowadays products are rarely designed, manufactured and maintained entirely by a single company. In most cases, a team of geographically dispersed engineering, manufacturing and service firms have to work together to design, manufacture and support products. For this reason, product data have to be defined and exchanged. This can be done effectively through the creation of virtual enterprises, enterprises formed to satisfy a specific demand. The VE can be graphically dispersed, as presented in the following figure.

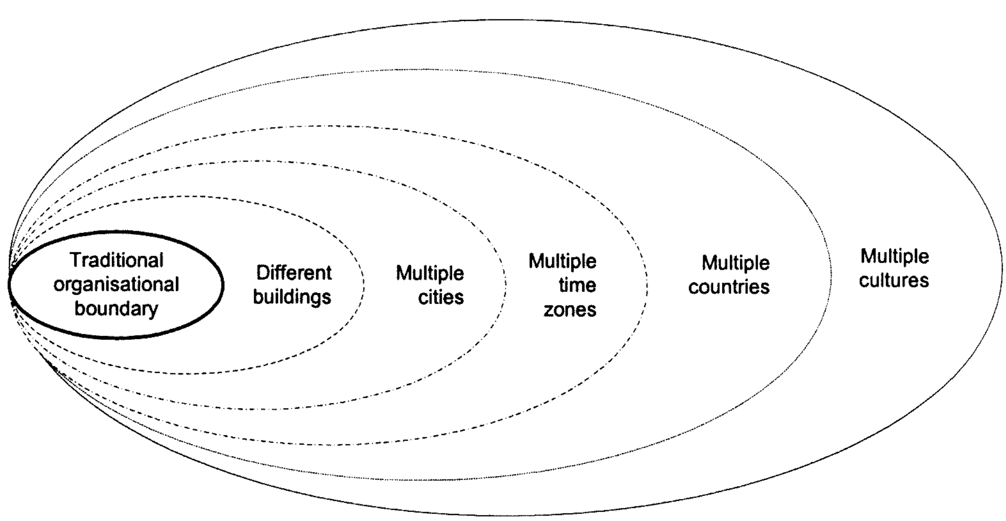

Figure 3.1: Characteristic dispersion of the VE
Sources: Barnes and Hunt (2001: 174)

This corresponds to a suggestion by Davidow and Malone (Walters & Buchanan 2001) in the early 1990s:

The complex product-markets of the twenty-first century will demand the ability to deliver, quickly and globally, a high variety of customised products. These products will be differentiated not only by form and function, but also by the services provided with the product, including the ability for the customer to be involved in the design of the product ... a manufacturing company will not be an isolated facility in production, but rather a node in the complex network of suppliers, customers, engineering and other "service" functions ... Profound changes are expected for the company's distribution system and its internal organisation as they evolve to become more customer-driven and customer-managed. On the upstream side of the firm, supplier networks will have to be integrated with those of customers often to the point where the customer will share its equipment, designs, trade secrets and confidences with those suppliers. Obviously, suppliers will become very dependent upon their downstream customers, but by the same token customers will be equally trapped by their suppliers. In the end, unlike its contemporary predecessors, the virtual corporation will appear less a discrete enterprise and more an ever-varying cluster of common activities in the midst of a vast fabric of relationships.

Virtual enterprises are often confused with extended enterprises. *Extended enterprises* differ in the time-span of the commitment between the organisations forming the enterprise. The VE is concerned with partnership to satisfy a niche market quickly, while the extended enterprise is designed for longer partnerships where co-operation and integration across the value system are being facilitated (Browne & Zhang 1999).

3.3.2 Definitions

Virtual enterprises are defined in terms of the needs and situations of the people using them. According to the National Industrial Information Infrastructure Protocol (NIIIP) Consortium (Botha 1999:55), a *virtual enterprise* (VE) is a temporary consortium or alliance of companies formed to exploit fast changing opportunities. Within this environment, companies share costs, skills, and access global markets with each participant contributing its core expertise.

Nagel and Allen (Botha 1999:56) compliment this description by defining a VE as a network of independent companies linked by the free flow of information, in which there is no hierarchy, no central office and no vertical integration; just the skills and resources needed to do the job.

These descriptions are much the same as those used by the IMS Project (Browne & Zhang 1999). These authors define a VE as the next generation of manufacturing enterprise, which consists of a globally distributed assembly of autonomous work units with the main goal of achieving a profit by serving customers in a fast changing environment. One of the fundamental problems with this definition is that it only considers manufacturing enterprises.

Barnes and Hunt (2001:196) defines a VE as a temporary alignment of multiple organisations around a single core organisation, combining the core competencies of its participants to produce and deliver customised demand at low cost and low throughput times, which the participants cannot achieve individually.

Fuehrer and Ashkanasy (Botha 1999:57) defines a VE as a temporary network organisation, consisting of independent enterprises, institutions, or specialised individuals that come together spontaneously to exploit an apparent market opportunity. In the VE, the enterprises bring their core competencies into the network to create a value-adding partnership facilitated by information and communication technology. In this environment, the VE acts in all appearances as a single organisational unit.

Gibbs and Keating (Botha 1999:57) describe a VE as companies that form a value chain through alliances and partnerships, where each company performs those functions it does best. The signature of the VE's new control structure is based on a relationship of trust, rather than on one of fear and suspicion.

Reid et al. (Botha 1999) define a virtual enterprise as a form of joint venture, but with important differences. It can be viewed as a temporary alliance of member companies, which all join to take advantage of a market opportunity. This VE will possess almost no employees or inventoried resources. Each member company will provide its core competencies in areas such as marketing, engineering and manufacturing to the VE. Only a small headquarters' staff may be required to deal with administrative and management tasks, but the actual work will be performed by geographically separated shareholders joined through electronic networks. When the market opportunity has passed, the VE could dissolve or reconfigure to exploit other market opportunities. The VE differs from existing inter-organisational models in terms of the degree of shared accountability and responsibility of participants and the structure to which companies contribute their core competencies.

Many more definitions are available in the literature, but the basic components present in a VE are covered by the above definitions. Botha (1999) and the author identified the following characteristics of a VE:

- **Boundaries**. The VE is not bound by organisational, geographic, or time zone boundaries, because of the extensive use of information and communication technology.

- **Change management.** The flexibility of network partnerships ensures that change is monitored and accommodated. Change can be implemented quickly and cost-effectively, because the investment for each partner is specific, and excessive and expensive assets are avoided.

- **Contracts and agreements**. As a result of the dynamic nature of a VE and the speed at which it operates, there will be no time to formalise the relationships between partners with legal agreements in the traditional sense. Clements (1999) suggests that the use of enterprise models must be employed to introduce the necessary standards for the VE.

- **Competition.** Organisations that previously competed against each other, can become part of a VE to exploit a fast-changing opportunity quickly.

- **Core competencies**. The VE focuses on core competencies, which means that companies concentrate on what they do best and outsource the rest. The individual members of the VE retain their independence and continue to develop their core competency.

- **Customer/supplier view**. Where the customer is concerned, the VE will present the appearance of a single organisational unit. This view will be the same for the suppliers of the VE; to them the VE will presents itself as a single organisation.

- **Customer focus**. The VE will be totally customer-focused, where a customer's needs must first exist, and only after it has been identified, will the VE be formed. The flexibility and customised responses of virtual networks are characterised by longer and more profitable customer relationships.

- **Flexibility.** The combination of speed and leverage provides a VE with the ability to change product-service specifications to meet a diverse range of customer needs or the rapidly changing requirements of the market.

- **Geographical location**. The partners of a VE will most probably be geographically dispersed.

- **Information technology.** A key aspect of the VE is its use of IT. Wright and Burns (1998) mention that the advances in communication, the World-Wide Web, and IT have created the marketplace for VE.

- **Leverage.** Widespread synergy is achieved by combining the best capabilities of a number of organisations. SMEs can share significant operational influence at a fraction of the costs incurred when independent. Shared activities, such as purchasing, developed in Internet-based buying, is a typical benefit.

- **Lifespan.** The normal lifespan of a VE is the duration of the project, after which it may disband, continue until a next project is identified, or drop partners and add new partners to satisfy a new market opportunity.

- **Opportunities.** A VE is formed to exploit fast changing market opportunities, where traditional organisations will react too slow or cannot react fast enough to be effective in satisfying the customer's needs in a cost-effective way.

- **Partners.** The partners of a VE can consist of specialised individuals, business units or whole organisations. The size of participating businesses does not matter. It is possible for companies that are too small to compete internationally to establish an international presence. The partners can be also changed according to the project or task at hand.

- **Shared vision and goals**. The partners of the VE will share the same vision, and will strive to achieve the same goals in the VE in a world-class and cost-effective manner.

- **Sharing of resources, costs and risks**. In a VE, costs, skills and markets are shared by the partners, reducing the risk associated with the project. The main advantage of a VE is that all the partners will share in the benefits derived from the operational activities. A very necessary component of the VE is the sharing of information. Zhao, Cheung and Young (1999) highlight the importance of this by suggesting a data model to support manufacturing virtual enterprises. This is presented in Figure 3.2onthe following page.

- **Size.** The size of the VE is dependent on the tasks that must be accomplished and resources required to satisfy market opportunity. A VE can consist of two or more legally independent entities.

- **Speed.** A lack of management hierarchy, as well as advances in IT, ensure that the information required for decision-making is readily available. The fact that each member has a specialist input to the "product" that it alone manages, ensures rapid decisions and actions. The time to market is minimal, because a product variant or a new product is the result of the collaboration of a number of partners, each with his/her relevant core capabilities.

- **Standards.** Extensive use of standards must be used. This is described by Zimmerman (Botha 1999) as the rules of co-operation, and it will assist with the integration of the different software and hardware interfaces with regard to information technology. The IT infrastructure of the different partners can then easily be integrated.

- **Technology.** Technology can be seen as the "glue" that binds the various corporate components together. It is possible for SMEs in a VE to exchange data at the same speed as internal departments of a large organisation. Technology makes contributions and interaction between the partners possible, aspects that were not possible in the past (Franks 1998).

- **Trust.** Trust is the most important characteristic of VEs. Partners must function in an interdependent state, and should therefore trust each other that sensitive information will not be exploited when the VE is disbanded, that resources utilised by partners will not be misused, and that partners will not exploit each other.

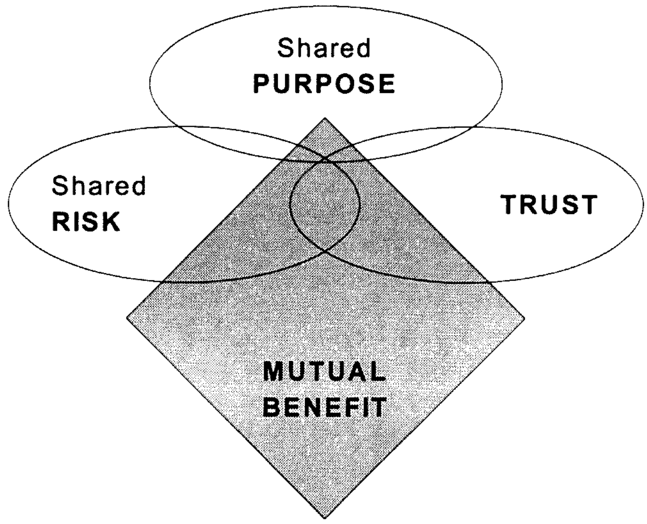

Figure 3.2: Critical success factors for the VE
Source: Barnes and Hunt (2001: 178)

3.3.3 Dimensions and stages of the virtual enterprise

Venkatraman (Barnes & Hunt 2001:251) identified three stages of virtuality through which a company goes in order to achieve the three main efficiency objectives, namely *resource efficiency*, *market efficiency*, and *process efficiency*. The stages and dimensions of the virtual enterprise are presented in Figure 3.3.

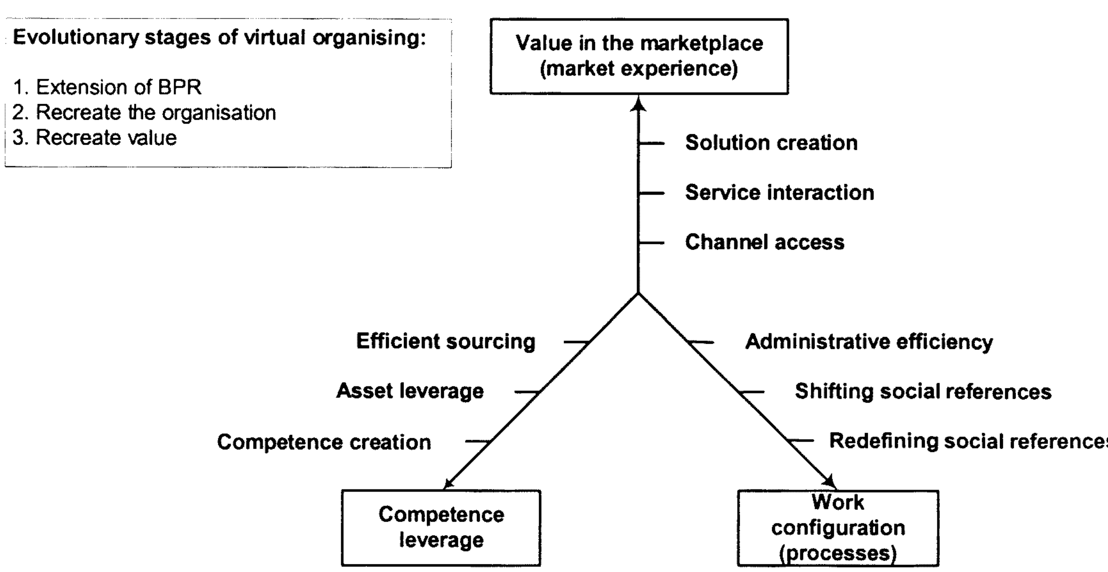

Figure 3.3: Dimensions and stages of virtual organising
Source: Venkatraman (Barnes & Hunt 2001:251)

The power of this framework lies in the analytical tool for comparing companies in specific categories. To gain an understanding of how the framework can be used, two examples will be presented. Each of the three legs will be described in turn. A graphical representation of the first example is given in Figure 3.4.

The first leg is *Market experience*. In the example, the partners in the network are presented in a jointly produced brochure. The brochure presents all the necessary information for customers to contact the dealers with the required expertise. In addition to the shared advertising brochure, the companies in the VE also exhibit together at trade fairs, and have a shared home page on the Internet. The VE is thus still at stage 1 (see Figure 3.3: *Evolutionary stages of virtual organising*, for the definition of the stages), *channel access*, in the *market experience* leg.

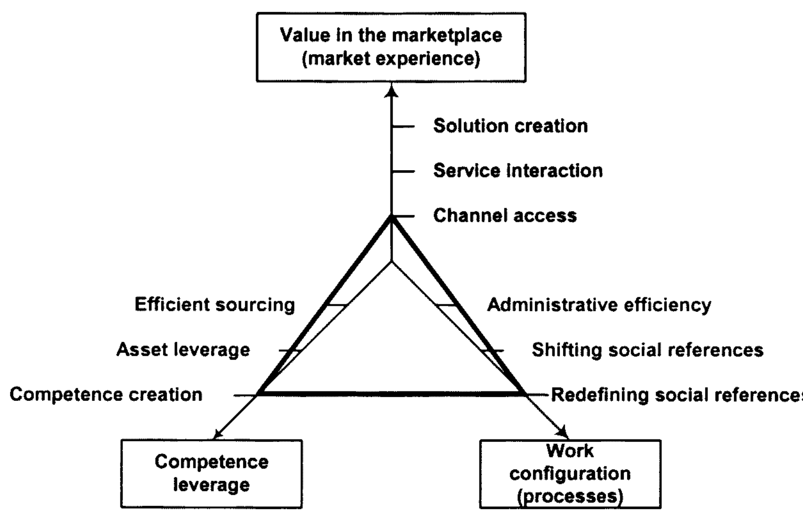

Figure 3.4: Example 1 of the virtuality framework

Source: Barnes and Hunt (2001:255)

The second leg to be discussed, is Competence leverage. One of the main reasons for companies to come together, is to present a joint front to manufacturers. In the example, two companies have agreements with vendors granting the companies exclusive distribution rights to the network. The company that signs the agreement, sells the product for 10% more than what they paid for it, to the member companies. This margin recompenses the company for its services in selecting and evaluating the manufacturer. In this example, each member company plays its part in acquiring expertise. The expertise so acquired, is then transferred between the members, thereby assisting in competence creation.

The final leg is *Work configuration*. In the example, legal and economic ties are emerging between the companies within the VE. A company can become part of the VE, but certain rules must be adhered to. If these rules are broken, the VE can call for the exclusion of the offending member. In the example, the trend is towards shifting and redefining social references.

In the example, the aim of the VE was to set up an association in order to attempt to negotiate better conditions with suppliers. The VE also attempted to promote expertise and to achieve cost savings in administration and advertising by centralising as many activities as possible.

The second example concerns an IT service specialist, Seitz, for the manufacturing and service industry. The company provides ERP software in the SAP environment to medium-sized users. Other products and services from this company include add-on and value-added solutions to compliment SAP R/3, outsourcing (facility management), hardware, training/project management and general contractor services in R/3 projects. Figure 3.5 represents this example in the virtuality framework.

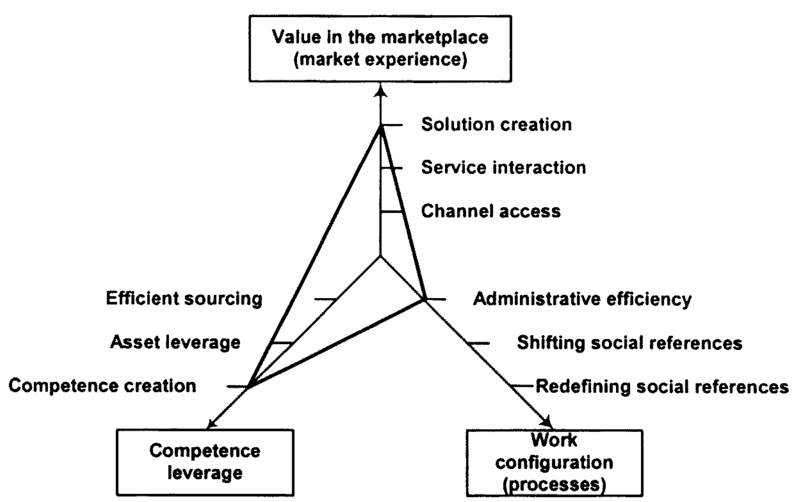

Figure 3.5: Example 2 of the virtuality framework

Source: Barnes and Hunt (2001:258)

In the *Market experience* leg of the model, Seitz is recreating value by combining their own developed products with standard solutions from SAP R/3. The company offers a customised solution for every project, although the product components are in many cases highly standardised. Through all of the above, the company is already in the *solution creation* stage of the specific leg.

In the *Competence leverage* leg, the company is in the *competence creation* stage. Seitz achieved this by forming a partnership with thirty companies consulting on R/3 projects. In these projects, Seitz products complement the services provided by the consulting companies. In addition to this, Seitz can provide a maintenance service once the solution is installed. This working together results in a higher quality of service at a lower cost. Seitz is also able to offer a service requiring a level of expertise that it could not develop alone (asset leverage).

The *Work configuration* leg is in the *extension of BPR* stage, because nearly 10% of employees no longer have a permanent workplace. They are free to use the company's infrastructure, but use different sites, facilities and tools, depending on the particular tasks (Barnes & Hunt 2001:260). In this instance, Seitz places great emphasis on creating more flexible work models.

In the above instance, the strategic management of the network of companies is afforded a high degree of autonomy. The model may differ from the previous one, but suits Seitz better overall.

An important aspect with regard to this model should be made clear. The stages in each of the dimensions do not represent the maturity the organisation has achieved in that specific dimension. The second example indicates that it suits the company better to be in the first stage within the *Work configuration* leg than it would in any other stage.

3.3.4 SMEs within a virtual enterprise

Small and medium companies participate in a VE to get access to the resources of a large organisation while still keeping the agility and independence of a small organisation (Browne & Zhang 1999). As already mentioned above, the VE is a perfect vehicle for these organisations to establish an international presence.

3.3.5 Virtual enterprises and the Internet

The establishment of interorganisational systems (IOS) has been facilitating the cost-effective diffusion of information between firms, because it reduces the co-ordination costs associated with the marketplace and permits increased collaboration between firms (Barnes & Hunt 2001:153). IOS has been set up for the exchange of product information, orders and invoices.

Barnes and Hunt (2001:154) defines an IOS as ... *the computer and telecommunications infrastructure developed, operated and/or used by two or more firms for the purpose of exchanging information that supports a business application or process* ... These authors also note that these firms can be suppliers and customers in the same value chain, strategic partners, or even competitors in the same or related markets, which corresponds with the definition of a virtual organisation. One of the mediums for an IOS is the Internet, known in this case as a *completely open system*. Another medium is EDI, based on value-added networks, which is based on a common purpose computing facility and communications protocol.

The Internet is drawing increased interest from organisations since it represents a potential new medium for the exchange of electronic trading documents with unsophisticated small suppliers (Barnes & Hunt 2001:233). The Internet is not only a global network of networks with a high throughput and low costs, but it is ideally suited for the transfer and presentation of digital business documents through the open and highly standardised protocols that are used.

There is a new breed of third-party Internet-based EDI service providers, IVANs, that offer a service to allow traditional EDI-enabled partners to reach other EDI-enabled trading partners and small unsophisticated trading partners. A traditionally structured EDI message will be received by an IVAN, and then routed via private networks or the Internet, or it will be converted to Web-forms or faxes for small trading partners. These IVANs also support the reverse translation processes (Barnes & Hunt 2001:246).

The importance of the Internet lies in using the Web (or, for that matter the delivery mechanism) to create a competitive advantage rather than to sell "old economy" products in a different way (Walters & Buchanan 2001).

3.4 Supply chain management

3.4.1 Introduction

Supply chain management (SCM) can be seen as the management of the following processes (See also Figure 3.6):

- Planning
- Sourcing

- Producing
- Distribution (and delivery)

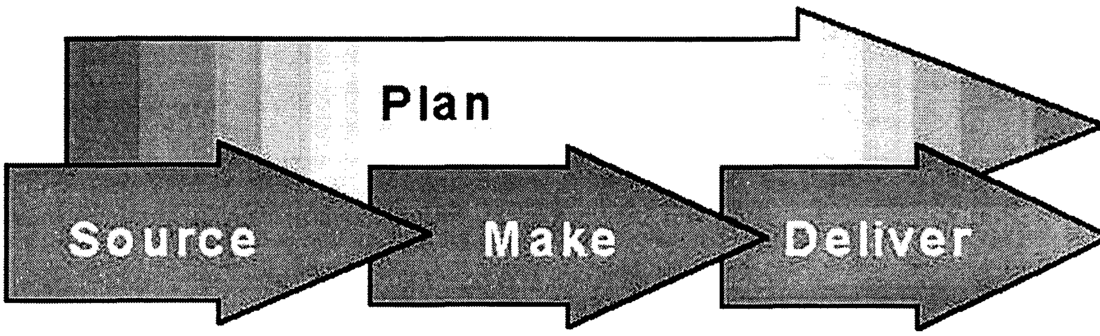

Figure 3.6: Supply chain management structure

SCM is a concept that has gained considerable support as managers have increasingly recognised the importance of logistics as the last cost-cutting frontier. The main goal of SCM is the delivery of the product to the final customer, at the lowest cost, in the shortest time and with the highest added value. During this whole process, the competitive advantage of the supply chain must be taken into consideration.

3.4.2 Definitions

Supply chain management is the management of all activities, processes and systems that support the sourcing, producing, storing, distribution and delivery of an associated product to the final customer. SCM attempts to consider this process as a whole. According to Tarn, Yen and Beaumont (2002:26), SCM enables supply chain partners to work in close co-ordination and co-operation through information-sharing to facilitate supplier-customer interactions and to minimise transaction costs.

According to Ferguson (Tarn et al. 2002), the concept of SCM incorporates two important ideas:

1. SCM is a collaborative effort that combines many parties or processes in the product cycle, and
2. SCM covers the entire product cycle, from the introduction of raw materials to the point at which the consumer purchases the product.

The evolution of SCM has gradually formulated the B2B relationships in recent years. The providers of the enterprise system solution quickly recognised the potential of SCM, and are continuing to develop systems that can allow better B2B relationships and improve production and forecasting simultaneously.

3.4.3 Functions of supply chain management

SCM systems support demand and manufacturing planning and B2B communications. The importance of the planning function within SCM must be emphasised, because randomness and uncertainty can ultimately create chaos in a company's distribution network. SCM offers the flexibility and speed necessary to guard against demand uncertainty. The philosophy behind SCM is that a firm has the right product in the right place, at the right price, at the right time and in the right condition. Under this assumption, an enterprise not only requires the free flow of information within its organisational boundaries, but also the timely sharing of the right information with the right business partner (Tarn et al. 2002).

3.4.4 Supply chain management and the Internet

SCM is the management of an organisation's suppliers' suppliers, to the organisation's customers' customers, and thus reaches beyond the boundaries of a single company. The Internet plays an integral role in the management of information between suppliers, manufacturers, distributors and retailers. Companies like Volkswagen SA have started to standardise this flow of information between themselves and their suppliers by insisting that all the parties involved use the same ERP software, namely SAP.

The position of VE is increasingly becoming more important in SCM. Companies are outsourcing and forming strategic alliances that need the sharing of information that was once seen as confidential. The Internet has made it possible for business partners and customers to participate in commercial trading, communication and interaction. The Internet has thus enabled all suppliers in a specific supply chain to identify and coordinate data transfer among all the partners.

This data transfer has not been without its share of problems. One of the main areas of concern is that while the transfer of data among suppliers, manufacturers and distributors must be reliable and efficient, sensitive data must still be protected.

3.5 Discussion and conclusion

Virtual enterprises are organisations with little or no legal agreement, that are formed to exploit fast changing opportunities, while sharing costs and skills. This environment makes extensive use of e-mail and information technology. Within a virtual enterprise (VE), the emphasis is on the sub-contracting of activities (or the use of outsourcing) and the linking of an enterprise's information systems with those of partner companies. In a purer format, a VE will consist of functions provided by other enterprises.

Such a structure can easily and quickly be changed when the need arises. This concept relies heavily on the extensive use of standards, advanced computer communications facilities, or electronic data interchange (EDI) techniques, to name a few. Within this environment, there is a need for better process management and more integration within more decentralised and modular individual enterprises, as well as among enterprises co-operating regarding collaborative projects.

The VE is used by SMEs to get access to the resources of a large organisation while retaining the agility and independence of a small organisation. SMEs can become global players, and can establish a presence in the supply chain, through the effective use of VEs.

The GCC, through its Training Centre (see Appendix B for description) is developing a 3-Dimensional Business Simulator (3DBS). The 3DBS can demonstrate the principles used in operations management. The field of operations management include the emerging discipline of virtual enterprising, and the 3DBS will demonstrate the principles used and technologies employed within a VE. The 3DBS can thus be seen as a "working model" of a VE, with all the elements of a VE, including such elements as e-commerce and ERP. Appendix C contains a complete description of the 3DBS.

Chapter 4

The value chain

4.1 Introduction

The value chain is a model that describes a sequence of value-adding activities of a single organisation, connecting an organisation's supply side (raw materials, inbound logistics, and production processes) with its demand side (outbound logistic, marketing and sales) and includes supporting activities (firm infrastructure, human resource management, technology development and procurement).

The purpose of a value chain is to identify a competitive advantage. Traditional approaches to achieving and maintaining a competitive advantage are no longer sufficient. Gustin, Stank and Daugherty (1994) suggest that information is one of the most important elements in a competitive advantage, and that the link between information and competitive advantage is critical to achieving integration. They viewed information technology as resources to be used by the firm in gaining a competitive advantage in the marketplace.

In this chapter, Porter's Value Chain and Alderson's General Theory of Marketing are presented. Although there are substantial differences in the audiences that these two theories were developed for, they are remarkably similar. Both of these theories are at the macro-(business) level of analysis, and both are conceptualised as the activities required to transform raw materials in their natural state to finished goods in the hands of the consumer. These two ideas evolved independently, and were received differently in two fields separated by several disciplinary boundaries, including lack of a common vocabulary.

4.2 Definition of value

The customer perceives value when cost is reduced without reducing the performance of the product, or the performance is increased without increasing the cost. The American Society of Quality defines *value* as *the ratio of quality to price.* It is important to note that value can be interpreted differently, depending on the context in which it is used. It can be perceived to describe the degree of importance of an object to a person's need, or the cost associated with the object (Poon & Lau 2000). Boulton, Libert and Samek (2000:11) define the creation of value by modern companies as ... *the exploitation of its portfolio of brands, an intangible asset, to generate new value for its customers and wealth for its investors and other stakeholders ...*

4.3 Porter's Value Chain

According to Gibson, Greenhalgh and Kerr (1995), *manufacturing* is the process of adding value to raw materials by converting them to finished products which are worth more to customers than the unprocessed materials, and which can therefore be sold at a higher price. The value is added through either direct or indirect activities that convert the raw materials into sellable products. A firm's activities that are performed to design, produce, market, deliver and support its product, are called its *value chain.* The relevant level for constructing a value chain, is a firm's activities in a particular industry (the *business unit*). An industry- or sector-wide value chain is too broad, because it could obscure important sources of competitive advantage (Porter 1985:36). The value chain is graphically presented in Figure 4.1.

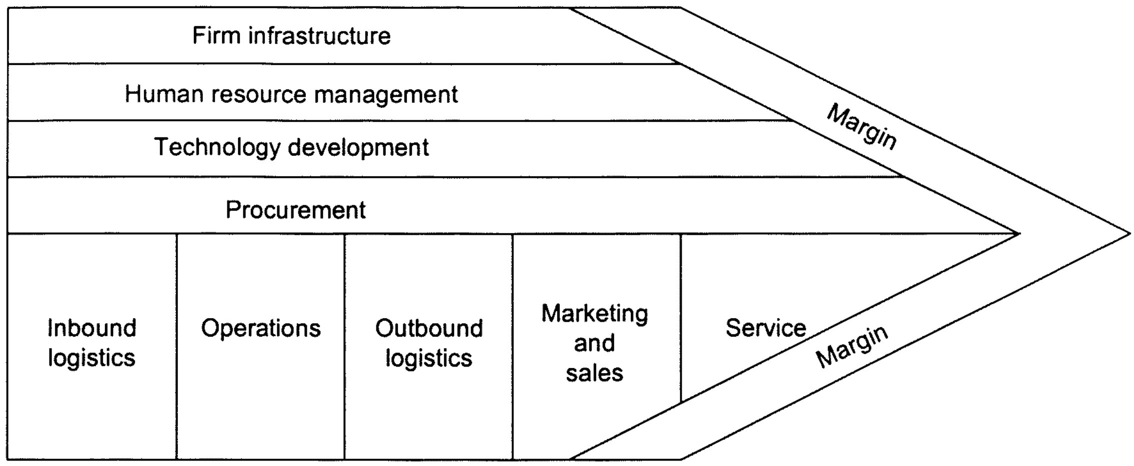

Figure 4.1: Porter's Value Chain

Source: Gibson et al. (1995:9)

The activities in the value chain can either be *support activities* or *primary activities*. The *primary activities* are the physical activities concerned with transforming the raw materials into sellable goods, the physical logistics concerned with the transformation process, and the sales and marketing activities involved in making customers aware of the products the firm is selling. The *support activities* provide the necessary reinforcement or assistance, which allow the primary activities to function smoothly over time, and to increase the degree of competitiveness of the organisation. These activities include firm infrastructure, human resource management, technology development and procurement.

The above-mentioned activities, as well as the elements of each, are as follows:

- **Primary activities:**
  - inbound logistics – incoming material storage, data collection, service and customer access;
  - operations – assembly, component fabrication, and branch operations;
  - outbound logistics – order processing, warehousing, and report preperation;
  - marketing and sales – sales force, promotion, advertising, proposal writing, and web site hosting;
  - after-sales service – installation, customer support, complaint resolution and repair.
- **Support activities:**
  - firm infrastructure – financing, planning, and investor relations;

- human resource management – recruiting, training, and compensation system;
- technology development – product design, testing, process design, material research, and market research;
- procurement – components, machinery, advertising and services.

Porter (Gibson et al. 1995:9) also identifies three activity types that may be present in either primary or support activities. They are:

- *direct activities*, concerned with adding value to the product (product design, fabrication, assembly, etc);

- *indirect activities* that make it possible to perform direct activities on a continuous basis. These activities include production scheduling, financial administration, etc.;

- *quality assurance activities*, concerned with ensuring the quality and conformance regarding standards of other activities, and include inspection, testing and reworking.

The three different types of activities are present in both the primary and support activities. Gibson et al. (1995:10) uses the example of physical machining of a part, describing it as a *direct primary activity* as it adds value directly to the product, whereas the setting up of the machine is an *indirect primary activity* as it does not directly add value to the product. Gibson et al. also use the example of product design, describing it as a *direct support activity*, because it adds value directly to the product, whereas the administration of the design department is an *indirect support activity.*

The activities in the value chain should be seen as a set of linked, interdependent activities, in which the way in which one activity is performed can affect the cost or efficiency of the activities down the chain.

4.3.1 Competitive advantage

Porter (1985) describes three strategies for achieving a competitive advantage in an industry:

- cost,
- differentiation, and
- focus

The first strategy (*cost*) involves becoming the cost leader in an industry, where the organisation sets out to become the low-cost producer in its specific industry. Organisations following this strategy should find and exploit all sources of cost advantage in their industry, and even in related industries.

The second strategy that an organisation can follow is *differentiation*. In this strategy an organisation seeks to be unique in its industry along a specific dimension that is widely valued by customers. The organisation will concentrate on one or more attributes that many buyers in the industry perceive as important, and will then position itself to meet the needs of those customers (Porter 1985:14).

The third strategy is *focus*. This strategy has two variants: the first is a *cost focus*, where an organisation seeks a cost advantage in its target segment, and the second is a *differentiation* focus, in which case an organisation seeks differentiation in its target segment (Porter 1985:15). The *cost focus* exploits special cost needs of buyers in a specific segment, while the *differential focus* exploits the special differentiation needs of buyers in a specific industry. The difference between this strategy and the other two (i.e. *cost* and *differentiation*) is that the focuser dedicates itself to one segment exclusively.

The strategy a business unit follows is its route to a competitive advantage. A specific strategy should be chosen and then pursued. It is nearly impossible to pursue more than one strategy at once, since each strategy implies different skills and requirements for success. The strategy that is important for an organisation to be successful, taking into consideration the culture of the organisation, is the appropriate one.

4.4 Alderson's General Theory of Marketing

Wroe Alderson developed his marketing theory in 1965 and it revolves around the interaction of firms and households, each of which he regards as an organised behaviour system. The goal of each of these systems is survival. Individuals join these systems because they expect that, through their participation, they will be more likely to achieve their individual goals. These organised behaviour systems exist within a heterogeneous market. Market heterogeneity is seen both on the demand side, in the heterogeneity of assortments desired by households, and on the supply side, in heterogeneity of resources in their natural state.

According to this theory, the basic functions of firms are to perform sorts and transformations. *Sorts* alter heterogeneity, and *transformations* add space, form or time utility. Sorts and transformations are typically followed by transactions that take place between firms, and ultimately, between firms and households. The complete sequence of sorts and transformations required to convert raw material into finished goods, is called *transvection*. This is graphically represented in the figure below.

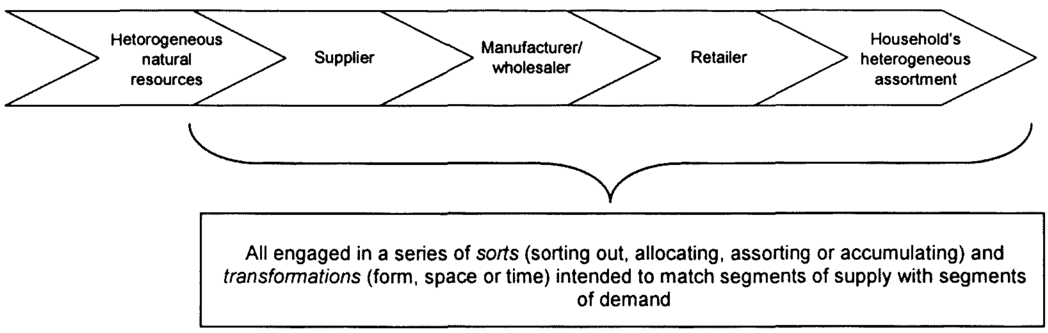

Figure 4.2: Alderson's General Theory of Marketing

Each of the terms used above, is briefly explained.

4.4.1 Market heterogeneity

Traditional economic models assume market homogeneity by stating that perfect competition is present. Alderson assumes that markets are imperfect, and his models assume a perfect heterogeneous market. This means that each small segment of demand can be completely satisfied by only one unique segment of supply. Markets are cleared (all products produced are sold) only when the naturally occurring heterogeneity of resources can be altered to match the heterogeneity demanded by consumers. This differs from traditional models, since the key mechanism that clears homogeneous markets, is price. Alderson defends his use of heterogeneous markets by stating that there are either some goods left which nobody wants, or some wants remain unsatisfied for the lack of corresponding goods (Alderson 1965:29).

According to Alderson (1965), heterogeneous markets can be cleared by either innovation or information. Innovation can be achieved by producing goods that satisfy a certain need that is currently unmet, or by inducing demand for existing products through marketing efforts. The effective use of information can be used by customers to communicate unambiguously what they need, thus resulting in a situation where no unwanted goods will be produced. This information can be seen in two ways:

- Firstly, this information can be part of the marketing process, where the purpose of marketing is to match the two markets.
- Secondly, technology can be used to combine innovation with information through the use of mediums like the Internet (although the Internet was not yet a factor when Alderson developed his theory, the relevance of the Internet in his theory is remarkable).

4.4.2 Organised behaviour systems

Alderson (1965) defines an *organised behaviour system* as any system with a criterion for membership, a rule or a set of rules for assigning duties, and a preference scale for outputs. The two principal organised behaviour systems in this theory are households and firms.

Households engage in purchasing in order to build up an assortment of goods that would support expected patterns of future consumption behaviour. The household has power as a system, because it offers a surplus to its participants that they would not expect to enjoy alone (Alderson 1965:38).

In contrast to this, *firms* are behaviour systems that evolved as a result of the specialisation of labour, although originally in the Middle Ages, the firm was scarcely more than a household producing a surplus of certain types of goods (Alderson 1965:38). The primary goal of firms is survival, and firms seek growth, because they believe that it is necessary for survival. This survival motive is achieved, because the members of a firm believe they can receive more for their production within the firm than when acting alone. Furthermore, firms can only survive by ensuring the patronage of a group of households, resulting in continuous competition among firms for differential advantage. From this it can be seen that households are primarily *consuming* entities, and firms are primarily *producing* entities.

4.4.3 Sorts and transformations

In heterogeneous markets, the matching between differentiated segments of supply and differentiated segments of demand is effected through a series of sorts and transformations. *Sorting* is the physical process through which goods, materials or components are assigned to appropriate segments of demand. Alderson (Priem, Rasheed & Amirani 1997) identifies four different types of sorting. They are:

1. *sorting out*, i.e. the process of breaking down a heterogeneous collection into smaller homogeneous collections;
2. *assorting*, i.e. the building up of a large heterogeneous collection from several homogeneous collections;
3. *allocation*, i.e. the breaking down of a large homogeneous collection into several smaller homogeneous collections;
4. a*ccumulation*, i.e. the building up of a large homogeneous collection from several smaller homogeneous collections.

Alderson (1965) also mentions that there should always be a transformation between two successive sorts. He defines a *transformation* as a change in the physical form of a product or in its location in time and space, which is calculated to increase the value of the product for the ultimate consumer who adds the product to his/her assortment (Alderson 1965:138).

4.4.4 Transactions and transvections

Alderson (1965: 75) defines a *transaction* as the product of a double search in which customers are looking for goods and suppliers are looking for customers. Transactions can then be further divided into *fully negotiated transactions* or *routine transactions*. *Fully negotiated transactions* may either be *large* transactions or *controlling* transactions, which define the framework within which a number of subsequent transactions will take place.

Alderson (1965: 86) defines *transvection* (from the Latin *trans* and *vehere* meaning *flowing through*) as a unit of action by which a single end product is placed in the hands of the consumer after moving through all the intermediate steps in the marketing process, from the original raw materials to the finished product. Alderson coined this term (*transvection*) to fill a gap in the English vocabulary and to provide him with a tool to describe exactly what is meant. A *transvection* is the outcome of a series of transactions, sorts and transformations that creates meaningful heterogeneity from meaningless heterogeneity.

4.5 A comparison between Porter's model and Alderson's theory

Priem et al. (1997) compared Alderson's General Theory of Marketing to Porter's Value Chain, and they observed a number of similarities and differences. These are explained briefly.

4.5.1 Similarities

In both the Transvection Theory (another name for Alderson's General Theory of Marketing) and Porter's Value Chain, strong similarities can be seen. Both concepts represents the sequence of activities required to transform a product from raw materials to a finished item in the hands of the consumer, and both concepts are suggested as planning tools to attain a competitive advantage.

Porter's model suggests that the primary value chain activities (inbound logistics, operations, outbound logistics, marketing and sales, and services), and support activities (procurement, technology development, human resource management and firm infrastructure) that support the primary activities, are the potential sources of competitive advantage. The competitive advantage can be achieved by evaluating the value produced by each activity and the cost associated with the activity. Such cost-benefit information can then be used by the organisation in resource allocation decisions. Alderson's theory describes the degree to which the sorts and transformations in a transvection are optimised as the source of differential advantage. This advantage can be achieved through transvection cost minimisation or through a transvection that better matches heterogeneous segments of supply and demand.

4.5.2 Differences

Alderson's theory is primarily descriptive, attempting to explain and predict marketing phenomena. This is in contrast to Porter's model, which offers prescriptions for how an organisation's value chain and the value system of which it is part, should be evaluated and altered to improve competitive advantage.

Porter's Value Chain provides a detailed typology of activities and relates distinctive competence in various activities to sustainable competitive advantage. Alderson's approach is more careful in the use or disposal of money or resources, by classifying the activities as either sorts or transformations, and it may conceptually be richer with its emphasis on heterogeneity.

4.5.3 Sources of competitive advantage

Both Alderson and Porter propose similar strategies for building a competitive advantage. Alderson (1965) argues that the search for differential advantage explains the dynamics of competition, and proposes market segmentation, the transvection itself and advertising or product and process innovation as potential sources of differential advantage. The assortments desired by each household differ and collectively represent a heterogeneous market. Firms compete for differential advantage in obtaining the support of households, which lead to innovation in marketing (improvement in creation of assortments for the heterogeneous demand). To meet the heterogeneous demand, heterogeneous supply occurs when new firms enter the field, because they expect some differential advantage that would give them a niche. Competitors move to neutralise this advantage through activities that are intended to enhance value to their own advantage.

Porter (1985) identifies three generic business-level strategies for achieving competitive advantage: *differentiation*, *cost leadership*, and *focus*.

Thus, each author's strategies involve the following (Priem et al. 1997):

- cost savings (in sorting activities of the transvection process or value activities in the value process);
- differentiation (by creating a unique product, technology, appeal or process);
- focus (market segmentation through emphasis on a particular product line or market segment).

This is briefly compared in the following table.

Table 4.1: Comparison of Porter's model and Alderson's theory

Advantage	Porter's model	Alderson's theory
Cost advantage	The cost of overall value activities is lower than that of competing firms. The basis of these lower costs are hard for competing firms to copy.	The shortest path to the market is the one that results in the minimum cost (least number of sorts and transformations).
Differentiation	A unique product (service) that is valuable to its buyers beyond simply offering a lower price.	Fulfil a unique function (e.g. through product, customer, operations or locations).
Focus (segmentation)	Matching the firm's abilities with the needs of a particular segment of the market.	Identify consumers who have similar needs from the diverse needs of the overall population and try to serve them.

4.6 The value system

Porter (1985:33) notes that the value chain disaggregates a firm into its strategically relevant activities in order to understand the behaviour of costs and the existing and potential sources of differentiation. Each firm's value chain is imbedded in a larger and more complex stream of activities defined by Porter as the *value system*. This system is presented in Figure 4.3.

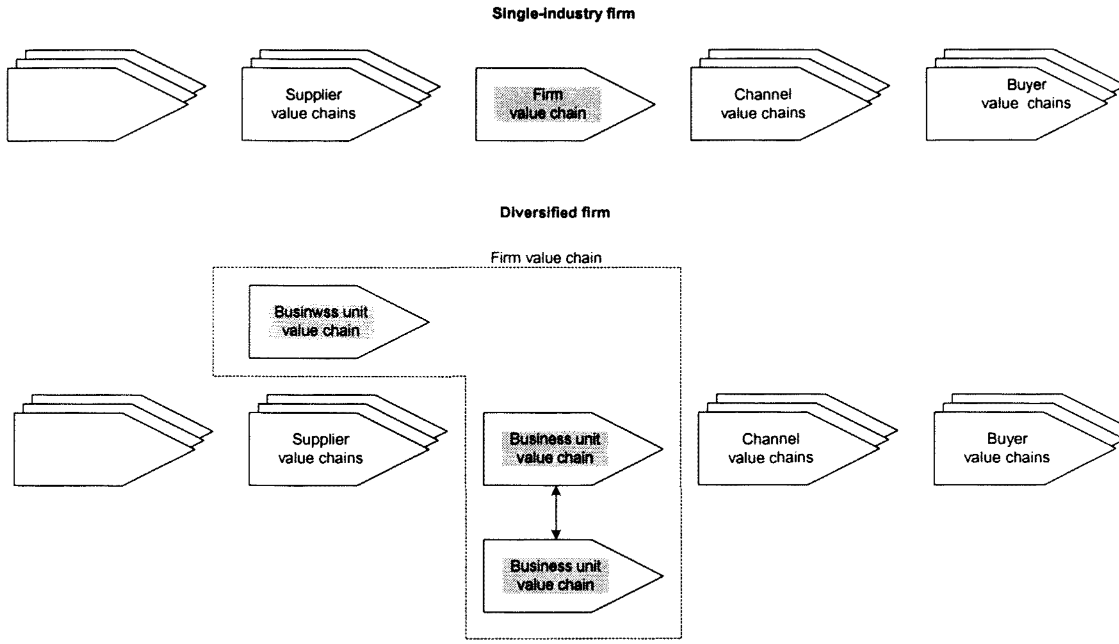

Figure 4.3: The value system

Source: Porter (1985:35)

The value system consists of the value chains of different firms within an industry. The value chain originates from the suppliers that create and deliver the purchased inputs used in the firm's value chain. The products produced by the suppliers can also influence a firm's performance through the value that is being added (not only in monetary terms) by these suppliers.

After the product has passed through the firm's value chain, it moves to the channel's value chains. It is the responsibility of the channels to deliver the product to the buyer. The channels also perform additional activities that affect the buyer, as well as influencing the firm's own activities. The activities referred to by Porter (1985) are those that add value to the product, and for a specific organisation this can be affected by, for example, the quality of the product delivered by the channels.

The product then moves to the buyer's value chain. The role of the product in the buyer's value chain is the ultimate basis for differentiation, because it is in the buyer's value chain that the needs of the buyer are determined.

It can be seen from this description, and in Figure 4.3, that a firm can find itself in any position within the value system. The firm's value chain can be the supplier, channel or buyer value chain of another firm. Gaining and sustaining a competitive advantage can only be achieved by understanding the firm's value chain, and by considering its position within the value system.

4.7 Conclusion

Although Porter and Alderson's models were realised long before the introduction of e-commerce, ERP and other new technologies, their relevance is still important in this age. The business environment has changed dramatically, and companies need to find new sources of competitive advantage to remain competitive.

Although this chapter did not deal explicitly with e-commerce and the other new information technology advances, the value chain presented here is important for understanding, for example, the necessity for e-commerce in the survival of business. This chapter is also necessary for understanding the reasons for implementing something like business-to-business e-commerce within a company. By identifying the value chain in a business unit, an organisation can evaluate the added value of the use of e-commerce in its own trading processes. The value chain can also be used to identify a strategy for a competitive advantage, a strategy where e-commerce can play a vital role. For example, if a cost strategy is followed, e-commerce can serve as the vehicle for delivering a lower cost product to the buyer by reducing the cost associated with the product. When a differentiation strategy is followed, e-commerce can be used to introduce uniqueness to customers (in the case of UPS, this will be the ability to "see" into the organisation's computer system for tracking parcels as they go through the channels) for which a premium can be charged.

Alderson's General Theory of Marketing is introduced as an indication that nothing in business is new. Alderson developed his theory in 1965, long before Porter developed the notion of the value chain. However, both these models concentrate on achieving a competitive advantage, although through different processes. The relevance of these two models today is the same as when they were initially developed, the only difference is that they should now be viewed from a different perspective so as to include the technology employed at the moment.

Chapter 5

Defining e-commerce, and the technology that supports it

5.1 Introduction

The original purpose of the Internet was to satisfy communication and research-sharing demands emanating from the academic and research world (Leiner, Cerf, Clark, Kahn, Kleinrock, Lynch, Postel, Roberts, & Wolff 2000). During the past few years these original users were joined by a new generation of users with a wider range of backgrounds than academia and researchers. The most important aspects to have an impact on the Internet are e-mail and the World-Wide Web (www). The www enables individuals and organisations to provide a global audience with full multimedia information that can be accessed easily. This revolutionised the way people do business, since it provides the potential to affect fundamental changes in the way people and organisations buy and sell products. The Internet created a radical new marketplace without physical or fiscal limits.

5.2 E-commerce

5.2.1 Definition

According to Kalakota and Robinson (1999:4) *e-commerce* is the buying and selling of products over the Internet. This is a very limited definition for a term as broad as e-commerce. Watson, Berthon, Pitt & Zinkhan (2000:1) describe *e-commerce* as the use of computer networks to improve organisational performance. This is achieved through the use of information technology to enhance communications and transactions with all stakeholders in an organisation. These stakeholders include customers, suppliers, government regulators, financial institutions, managers, employees and the public at large.

This definition complements Kalakota and Robinson's view (1999:4) on e-business. These authors define *e-business* as both the front- and back-office applications that form the electronic backbone for modern organisations. Their definition of e-business encompasses their definition of e-commerce. Although Kalakota and Robinson (1999) make a distinction between e-commerce and e-business, the two terms will be used interchangeably in this thesis.

Fellenstein and Wood (2000:23) have two viewpoints on *e-commerce*. The first viewpoint defines *e-commerce* as a set of electronic, networked transactions, including those pre-transaction and post-transaction activities performed by buyers and sellers. The second viewpoint describes *e-commerce* as an evolving utility of packaged software applications that link multiple enterprises and consumers, for the purpose of conducting electronic business (pre-sales, sales, and post-sales). These authors summarise the different viewpoints by defining the *requirements* for e-commerce as those business strategies that are focused on optimising the relationships between businesses, as well as between businesses and consumers, making sure each is capable of using information technology.

Barnes and Hunt (2001:1) *define e-commerce* also as trading electronically, but they note that the *implications* of e-commerce are more important than the precise definition. The implications include that the interactivity and connectivity of the new electronic medium have huge potential for many other aspects of business operations, including knowledge and information flows, improved quality and service and the distribution of digital products.

Kalakota and Whinston (Lawrence, Corbitt, Tidwell, Fisher & Lawrence 1999:4) point out that electronic commerce has many definitions, depending on the perspective from which it is viewed. These ideas are described in the following table.

Table 5.1: E-commerce from four perspectives

Perspective	Description
Communication	To deliver information, products/services and payments over the telephone, communication networks, or other means.
Business	To automate business transactions and work flows.
Service	To cut service costs while improving the quality of goods and increasing the speed of delivery.
On-line	To provide the capability of buying and selling products and information over the Internet and other on-line services.

Source: Kalakota and Whinston (Lawrence, et al. 1999:4)

Within the virtual enterprise, the focus is on the commerce relationships of the different businesses. It is for this reason that the business-to-business e-commerce relationships will be emphasised, and not the business-to-consumer relationships.

5.3 Business-to-consumer (B2C) vs. business-to-business (B2B)

The relationship between the various role players can be either business-to-consumer or business-to-business related with regard to e-commerce. This section will explain the differences between them, and the choice for virtual enterprises.

5.3.1 Business-to-business (B2B)

Traditionally, the relationship between providers and consumers has been specific, contractual and largely static. The Internet, wireless, and emerging digital streaming technologies have changed all that, opening up the possibilities, and increasing the desire for providers to have as many consumers as possible, and for consumers to have a choice among many alternative providers. In this more dynamic environment the traditional challenge of managing a one-to-one relationship is giving way to the much greater challenge of managing many-to-one and one-to-many relationships.

Business-to-business e-commerce is described as the use of the Internet to facilitate commerce among companies, promising vast benefits, such as dramatically reduced costs, greater access to buyers and sellers, improved marketplace liquidity, and a new array of efficient and flexible transaction methods (Wise & Morrison 2000:88).

The purpose of B2B e-commerce is to streamline administrative routines and to help companies consolidate their purchasing practices, enabling them to receive better discounts and services from their suppliers (Attaran 2001).

Business-to-business (B2B) e-commerce is a type of e-commerce involving a transaction from one business to another over the Internet. This type of commerce incorporates everything from manufacturing to solution providers. The Aberdeen Group reported that by 2001 B2B transactions have already surpassed individual consumer transactions by 10:1. They also predict that American B2B e-commerce will grow 41% annually over the next five years (that is between 2002 and 2007).

5.3.2 Business-to-consumer (B2C)

Business-to-consumer e-commerce is similar to traditional retailing by a business to a consumer, but the B2C retailing is done over the Internet rather than at a traditional brick and mortar store location.

5.3.3 The choice between B2B and B2C

It was decided to concentrate on B2B e-commerce for this project, since the Economist Intelligence Unit (EIU) estimates that the B2B market in South Africa is US$ 250-488 million, with the potential for extensive growth. South Africa is already one of the top 20 countries in terms of the number of Internet sites. According to the 2nd South Africa Web Commerce Survey 1999 (Pastore 1999) B2B transactions would have overtaken consumer spending for the first time in 1999, after the dramatic rise from R15 million in 1997 to R207 million in 1998.

The geographical position of South Africa in respect to the rest of the world offers some unique challenges. To be globally competitive, South African companies need to become part of virtual enterprises (VE), effectively using their position in the supply chain to sustain a competitive advantage. The only true way to use a VE effectively to the advantage of SMEs, is to embrace all the software tools necessary to communicate effectively. Thus, ERP must be used in conjunction with e-commerce, so that effective scheduling, manufacturing and delivery will be possible within the manufacturing environment.

B2B e-commerce has three distinctive waves. During the first wave, only web "fronts" are created. All information entered onto these web sites, needs to be processed manually. The second wave makes use of ERP packages. Human intervention is still necessary, but only to assist with the scheduling. This wave can be graphically represented in the following figure.

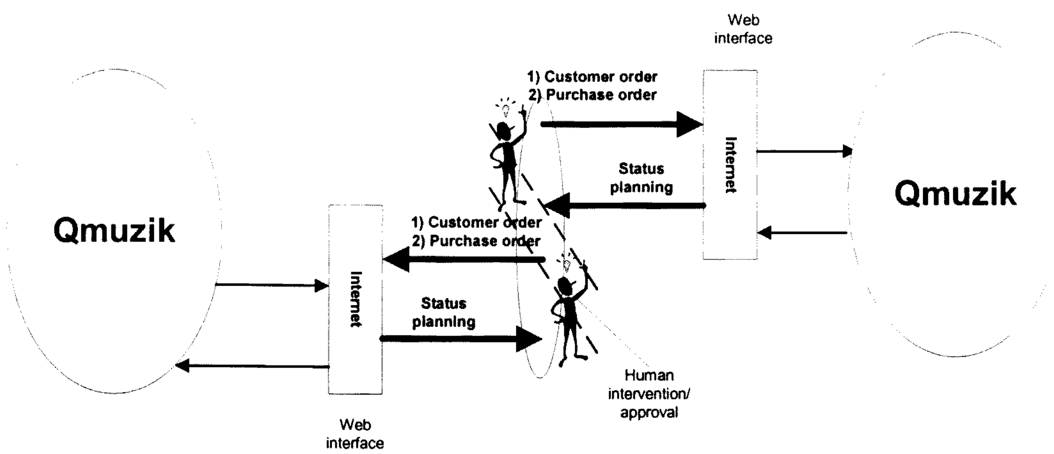

Figure 5.1: Second wave B2B e-commerce

Figure 5.1 illustrates how a purchase/customer order is sent over the Internet. Human intervention occurs to approve the order, and the status and other information is sent back to the originator of the order.

In the third wave, ERP packages will communicate with each other without any outside intervention. It is the opinion of the author that this is the future of B2B commerce, where humans do not need to intervene in the scheduling done by the ERP packages.

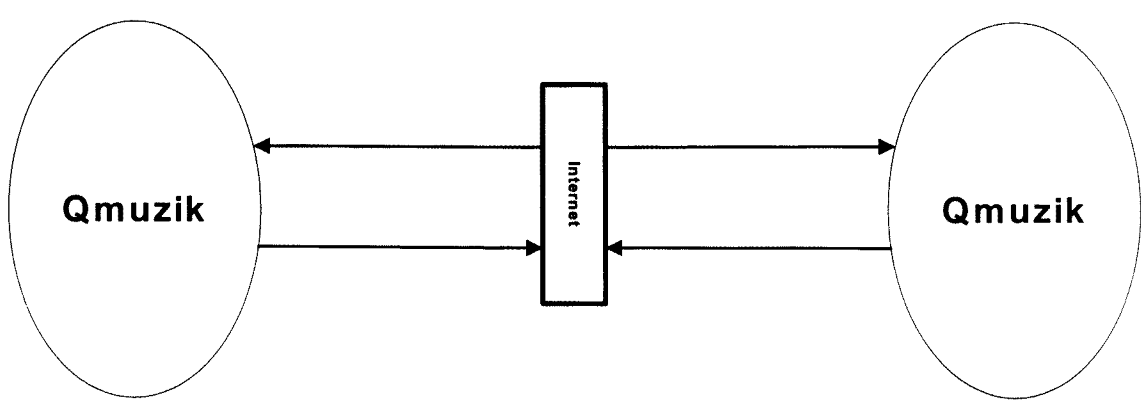

Figure 5.2: Third wave B2B e-commerce

5.3.4 Brief history of e-commerce

In August 1962, J.C.R. Licklider of the MIT wrote a number of memos describing his vision of a series of globally interconnected sets of computers through which everyone could access data and programs from any site. This vision ultimately led to the development of what is now known as the Internet.

The Internet is a computer-based network of multiple interconnected public and private networks throughout many areas of the world. The Internet started in 1969 as a project of the Advanced Research Projects Agency (ARPA) of the US Department of Defence, for the sole purpose of linking various kinds of computer systems, at that time installed and scattered all over the world. The original purpose of the Internet was to create a global, electronic, collaborative environment that would be used primarily by scientists, key military personnel and educators (Fallenstein & Wood 2000:8).

Commercialisation of the Internet involved not only the development of competitive, private network services, but also the development of commercial products implementing Internet technology. Originally, commercial issues mainly comprised of vendors providing the basic networking products, and service providers offering the connectivity and basic Internet services. The Internet has now become almost a "commodity" service, and lately most of the attention has been on the use of this global information infrastructure for support of other commercial services.

Use of the Internet has been tremendously accelerated by the widespread and rapid adoption of browsers and World-Wide Web technology, allowing users easy access to information linked throughout the globe. Products are available to facilitate the provisioning of that information and many of the latest developments in technology are aimed at providing increasingly sophisticated information services together with the basic Internet data communications.

Electronic data interchange (EDI) and e-mail have been in use for quite some time. EDI technology has already been used for many years to transmit information such as purchase orders, invoices, material releases, shipping notices and product inquiries electronically. This technology is based on the traditional client/server technology. The sender must have an application that can send the information in the format, usually proprietary, to be read by a receiving application. The network vehicle for these transactions is a Value-Added Network

(VAN). Identical processing systems are not required, only the standards need to be set up before the transfer (Attaran 2001). Many suppliers have lost contracts to large corporations and government departments, since these corporations and departments have insisted that all their suppliers use these technologies. The combination of the Internet and EDI have made it possible for smaller businesses to become part of the e-commerce phenomenon, because expensive hardware and software supporting this technology are a thing of the past.

5.4 The technology that supports e-commerce

The Internet's explosive growth has changed the face of modern businesses. The following figure illustrates the growth of technology for different products.

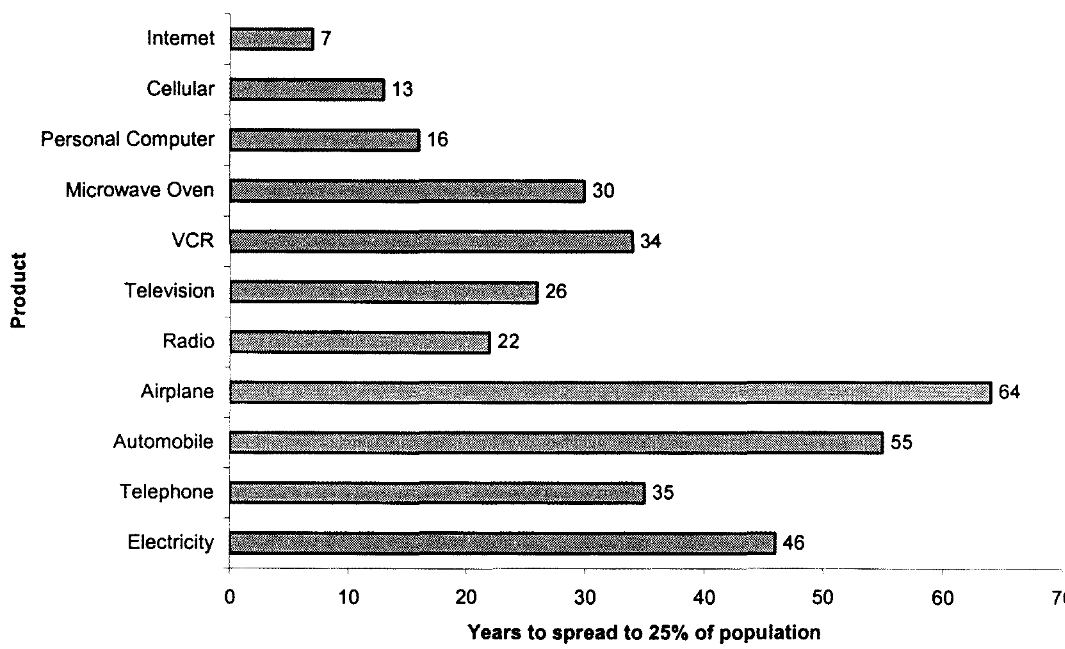

Figure 5.3: The growth of technology

Source: Korper & Ellis (2000:3)

Figure 5.3 shows that it took 46 years for electricity to be used by 25% of the population, while it took only 7 years for the Internet to be used by the same percentage of the population. If it is considered that electricity was invented in 1873, while the Internet was only introduced in 1991, this growth is phenomenal. The Internet is also compared to other products in Figure 5.1, to show the growth of it versus other high technology products.

The advantage of the Internet is that a common communication protocol exists. This protocol is called TCP/IP (Transmission Control Protocol/Internet Protocol), and it consists of two parts. The TCP part handles the transport of data, while the IP part performs the routing and addressing.

The TCP part is responsible for splitting the message into distinctive packages at the sending computer, uniquely numbering each packet, transmitting the packets over the Internet, and putting them together in the correct sequence at the receiving computer. The IP part determines the best route for the different packets through the network. The dynamic nature of the routing means that packets from the same message could take different paths and might therefore not necessarily arrive in the sequence in which they were sent.

It is only possible to send a message from one computer to another if every server on the Internet is uniquely addressable. This is achieved through the assignment of unique IP addresses, a unique 32-bit number, consisting of four groups of decimal numbers in the range of 0 to 255.

E-commerce is built on top of a layered, integrated infrastructure. Each layer is founded on the layer below it, and cannot function without it. This layered approach (illustrated in Figure 5.4) is described by Watson, Berthon, Pitt & Zinkhan (2000).

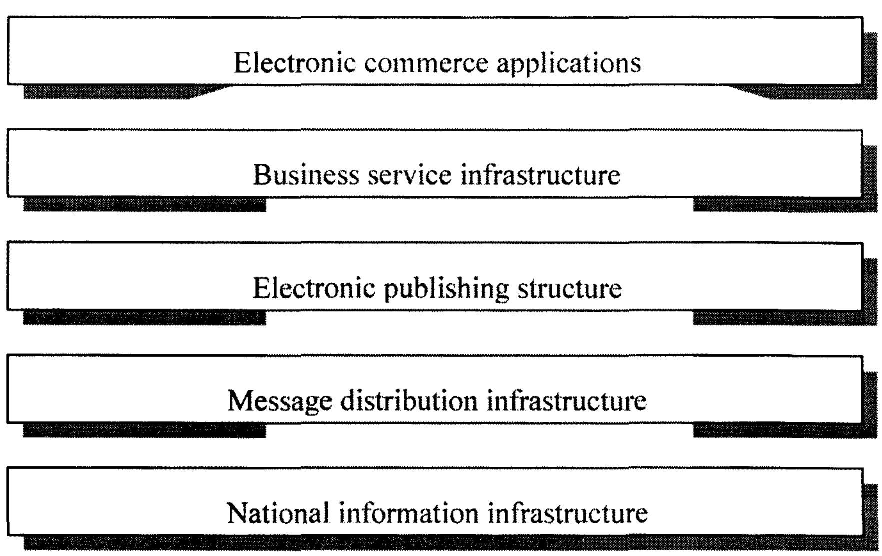

Figure 5.4: Electronic commerce infrastructure

Source: Watson <u>et al.</u> (2000)

The *National information infrastructure* (NII) is the foundation of e-commerce, because one or more of the communication networks comprising the NII must transmit all traffic.

The next layer, called the *Message distribution infrastructure*, consists of software designed for sending and receiving messages. Its purpose is to deliver a message from a client to a server.

On top of this is the *Electronic publishing infrastructure*, a layer concerned with content that permits the publishing of a full range of text and multimedia. This layer consists of three key elements:

- a *uniform resource locator* (URL), which uniquely identifies a server;
- a *network protocol* (in this case TCP/IP), which is responsible for the transportation and routing of the data;
- a *structured markup language*, HTML. A *markup language* is a mechanism which identifies structures in a document, while *structured information* contains both content and some indication of what role the content plays.

The next layer is the *Business service infrastructure*, designed to support common business processes. This layer is concerned with facilities for encryption and authentication, and support services for secure transmission of credit card numbers and electronic funds transfer.

The final layer is actually an application, called the *Electronic commerce application* (ECA). This layer can be seen as the purpose of the whole infrastructure. Watson et al. (2000) use the example of a bookseller to describe the ECA. In this case, the ECA is the on-line book catalogue.

5.5 Conclusions

This chapter introduced the reader to the basic concepts of e-commerce. The purpose of this chapter is to give the reader an overview of e-commerce, and the technology needed to support it. It presents e-commerce at a strategic level, with only the associated information required to understand it at that level.

E-commerce is one of the technologies that is an absolute necessity within the virtual enterprise. It will be impossible for many globally dispersed corporations to work together on the same product without e-commerce. The Internet, and e-commerce make it possible for these corporations to share the same information and schedules in real time. It is therefore of the utmost importance that the partners of the VE understand the possibilities that this technology offers, and how to use it.

Chapter 6

Electronic commerce within the value chain

6.1 Introduction

According to Walters and Lancaster (1999), the use of e-commerce will provide customers with a range of value criteria: convenience, information, personalisation and interactivity, each of which creates competitive advantage characteristics difficult to emulate without information technology to contain costs. These authors also mention that it is possible to add value by offering additional information, transactions and services, or by selling complementary products/services. Value chain analysis helps in identifying key value-adding processes that could be made more effective using information technology.

Evans and Wurster (Walters & Lancaster 1999) suggest that the new economics of information, available through use of the Internet, will alter the sources of competitive advantage achieved through the value chain. It is important to note that fast-paced competition, rapidly shifting markets and developing technologies create a host of variables that should be reviewed and assessed.

E-commerce is one of the most important enabling technologies of the virtual enterprise, and is critical in the fast-paced market place within which the VE competes. The business models available within the e-commerce environment must be completely understood for the VE to make effective use of them. It will also assist with the extensive use of standards that is a critical element, since the better these models are understood, the easier the integration of the different partner's IT infrastructures will be.

This chapter will consider aspects that need to be addressed in the early stages of establishing an e-business. These steps are necessary to design an e-business effectively while taking the value chain of the specific organisation in consideration.

6.2 Planning an e-business

The most important aspect to consider when planning an e-business, is to remember that everything must not be tried at once. The initial focus should be on the areas that can most immediately gain from the investment. This will result in a clear-targeted starting point being identified, with clear goals and boundaries, which will serve as the foundation from which the other e-business initiatives will flow.

6.3 E-business evolution

Traditionally e-commerce was seen as the external channels beyond the boundaries of an organisation. To be successful in the global marketplace, firms need to consider every aspect of their strategy and operations, being acutely aware of the new range of options that are required to survive, compete and succeed. There are already examples of this seamless and borderless marketplace, where suppliers, distributors, developers and customers converge on the desktop.

Companies making the transition to e-business should consider the evolution of e-business, its impact on the organisation, its partners and its customers. As the e-business evolves, it can progress through multiple stages of maturity. This can be seen in Figure 6.1

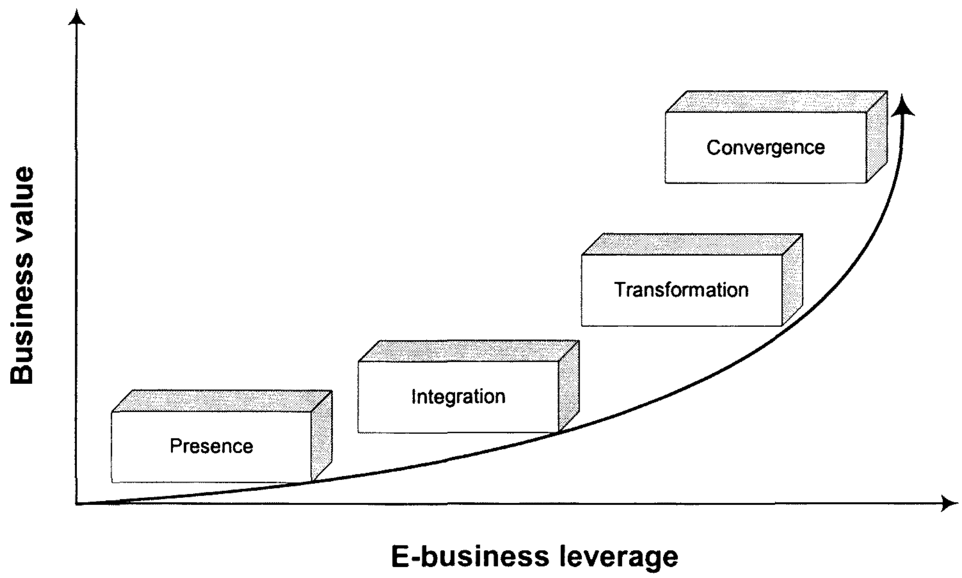

Figure 6.1: E-business evolution

Source: IDC (2000)

Although some companies only establish a presence on the web, there are others that evolve through supply chain integration, industry transformation and convergence between industries. Each of these phases, are briefly explained (PricewaterhouseCoopers LLP 2000).

- **Presence.** The first stage in e-business establishment commonly involves the development of an electronic presence, usually a web site, which presents information about the company, its products and its key differentiators. In the business-to-business environment, this step corresponds with the use of electronic channels, such as EDI, to suppliers and key partners. The goal is to improve timeliness, cost-effectiveness and reach. Risks are small, except for companies deciding to continue evolving.

- **Integration.** In this second stage the e-business model starts to play a major role in the structure of the organisation. Prompt and effective customer service becomes critical to retaining and acquiring customers as companies in this stage continuously try to provide enhanced, more relevant features to their customers. This can only be achieved through closer relationships with suppliers, and by working together with vendors to develop customised content. Competitive advantage can be achieved through a greater exchange of critical information, bringing greater understanding and value to all players. The external factors (regarding tax, legal and risk) start to play a larger role when the organisation enters the global market.

- **Transformation.** In the third stage the company extends itself electronically past its immediate group of suppliers and customers. Core competencies are identified, and the fundamental business processes are transformed to an electronic model. Only the operations that are critical to the market position are retained. This stage also identifies additional challenges, such as knowledge, which becomes shared at a unprecedented level with customers and partners.

- **Convergence.** In the fourth stage the enterprise leverages its knowledge to focus on creating the greatest value for its customers. The enterprise embraces true integration with other partners both within and outside the companies own industries. In this stage, an organisation can become part of a VE that might exist for only a single contract, a single customer or a single instance. Customers gain convenience and choice, and firms benefit from being part of the extended, cross-industry virtual enterprise.

PricewaterhouseCoopers LLP (2000) also identified the following steps that need to be considered when evolving into an e-business environment. These steps are necessary to create a lasting, competitive advantage that generates significant value for the company, its customers and its partners.

- Recognise that e-business is business-driven, and not an IT exercise. A vision must be developed of how the e-business model can create a competitive advantage for the firm, and which markets can be exploited through e-commerce.

- Form an e-business steering committee that spans all business lines. This will create a cross-functional team that will help drive the success of the e-business.

- Build ownership of the e-business strategy. If ownership is secured from all areas of the organisation, it will ensure commitment from all organisational levels facilitating the design.

- Plan the integration of the e-business into individual tasks. Develop goals, targets and milestones, and track progress according to these objectives.

- Determine and manage the tax, legal, privacy and regulatory risks. A competitive edge can be achieved by considering these issues that might possibly not be addressed by competitors.

- Consider people and cultural issues. If the impact of e-business on key stakeholders is understood, plans can be developed to address these issues, enabling a successful transformation into the e-world.

- Identify key business partners for the company. Partners must be identified in areas that can complement the core competencies of the organisation.

Following these steps, the business models in the following sections can be successfully implemented. These steps will assist with the process of establishing the e-business, and will make sure that all the necessary aspects are addressed.

The next section will supply the rationale for the using the Internet as a channel for commerce. It will describe how the Internet can help the customers with their buying (searching) experience.

6.4 Reconstructing the value chain

The Internet offers the possibility of breaking up old structures and creating relationships with new intermediaries. In order to be a successful intermediary on the Internet, it is necessary to add real value to the core product, as the Internet offers many more possibilities to compare product and service offerings of different on-line businesses. Until recently, buying a second-hand house required scouring the newspapers and ringing several estate agents in order to view properties. The estate agents then started presenting their property portfolios on-line, so that it became easier to check market availability. It was however still necessary to look up the web sites of all the estate agents at least weekly to ensure that a new property on the market was not missed. New portal sites are however now available that contain the databases of several estate agents, so all that is needed is to mention the requirements to only a couple of portal sites in order to receive e-mail notification of almost every house on the market in a specific price and area category. It is also possible to check the location of local amenities, such as churches, schools, shops, leisure facilities and so on in this way.

Instead of bypassing the traditional resellers to talk to the end-customers directly, manufacturers can now treat their immediate partners as customers. This can be achieved by offering them access to an Extranet where they can order their products, and allow them to customise the appearance of the web site, into what a company expects from an end-customer web site. The Web offers a great opportunity to expand the business. Michael Dell, the owner of Dell Computers, when asked about how to resolve the channel conflict, once said that the Internet posed no threat to the traditional channels. All that was needed to keep everyone happy, was to increase the number of orders.

By implementing new processes and opening up communication, the supply chain is converted to a true demand-pull supply of goods and services that removes the traditional channels. The Internet may remove the need for intermediaries in the current form, but new intermediaries will appear. By failing to recognise the significance and the possibilities of the Internet, many businesses will be forced out of traditional value chains while their customers and suppliers start to communicate in a more direct way and also start to experience increased margins by dealing directly. By embracing the Internet, its technologies and the new ways and means of dealing with others, every company is now able to offer a better service to existing customers and to build profitable new businesses.

The next sections will give a description of the different business models that can be used by manufacturers to connect with their customers and suppliers.

6.5 Tetteh and Burn's on-line business models

Tetteh and Burn's field of expertise is the promotion of SMEs in the digital market. Their view on SMEs is mostly concerned with business-to-consumer e-commerce, which can be seen in their models. Although this thesis is mostly concerned with B2B commerce, similarities do exist between the different types of e-commerce. In many instances the organisation will start by promoting their product through B2C, until their business model can change through e-business evolution to the B2B model. For the sake of completeness, the models of Tetteh and Burn are included.

Tetteh and Burn's identified three generic business models, namely:

- virtual face;
- virtual alliance; and

- virtual community.

6.5.1 The virtual face

In this model, the enterprise uses the Internet to establish a web presence, and then uses this web presence to advertise itself and its products. Enterprises in this model type are normally single entities trying to establish a global presence.

6.5.2 Virtual alliance

This model takes advantage of the partnership of businesses that forms an alliance both on-line and off-line. The core operations and offerings that these businesses bring to the table, are made possible by sharing resources, competencies and markets. This structure takes advantage of the VE-concept, since this model provides a cost-effective collaborative platform where individual businesses pool their critical resources to achieve the objective of individual businesses through collaboration.

6.5.3 Virtual community

Virtual communities add value through the information the members add onto a basic environment that is provided by the virtual community company. A virtual community can be an important add-on to other marketing operations in order to build customer loyalty and receive customer feedback. In this model, the owner of the virtual community supplies and manages the infrastructure on behalf of the participating businesses. This reduces the need for substantial investments in the technology and infrastructure required for operating a business on the Internet.

6.6 Timmers's eleven models

Timmers's eleven models compliment the models proposed by Tetteh and Burn. Although Timmers's models are developed with the value chain in mind, they hold remarkable similarities to those proposed by Tetteh and Burn. Timmers's models can be seen as an expansion of those proposed by Tetteh and Burn.

A systematic approach to identifying architectures for business models can be based on value chain de-construction and re-construction, that is identifying value chain elements and identifying possible ways of integrating information along the chain (Timmers 1998). This de-construction and re-construction can be described as follows:

- *Value chain de-construction* means identifying the elements of the value chain (primary as well as support activities).
- Interaction patterns are identified, which can be 1-to-1, 1-to-many, many-to-1, or many-to-many. The numbers involved (1 or many) refer to the number of parties involved.
- *Value chain re-construction* is then done, in other words the integration of information processing across a number of steps in the value chain.

The possible architectures for business models are then constructed by combining interaction patterns with value chain integration. Timmers (1998) identified the following eleven types of business models:

- *e-shop* – promotion, cost reduction and additional outlet (seeking demand);
- *e-procurement* – additional inlet (seeking suppliers);
- *e-auction* – electronic bidding (no need for prior movement of goods or parties);
- *e-mall* – aggregators, industry sector marketplace (collection of e-shops);
- *third party marketplace* – common marketing fronted and transaction support to multiple businesses;
- *virtual communities* – focus on added value of communication between members;
- *value chain service provider* – support part of the value chain, e.g. logistics, payments, etc.;
- *value chain integrators* – added value by integrating multiple steps of the value chain;
- *collaboration platforms* – e.g. collaborative design;
- *information brokers* – trust providers, business information and consultancy;
- *trust services*

Each of these models is described briefly in the paragraphs below.

6.6.1 E-shop

The e-shop is usually the starting point for a company or a shop to establish a web presence. The benefits sought after by such companies are: increased demand, a low-cost route to global presence and cost reduction of promotion and sales. The benefits for the customer can be lower prices compared to the traditional offer, wider choice, better information and convenience of selecting, buying and delivery, including 24-hour availability.

6.6.2 E-procurement

This business model is the electronic tendering and procurement of goods and services. The benefits of this model include having a wider choice of suppliers, which is expected to lead to lower costs, better quality, improved delivery and reduced cost of procurement. The benefits to the suppliers include more tendering opportunities, lower cost of submitting a tender, possibilities for tendering in parts, which might be better suited for smaller enterprises, and collaborative tendering.

6.6.3 E-auction

This business model offers an electronic implementation (on the Internet) of the bidding mechanism. This bidding process is also known from traditional auction, and works in exactly the same manner. The benefits for suppliers and buyers are increased efficiency and time-saving, as there is no need for physical transport until the deal has been established, and global sourcing. This model is an excellent way for companies to reduce their surplus stock.

6.6.4 E-mall

An electronic mall consists of a collection of e-shops. Some of the e-malls specialise in terms of a certain market segment, and then become more of an industry marketplace. The benefits for the customer are the same as for e-shops, with the added convenience of easy access to other e-shops and ease of use through a common user interface. The benefits for the e-mall members are lower cost and complexity in order to be on the web, with sophisticated hosting facilities, such as electronic payment, and additional traffic generated from other e-shops on the mall, or from the attraction of the hosting brand.

6.6.5 Third party marketplace

This business model is suitable for companies that wish to leave web marketing to a third party. This model incorporates once-off events, or in the case of business-to-business e-commerce, where an ISP could utilise this model by using their web-building expertise.

6.6.6 Virtual communities

Virtual communities have already been discussed in Section 6.5.3.

6.6.7 Value chain service provider

These companies specialise in terms of a specific function within the value chain (e.g. electronic payment, logistics, etc.), with the intention of making it into their distinct competitive advantage. Revenue is collected on a fee- or percentage-based scheme.

6.6.8 Value chain integrator

The focus of these companies is to integrate multiple steps of the value chain, with the potential to exploit the information flow between those steps as further added value. Revenues are realised from consultancy fees or transaction fees.

6.6.9 Collaboration platforms

Companies in this model provide a set of tools and an information environment for collaboration between enterprises. This model serves as the managing platform for VEs.

6.6.10 Information brokerage

A whole range of new information services are emerging, to add value to the huge amount of data available on the open network or coming from integrated business operations, such as information search, customer profiling, business opportunities brokerage, etc.

6.6.11 Trust services

Companies in this model provide trust services, where a trusted third party provides certification and notarisation.

6.6.12 Eleven models – a summary

These eleven business models are currently found on Internet e-commerce, in the business-to-business sector as well as in the business-to-consumer sector. Some of these models are essentially an electronic re-implementation of traditional forms of doing business, such as e-shops. Many of the others go far beyond the traditional business model, such as value chain integrators and these seek innovative ways to add value through information management and a rich functionality. Creating these new business models is feasible only because of the openness and connectivity of the Internet.

The next section will consider only B2B business models, as considered by Wise and Morrison. The B2B models are the essence of e-commerce for the virtual enterprise. The models used by Wise and Morrison incorporate many of the aspects and elements of the modes that were described in the previous sections; therefore it is necessary to understand them before moving to the next section.

6.7 *Wise and Morrison's B2B models*

Wise and Morrison (2000:89) noted that the transfer of physical goods might be the end result of a business transaction, but in the digital age some of the value has shifted from the product itself to the information about the product. The information that shapes the transaction – price, availability, quality, quantity, etc. – can now be exchanged electronically through e-commerce.

Wise and Morrison (2000:94-95) suggests five business models specifically for the B2B environment, namely:

- mega-exchange;
- specialist originator;
- e-speculator;
- solution provider;
- sell-side asset exchange.

Figure 6.2 describes the position of these models within the B2B environment.

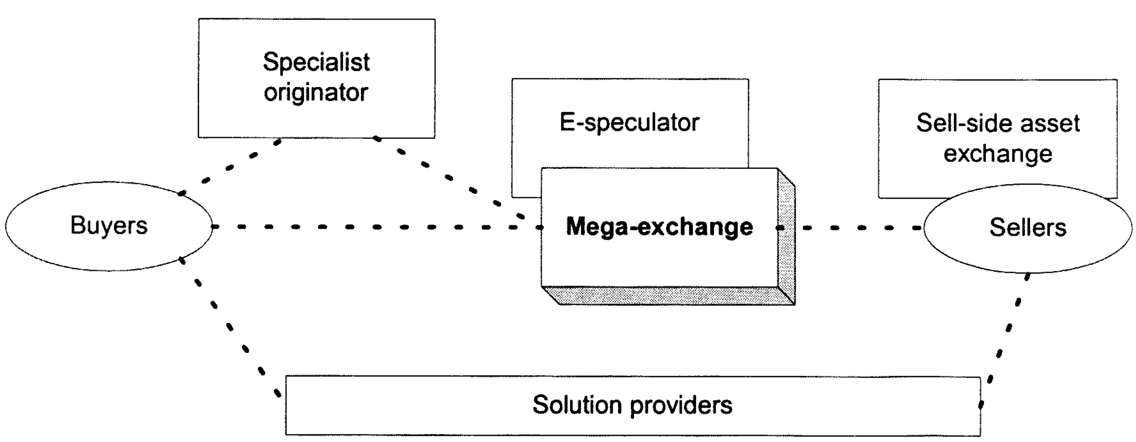

Figure 6.2: The Wise and Morrison models
Source: Wise and Morrison (2000:93)

Each of these models is briefly explained in the following paragraphs.

6.7.1 Mega-exchange

Most transactions on the Internet will go through mega-exchanges, being the hub for business conducted over the Internet. The purpose of the mega-exchange will not be to generate transaction fees and to increase shareholder value, but to benefit the partner B2B organisations through more lucrative e-commerce endeavours, such as origination or speculation.

6.7.2 Specialist originators

These businesses will structure and take orders for complex transactions, aggregate them – i.e. bundle them into large order requests – and then send them to mega-exchanges for execution. This can be achieved by creating standards for trading complicated products and providing real-time support for customers on-line.

6.7.3 E-speculator

The e-speculator will concentrate on relatively standard products that can be transferred easily among a large group of buyers. The advantage will come in the form of better market information than currently available to competitors.

6.7.4 Solution providers

Solution providers will leverage distinctive technical expertise to become indispensable to customers, thus reducing the importance of price in the buying decisions. This model will be used extensively in markets where the product itself represents a small portion of the customer's overall cost, but where the same product heavily influences those costs.

6.7.5 Sell-side asset exchange

In this model, suppliers will trade orders among themselves. In markets where demand and supply are mismatched, it will be to companies' advantage to keep fixed assets fully utilised.

These models are important if a company wants to play a role as a service provider to the B2B e-commerce environment, or simply wants to transact business with other companies over the Internet. It is also important to note that not all products are suited for Internet transactions. There will be certain products and services that will only be sold primarily through personal relationships.

An overview of these models is presented in the following table.

Table 6.1: Overview of Wise and Morrison's B2B models

Model	Key enabling characteristics	Relevant industries or markets	Required capabilities	Sources of competitive advantage	Sources of profit
Mega-exchange	Maximum liquidity Common transaction standards	Most vertical industries Major horizontal purchase categories	Large-scale transaction processing Perceived neutrality	Scope and liquidity Standard-setting	Profits are slim or exchange is of a non-profit nature
Specialist originator	Complex products Relatively expensive products	Electronic and mechanical components Automotive and aircraft components	Strong consultative sales skills Deep product-understanding Strong customer relationships	Deep knowledge of product category Effective use of decision-support software Access to qualified suppliers Ability to bundle transaction volume	Transaction commissions Slotting fees from vendors, exhanges
E-speculator	High degree of product standardisation Moderate to high price volatility	Electric power Chemicals Replacement auto parts	Financial engineering and hedging skills In-depth knowledge of market and market dynamics	Timely market information Transaction scale Alignment with major buyer or seller	Playing the spread Selling hedging instruments to participants
Solution provider	Product cost a small portion of overall costs Product-related issues impact other costs	Specialty chemicals Engineered plastics Cutting tools	Strong technical skills Problem-solving mindset	Brand strength Rich set of offerings Customer lock-in	Higher product markets Valuable add-ons and refills
Sell-side asset exchange	High fixed costs Relatively fragmented supplier and customer base	Transportation Metal machining Construction	Strong supplier relationships Ability to offer additional relevant services Neutrality	Liquidity First mover with key suppliers	Selling ancillary products/services to members

Source: Wise and Morrison (2000:94-95)

Wise and Morrison (2000) states that role specialisation will be key to the future. However, B2B commerce will include a lot more than just facilitating transactions, as the authors suggest. Wise and Morrison (2000) predicts that new roles, ranging from customer profiling and invoice rationalisation to new product development recommendations, will emerge and disappear from the current landscape.

The first role will emerge by combining the visibility of transactions within the mega-exchanges and the value-added services of solution providers. Mega-exchanges will provide invoice consolidation and rationalisation for both buyers and sellers. Mega-exchanges will also have the ability to rationalise and consolidate buyer-seller transactions internal to its network of participants. Rationalisation will drastically improve cash flow, while consolidation will provide deeper transactional information on the set of participants.

Secondly, specialist-originators will not only develop deep product knowledge, but also profound customer insight through profiling. By understanding customer needs, originators will enormously improve buyer-seller matching efficiency. At the extreme, originators could even predict future needs and suggest potential products and services meeting these needs. Programs like Efficient Customer Response (ECR), where suppliers monitor and manage buyers' inventories, could be offered.

Thirdly, the deep knowledge that originators have of customer needs allow them to partner with product innovators and suggest product improvement or even new products.

Lastly, buying groups, as we know them, will disappear. In the past buying groups were able to negotiate benefits regarding price and payment terms by offering their members access to customers. In exchange, the buying group would re-distribute the products (bearing the cost) and invoice individual members. This was a strong value proposition for the sellers, buying groups and buyers. In most of the cases, the seller would lose individual buyer information, a small price to pay for the added profits brought on by the buying groups. As exchanges provide ubiquitous access to both buyers and sellers, logistics and distribution providers or sell-side asset exchanges will perform activities usually performed by buying groups.

E-marketplaces will differ fundamentally from industry, as the former will be driven by unique requirements and business processes. Next-generation e-marketplaces are already emerging, combining the scale of the mega-exchange with the collaborative commerce capabilities required in industries that produce tangible goods. The mega-exchanges serving industries with these characteristics will assume qualities of the solution providers and specialist originators as they leverage the power of the Internet to provide richer functionality and business services.

In the electronics industry, for example, the trend toward outsourced manufacturing has given rise to geographically dispersed design, manufacturing and distribution partners, who are now harnessing the communication and collaboration power of the Internet. Companies are increasingly seeking value discovery rather than pricing pressure, and companies are discovering value through collaboration. This drive toward collaborative commerce will stretch today's definition of liquidity to extend beyond the trade of goods for cash to the agile exchange of intellectual capital. The crucial question facing enterprises today, is whether to invest the substantial time and resources to build their own private e-marketplaces or to outsource the collaborative platform to next-generation e-marketplaces.

6.8 E-commerce hubs

Kaplan and Sawney (1999) define *eHubs* as neutral Internet-based intermediaries that focus on specific industry verticals or specific business processes, host electronic marketplaces, and use various market-making mechanisms to mediate any-to-any transactions among businesses. They further argue that eHubs create value by aggregating buyers and sellers, creating marketplace liquidity and reducing transaction costs.

Large companies need heavy-duty software and infrastructure to support moving their procurement processes on-line. These companies have a set of complex needs, such as integration of e-procurement applications with enterprise resource planning and legacy systems, as well as advanced functionality for workflow, inventory management and the processing, approval, and payment of orders.

In contrast to this, most SMEs do not require such sophisticated B2B functionality, nor can they afford it. As a result, trading hubs that cater for the needs of large companies can now address this problem for SMEs as well. The large companies are attracted to B2B as a way of reducing the costs and lifting the efficiency of procurement by automating the process from the placing of orders to payment. Many of these companies have approached the B2B world by creating trading hubs in partnership with IT integrators, software suppliers, and other large players in the industry. In contrast, SMEs do not have the necessary human or financial resources to establish these gigantic trading hubs, nor do they process the transaction volumes that would make it viable for them to do so.

Third-party portals have stepped into this gap, offering SMEs the benefits of the improved efficiency and access to a larger pool of trading partners that B2B trading hubs can offer them as suppliers of goods and services.

6.9 The value dynamics business models

Boulton, Libert and Samek (2000) use a different approach when designing a business model for the new economy. The new economy is an environment that emerged in the late 1990s and which is the result of numerous convergent forces, such as new communications and Internet technologies, globalisation, industry consolidation, a new generation of people entering the workplace and the increased importance of intangible assets. Their model fits perfectly within the framework of virtual enterprises.

They use a concept called *value dynamics* to construct a business model. Value dynamics is an asset-centric and integrated approach to business strategy, which suggests that the combinations and proportions of assets constituting or representing the business model determine the economic outcomes (Boulton et al. 2000:249). The basis for this is the company's assets, especially the ones necessary for establishing a competitive advantage in a specific industry. Boulton et al. define an asset as follows:

- Assets are *tangible* and *intangible* and extend beyond the balance sheet. They should be located where they will be strategically effective.
- Assets are, therefore, both *owned* and *leased*, controlled and uncontrolled. They offer sources of value that are within an organisation's control and outside it.
- Assets are sources of both *financial* and *non-financial* benefits. Intangible assets, such as customers, provide information as well as cash, from sales revenues. Employees provide skills and ideas, and over a period of time, knowledge and learning. Organisations provide processes and systems.
- Assets have *distinct lifecycles.*
- Assets include *internal* and *external* sources of value. The asset base of the virtual organisation includes numerous external relationships.

Boulton et al. (2000) define five types of assets that can be manipulated namely:

- *Physical assets*, assets that include land, buildings, equipment and the inventory. These are the things that can be seen, touched, counted and weighed, and they are central to strategic decisions about a company's decisions on real estate investments, its productive capacity, the security of its raw material supply and its finished goods inventory.

- *Financial assets* include assets such as cash, receivables, investments and sources of debt and equity. A financial asset is a source of capital that can be exploited to create value.
- *Organisation assets* provide the glue supporting an organisation's ability to compete, and enable it to respond in a coherent way to the challenges offered to the company. Assets within this group include leadership, strategy, structure, values, brand, innovation, knowledge, systems, processes and intellectual property. These assets enable other assets to work with each other. It also provides systems to talk to each other and assists in decisions to mesh with each other. Organisational assets are intangible assets.
- *Customer assets* not only include the end-users of a product or service, but also the company's channels and affiliates. Each of these is an essential link in the outbound value chain that runs from the origination of goods and services to the ultimate consumer. Customer assets are intangible assets.
- *Employee and supplier assets* consist of an organisation's employees, members of its inbound supply chain and its partners. All of these bring or supply skills, knowledge and connections, or products and services. This group of assets is an intangible asset.

The interactions between these assets are presented in Figure 6.3.

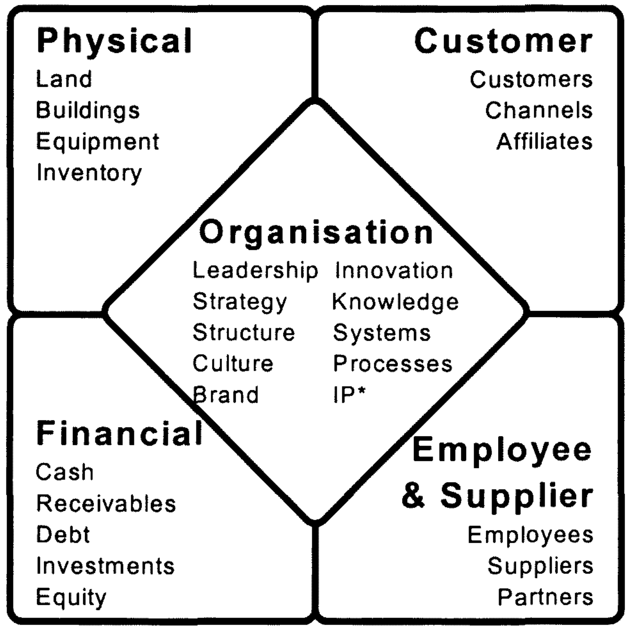

Figure 6.3: Value dynamics

Source: Boulton et al. (2000:29)

IP*: Intellectual property

This framework classifies the assets of the company in five broad categories that provide a method to identify and organise all of a company's sources of value creation. The strength of this framework brings about the expansion of traditional accounting to include both tangible and intangible assets, as well as sources of value inside and outside the organisation.

Each of these asset types plays a vital role in the organisation; it is just the combination that differs. The combinations of assets create new business models never tried before. A shift must occur to move from the old economy to the new economy by using these new combinations of assets. In Figure 6.4, the traditional approach is compared to the approach of managing assets in the new economy.

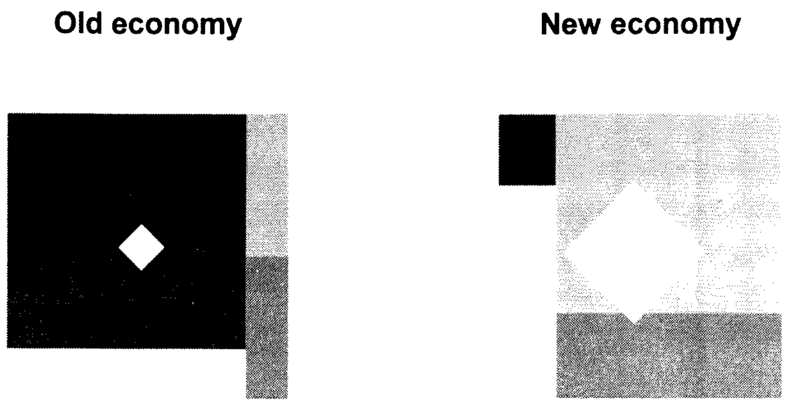

Figure 6.4: Value images – old and new economy

Source: Boulton et al. (2000:151)

In the old economy, the focus was on managing the physical assets. In the new economy, less emphasis is placed on physical assets, and more on customer, organisation, and employee and supplier assets. These combinations of assets must be used to create a business model that links the assets to value creation. A company should make use of its full range of assets, and should not just expect to migrate from left to right, from tangible to intangible, on the value dynamics map (Boulton et al. 2000:150).

The graphical representation of this process is termed *value imaging* (Boulton et al. 2000:151), because it provides a new and visual way of envisioning business models in the past, present and future. Figure 6.4 represents two Value Dynamic maps. The first one is for a company in the old, industrial economy, where investment is made in physical, capital-intensive assets. It is for this reason that the physical assets section of the value image is the largest portion of the figure. The second one represents a business in the new economy (*dot coms*), which is more likely to emphasise investments in intangible assets, like intellectual property, brands, systems and relationships. It is for these reasons that the emphasise is placed on the organisation, employee and supplier, and customer assets by increasing the portion of the area they present.

Value imaging shows which assets a company uses to create value conceptually. Companies could be in completely different industries, but might be quite similar in terms of the assets they use to create value. Each individual company should find the right combination of physical, financial, employee and supplier, and customer assets to create new value. This whole process is not a once-off exercise, but an ongoing process. The market should be evaluated constantly, and new possibilities for creating value should be considered. When new possibilities arise, the whole value dynamics framework can change to incorporate a new business model.

A business model should be designed to create value, and it should be realised that some business models create more value than others. The business model should extend beyond the boundaries of the organisation, considering the value created for customers, employees, and investors. Three aspects should be considered when designing or redesigning the business model for value creation, namely (Boulton et al. 2000:163-168):

- *The assets the organisation are using and the specific value they contribute.* The assets that contribute the most value might not have the highest book value or be the most expensive. Many different sources should be used to identify these assets, since not all of them are tangible or are included in the traditional accounting systems. Informed estimates should be made of the importance of the value of these assets.
- *The assets necessary to succeed in the new economy.* The current business model should be considered and evaluated for a possible increase in the model's value.
- *The asset portfolio strategies necessary to succeed.* This aspect points to the tactics to be followed when implementing a business model. The stategies needed are the following:
  - building assets by developing or creating new sources of value;
  - enhancing assets by introducing performance management systems;
  - connecting different assets (for example by letting customers place orders directly with suppliers);
  - converting an asset to a different function (for example by reconfiguring an idle plant to turn out a new product); and
  - blocking, which means that an asset is exploited to make it more costly and to prevent rival companies from duplicating the specific asset portfolio.

6.10 Return on investment associated with e-commerce

Since only 28% of companies implementing e-commerce report significant revenue increases during the first year of operation (IDC's IT Advisor Service 2000), there are certain procedures that need to be considered before starting with the e-business venture. The results of the ROI study can be useful in determining specific procedures for implementing the e-business model and assigning a value in order to gain a competitive edge over the competition.

The aspects to consider when calculating the return on investment of a new e-commerce venture include, the following (IDC's IT Advisor Service 2000):

- degree of e-commerce functionality;
- data warehousing and data mining;
- integration of e-commerce and legacy applications;
- web site hosting;
- web site design;
- consultant costs (if outside consulting is deemed necessary) for the launch of e-commerce; and
- impact of globalisation.

The first aspect to consider in ROI calculations, is the cost of integrating the business systems. If a company has not already integrated these functions, it will need to create a solid communication link between the back office applications, the supply chain and the system of customer relations. Once these systems have been integrated, the new functions should be added to the process. These include the on-line catalog of goods and services offered, plus any descriptive material, connection to other systems, order entry, return processing, sales functions and payroll system.

The cost of data mining and data warehousing should also be considered during the ROI calculations. These processes will be used by the marketing department to increase revenue; thus the ROI calculations should assess the potential for this increase as well. ROI calculations can also assist with the implementation strategy of the integration of the legacy and web-based systems.

The next aspect to consider, is whether in-house expertise will be used to deploy the e-commerce solution, or whether consultants will be used. The outsourcing decision should also include aspects such as web site hosting, integration of legacy systems with the web front-end and the actual launch of e-commerce. The ROI analysis can be used to assist with the decision whether in-house expertise should be developed, or whether outsourcing would be more cost-effective.

The impact of globalisation can be a source of additional revenue growth from foreign sources. The ROI analysis can determine the growth from these foreign sources relative to the expenses occurred, such as mirror databases in foreign locations (to improve response time), building web sites in foreign languages and currencies, developing currency-conversion routines and international payment processing, and storing of goods locally to control delivery times and costs.

When calculating the ROI, the following should be kept in mind (IDC's IT Advisor Service 2000):

- the annual maintenance cost, as a percentage of development cost, runs between 50% and 100% for most e-commerce sites;
- site promotional cost, on average, runs at about 34% of the annual maintenance cost of an e-commerce site;
- cash flow is used as the basis of ROI calculations. Cash flow is the net total of cash revenues less cash expenses for each year during a project's life;
- three categories of data should be collected: the initial investment, the operating cash flow, and the termination costs at the conclusion of the project;
- ROI is based on the net present value (NPV) after taxes. Before calculating the NPV, assumptions should be made about interest rate, the value of money, and a decision rule by which it can be judged how good the NPV is.

The ROI analysis should include both known and unknown factors, and should use discretion about projected revenues from an untried business model. Although costs are easier to quantify than projected revenues, accurately projecting costs on a new venture, such as an e-commerce effort, requires an in-depth assessment of a firm's current procedures, skills and IT assets, as well as which additional capabilities are required in order to succeed in the e-commerce effort. Assessing benefits requires a detailed examination of a firm's practices and how these might change as a result of the new venture. In addition, revenue estimates depend heavily on the firm's assessment of the industry in which it participates as well as of its own stature and the state of competition, both current and future.

6.11 E-commerce's role in achieving the goals of virtual enterprises

Today's business environment is changing rapidly in terms of the business relationships that are forming. Companies must have the ability to establish strong partnerships and clear communications to form an effective virtual enterprise. ERP systems in the past were unable to provide successful links companies outside of the company operating on the system. The system application were often set up with the purpose of improving transaction processing within a specific company and not outside of it. The shift toward B2B e-commerce puts an emphasis on accessing data that reside in the system of partners, suppliers and customers. Virtual enterprises are more geared for the B2B relationship because these systems provide the means for closer relations between the partners. This is a critical advantage for companies as they move into new methods of doing business that require effective methods of sharing information.

The advances is information technology made it possible for geographically separated shareholders to be joined through electronic networks. The use of e-commerce, and Internet, made it possible for data to be transferred at the same speed as internal departments of a large organisation. It also made supplementary services possible – services like getting the customer involved in the design of the product.

Another advantage of using e-commerce is that it makes the VE boundary-less, the VE are not bound by organisational, geographical or time zone boundaries, because the Internet is present worldwide, and it does not work according to predefined working hours.

6.12 Discussion and conclusion

In the first section of this chapter the evolution of an e-business and the steps required within this evolution were described. It is necessary to understand this evolution in order to know where the e-business will gain its competitive advantage in the future, and what the possibilities for growth are. This first section also includes a description of the necessary steps that must be considered in order to be successful in this evolution.

In the second part of this chapter the reader was introduced to the different business models found in the evolution within e-business. Different B2C and B2B models were discussed, although the focus of this thesis is on B2B. The reason for including the B2C models is that they not only share a lot of similarities with their B2B counterparts, but they are mostly the starting point of the e-business evolution.

The discussion on business models started off with business models designed by Timmer and Tettah and Burn, and concluded with Wise and Morrison's models and e-commerce hubs.

The last two types of business models are more evolved than the first two, and through this evolutionary process, it is the e-commerce hubs that are the vehicle for SMEs, and ultimately virtual enterprises, into the B2B e-commerce environment.

The value dynamics framework was also discussed in this chapter. This framework can be used in e-commerce, but the basic principles are of value to all enterprises, especially the virtual enterprise. This framework could help organisations to identify their assets that can create value, because it takes into account elements other than just financial considerations in decisions. In the final part of this thesis it will be shown that it is these non-traditional (customer, employee and supplier, organisational and physical assets) elements that are used to evaluate performance in virtual enterprises. These assets will introduce productivity, time, flexibility and quality to the performance measurement structure in the new economy, where the traditional financial measures are inadequate.

The final section of this chapter considers the ROI associated with e-commerce. This will assist organisations in their procedures for implementing a specific business model, and could also help these organisations to assign a dollar value in order to gain a competitive edge over their competition.

Chapter 7

ERP as backbone of the virtual enterprise

7.1 Introduction

Before a company can take advantage of the opportunities in the virtual business world, the right platform must exist. The real benefits of e-business and business community integration will only be realised when those solutions are built from the basis of a company' s core enterprise resource planning (ERP) system, integrating all parts of the organisation from research and development (R&D), procurement, manufacturing, logistics, service and support, order administration, sales and marketing, and finance. ERP software equips a company with access to high-quality business information and the ability to act based on a professional analysis of the state of the business. Having an accurate and timely picture of the current business is vital to exploit new opportunities, open the doors to customers/suppliers, and expand the business across traditional organisational boundaries.

7.2 Definition

Kumar and Van Hillegersberg (Tarn et al. 2002:27) defines *enterprise resource planning* (ERP) *systems* as configurable information system packages that integrate information and information-based processes within and across functional areas in an organisation.

ERP is a software system that aims to serve as backbone for the whole enterprise. It integrates key business and management processes to provide a sky-level view of much of the processes in an organisation, the state of these processes, and the organisation as a whole. ERP tracks company financial data, human resource data and (if applicable) all the manufacturing information, such as where inventory is stored, and when it needs to be taken from the parts warehouse to the shop floor.

Although software has been commercially available for all the different processes, the different software packages did not communicate with each other, except with a lot of effort from programmers who needed to rewrite the code. The idea behind ERP is that the software needs to communicate across functions. With an ERP system, the financial software can issue an accounts payable check as soon as the loading dock clerk confirms that the goods have been received in the inventory. Similarly the accounts receivable module can generate an invoice as soon as the shipping clerk says the finished goods are on the truck on the way to the customer. All this can be done with a minimum of human intervention and paperwork.

ERP consists of an integrated collection of pre-configured applications that enable companies to plan and manage resources on a real-time basis. When changes are entered into one module of the system, other related data elements and modules are automatically updated (Kalakota & Robinson 1999:177).

ERP aims to replicate business processes (how to record a sale, how to verify the pay cheques of hourly workers) in software, and guide the employees responsible for those processes step by step through them. In general, ERP aims to automate as many procedures as desired.

One of the great benefits of ERP is *integration*. If a new sales order is added to the system, everything related to the order also changes, including sales commissions, inventory requirements, manufacturing schedules and the balance sheet. With ERP-enabled integration, all employees can use the same information and business processes and get the same results when the system is queried. ERP systems have become fixtures to provide a basis for business management integration across business functions (Tarn et al. 2002:26).

7.3 History and evolution of ERP

Material resource planning (MRP) was introduced in the 1970s to assist with the *master production schedule* (MPS). The MPS specifies the quantity of each finished product required in each planning period. MRP is a production planning and control technique in which the MPS is used to create production and purchase orders for lower level products. During the next decade, MRP evolved into *manufacturing resource planning* (MRP II), which included the functionality of MRP, but also embraced other functions, such as processing and distribution. This integration between functions also made these systems an attractive option for the integration of other functions, such as finance, human resources and project management. It was decided to rename this new integrated functionality to *enterprise* *resource planning* (ERP), since it covered extensive domains (Kalakota & Robinson 1999). An overview of ERP systems including some of the most popular functions within each module, is presented in Figure 7.1 (Chen 2001).

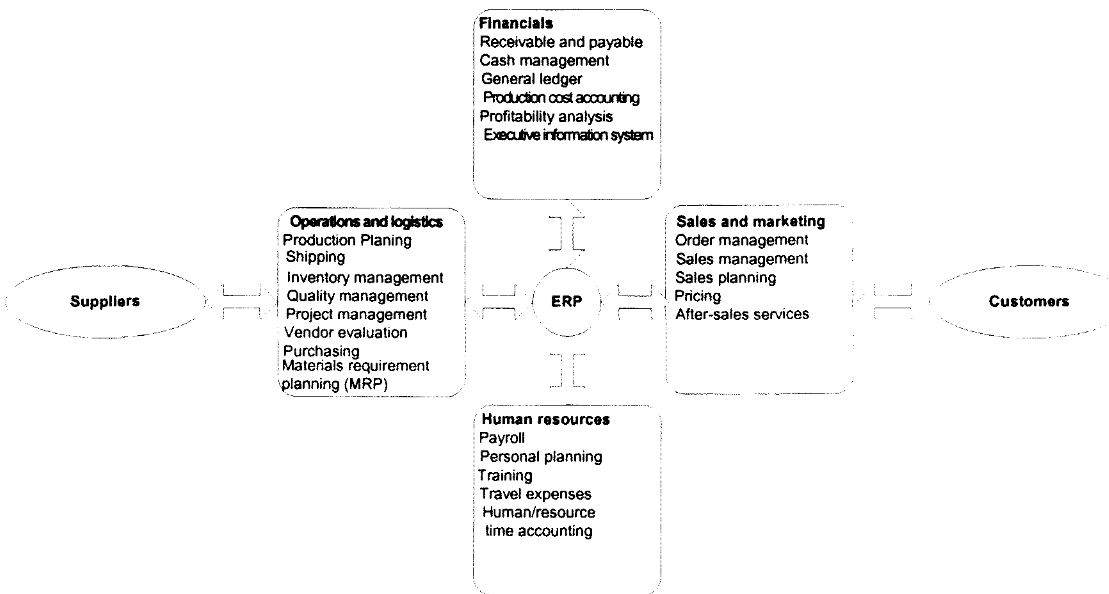

Figure 7.1: Overview of ERP systems

Source: Chen (2001)

Traditional corporate computing typically consist of a 20-year-old general ledger system on a mainframe that is too old and too slow for modern business, the so-called *legacy system*. The old system worked well in its day, when customers expected orders to be executed over several weeks, but today, in the age of overnight delivery and split-second Internet speeds, it is no longer good enough. Top management realises that outmoded systems must be fixed, and fast. Overhauling the antiquated legacy systems is the first step in back-office transformation.

7.4 Integrated back-office applications

The implementation of an ERP system can have significant improvements in operations. Glovia reported the following improvements after implementing an ERP system (Kalakota & Robinson 1999:168):

- sales order processing lead time was reduced from 1 hour to 10 minutes;

- purchase order lead time was reduced first from 10 hours to 4 hours, and then to less than 5 minutes;
- production scheduling run time was reduced from 18 hours to 30 minutes;
- ninety-eight percent of orders are now delivered on time.

Aubrey (Chen 2001) observed that when CSR Wood Panels in Australia implemented QAD's ERP system, they were not only able to reduce their total inventory after the implementation by $37 million per year, but the real value of ERP is now a streamlined delivery process, structural organisational change, and the ripple effect of easily accessible information and heightened customer satisfaction.

These improvements show what is possible with the implementation of an ERP package. However, the ERP decision is very complex, and can make or break a company. Kalakota and Robinson (1999:169) describe the following forces that are driving ERP:

- the need for organisations to create a framework that will improve customer order processing;
- the need to consolidate and unify business functions such as manufacturing, finance, distributions/logistics, and human resources;
- the need to integrate a broad range of disparate technologies, along with the processes they support, into a common denominator of overall functionality;
- the need to create a new foundation on which next-generation applications can be developed. The goal is to deploy application frameworks that reflect current industry practices and which are capable of being supplemented by ancillary applications such as SCM, HRM, E-Procurement, CRM, etc.;
- the need to provide a digital nervous system that can deliver information to those who need it, in real-time, and not with several days or weeks delay;
- the need to manage local activities and to coordinate worldwide operations. With globalisation has come price pressures as customers insist that manufacturers produce higher-quality goods with shorter delivery.

When implemented properly, ERP really works. It streamlines processes, facilitates better co-ordination within an enterprise, improves customer service and enhances a company's bottom line. When trouble strikes, the problem usually lies in the demand for quick fixes and rapid cures to underlying structural problems. ERP suites cannot fix these problems, and companies that do not realise this only incurs more costs.

7.5 ERP and e-commerce

The basic functionality of ERP and the Internet is different. ERP is an integrated transaction-processing system that handles businesses' internal information. The Internet is fundamentally a distribution medium and it does not involve a lot of processing. The information flowing through the Internet is becoming more amenable to processing all the time, with advances like Java and XML. But it is still processed by applications, and the best business applications are still enterprise packages from major vendors.

ERP vendors have been successful in automating what has been or which can be standardised. However, this success has been turned into a criticism, since it tends to impose idealised business processes upon organisations. This results in problems when this standardisation is extended to the Internet.

Firstly, the Internet environment is still a relatively immature one, which means that standards and best-practices are still being formed. Secondly, ERP's standardising characteristic has worked well within the four walls of an organisation, but in the new world of inter-company collaboration, there is a question regarding whether e-commerce versions can deliver the necessary flexibilities. The ERP vendors face big challenges persuading customers to stick with them, as they have found it difficult to meet the demands of companies migrating to e-business. The strength of ERP is in automating companies' internal operations, but the focus of e-business is external, on customers and suppliers.

7.6 Qmuzik

Qmuzik is an ERP suite with its origin in South Africa. Qmuzik was developed to satisfy the requirements of the defense industry in South Africa, where it was required to develop an ERP suite that could simultaneously cater for the engineer-to-order, the make-to-order and the make-to-stock environments. Qmuzik is currently the system of choice for development and training in the Department of Industrial Engineering, University of Stellenbosch and their associated spin-off company, the GCC. The rationale for choosing Qmuzik above other packages, is described in Appendix B.

7.7 Evolving ERP into XRP

Customer relations and customer interactions become the external-focused processes when a company starts doing business over the Internet, rather than simply automating their internal processes. The full e-business functionality that is added to an ERP suite moves beyond just providing read-only access to customer data. This full e-business package can include an e-business Internet server that implements an electronic storefront and provides tight linkages between the web site's catalogue, the order-entry system, the customer database, and other elements and the corresponding ERP suite functionality. This complete package can also include Internet-based supply chain integration, where one organisation's ERP suite can communicate electronically with the corresponding systems of suppliers, distributors and other business partners.

This depth of integration is not merely an automation of operations, but it extends to collaboration and trust that should be built between partners. This has resulted in the formation of a new term to describe the all-encompassing software, *eXtended **R**esource **P**lanning* (XRP). XRP will result in the following improvements that will be seen right through the business:

- supplier management – reduced purchase order processing costs and cycle times;
- inventory management – shorter order-ship-bill cycles;
- supply management – integrated end-to-end supply chain activities at lower cost;
- channel management – tighter targeting of customers and the ability to react to changes in demand by modifying the distribution chain;
- customer asset management – leverage maximum value from customers by on-line sales force automation, customer service and help desk operations.

XRP will supply in the future needs of the evolution of a business. Organisations, even to the extent of the virtual enterprise, will need insight into their suppliers and customers system, and XRP will make this possible. XRP will be the vehicle for the VE to move forward into the new millennium.

The next section will describe how SMEs, that are too small to be able to afford a complete ERP solution, can take advantage of the technologies associated with ERP system.

7.8 ERP in the application service provider (ASP) business model

Small and medium enterprises cannot afford to implement an ERP suite, because of the renowned cost, lengthy lead-times and complexity of installing ERP and other systems. These factors have lead to the creation of application service providers (ASP), where the software vendors do not install and implement the applications in-house, but rather use the ASP to make applications available on a subscription basis. Instead of being sold (licensed) as a product to an enterprise customer and installed on the computer system of the customer, the packaged application software is provided as a service that is hosted at the ASP's data centre and that can be accessed remotely.

An ASP is a firm that manages and delivers application capabilities to multiple entities from data-centres across a wide area network (Ekanayaka, Currie & Seltsikas 2000). In this context, an ASP may be a commercial entity, providing a paid service to customers, or a nonprofit government organisation supporting end-users. ASP solutions are application-centric, which means that the core value of ASPs is to provide access to, and management of, an application that is commercially available.

IT outsourcing is the principle business element used in this model. *IT outsourcing* is defined as a contract which calls for vendors to provide resources for a monetary fee, and that are then deployed under the buyer's management and control (Ekanayaka et al. 2000:193).

This approach allows small companies to use the same applications that the larger companies use, but without incurring the associated set-up and maintenance cost. The ASP model is probably the only practical way for growing SMEs to get sophisticated applications up and running fast. The SME need little or no IT infrastructure. The applications hosted by the ASP require minimal or no customisation.

Another advantage of the ASP model is that acquiring and retaining skilled IT employees – traditionally a problem for SMEs – is no longer the SME's responsibility. The economies of scale of the ASP will result in them being able to acquire and retain highly qualified IT employees. Since the ASP model makes use of a pay-as-you-go model, where companies pay a fixed rate each month for the number of seats (users) they require, it provides companies with a predictable cash flow.

The ASP offering is designed to be a one-to-many solution with limited or no customisation, enabling ASPs and their customers' economies of scale, and thus cost savings. The customers receive the same applications through web-enabling technologies that they would have received by means of the traditional implementation method. This can be seen through the introduction of the web-enabled solutions of the five big ERP-vendors (*J.D. Edwards*, *Baan*, *Oracle*, *Peoplesoft* and *SAP*).

There are, however, some trade-offs in this model. Business processes cannot be implemented in the same way as before. Best-practice models should be used, and SMEs will have to adapt to the practices in these models. Although this is not the perfect way to do this, the cost advantage associated with this model will outweigh the effort associated with changing the current business practices that SMEs are using.

7.9 ERP's role in achieving the goals of virtual enterprises

This section will explain the role of enterprise resource planning (ERP) software in achieving the goals and objectives of virtual enterprises. The main purpose of the ERP system is to serve as a transaction capturing system. In addition to capturing transactional data, the ERP system also captures critical product data.

In the global business perspective, companies are actively expanding outside of their original area to seek new opportunities over the world. While the dynamic and fast changing external environment has put great pressures on companies' operations and decisions, how to react quickly to external changes and how to compete effectively in the global environment becomes crucial. Inside a dispersed company, like a virtual enterprise, it requires building integrated information systems, which allow data transmission across the border of a geographical area to another. Furthermore, the enterprise demands more effective communication between the different partners. The VE want to build corporate applications through which different partners can cooperate more efficiently with each other. They need to establish a streamline business process, which can significantly enhance the communication and cooperation between the partners. To achieve this goal, functional integration is required, which is the process of integrating all business functions. This is achieved by using an ERP system.

ERP systems are configurable information systems packages that integrate information and information-based and across functional areas in an enterprise. In this sense, ERP systems are designed to integrate business functions and allow data to be shared across many boundaries and divisions in an organization. Within the virtual enterprise, the boundaries and divisions are shifted to include the partners that make up the different business units.

The ASP business model (described in the previous section) is a perfect model to use an ERP system in virtual enterprises. Through this web-enabled technology, the product data can be defined and exchanged by all the different partners. All these data will be stored in a central database. It will also aid in the management of marketing, engineering, manufacturing, sales and service data for the virtual enterprise.

The ASP model makes it possible to deliver all product and transaction data in a quick and efficient manner to any of the globally dispersed partners. The partners may be present in geographically dispersed locations, with the possibility of being in different time zones, which make the transfer of data through traditional means very difficult.

The use of an ERP system will aid in data integrity being kept. Data integrity is vital for the effective communication of schedules and product related data between the partners in the Virtual enterprise. The partners responsible for production, customer service, accounting and finance are then able to rely on the information in the system to make more effective decisions. As an example, take the simple ERP function of entering a sales order. After the sales order is entered on a computer, the transactional data go through the entire enterprise. The system then updates the inventory of parts and supplies automatically and worldwide if needed. Production schedules and financial data change as well. Most efficient of all, the employees of the different partners have the information needed just in time to complete their tasks. The feedback of this system is fast, and the salesperson receives information so that he/she can inform the customer of the delivery dates.

7.10 Discussion and conclusion

The ERP system is a critical IT necessity for the virtual enterprise. It is almost impossible to manage globally dispersed business units effectively, producing a single product (or group of products), without the aid of an ERP system. The ERP system will help with the management of the complete enterprise within the VE, including the corporate processing such as manufacturing, accounting and human resource management. As an example, Figure 7.2 presents the reader with the order acquisition and fulfilment process of the 3DBS.

The suppliers will deliver raw materials, and after it has been inspected, it is entered into the *raw materials warehouse*. In the *sales department* of the organisation, a *customer order* is entered. The raw materials are inspected (*goods inspection*), and then entered into the ERP system as raw materials. The *production planning department* will do an MRP run at predefined times, which will schedule *works orders*. After the *works orders* have been released, and the materials dispensed, the products are manufactured. The products are inspected, and if the quality is acceptable, the products are delivered to the customer. If the quality of the products is not acceptable, the products are scrapped. The usable materials are re-entered into the warehouse, and a new *works order* is created. At any stage, the *engineering department* can design a new product, for which the configuration data must be captured to inform all the other departments of this new product.

The ERP system captures all these transactions, and enters the data into a single database. This process shows that the complexity of the ERP system should never be underestimated.

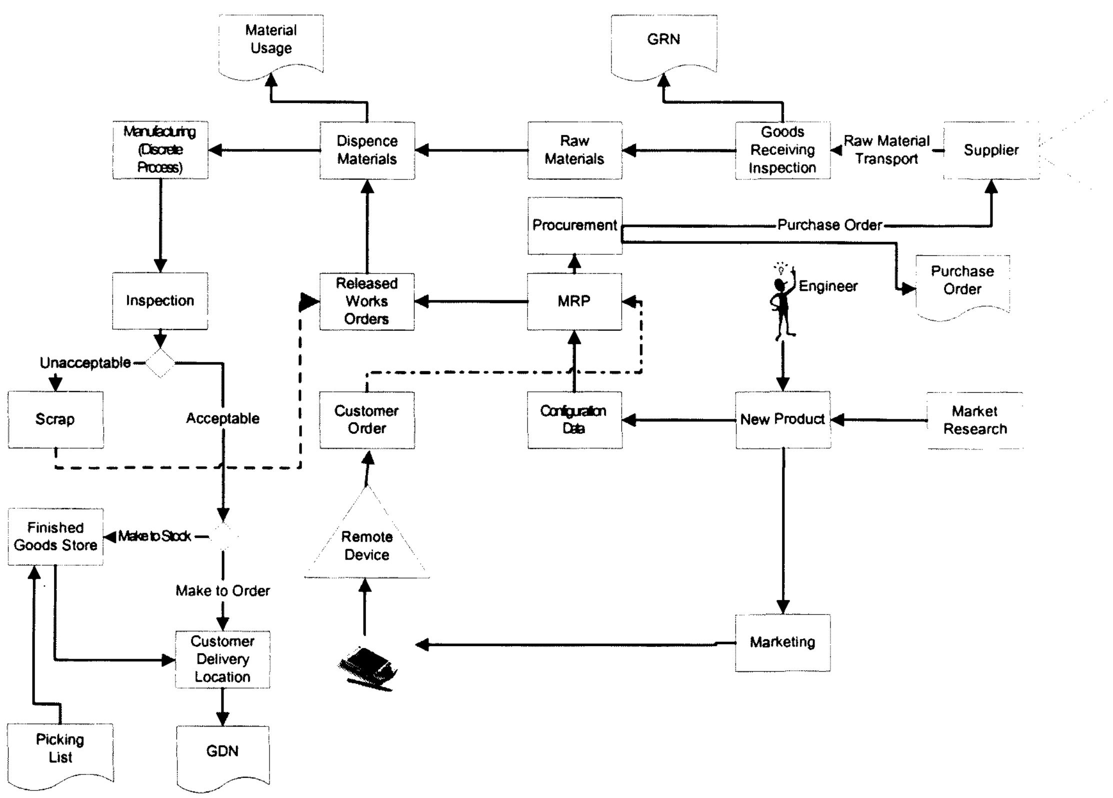

Figure 7.2: Order acquisition and fulfilment process

The ASP ERP business model provides certain additional benefits for the virtual enterprise. Integration of ERP systems between partners will not be necessary, since the partners within the VE will all be using the same ERP system, through the Web. It will also be advantageous from a financial perspective. There will be no additional IT integration costs, and the licensing fees will only be incurred for the lifespan of the virtual enterprise.

Another additional benefit of using an ASP model is that, since the same system is used, reports will be available to all managers of the different business units. The ASP will not distinguish between a VE and a traditional organisation, since from the ASP's viewpoint they will operate exactly the same. Thus, the ASP will consider a VE as a single entity, with users (seats) just logging in from geographically different locations. The rest of the set-up will be the same as for any other "traditional" organisation, including reports on subjects such as performance.

Companies who wish to use the ASP model, but who also want to host their own ERP system can then use the XRP model. The XRP model is not the best choice, but is a good second for companies not prepared to outsource their critical ERP system.

The negative side of using the ASP model is that businesses using this model have to adapt to "best-practice" models from the ASP Providers. This might not be the best possible scenario, but the ease and speed with which this model can be implemented, far outweigh this negative aspect.

Chapter 8

A key performance indicators structure for measuring performance

8.1 Introduction

It is impossible to improve, with certainty and sustainability, operations if they are not measured, and it is impossible to measure something that is not defined. Flapper, Fortuin and Stoop (1996:27) mention that the success and continuity of an organisation depends on its performance, and a good manager needs to keep track of the performance of the system for which he/she is responsible by means of performance measurement.

For the above reasons, this chapter will consider the development of a performance measurement structure. Key performance indicators will be defined for this structure, which will assist in the rapid intervention by management if operations are not operating as planned.

The structure is developed in such a way that it is generic enough to be able to demonstrate the principle use of KPIs in virtual enterprises. The ongoing part of this project within the bigger scope of the operations of the Training Centre will be to be to demonstrate the principles on the 3-D Business Simulator.

The flow of this chapter is depicted in Figure 8.1. Two existing performance measurement systems will be described first. They are the *Balanced Scorecard* and the *Performance Pyramid* (SMART system). Problems in using these two structures for the management of virtual enterprises will be identified, and a new structure, the *Performance Tree*, will be developed. The author will identify and describe key performance indicators to populate the "branches" of the Performance Tree (time, flexibility, cost, quality and productivity) and will then describe how this structure can be implemented in a "dashboard"-manner to indicate when performance is declining.

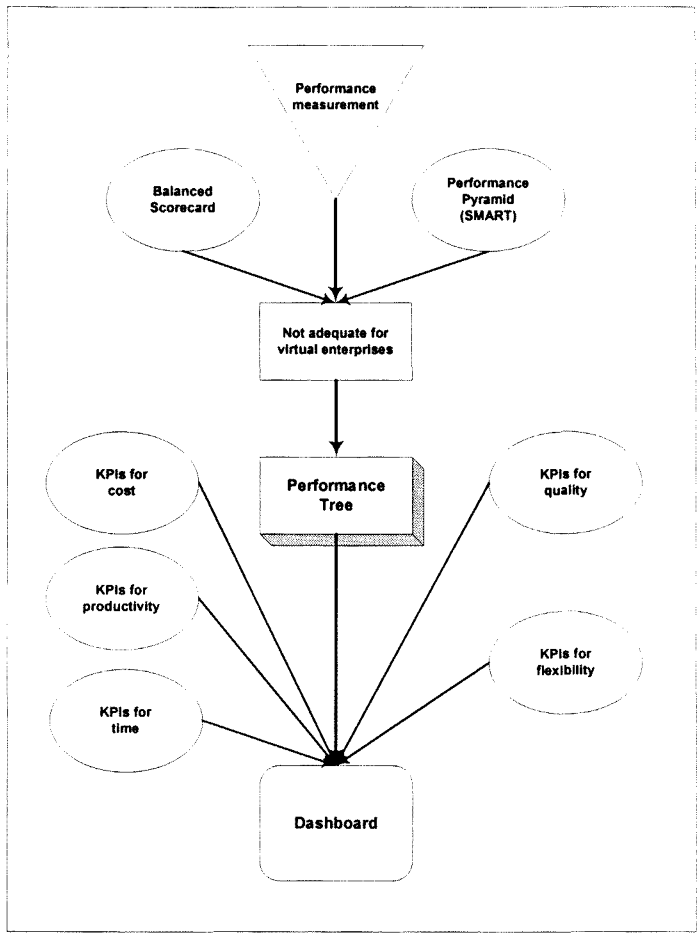

Figure 8.1: Course of Chapter 8

8.2 Definition of performance measurement

Neely, Gregory and Platts (1995:80) define *performance measurement* as the process of quantifying the efficiency and effectiveness of action. In this definition, *effectiveness* refers to the extent to which customer requirements are met, while *efficiency* is a measurement of how economically the organisation's resources are utilised when providing a given level of customer satisfaction.

Flapper et al. (1996:27) define *performance measurement* as the measurement of the way in which the organisation carries its objectives into effect. These two definitions supply the rationale behind the development of the Performance Tree, the structure developed in this chapter.

8.3 Structure for performance measures

Although measurement could be the process of quantification, its effect is to stimulate action, which is only possible through consistency of action (Neely et al. 1995:81).

Many different structures for performance measurements have been designed to meet the challenges of the 21st century. Since the early 1990s consideration has been given to non-financial performance measures to aid the traditional financial performance measures (Jarvis, Curran, Kitching & Lightfoot 2000). While financial performance measurements are important for strategic decisions and external reporting, the day-to-day control of manufacturing and distribution is better handled by means of non-financial performance measures (Gunasekaran, Patel & Tirtiroglu 2001).

This chapter will consider the structures developed during the last decade, and will also propose a new structure for measuring performance specifically in virtual enterprises. This structure will present key performance indicators (KPIs) that can be used to indicate when something is wrong within the organisation and further investigation is required. It is well documented that metrics have to relate to short-time constants, fast feedback and quick decisive action (Bauly 1994:37). These aspects should be considered when developing a performance measurement structure.

The proposed structure is also consistent with the thoughts of Neelay et al. (1995) on the need for performance measures to be defined in terms of quality, flexibility, delivery speed, delivery reliability and cost.

The proposed structure was developed around the framework that is presented in Figure 8.2, which highlights the fact that performance measures can be examined at three different levels (Neely et al. 1995:80):

- the individual performance measures;
- the set of performance measures – the performance measurement system as an entity; and
- the relationship between the performance measurement system and the environment within which it operates.

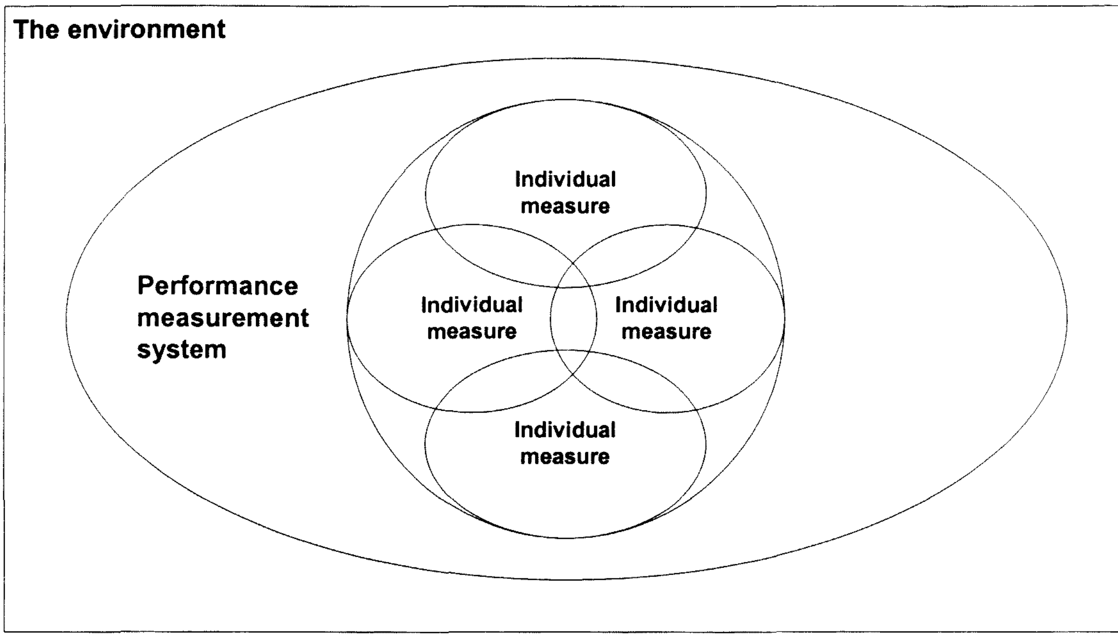

Figure 8.2: Framework for performance measurement system design
Source: Neely et al. (1995:81)

The use of a framework like the above-mentioned one will make sure that the environment that is considered (in this case, a virtual enterprise) is completely measured. At the level of the individual measure, the use of this framework will make sure that the elements measured are analysed with regard to cost, benefit of the measure, reason for measuring, and the specific measures used.

At the next higher level, the system can be analysed by exploring issues such as whether all the appropriate elements (internal, external, financial, non-financial) have been covered, whether the measures relate to rate of improvement, whether the measures have been integrated, and whether any of the measures conflict with each other.

At the highest level, the system can be analysed by assessing the environment within which the organisation is competing. The system is analysed by assessing the strategies of the enterprise, making sure whether the measures are consistent with the existing recognition and reward structure, whether the measures focus on what the competition is doing, and whether the measures focus on customer satisfaction.

Similarly, the thoughts of Maskell (Neely et al. 1995) on the performance measurement system design were also incorporated. These are:

- the measures should be directly related to the firm's manufacturing strategy;
- non-financial measures should be included;
- it should be recognised that measures vary between locations – one measure is not suitable for all departments and sites;
- it should be acknowledged that measures change as circumstances do;
- the measure should be simple and easy to use;
- the measure should supply prompt feedback;
- the measure should be designed so that they stimulate continuous improvement rather than simply monitor.

The developed structure will explore these issues by making use of the guidelines presented.

8.3.1 The Balanced Scorecard approach

The key to managing performance is to introduce non-financial measures to assist with the traditional financial measures. This philosophy has been used with great success by pioneers such as Robert Kaplan and Edward Norton by making use of the *Balanced Scorecard* (BSC). Kaplan and Norton (Van der Merwe 1999) summarise the rationale for the Balanced Scorecard as follows:

> *The Balanced Scorecard retains traditional financial measures. But financial measures tell the story of past events, an adequate story for industrial age companies for which investments in long term-capabilities and customer relationships were not critical for success. These financial measures are inadequate, however, for guiding and evaluating the journey that information age companies must make to create future value through investment in customers, suppliers, employees, processes, technology, and innovation.*

The Balanced Scorecard attempts to take a "balanced" view of the organisation by introducing non-financial perspectives. Arguably one of the greatest strengths of the BSC is this well packaged framework that makes explicit the links between the different dimensions of business performance. This is achieved by considering the following perspectives:

- the learning and growth perspective;
- the business process perspective;
- the customer perspective; and
- the financial perspective.

The interaction between these perspectives can be seen in the following figure.

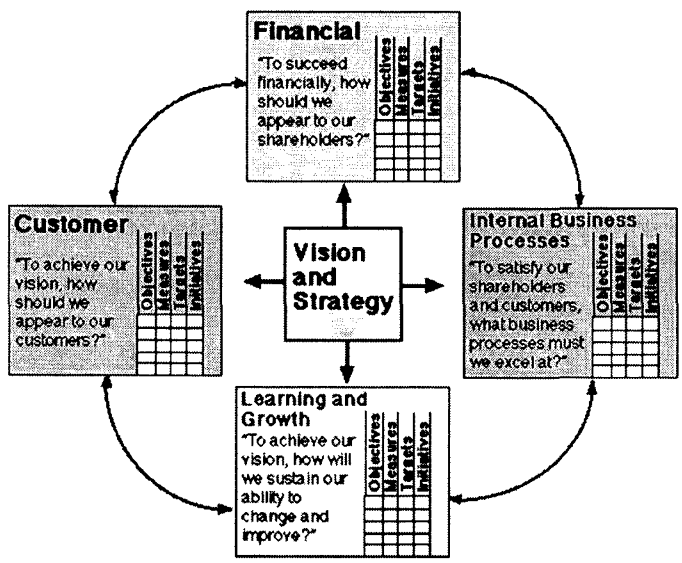

Figure 8.3: Perspectives of the Balanced Scorecard

Source: Balanced Scorecard Council Website

Each of these perspectives is briefly explained:

- **The learning and growth perspective.** This perspective includes employee training and corporate cultural attitudes related to both individual and corporate self-improvement. In a knowledge-worker organisation, people – the only repository of knowldege – are the main resource. It is becoming necessary for knowledge workers to be in a continuous learning mode. Metrics can be put in place to guide managers in focusing training funds where they can help the most. Kaplan and Norton (Van der Merwe 1999) emphasise that *learning* is more than *training*; learning should also include things like mentors and tutors within the organisation, as well as the ease of communication among workers that would allow them to get help on a problem readily when it is needed.

- **The business process perspective.** This perspective refers to the internal business processses. Metrics based on this perspective allow the managers to know how well their business are running, and whether its products and services conform to the customer requirements (the mission). These metrics need to be carefully designed by those who know these processes most intimately. In the context of the unique missions of organisations these are not something that can be developed by outside consultants (Van der Merwe 1999).

- **The customer perspective.** Recent management philosophy has shown an increasing realisation of the importance of customer focus and customer satisfaction in any business (Van der Merwe 1999). These are leading indicators: if customers are not satisfied, they will eventually find other suppliers that will meet their needs. Poor performance from this perspective is thus a leading indicator of future decline, even though the current financial picture might look good.

- **The financial perspective.** Kaplan and Norton (Van der Merwe 1999) do not disregard the traditional need for financial data. Timely and accurate financial data will always be a priority, and managers will do whatever necessary to provide it.

Briefly summarised, the balanced scorecard informs managers about the knowledge, skills and systems that employees will need (*learning and growth*) to innovate and build the right strategic capabilities and efficiencies (*the internal processes*) that deliver specific value to the market (the customer), which will eventually lead to higher shareholder value (*the financials*) (Cumby & Conrod 2001).

The BSC approach will prevent the problems associated with traditional management control. Unlike many management trends, the BSC elevates operational measures – such as on time delivery, order cycle time, product returns, etc. – to an equal status with more traditional measures. Often referred to as "leading indicators", these operational measures can identify trends well in advance of profit and loss results. Therein lies much of the value of a well designed scorecard.

The revised model used in this thesis will consider two of these perspectives: the customer perspective and the business process perspective. A supplier perspective is introduced, since the quality, timeliness and processes of the supplier will ultimately influence the organisation's product, which may in part be a component of the VE's product. The financial perspective will always be a part of any performance indicators, but in the case of virtual enterprises only certain of the financial indicators are of importance. The virtual enterprise is a "short-term" enterprise, and the traditional financial indicators that calculate long-term viability are of no importance.

It is important to note Neely et al.'s (2000) remarks on the Balanced Scorecard. These authors discuss the value of the framework, but also implicitly make clear that it is only a framework. The BSC suggests some areas in which measures of performance might be useful, but provide little guidance on how the appropriate measures could be identified, introduced and ultimately used to manage the business.

One of the reasons for not using the complete Balanced Scorecard is that it is primarily designed for use by senior managers to provide them with an overview of performance. It is therefore not intended for, nor applicable at factory level. Another reason for not using it is that, although the Balanced Scorecard provides a useful framework, there is little underlying it in terms of the process of performance measurement system design. The current literature on the subject does not aid companies in designing a scorecard, and it will be necessary to employ expensive consultants when this process is undertook.

8.3.2 The Performance Pyramid

Lynch and Cross (Neely, Mills, Platts, Richards, Gregory, Bourne & Kennerley 2000) designed a structure they termed the *Performance Pyramid*, which can be seen in Figure 8.4.

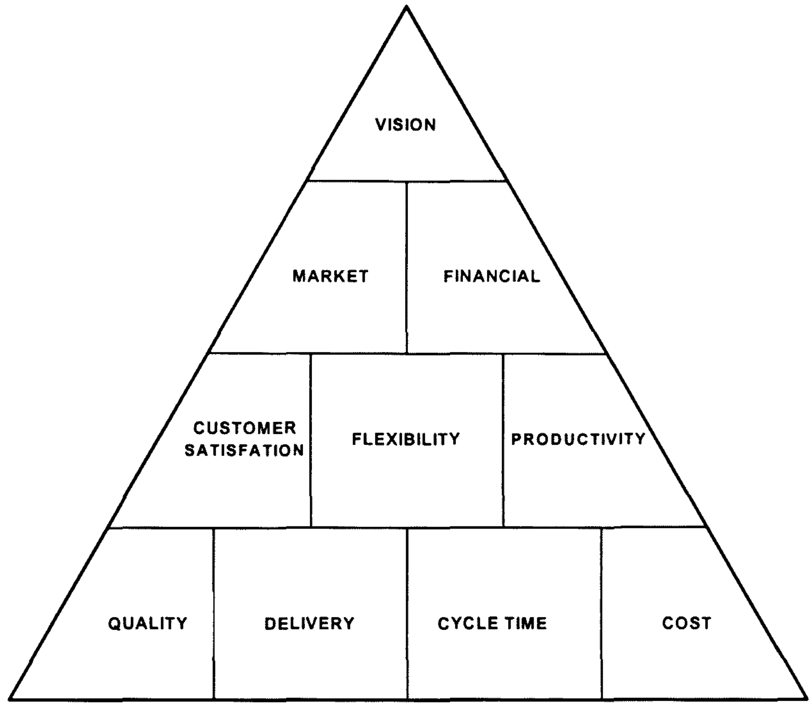

Figure 8.4: The Performance Pyramid

Source: Lynch and Cross (Neely et al. 2000)

The strength of this framework is that it ties together the hierarchical view of business performance measurement with the business process view. It also makes explicit the difference between measures that are of interest to external parties (*customer satisfaction*, *quality* and *delivery*), and measures that are of primary interest within the business (*productivity*, *cycle time* and *cost*).

The performance pyramid was evolved into the SMART (**S**trategic **M**easurement **A**nalysis and **R**eporting **T**echnique) system. At the top is the *corporate vision* or *strategy*. At this level management assigns a corporate portfolio role to each business unit and allocate resources to them. At the second level, objectives for each business unit are defined in *market* and *financial* terms. At the third level more tangible operating objectives and priorities can be defined for each business operating system in terms of *customer satisfaction*, *flexibility* and *productivity*. At the fourth level, the department level, *customer satisfaction*, *flexibility* and *productivity* are presented by specific operational criteria: *quality*, *delivery*, *process time* (cycle time) and *cost*. As the foundation of the performance pyramid, these operational measures are the key to achieve higher-level results and to ensure successful implementation of the company strategy. Ghalayini and Noble (1996) give the following example: *quality* is defined as translating the "voice of the customer" into appropriate company requirements at each stage, from product/service concept to delivery. For marketing and research and delivery this means innovative designs within price and reliability ranges expected by the customer. For production, quality is translated into reliability, aesthetics, and perceived quality.

The SMART system is not used in its entirety within the Performance Tree because it does not provide any mechanism to identify key performance indicators for quality, process time, cost and delivery. Another disadvantage of the SMART system is that it does not explicitly integrate the concept of continuous improvement.

8.4 The Performance Tree

The literature review referred to in the previous sections highlights the fact that despite widespread interest in the topic of performance measurement, little detailed attention has been paid to the question of how managers can decide which performance measures they should adopt. As a result, the author decided to develop a detailed performance measurement system, with the above-mentioned literature as inputs, and utilising the philosophy on which they were built.

The structure proposed by the author will consider financial as well as non-financial indicators. The need for new non-traditional performance measures can be seen in Table 8.1. The structure of this proposed performance measurement system is presented in Figure 8.5.

Table 8.1: Comparison between traditional and non-traditional performance measures

Traditional performance measures	Non-traditional performance measures
Based on outdated traditional accounting systems	Based on company strategy
Mainly financial measures	Mainly non-financial measures
Intended for middle and top managers	Intended for all employees
Lagging metrics (weekly or monthly)	On-time metrics (hourly or daily)
Difficult, confusing and misleading	Simple, accurate and easy to use
Lead to employee frustration	Lead to employee satisfaction
Neglected at the shop floor level	Frequently used at the shop floor
Have a fixed format	Have no fixed format
Do not vary between locations	Vary between locations
Do not change over time	Change over time as the need changes
Intended mainly for monitoring performance	Intended to improve performance
Not applicable for JIT, TQM, CIM, FMS, OPT, etc.	Applicable to JIT, TQM, CIM, FMS, OPT, etc.
Hinder continuous improvement	Help in achieving continuous improvement

Source: Ghalayini and Noble (1996)

The proposed structure considers the SMART system, and combines it with the Balanced Scorecard philosophy. Although the virtual enterprise KPI structure is not in the form of a pyramid, the information in the building blocks of the SMART system is considered within the proposed structure. Due to the form of this proposed structure, it is called the *Performance Tree.*

To measure the performance effectively, it is necessary to develop a model for managing the measurement. The first step is to specify performance targets. An organisation may establish targets based on a range of acceptable performances. Appendix A provides the reader with a target value for each of the identified key performance indicators.

The next step is to normalise the scores to scale. The structure possesses a variety of disparate measures, therefore it is necessary to provide an easy way to integrate them. In the case of this thesis, the scores are normalised to range between –1 and 1.

One of the benefits of the structure is its ability to align disparate operational activities towards achievement of the overall vision of the virtual enterprise. The ability to establish linkages and to organise KPIs into a cohesive model, is critical towards providing this benefit.

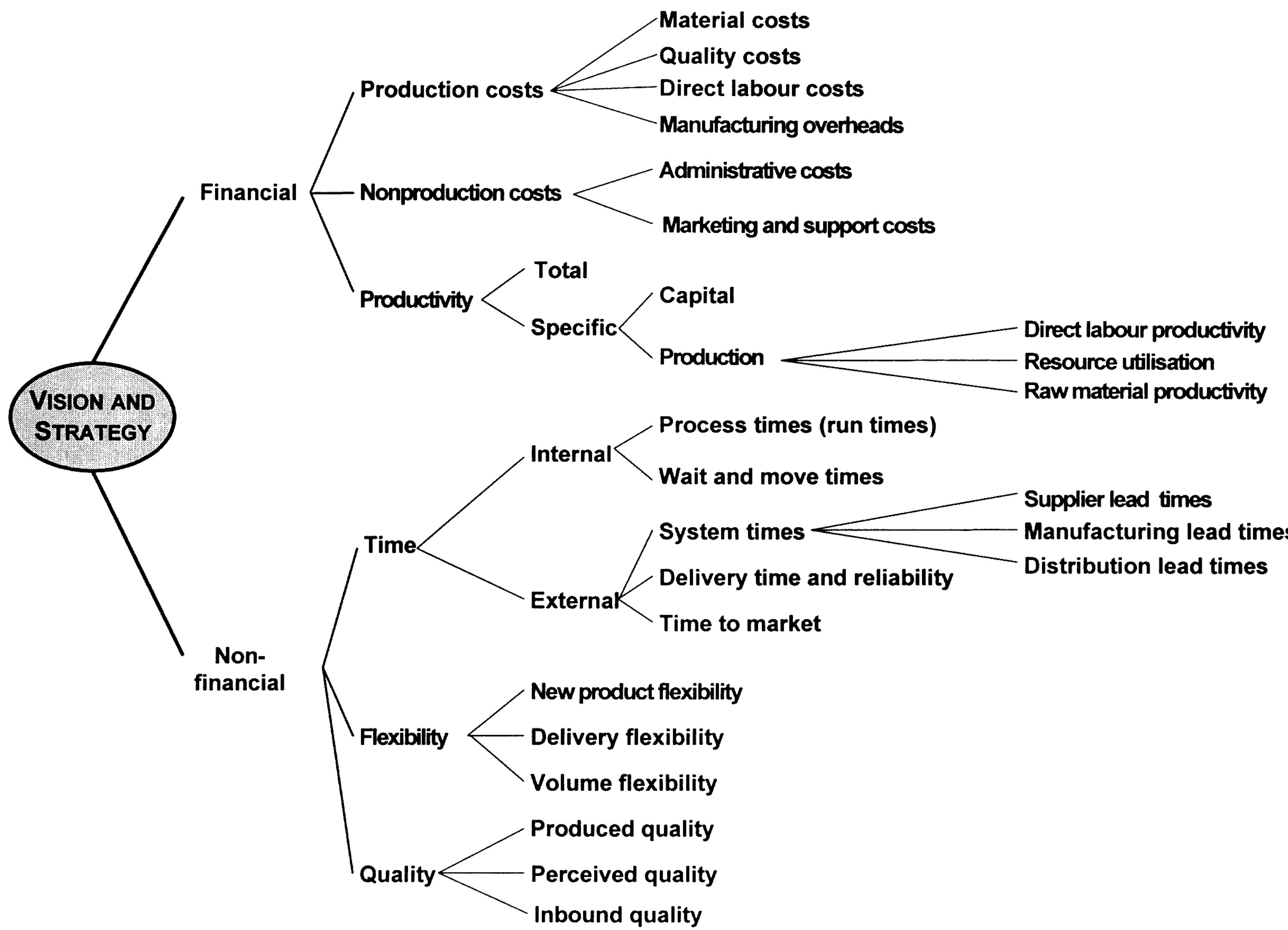

Figure 8.5: The Performance Tree

The building blocks of this structure, as well as key performance indicators for the different critical measures are described in the rest of this chapter.

8.5 Rationale for selecting key performance indicators

The rest of this chapter will present the reader with a complete model for measuring performance within a virtual enterprise. To help with these performance measurements, key performance indicators (KPIs) will be used. The purpose of KPIs is to indicate, within a specified range, the state of the element under consideration. It is important that these indicators should be quantifiable, and as little as possible subject to user interpretation. Therefore, KPIs will only be selected if they are easily measurable and quantifiable, and if there is very little chance of subjective interpretation.

8.6 Financial performance measures

The financial performance measures consider the following inputs:

- production costs;
- non-production costs; and
- productivity.

Each of these inputs is described in the paragraphs below.

8.6.1 Production costs

This section will make use of cost standards (or standard costing), because standard costing makes it possible to set objectives, and then to measure the variance relative to a standard – that is, what should have happened and what actually did happen. This is the method Dornier, Ernst, Fender and Kouvelis (1998:388) prefer for evaluating performance in global operations and logistics, a field that shares a lot of similarities with virtual enterprises. Cost standards can be used to determine the efficiency and effectiveness of the activities performed by the organisation. It is for this reason that the author decided on standard costing for evaluating the production costs. Although Neely et al. (1995) argue that this will result only in short-term control, it is the opinion of the author that long-term control and financial viability is not of any concern to the virtual enterprise, but rather that of the individual companies of which the VE consist.

Another reason for choosing standard costing is the legal form of the virtual enterprise. Since there are no legal agreements between the different partners of the VE, there are no financial statements for the complete virtual enterprise. This excludes the extremely well documented and widely used financial ratios structure developed by the Du Pont Powder Company, the *Du Pont Pyramid of Financial Ratios*.

8.6.1.1 Cost of Quality

Quality costs are categorised as (Angell & Chandra 2001:112):

- *the price of conformance*, which includes both prevention and appraisal costs, and
- *the price of non-conformance*, which includes internal and external failure costs.

Investment in *prevention costs* seek to eliminate the opportunity for quality defects by supporting activities such as quality programme management, training and education, quality promotion, process capability studies, failure mode and effect analysis, quality and function deployment, design of experiments, design for manufacturing, market research, internal and external customer surveys, quality planning, supplier certification programmes, preventative maintenance and cross-functional design teams.

The price of non-conformance includes *internal* and *external failure costs*. *Internal failure costs* are costs that occur when defective goods are still in the factory before shipment to customers. *External failure costs* appear when poor quality products are shipped to customers. These costs cover activities such as complaint adjustment, receipt and replacement of defective products, warranty charges and allowances or concessions made to customers for their trouble. Unfortunately, many external failure costs are unknown and unknowable, so that even with eventual perfect product quality, these intangible costs can linger due to the high multiplier effect of customer dissatisfaction (Angell & Chandra 2001:113).

8.6.1.2 Direct material costs

Direct materials are those materials that form an integral part of the finished product and that can be physically and conveniently traced into it.

The *material price variance* measures the difference between what is paid for a given quantity of materials and what should have been paid according to the standards that have been set. The formula for this variance is presented in Appendix E (equation E.1).

There are many factors that influence the prices paid for raw materials: the size of the lots purchased, delivery method, quantity discount available, rush orders and the quality of materials purchased, to name a few.

The *material quantity variance* measures the difference between the quantity of materials used in production and the quantity that should have been used according to the standard that has been set. The formula for the materials quantity variance is presented in Appendix E (equation E.2).

The *material quantity variance* is best isolated at the time that materials are placed into production. Materials are drawn for the number of units to be produced, according to the standard bill of materials for each unit. The m*aterials quantity variance* calls attention to the excessive use of materials while production is still in process and provides an opportunity for early control of any developing problem.

The excessive use of materials can result from many factors, including poor quality of inbound materials, faulty machinery, untrained workers or poor supervision. Generally speaking, it is the responsibility of the production department to see to it that the use of material is kept in line with standards. Quantity variance could also be ascribed to the purchasing department who might have bought inferior quality raw materials in order to economise on price, where these materials then proved unsuitable for production.

8.6.1.3 Direct labour costs

Direct labour costs are those labour costs that can easily and conveniently be traced to products. It is also referred to as *touch labour*, since the direct labour workers typically touch the product while it is being made.

The price variance for direct labour is commonly termed a *labour rate variance.* The formula for labour rate variance is presented in Appendix E (equation E.3).

In most organisations, the rates paid to workers are quite predictable; therefore, rate variances, in terms of the amounts paid to workers, tend to be almost non-existent. Rate variances can arise, through the way labour is used. Skilled workers with high hourly rates of pay could be used for duties that require little or no skill and this could then call for low hourly rates of pay. This will result in unfavourable labour rate variances, since the rate paid for actual labour hours will exceed the standard rates authorised for the particular task being performed.

A reverse situation can occur when unskilled or untrained workers are assigned to jobs that require some skill or training. The lower pay scale for these workers will result in favourable rate variances, although the workers could be highly inefficient in terms of output. It is also possible that unfavourable labour rates can arise from overtime work at premium rates if any portion of the overtime premium is added to the direct labour account.

The quantity variance for direct labour, more commonly referred to as the *labour efficiency variance*, measures the productivity of labour time. The formula for this measure is presented in Appendix E (equation E.4).

The possible causes for an unfavourable labour efficiency variance include poorly trained workers; poor quality materials, requiring more labour time in processing; faulty equipment, causing breakdowns and work interruptions, and poor supervision of workers.

8.6.1.4 Manufacturing overheads

Manufacturing overheads include all costs of manufacturing, except direct materials and direct labour. It includes such items as indirect materials, indirect labour, maintenance and repair on production equipment, water and electricity, property tax, depreciation, etc. on manufacturing facilities. Water and electricity, property tax, depreciation and others are however associated with selling and administration functions and are therefore not included as part of manufacturing overheads.

The *variable overhead spending variance* measures deviations in the amounts spent for overhead inputs, such as utilities. The formula for this variance can be seen in Appendix E (equation E.5).

Two things affect the overhead spending variance. First, a spending variance may occur simply because of price increases over and above what is shown in the flexible budget. This means that the prices paid for overhead items may have gone up during the year, resulting in unfavourable spending variances. Secondly, the overhead spending variance is affected by waste or excessive usage of overhead items.

The *variable overhead efficiency variance* is a measure of the difference between the actual activity in a specific period and the standard activity allowed, multiplied by the variable part of predetermined overhead rates. The formula for the measure can be seen in Appendix E (equation E.6).

The term *overhead efficiency variance* is a misnomer, since this variance has nothing to do with efficiency in the use of overheads. What the variance really measures, is how efficiently the base underlying the flexible budget is being utilised in production. If more hours are worked than are allowed at standard, then overhead efficiency variance will be unfavourable to reflect this inefficiency. As a practical matter, this inefficiency is not in the use of overhead, but rather in the use of the base itself. This measure is hardly ever used since flexible budgets are not frequently used by organisations.

8.6.2 Key performance indicators for production costs

The KPIs defined for the above production costs will make use of standard costing. The KPIs identified are:

- direct materials price variance;
- material quantity variance;
- labour efficiency variance; and
- variable overhead spending variance.

These KPIs are easily measurable, and the data can be found through the standard ERP system. It is important to understand the ERP software in such a manner that the correct data are extracted.

8.6.3 Non-production costs

Generally, non-manufacturing costs are sub-classified into two sections:

- marketing and selling costs; and
- administrative costs.

Each of these sub-classifications will be briefly explained in the following paragraphs.

8.6.3.1 Marketing and selling costs

Marketing and selling costs include all costs necessary to secure customer orders and to get the finished product in the hands of the customer. Examples of marketing costs include advertising, shipping, sales travel, sales commissions, sales salaries and costs regarding warehousing of finished goods.

8.6.3.2 Administrative costs

Administrative costs include all executive, organisational and clerical costs associated with the general management of an organisation rather than those costs associated with manufacturing, marketing or selling. Examples of administrative costs include costs regarding executive compensation, general accounting, secretarial, public relations, and similar costs involved in the general administration of the organisation as a whole.

8.6.4 Productivity

Productivity is conventionally defined as the ratio of total output to total input. Thus, productivity is a measure of how well resources are combined and used to accomplish specific, desirable results. Ruch (Neely et al. 1995) has pointed out that higher productivity can be achieved in a number of ways, including:

- increasing the level of output faster than that of the input (*managed growth*);
- producing more output with the same level of input (*working smarter*);
- producing more output with a reduced level of input (*the ideal*);
- maintaining the level of output while reducing the input (*greater efficiency*);
- decreasing the level of input, but decreasing the level of input more (*managed decline*).

Productivity measurement is an important tool for evaluating a business unit's performance through production activities (Chen & Liaw 2001:1180).

Productivity measures are dived into:

- Total productivity, and
- Specific productivity

8.6.4.1 Total productivity and specific productivity

Problems arise with the measurement of productivity, because it is difficult not only to define inputs and outputs, but also to quantify them. Craig and Harris (Neely et al. 1995) suggest that firms should seek to measure total, rather than partial, productivity. This point was later emphasised by Hayes et al. (Neely et al. 1995) when they described how firms could measure total factor productivity.

Total Factor Productivity (***TFP***) is defined in Appendix E (equation E.7).

TFP can be reformulated to involve labour productivity (L_p) and capital productivity (C_p), which are partial indices measuring the value added per unit of labour input and per unit of capital input, respectively (Chen & Liaw 2001:1182). The labour productivity (L_p) and capital productivity (C_p) are defined in Apendix E (equations E.8 and E.9).

8.6.5 Key performance indicators for productivity

The KPIs identified for productivity include the following:

- TFP (total factor productivity);
- C_p (capital productivity);
- L_p (labour productivity).

All of the above are well documented measures that are in use in a variety of leading-edge organisations that want to measure the performance of their productivity. It was for this reason that the author decided to include these KPIs in the structure.

8.7 Non-financial performance measures

Three non-financial performance measures have been identified by the author, namely:

- flexibility;
- time; and
- quality.

Each of these measures is explained below.

8.7.1 Flexibility

The dimensions of flexibility is range and response, where *range* refers to the issue of how far the manufacturing system can change and *response* focuses on the question of how rapidly and cheaply it can change (Neely et al. 1995).

Beamon (1999) gives a complete description of the four flexibility indicators. They are:

- *volume flexibility*, a measure of the proportion of demand that can be met (Beamon 1999:287);
- *delivery flexibility*, the ability to move planned delivery dates forward to accommodate rush orders and special orders (Beamon 1999:288);

- *mix flexibility*, a measure of the range of different product types that may be produced during a particular time period, or the response time between product mix changes (Beamon 1999:289); and
- *new product flexibility*, defined as the ease with which new products introduced (Beamon 1999:289).

Each of these measures is described in more detail in Appendix E (equations E.10 through E.22).

8.7.1.1 Key performance indicators for flexibility

The key performance indicators defined for flexibility are:

- volume flexibility (F_v);
- delivery flexibility (F_D); and
- mix flexibility(F_M).

Volume flexibility is a measure of the percentage of demand that can be met, while *delivery flexibility* is a measure of the ability of the organisation to accommodate rush orders and special orders. The *mix flexibility* is an indicator that is very difficult to measure, but it gives an indication of a SME's agility within a virtual enterprise. All of these measures are of importance for the virtual enterprise, since they represent the measures that are most important to customers, and the VE as a whole, with regard to flexibility. The volume flexibility and delivery flexibility are both measures that represent ratios of the customer's perceived view of flexibility.

8.7.2 Quality

This section will concentrate on performance measures that measure both the output, and the process itself. The author identified three types of quality measures:

- produced quality;
- perceived quality; and
- inbound quality.

Each of these measures is explained briefly.

8.7.2.1 Produced quality

Produced quality can be measured through the effective use of statistical process control (SPC) and the number of defective goods returned during the warranty period. The purpose of the SPC is to control the scrap and the discards in the manufacturing process through the use of tools such as control charts, Pareto charts (a tool for classifying process upset causes), process capability indices, etc.

A measure for produced quality is the number of defective parts per million. The formula is described in Appendix E (equation E.23).

8.7.2.2 Perceived quality

The *perceived quality* is the reputation, image, product capabilities, service, speed of delivery, dependability or other inferences regarding the attributes of a product as perceived by the customer. It is a very subjective measure since it is a measure that is extremely difficult to capture. Surveys need to be conducted to accumulate the necessary data required to make decisions based on the perception of customers about the quality of the product. After changes have been made, it is necessary to conduct a completely new survey to evaluate these changes.

Perceived quality is used in determining value in the marketing field. *Value* is defined as the ratio of perceived quality to price: higher value is obtained when the customer gets greater perceived quality for a particular price, or the same perceived quality for a lower price (Meredith, McCutcheon & Hartley 1994:8).

8.7.2.3 Inbound quality

Inbound quality is the most important aspect of quality for the virtual enterprise. The VE's structure is made up of a variety of small firms, each producing that part of the final product for which their business unit is responsible. The quality of the component for which each individual business unit is responsible, interacts with the downstream operations in the other partner firms. The inbound quality is calculated so that different business units can be evaluated against one another.

The measure for produced quality is used in inbound quality through *data envelope analysis* (DEA), which is a linear-programming-based methodology that can evaluate multiple inputs and multiple outputs to calculate a ratio (*performance measure*) of total weighted output to total weighted input. This ratio is the relative efficiency of a decision-making unit (DMU). A DMU can be any economic agent with limited resources, and which is aspiring to attain specified performance goals with as few inputs as possible (Forker & Mendez 2001: 197).

The strength of this measure is that DEA calculates a combined index of overall performance using multipliers (weights) that maximise each DMU's efficiency score, relative to other DMUs (firms) in the comparison set. This means that the multipliers can vary from firm to firm, which allows the comparison of the account for structural differences among organisations. The formula is described in Appendix E (equations E.24 and E.25).

8.7.2.4 Key performance indicators for quality

The KPIs identified by the author for quality are:

- produced quality; and
- inbound quality.

The perceived quality is extremely difficult to measure (since it is very subjective), and is not included as a KPI. The other two indicators are of extreme importance to the VE's quality of its products, and must therefore be included.

8.7.3 Time

Time has been described as both a source of competitive advantage and as the fundamental measure of manufacturing performance (Neely et al. 1995). This statement can be justified by considering *just-in-time* (JIT) manufacturing and *optimised production technology* (OPT). Under the JIT manufacturing philosophy the production or delivery of goods just too early or just too late is seen as waste. Similarly, one of the objectives of OPT is the minimisation of throughput times.

The importance of time must never be underestimated. For all businesses, *profit* is a function of the time taken to respond to the needs of the market. This in turn means that profitability is inversely proportional to the level of inventory in the system, since the response time is itself a function of time. The rate at which a product contributes money determines the relative product profitability, and it is the rate at which a product contributes money compared to the rate at which the factory spends money that determines absolute profitability (Neely et al. 1995).

Time is categorised as either *internal time* or *external time.*

8.7.3.1 Internal time

There are two types of internal times:

- process time; and
- wait and move time.

Each of these sub-classifications is described in more detail below.

8.7.3.1.1 Process time

Process time is the amount of time in which work is actually done on the product.

8.7.3.1.2 Wait and move time

Wait time include *inspection time* and *queue time. Inspection time* is the amount of time spent to ensure that the product is not defective, while *queue time* is the amount of time a product spends waiting to be worked on, to be moved, to be inspected, or in storage waiting to be shipped.

Move time is the time required to move materials or partially completed products from workstation to workstation.

8.7.3.2 Key performance indicators for time

The internal times can be classified as *value-added time* and *non-value-added time.* The classification of the value and- non-value-added times is given below, each with the activity times classified under them.

- Value-added time
    - process time;
- Non-value-added time;
    - set-up time;
    - wait time;
    - inspection time;
    - move time; and
    - queue time.

The *throughput time*, which is considered a key measure in delivery performance, can be evaluated by computing the *manufacturing cycle efficiency* (MCE) as described in Appendix E (equation E.26).

8.7.3.3 External times

External times are classified according to the following sub-classifications:

- Time to market;
- Delivery speed and reliability; and
- System times, which are sub-classified into
    - supplier lead time;
    - manufacturing lead time; and
    - distribution lead time.

Each of these sub-classifications is described in more detail below.

8.7.3.3.1 Time to market

Time to market is the time to engineer a product to order (see Figure 8.6). In this environment, the following lead times must be considered:

- development lead time;
- procurement lead time;
- production lead time; and
- distribution lead time.

The opportunity for organisations in this environment to reduce total lead time begins with the reduction of product lead times.

8.7.3.3.2 Delivery speed and reliability

The *delivery speed* is the time required to carry out orders. The *delivery cycle time* is the time from receipt of an order from a customer to the shipment of the finished goods. This measure is called the *delivery time* (***DT***) (Bartezzaghi, Spina & Verganti 1994:5). This measure can be rewritten as the inventory turnover. *Inventory turnover* is the number of times the average inventory balance has been used (and thereby replaced) during a specified time period. It is described in detail in Appendix E (equation E.27).

8.7.3.3.3 System times

Lead times are divided into:

- development lead time (LT_e);
- procurement lead time (LT_p);
- production (manufacturing) lead time (LT_m); and
- distribution lead time (LT_d).

The interaction between the product stages and the product environment with regard to lead times is graphically represented in the following figure. It is important to note that some of the product stages can overlap (it is possible that production can start while the procurement of non-critical components is still being done, and the same with fabrication and assembly).

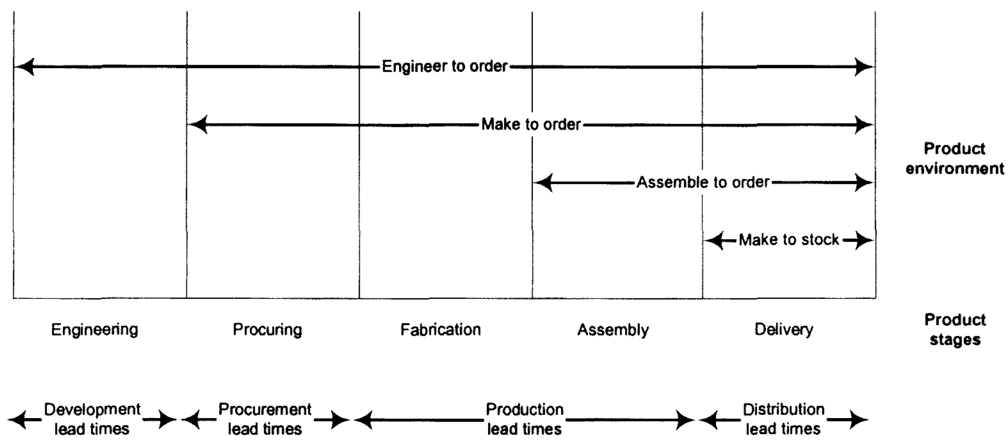

Figure 8.6: Interaction between product environment and product stages w.r.t. lead time
Source: Tersine and Hummingbird (1995:12)

Development lead time

The *development lead time* (LT_e) is the time associated with conceptualising a new product.

Procurement lead time

Procurement lead time (LT_p) is the time associated with the procurement stage in a product. It is an external time since it is dependant upon suppliers and other external influences.

Manufacturing lead time

Manufacturing lead time (LT_m) is the time associated with fabrication and assembly (for assemble to order products).

Distribution lead time

Distribution lead time (***LT_d***) is the time associated with delivery of the final product, and is present in all products.

8.7.3.4 Key performance indicators for lead time

The KPIs that are identified for lead time are:

- the *development efficiency* (***D_e***), a measure for organisations that regularly develop new products (Appendix E describe the calculation of this KPI); and
- the *capacity ratio* (***CR***), which a measure of the efficiency of capacity planning.

These two measures are described in detail in Appendix E (equations E.28 through E.31).

8.8 The Performance Measure Record Sheet

Neely, Richards, Mills, Platts and Bourne (1997) developed a framework that ensures that the measure is clearly defined and based on an explicitly defined formula and source of data. The framework consists of ten elements – title, purpose, relates to, target, formula, frequency, who measures, source of data, who acts on the data, what do they do, and notes and comments. These ten elements are briefly explained below (Neely et al. 1997):

- **Title.** The title of the measure should be clear. A good title is one that explains what the measure is and why it is important. The title should be self-explanatory and should not include functionally specific jargon.

- **Purpose.** If a measure has no pupose then it can be argued whether it should be introduced at all. It is therefore important that the rationale underlying the measure, should be specified.

- **Relates to.** As with purpose, if the measure being considered does not relate to any of the business objectives, then it can be questioned whether the measure should be introduced. Hence the business objective to which the measure relates, should be identified.

- **Target.** The objective of any business is a function of its owners and its customers. The levels of performance the business needs to achieve to satisfy these objectives, are dependant on how good the company's competitors are. Without knowledge of how good the competition is and without an explicit target, which specifies the level of performance to be achieved and a time scale for achieving it, it is impossible to assess whether performance is improving rapidly enough and hence whether the business is likely to be able to compete in the medium to long term.

- **Formula.** It is important that the formula should be defined in such a manner that it induces good business practice. Appendix E of this thesis defined these formulas.

- **Frequency.** The frequency with which performance should be recorded and reported, is a function of the importance of the measure and the volume of the data.

- **Who measures?** The person who should collect and report the data should be identified.

- **Source of data.** The source of the raw data should be specified. The importance of this question lies in the fact that a consistent source of data is vital if performance is to be compared over time.

- **Who acts on the data?** The person who acts on the data, should be identified. Different values within the measurable range might require different persons to act on the data, which must also be identified in this element.

- **What do they do?** This is the most important measure on the performance measure record sheet, not because it contains the most important information, but because it makes explicit the fact that unless the management loop is closed, there is no point in having the measure. The general management process that will be followed if the indicator appear to be acceptable or unacceptable need to be defined here.

A graphical representation of this performance record sheet is presented in the following table.

Table 8.3: Performance Measurement Record Sheet

Element	Details
Title	
Purpose	
Relates to	
Target	
Formula	
Frequency	
Who measures?	
Source of data	
Who acts on the data?	
What do they do?	
Notes and comments	

Source: Neely et al.(1997)

Appendix A will use the Performance Measurement Record Sheet for the identified KPIs. Some of the elements (who acts on the data, what do they do, etc.) are very company-specific, and should be regarded as such.

8.9 KPIs' role in managing the virtual enterprise

KPIs should be used to drive improvement. The Performance Tree, and the associated KPIs, is used to manage the different business units within the virtual enterprise. If the KPIs are understood and owned, they encourage the knowledge of what has been achieved and the sharing of best practices between partners (Basu 2001:10).

KPIs does not add any value unless appropriate actions are taken with a significant paradigm shift from measurement to management. The use of KPIs will aid employees, and managers, to manage the operations that need attention, and not spending unnecessary time on operations that are within tolerance.

The use of the Performance Tree will make the correct and timely knowledge available to all partners and customers, resulting in transparency throughout the whole supply chain. It is, however, of the utmost importance that each business unit know exactly what their role in the VE is, and how their business unit may influence the different performance elements. This is the only way how the unit can take ownership and responsibility for their part in the VE.

8.10 Discussion and conclusion

The first performance measurement structure that was considered, was the *Balanced Scorecard* (BSC). *The Balanced Scorecard* is one of the best-described performance measurement frameworks developed during the past decade. Performance measurement literature has praised Kaplan and Norton's vision to include non-financial performance measures with the traditional financial performance measures to measure performance in organisations. The reason why the author did not use the BSC, is threefold:

- It is primarily designed for use by senior managers to provide them with an overview of performance. In the case of the VE, it is critical that the management of performance should be the responsibility of the person directly responsible for the measured element. This will create a balance between acountability and authority.

- The BSC provides a useful framework, but there is little underlying it in terms of the process of developing and identifying the performance measurement system design.

- The BSC was developed to measure performance in "traditional" organisations, where the long-term viability of the organisation is of great importance (the learning and growth perspective). In the case of VEs, this is irrelevant.

The second structure that was considered, was the *Performance Pyramid*, which evolved into the SMART system. The SMART system was not used because it also does not define performance indicators for the elements described within it, and it does not explicitly integrate the concepts of continuous improvement.

It is for these reasons that the author decided to develop a new structure, taking into account the above two structures as input to the new structure, the *Performance Tree*. All problems raised in the above structures, were addressed in the Performance Tree. The Performance Tree makes use of key performance indicators to identify elements that need attention.

A summary of all the key performance indicators, corresponding to the specific performance measure elements, is given in Table 8.4.

The Performance Measurement Record Sheet for each of the KPIs identified, is completed in Appendix A. All information that is not company-specific is supplied in the tables.

Table 8.4: Summary of key performance indicators

No	Performance element	KPI	Measurable	Range
1	Cost of quality			
2	Direct material cost	Material price variance Material quantity variance	Yes Yes	-1 – 1 -1 – 1
3	Direct Labour Costs	Labour rate variance Labour efficiency variance	Yes Yes	-1 – 1 -1 – 1
4	Manufacturing overheads	Variable overhead spending variance Variable overhead efficiency variance	Yes Difficult	-1 – 1 -1 – 1
5	Marketing and selling costs		Yes	0 – 1
6	Administrative costs		Yes	0 – 1
7	Total productivity	Total factor productivity (***TFP***)	Yes	$0 - \infty$
8	Specific productivity	Labour productivity (L_P) Capital productivity (C_P)	Yes Yes	$0 - \infty$ $0 - \infty$
9	Volume flexibility	Volume flexibility (F_v)	Yes	0 – 1
10	Delivery flexibility	Delivery flexibility (F_D)	Yes	0 – 1
11	Mix flexibility	Mix flexibility (F_m)	Yes	$0 - \infty$
12	New product flexibility (F_n)		Difficult	
13	Produced quality	Acceptable parts per million (***APPM***)	Yes	0 – 1
14	Perceived quality		Difficult	
15	Inbound quality	Weighted acceptable parts per million ($u_1 APPM_k$)	Yes	0 – 1
16	Time	Manufacturing cycle efficiency (***MCE***)	Yes	0 – 1
17	Delivery speed and reliability			
18	Lead time	Development efficiency (D_e) Capacity ratio (***CR***)	Yes Yes	0 – 1 0 – 1

A graphical representation, giving the KPIs on the performance measurement structure, is presented in Figure 8.7. The latter figure is a presentation of all the KPIs that were described in the previous sections, presented on the Performance Tree of Figure 8.5.

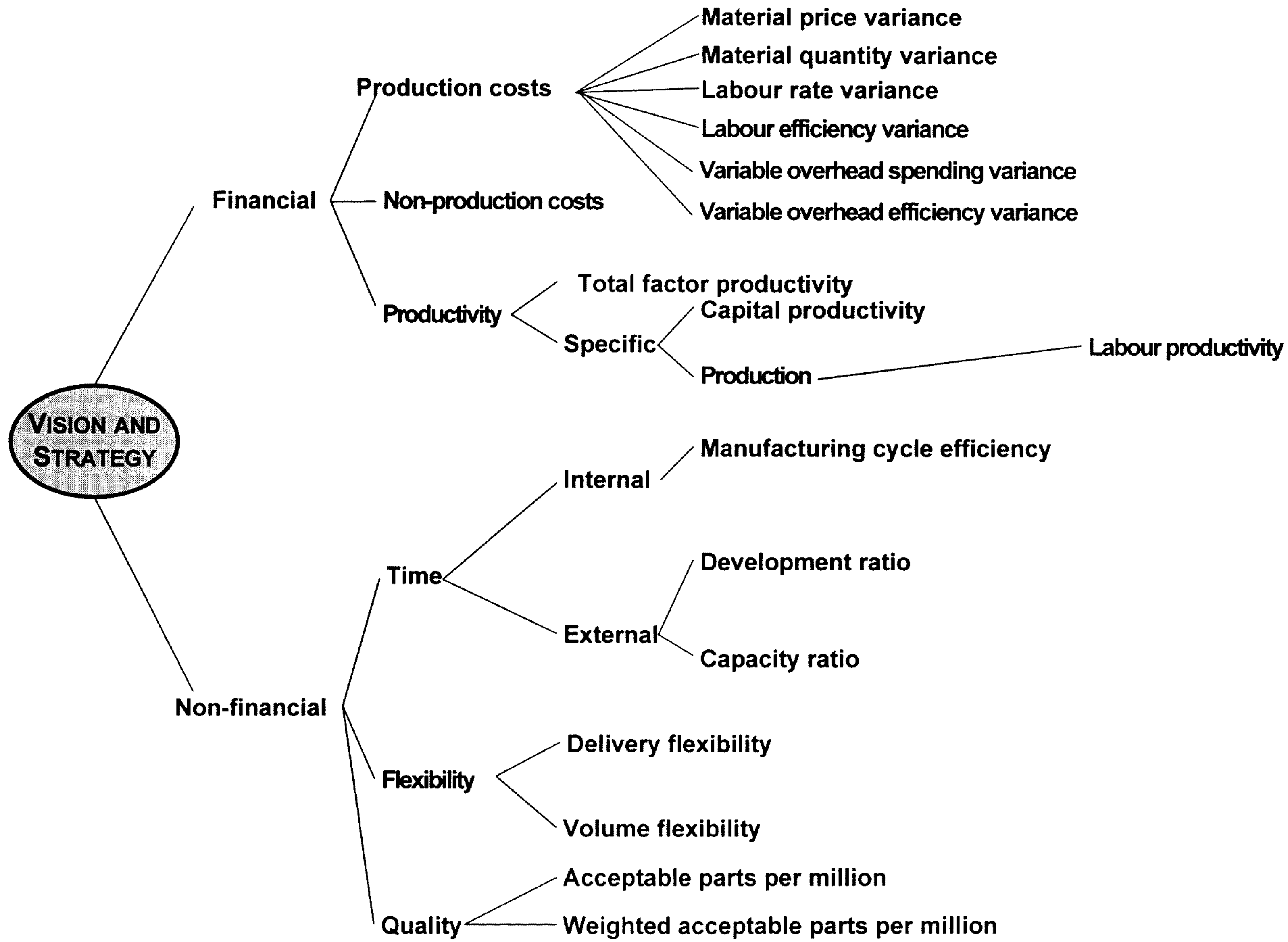

Figure 8.7: The Key Performance Indicators

The key performance indicators presented in this chapter is a structure developed especially for virtual enterprises, whose main aim is to manufacture a product. The structure needs to be implemented and then evaluated in order to decide whether it is complete and adequate. Unnecessary indicators will then be identified, and the structure can be revised if necessary. The structure can be implemented in a "dashboard"-manner where flags are raised when indicators are outside the preferred tolerance. This can be seen in Figure 8.7.

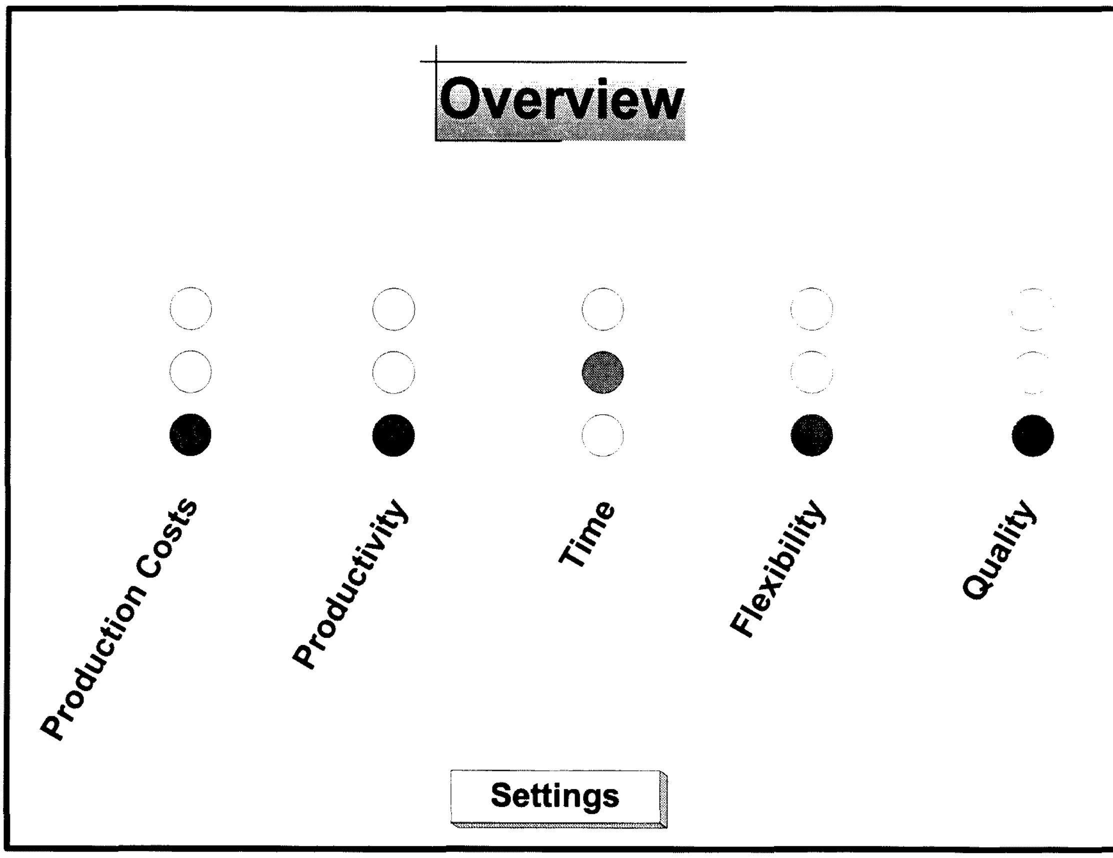

Figure: 8.8: Overview page

It must be possible for the user to click on the *out of tolerance* element as soon as it changes to orange. This will then take the user to the specific KPI that is outside the tolerance. (In the above example, it is the *Time* element that is out of tolerance. In this instance, when clicking on the orange button, the user will be taken to the *Time*-screen, where the specific KPI can then be identified.) There are five further pages that should be available to the user. The complete requirements for this KPI structure are presented in Appendix D.

An important point needs to be mentioned here. There are often two kinds of errors when measuring performance. They are (Schmenner & Vollmann 1994:58):

- The wrong measure is used to motivate managers, resulting in time being spent improving something that has few positive, and perhaps many harmful, consequences for the company; and
- A failure to use the right measure, resulting in something important for the company staying neglected.

Although the Performance Tree tries to eliminate these errors, attention should still be given to the processes of identifying the relative importance of each of the indicators when implementing the structure.

Chapter 9

The Performance Tree interface

9.1 Introduction

The explosive growth of Information Technology and software applications make it the ideal medium for providing managers with performance measurement data. The Internet, and its associated infrastructure and applications also make it easy for globally dispersed managers to view the same information in real time. The Internet is easily accessible, relatively inexpensive and easy to use, making it the perfect medium for transferring the necessary performance data.

The main goal of the author when developing the Performance Tree was to provide a common interface for managers to view the performance of the virtual enterprise. It is very difficult to assess performance if the necessary non-financial measures are not available. The author developed the framework in such a way that key performance indicators can identify problems in all of the non-financial areas (*quality*, *flexibility* and *time*) as well as in the financial areas (*cost* and *productivity*).

The basic principles employed by the author when developing the interface came from an interactive simulation, *Balancing the Corporate Scorecard 2.0*, developed by High Performance Systems, Inc. A brief overview of this simulation will be given in the next section.

9.2 Balancing the Corporate Scorecard 2.0

High Performance Systems, Inc. and the Harvard Business School Publishing developed the interactive simulation, *Balancing the Corporate Scorecard 2.0.* It creates a virtual environment where the Balanced Scorecard concepts are learned and applied. The player takes the role as the president of a small but growing producer of data-mining software, and must make critical decisions on pricing, headcount and investment, while interacting with employees and customers who are affected by those decisions. The purpose of the simulation is to discover first hand the Balanced Scorecard as a valuable tool for managing corporate performance without experimenting with a "real-world" company. The interface can be seen in the following figure.

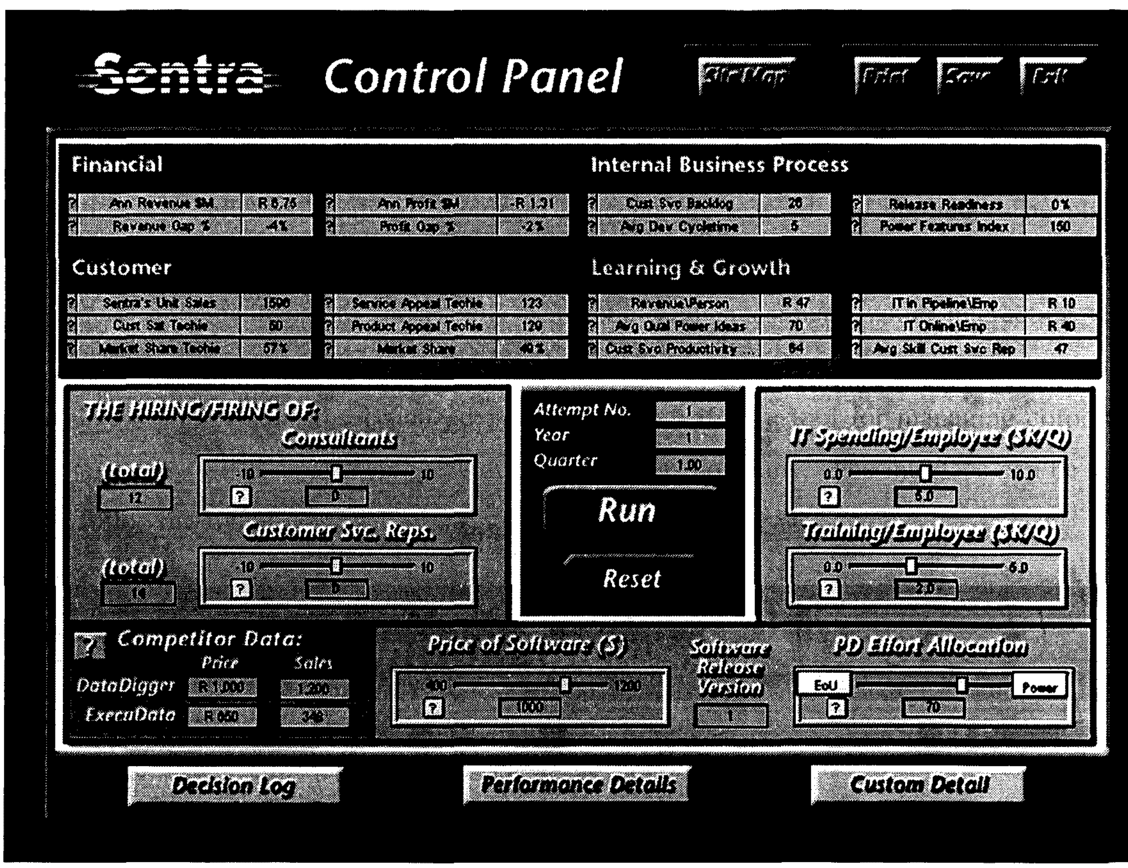

Figure 9.1: The simulation's control panel

The four different perspectives of the Balanced Scorecard are represented in the upper half of the control panel. This simulation also makes use of key performance indicators to identify the state of the business.

The main problems with this interface are:

- There are only a limited number of KPIs on the control panel, so it is necessary to substitute some of the KPIs for others within the simulation.

- The KPIs are not normalised, so in many instances it could be difficult to interpret them at a single glance.

The author dealt with these problems when developing the Performance Tree interface.

9.3 The Performance Tree interface

The majority of the data needed in the interface resides in the ERP database. The data not present in this database can be found in other operational databases used within the organisation (MES, etc.). The following figure presents the different sources of data required for the KPIs.

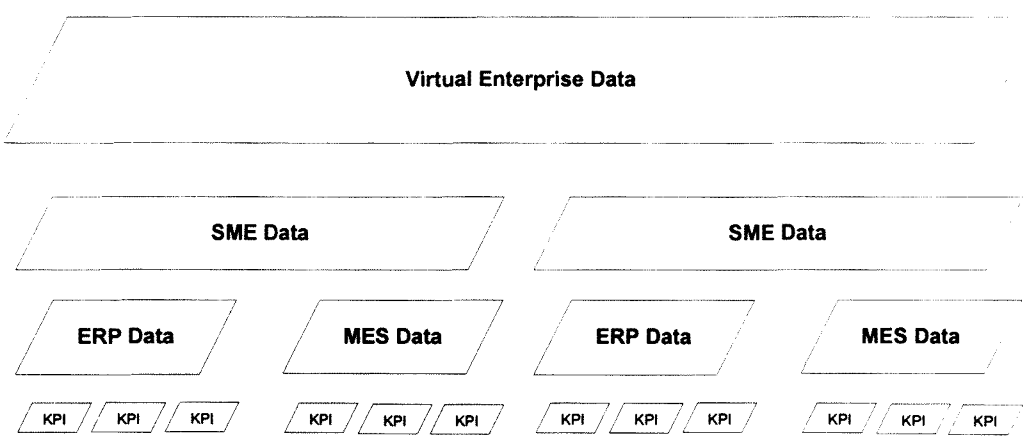

Figure 9.2: The different sources of data for the KPIs

In Figure 9.2 it can be seen that certain KPIs relate to data that can be found in the ERP system, while other KPIs relate to data that can be found in the MES system. The KPIs must then be consolidated from these different data sources, and represented at the SME-level. Each SME within the Virtual Enterprise must then consolidate their KPIs with the KPIs from the other SMEs to form the required performance data at the Virtual Enterprise level.

The ERP system, Qmuzik, as well as the TracIT MES system, use the Microsoft SQL database as the relationship database management system. These databases do more than just store and retrieve data; they also make sure of the integrity of the data entered.

It was decided to use Microsoft Access Queries to address the data within the SQL database. Since both SQL and Access are Microsoft products, the manipulation of data between Access and SQL are straightforward. The steps in the process of creating the interface are as follows:

- identify all the relevant tables and fields within the appropriate database;
- manipulate the data from the databases in such a manner that the KPIs can be represented;
- develop the physical interface.

This process, with the associated effort for each of these phases, is presented in the following figure.

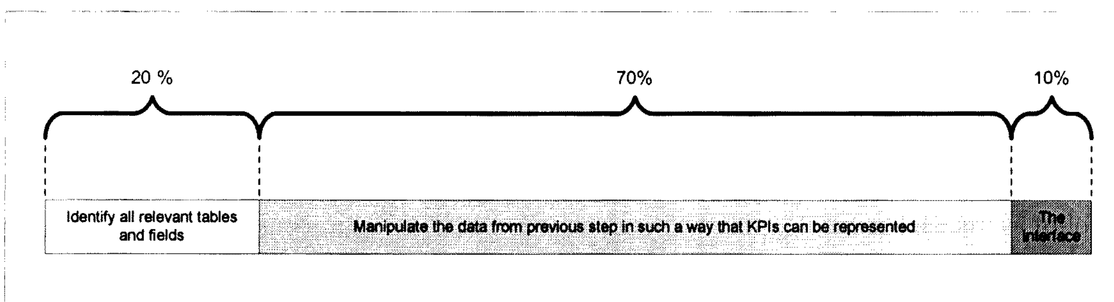

Figure 9.3: The steps in the interface development, and the associated effort

It can be seen from this figure that the majority of effort is spent on identifying the relevant tables and fields within the correct database, and then manipulating the data from the database in the correct manner to represent the required KPI.

The next section will describe these two steps for one of the KPIs that were identified, the *material price quantity.*

9.4 Example of identifying and manipulating required data for KPIs

An example of the KPIs can be seen in the following figure. In the example, the information for the KPI, ***material quantity variance*** is shown. The first two steps in the above process is completed at the stage of the example. A detailed description of the tables and fields, within the Qmuzik database, that were used, can be found in Appendix F. This Appendix also discuss the database investigation and the filters used to extract the correct data from the predefined tables and fields. The Appendix also include screen captures of the queries for a complete production cycle.

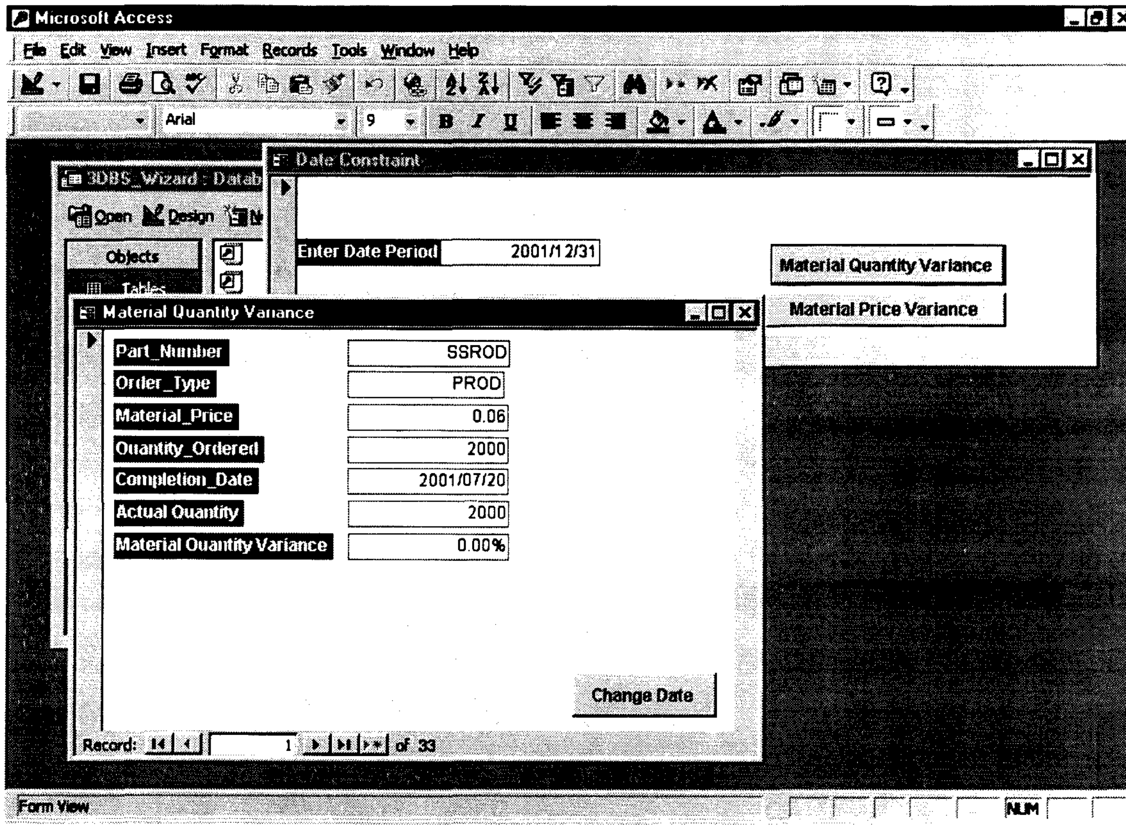

Figure 9.4: Example of material quantity variance

The database used in the example contains no production data. The data in the default database consists of test data for the 3-D Business Simulator. The current problem with this database is that the data are entered randomly by different team members, and therefore it is not realistic.

9.5 Discussion and conclusion

The Performance Tree interface can be a very powerful management tool if used correctly. The main purpose of the interface is to give managers a quick overview of the whole virtual enterprise. The Performance Tree will ultimately improve the operations and opportunities to cut cost, improve time to market and flexibility, while maintaining high quality. This will present the customer with the highest value possible.

As mentioned in the text above, the data within the current database is only test data, and very unrealistic. Within the context of the bigger project, the structure should be tested on real production data. One possibility will be to test the structure on an implementation site of one of Qmuzik's clients. The final 10% of the interface, the physical interface, will then be developed to suit the presentation needs of that specific organisation. The reason for this is that the physical presentation will form part of the organisation's "executive dashboard", and should conform to their requirements.

Another problem is the integration issues between the different databases where the necessary data reside. Within the 3DBS, these databases (ERP and MES) are not completely integrated, which makes it difficult to extract the data necessary for the KPIs. In the next version of the 3DBS, these integration issues will be addressed.

Chapter 10

Conclusions

In the near future, supply chains, and not single companies, will compete for market share. The virtual enterprise will be the small-to-medium enterprise's vehicle into this supply chain. The virtual enterprise can be seen as a process, where this process represents a continuous flow of activities designed and performed to deliver a product or service to the final customer. The supply chains will become closely integrated entities (*virtual enterprises*) that will work together to deliver the final products and services at the lowest cost, within the shortest time period and with the highest added value.

The advantage of the virtual enterprise concept is that the scope for research is very wide. It is a new concept, and with its link to supply chain management, a philosophy that is currently receiving a lot of attention, the relevance and possibilities as far as South African companies are concerned, are endless. The building blocks of this enterprise, B2B e-commerce and the use of the enterprise resource planning philosophy, have received much attention as a result of their nature of changing the operation of the 21^{st} century manufacturing enterprise. This thesis described how the integration of these concepts could lead to a restructuring of traditional companies, and especially SMEs, to compete in the global markets.

The thesis further considered the possibilities that the different B2B e-commerce models can offer the virtual enterprise. For this reason, a diverse set of models was presented to the reader. The evolution of e-business was discussed, with the necessary guidelines for moving the business model through this evolutionary process. The relevant section concluded with the calculation of the ROI associated with e-commerce.

The ERP philosophy was discussed in detail in Chapter 7. The need for this technology within the VE can clearly be seen by the vast amount of transactions that these systems capture, as well as the effective manner in which the enterprise can be operated through the use of such a system. The chapter was concluded with a discussion on two new developments within the field of ERP, namely XRP and the ASP model. These two models – especially the ASP model – introduce the future of ERP to the virtual enterprise. In terms of the ASP model, the VE will be able to outsource its ERP system, and all partners will have access to it on the Web.

One of the most important aspects companies should consider before joining a virtual enterprise is to undertake value chain analysis. The basic principles of this analysis have been introduced in 1965 (when Alderson introduced his General Theory of Marketing), and are just as relevant today as back then. With proper value chain analysis, companies will know exactly with which competitive advantage their business unit can supply the virtual enterprise. It will also be more difficult to replace these companies in the virtual enterprise with other, because the companies will concentrate on using this competitive advantage to secure their position.

The highly competitive, rapidly changing business environment should provide the opportunities for the practical implementation of the theoretical concept of virtual enterprises. Much work has been done on developing a structure to manage the value chain within virtual enterprises. The Performance Tree manages the business units within the virtual enterprise, and not the complete partner companies. It is for this reason that well documented and detailed developed structures, such as the Balanced Scorecard, are not used. The Balanced Scorecard considers for example a "Learning and Growth-perspective", something that is irrelevant for the virtual enterprise, since the virtual enterprise is not concerned with the long-term development of its workforce, neither with the long-term viability of the organisation. It can, however, be of extreme importance to the individual companies of which the business units of the virtual enterprise originates. Another problem that was found regarding both the BSC and the SMART system was that they are only frameworks, and not complete structures that include the methods for identifying and developing the individual performance measures.

The author considered inputs from diverse sources in the literature while developing the Performance Tree. This was done in order to become knowledgeable about all the new research on the components of the Performance Tree, and to make sure that all relevant topics were covered. Although most of the components of the Performance Tree have been studied and documented in detail, the author could not find a structure that combined the interaction between the complete set of performance measures. The key performance indicators identified within the Performance Tree will make it easier to use the performance measures, since 95% of the identified indicators make use of a normalised score to indicate when operations are not running smoothly.

A generalised Performance Record Score Sheet for each of the identified KPIs is also presented in Appendix A. This record sheet can be further developed to include company-specific information. The purpose of the record sheet in this thesis was to supply a generalised summary, with all the relevant information and targets, for the reader to understand the relationships between the KPIs and the performance elements better.

Chapter 9 discussed the interface, and the data required to represent the different KPIs. It was found that data from different operational databases are required to represent all the KPIs in the Performance Tree. One of the problems experienced with the current model of the 3D Business Simulator is that a lack of integration exists between the ERP and MES databases. This resulted in numerous problems with representing the required KPIs. However, certain KPIs were identified, and all necessary data was extracted from the Qmuzik ERP database to represent these KPIs. The identified KPIs were successfully presented through MS Access queries.

The requirements for the development of an executive "dashboard" were also introduced in Appendix D. The dashboard will make it possible to identify a problem area at a glance. Flags will be raised as soon as an indicator moves outside the specified tolerance.

This thesis considered all the critical success factors needed for operating the virtual enterprise. Figure 3.2 described these success factors, namely

- Shared purpose
- Shared risk, and
- Trust.

If these three factors are considered, all the parties concerned will mutually benefit from the venture. That is why the Performance Tree is "planted" in the vision and strategy of the enterprise. Without the partner business units knowing the exact purpose of the enterprise as a whole, the units will not be able to work together coherently. Therefore, all the elements of the Performance Tree "branch" out of the vision and strategy of the VE, resulting that all the partner business units know exactly what purpose they are fulfilling.

The shared risk and trust cannot exist without each other. The partners will share the costs, skills and markets while working on the project, thus effectively reducing the risk associated with the project. One of the critically important components of the VE, however, is the sharing of information. During the operating of the VE, the partners should trust each other that sensitive information, available through e-commerce from the ERP system, will not be exploited when the VE is disbanded, and that these and other resources that are utilised by the partners, will not be misused.

The Performance Tree aims to minimise the risk associated with this type of venture, but then the partners should support the process with the necessary trust to supply the correct information. This will then help the VE to satisfy its purpose, resulting in the mutual benefit of all the partners.

The Performance Tree was developed to help with the management of the business units, the value chains, of the virtual enterprise, and to assist these units to benefit the most from the VE. Measuring the specialised knowledge and expertise is extremely difficult; therefore the performance is measured, which will indicate that the first two characteristics are on track. If the steps presented in this thesis are followed, it will increase the chances of these business units' survival dramatically, thereby increasing the long-term viability of SMEs. The South African business environment already supports world-class technology, and with the effective operating of the SMEs within the VE, it will ultimately improve the competitiveness rating of South Africa.

Chapter 11

Recommendations

The South African small and medium enterprise should see the virtual enterprise as a vehicle for entry into the global market. The geographical position of South Africa, as well as the technological backlog experienced in Africa, makes it nearly impossible for Southern African companies to compete as a whole with other global players. The Southern African companies have specialised experience that is not available elsewhere at a cost-effective price, and it is this experience and knowledge that must be used to further the South African industry in the global markets. It is a well-known fact that during the Apartheid-era, South Africa was effectively shielded from external markets, and thus from external competition. This situation left the country with the dilemma of developing and designing most technological needs in-house. This resulted in even more expensive products, but with the additional benefit of more creative engineers and business individuals.

In the post-Apartheid-era, businesses should operate within markets that are not shielded from external competition. South African companies should use the experience gained during the previous regime to create sustainable growth within the economy. This can only be achieved if the role-players understand the marketplace and the opportunities available to them. One of the tools for understanding these possibilities is the 3-D Business Simulator.

The 3-D Business Simulator, developed by TracIT in conjunction with the GCC, should be used to train and expose managers to the concepts of virtual enterprises, and the technologies needed to support these enterprises. The 3-D Business Simulator is a simplistic, yet powerful three-dimensional tool that can introduce all the different aspects, such as e-commerce and ERP, to managers. The effects of decisions can also be shown with the aid of key performance indicators and the Performance Tree.

The 3-D Business Simulator already spans many disciplines within Industrial Engineering, and these disciplines need to be combined for further research within virtual enterprises. As an example, information systems should aid in the development of the e-commerce integration, and thus in the development of the "bigger project". The virtual enterprise will also need the expertise from other disciplines, such as computer science, managerial accounting, business management, etc., to be combined with the scientific knowledge of the engineers developing it.

It is recommended that the Efficient Operations Management group should use this thesis as a starting point for research and development of the virtual enterprise concept. The virtual enterprise makes use of all the different building blocks of operations management, and each of these building blocks can be developed to further not only the research on virtual enterprises, but also the research in operations management, and ultimately the research of the Industrial Engineering Department.

It is further recommended that the Performance Tree should be evaluated by implementing it. Currently, most of the key performance indicators are individually in use somewhere, but not in a well-defined structure. It is necessary that the complete structure be implemented, and the value and ease of use of the whole structure be considered. Only then will it be possible to identify the unnecessary KPIs and the shortfalls of the structure.

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Appendix A

Performance Measure Record Sheets

Table A.1: Material price variance

Element	Details	
Title	*Material price variance*	
Purpose	*To measure the difference between what is paid for a given quantity of material and what should have been paid according to standards that have been set.*	
Relates to	*Material costs*	
Target	*0*	
Formula	$[(AQ \times AP) - (AQ \times SP)] / SP$ $= AQ(AP - SP) / SP$	
Frequency	*Continuous*	
Who measures?	*Cost accountant*	
Source of data	*ERP system*	
Who acts on the data?	*Buyers*	*Cost accountant*
What do they do?	*Negotiate with suppliers (or evaluate new suppliers)*	*Re-evaluate standards*
Notes and comments		

Table A.2: Material quantity variance

Element	Details		
Title	*Material quantity variance*		
Purpose	*To measure the difference between the quantity of materials used in production and the quantity that should have been used according to standards that have been set.*		
Relates to	*Material costs*		
Target	*0*		
Formula	$[(AQ \times SP) - (SQ \times SP)] / SQ$ $= SP(AQ - SQ) / SQ$		
Frequency	*Continuous*		
Who measures?	*Quality department*		
Source of data	*ERP system*		
Who acts on the data?	*Quality assurance*	*Production manager*	*Security*
What do they do?	*Check quality* *Cost of quality*	*Set-ups*	*Security*
Notes and comments			

Table A.3: Labour rate variance

Element	Details	
Title	*Labour rate variance*	
Purpose	*To measure the rates paid to workers, which ca be indications of the wrong use of labour (skilled/unskilled labour), or the use of overtime*	
Relates to	*Direct labour costs*	
Target	*0*	
Formula	$[(AH \times AR) - (AH \times SR)] / SR$ $= AH(AR - SR) / SR$	
Frequency	*Continuous*	
Who measures?	*Cost accountant*	
Source of data	*ERP system*	
Who acts on the data?	*Human resources*	*Cost accountant*
What do they do?	*Change labour*	*Update standards*
Notes and comments		

Table A.4: Labour efficiency variance

Element	Details	
Title	*Labour efficiency variance*	
Purpose	*To measure the productivity of labour time.*	
Relates to	*Direct labour costs*	
Target	*0*	
Formula	$[(AH \times SR) - (SH \times SR)] / SH$ $= SR(AH - SH) / SH$	
Frequency	*Continuous*	
Who measures?	*Cost accountant*	
Source of data	*ERP system*	
Who acts on the data?	*Cost accountant*	*Production manager*
What do they do?	*More effective procedures* *Update standards*	*Set-ups,* *Internal control,* *etc.*
Notes and comments		

Table A.5: Variable overhead spending variance

Element	Details	
Title	*Variable overhead spending variance*	
Purpose	*To measure deviations in the amounts spent for overhead inputs.*	
Relates to	*Manufacturing overheads*	
Target	*0*	
Formula	$[(AH \times AR) - (AH \times SR)] / SR$ $= AH(AR - SR) / SR$	
Frequency	*Continuous*	
Who measures?	*Cost accountant*	
Source of data	*ERP system*	
Who acts on the data?	*Cost centre manager*	*Cost accountant*
What do they do?	*Put control measures in place*	*Update standard cost*
Notes and comments		

Table A.6: Variable overhead efficiency variance

Element	Details
Title	*Variable overhead efficiency variance*
Purpose	*To measure how efficiency the base underlying the flexible budget is being utilised in production. If more hours are worked than allowed at standard, the overhead efficiency variance will be unfavourable to reflect this inefficiency. As a practical matter, this inefficiency is not in the use of overhead, but rather in the base itself.*
Relates to	*Manufacturing overheads*
Target	*0*
Formula	$[(AH \times SR) - (SH \times SR)]/SH$ $= SR(AH - SH)/SH$
Frequency	*Continuous*
Who measures?	*Cost accountant*
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Footnote: The *variable overhead efficiency budget* is very difficult to measure since very few companies make use of flexible budgets.

Table A.7: Total factor productivity

Element	Details
Title	*Total factor productivity (**TFP**)*
Purpose	*To measure the total performance effectively in terms of resource employment in production*
Relates to	*Controlling total productivity at firm level*
Target	*Large as possible*
Formula	$TFP = \frac{Value\ added}{Labour\ inputs + Capital\ inputs}$
Frequency	*Period (quarterly/monthly)*
Who measures?	*Cost accountant*
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.8: Capital productivity

Element	Details
Title	*Capital productivity* (**C_p**)
Purpose	*To measure the value-added per unit of capital*
Relates to	*Controlling specific productivity at firm level*
Target	*Large as possible*
Formula	$C_p = VA / C = V_r \times C_t$
Frequency	*Period (quarterly/monthly)*
Who measures?	*Cost accountant*
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.9: Labour productivity

Element	Details
Title	*Labour productivity* (L_p)
Purpose	*To measure the value-added per unit of labour*
Relates to	*Controlling specific productivity at firm level*
Target	*Large as possible*
Formula	$L_p = VA / L = S_a \times V_r$
Frequency	*Period (quarterly/monthly)*
Who measures?	*Cost accountant*
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.10: Volume flexibility

Element	Details
Title	*Volume flexibility (F_V)*
Purpose	*To measure the proportion of demand that can be met considering only the ranges of volumes that are profitable*
Relates to	*Volume flexibility*
Target	*1*
Formula	$\Phi\,(\frac{O_{max}-\overline{D}}{S_D})-\Phi\,(\frac{O_{min}-\overline{D}}{S_D})$
Frequency	*Period (quarterly/monthly/weekly)*
Who measures?	
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.11: Delivery flexibility

Element	Details
Title	*Delivery flexibility (F_D)*
Purpose	*To measure the ability to move planned delivery dates forward, thereby accommodating rush orders and special orders.*
Relates to	*Accommodate rush orders and special orders (delivery flexibility)*
Target	*1*
Formula	$\frac{\sum_{j=1}^{J}(L_j - E_j)}{\sum_{j=1}^{J}(L_j - t^*)}$
Frequency	*Continuous*
Who measures?	*Planner*
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.13: Acceptable parts per million

Element	Details
Title	*Acceptable parts per million (**APPM**)*
Purpose	*To measure the acceptable parts per million parts produced*
Relates to	*Produced quality*
Target	*1*
Formula	$1-\frac{DPPM}{1{,}000{,}000}$
Frequency	*Continuous*
Who measures?	*Quality assurance*
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.14: Weighted acceptable parts per million

Element	Details
Title	*Weighted acceptable parts per million* (u_1APPM_k)
Purpose	*To measure the relative efficiency of a decision-making unit through calculating a ratio of total weighted outputs to total weighted inputs. It is calculated by using the maximum ratio of weighted APPM to weighted TQM practises.*
Relates to	*Inbound quality (quality of goods received)*
Target	*1*
Formula	$Max \quad u_1 APPM_k$
Frequency	*Continuous*
Who measures?	*Buyer*
Source of data	*ERP system, benchmarking*
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.15: Manufacturing cycle efficiency

Element	Details
Title	*Manufacturing cycle efficiency (**MCE**)*
Purpose	*To measure the ratio of value added time to total time (value added and non-value-added time).*
Relates to	*Internal time (throughput)*
Target	*1*
Formula	$\frac{Value\ added\ time}{Throughput\ (manufacturing\ cycle)\ time} = \frac{Total\ run\ time\ of\ all\ operations}{Tiime\ on\ production\ floor}$
Frequency	*Continuous*
Who measures?	
Source of data	
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.16: Development efficiency

Element	Details
Title	*Development efficiency (**D_e**)*
Purpose	*To measure the efficiency (time spend) on developing a new product*
Relates to	*Development lead time*
Target	*1*
Formula	$1 - \frac{LT_e}{PLT}$
Frequency	*Continuous*
Who measures?	*Development manager*
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Table A.17: Capacity ratio

Element	Details
Title	*Capacity ratio* ***(CR)***
Purpose	*To measure the ratio of primary lead time to lead time (time from when customer order is entered until product is delivered, including the wait time (WT) from when a customer order is entered until it becomes a works order (WO))*
Relates to	*Lead time*
Target	*1*
Formula	$\frac{PLT}{LT}$
Frequency	*Continuous*
Who measures?	
Source of data	*ERP system*
Who acts on the data?	
What do they do?	
Notes and comments	

Appendix B

Training Centre at the GCC

B.1 Introduction

To promote research and facilitate technology transfer between tertiary educational institutions and industry, the Department of Industrial Engineering at the University of Stellenbosch created the *Global Competitiveness Centre for Engineering* (GCC). The centre strives to promote global competitiveness in South African industry. This is being done by building on the research within the Department, providing the industry with technology and consulting services, and facilitating technology transfer to especially small and medium enterprises.

Although technology is advancing rapidly, many companies are failing to take full advantage of it, as they are struggling to improve or even use their current processes. Nearly a third of the total worldwide consulting effort goes into the improvement of operational efficiencies - companies are spending more and more money to improve their operations. Figure B.1 graphically represents this phenomenon on a worldwide scale. In South Africa, as in most other developing countries, the situation is probably even more difficult. Because of the low skill levels in general, as well as the fact that SA companies are small and cannot afford to employ expertise in all areas on a permanent basis, it places strain on the available consultants in the area of operational or productivity improvements. This improvement is a prerequisite for *lower cost*, *improved quality*, *faster throughput times* and ultimately being *more competitive*.

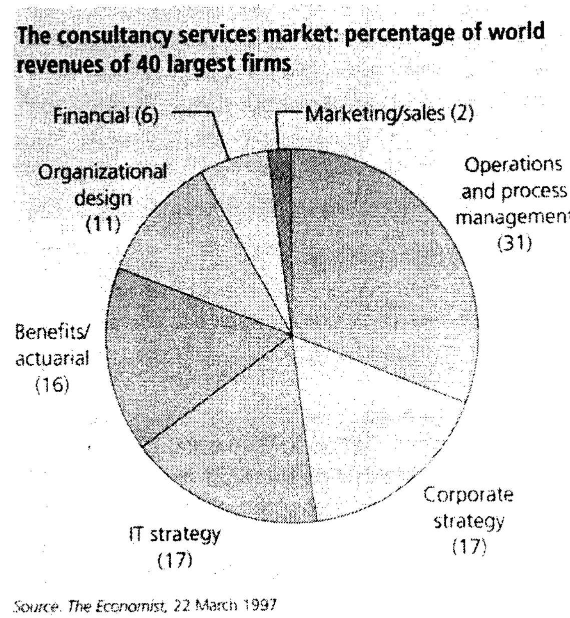


Figure B.1: The consultancy services market

Source: The Economist (22 March 1997)

B.2 Training Centre

The GCC, with its strong links to both academia and industry, is ideally positioned to enter the field of training, and has decided to exploit this market created by the government. One of the projects initiated within the GCC has a major deliverable as the establishment of a training academy. It is envisaged that the centre could provide training to:

- undergraduate (engineering) students,
- graduate students (M Eng, MBA, others); and
- industry

The GCC in collaboration with Qmuzik, TracIT Solutions and Indutech, is developing a business trainer that includes all the different layers of a generic production organisation. This tool, together with the necessary curriculum development, will form the basis for the GCC's training centre.

B.3 Transferring the knowledge

The work method employed in this project corresponds to the 5-step model of the GCC. The five steps are to *identify*, *acquire*, *master*, *multiply* and *transfer* leadiing-edge technologies to students and industry. This 5-step model also corresponds to the requirements for the South African Government's Skills Development Act, 1998 and the Skills Development Levies Act,

1999. This legislation introduced new institutions, programmes and funding policies designed to increase investment in skills development. The South African government places the responsibility of training the workforce on the shoulders of the companies – trying to convince them to become learning organisations, and ultimately more competitive in the world market.

The Training Centre of the GCC must comply with both the SAQA and NQF guidelines. This will ensure that the work done by the Training Centre will comply with the Skills Development Act No. 97 of 1998. Within this framework, the primary goal of the Training Centre is to promote not only the awareness of available business solutions, but to be actively engaged in providing a basis and opportunity for the general upliftment of workers within the operational activities of their company.

Appendix C

3-D Business Simulator

C.1 Introduction

One of the GCC's Industrial Partners is the ERP software developer Qmuzik. Qmuzik was used as the ERP solution in the 3-D Business Simulator.

C.2 Why Qmuzik?

The question why to use Qmuzik versus other well established ERP players like *SAP*, *BaaN*, *JD Edwards,* etc. often arise. Why indeed would the GCC use a locally developed ERP system when exposure can be given to these international systems that students are more likely to find at their future employers.

The GCC answer this question by giving the facts for the user to interpret and also by making an analogy to something more tangible than the ERP concept (Van Eeden et al., 2001a).

C.2.1 The analogy

Suppose that a person could learn like an "empty brain" about transport. The concept of transport as applied in bicycles, motor vehicles, aircraft and space shuttles are basically the same, i.e.

Move from A to B

- House to university – bicycle
- Stellenbosch to Cape Town – motor vehicle
- Cape Town to London – aircraft
- Earth to Moon – space shuttle

Propulsion mechanism / energy conversion

- Human muscles – bicycle
- Petrol/diesel/aircraft fuel – motor vehicle/aircraft/space shuttle

Steering mechanism

- Handle bars - bicycle
- Steering wheel and throttle - motor vehicle
- Joystick and throttle – aircraft/space shuttle

Capacity to carry passengers and cargo

- Seat and a carrier - bicycle
- Seats and a trunk - motorcar
- Seats and a cargo hold – aircraf /space shuttle

To learn a person about the above, and many other, aspects of transportation you could chose the m*otor vehicle* as it will explain the principles as applied in any other means of transportation. It provides the following opportunity within the *time* and *budget* allocated to the University:

- showing the student a real operating motor vehicle;
- letting the student drive the car; and
- letting the student experience the softer issues not captured in the operation manuals of any of the above.

This would not be possible in aircraft or space shuttles.

A SAP consultant spends on average more than 3000 hours on SAP before being able to operate/support the system efficiently – compared to the typical 10 contact hours available to teach students about the ERP world.

C.2.2 The facts

- Qmuzik is locally developed and the first stages of development reads like that of any of the major products;
- Qmuzik does not suffer from traditional legacy problems, for instance referential integrity at database level, like all the major players;
- Qmuzik has a user base of more than 30 clients growing continuously. Small but significant;

- Cost of operation is a fraction of major systems because of the technologies employed and flexibility to users rather than adaptability by consultants' methodology employed. It is not necessary to hire a consultant at exorbitant rates to change the application as the system settings and options are all customisable via the front-end; and
- Qmuzik, and it's biggest VAR, has committed to continued support to the US on an ongoing basis to supply and transfer the knowledge required at no or minimal cost to the University. This process started in 2000 and is currently in process;

The concepts applied in Qmuzik are the same as those in other systems, however the system is smaller in terms of functionality and easier to operate and maintain than the larger ones. A recent internal audit in a large South African organisation using Qmuzik, SAP and other ERP systems has shown significant savings in information technology costs in the three divisions running Qmuzik.

C.3 Business Simulator

C.3.1 Introduction

The *business simulator* that is being developed, will be used to improve the education and training of managers, practitioners and students in the fields of:

- Operations management;
- Manufacturing execution systems;
- Asset management;
- Shop floor data acquisition systems; and
- Computer and instrumentation control of shop floor equipment.

Figure C.1 is a picture of the conceptual 3-D Business Simulator built to illustrate the principles to interested parties.

The idea for a *3-D Simulator* originated through the complexity of current event driven transaction dynamics in the supply chains of specifically the motor industry. In order to facilitate the understanding of these business dynamics, and the impact that operational changes might bring about, it was decided to simulate these events. This business simulator is a scaled version of a virtual enterprise, where the actions and interrelationships of the different functional areas within an enterprise can be physically demonstrated, while the required transactional data capturing and processing is done automatically.

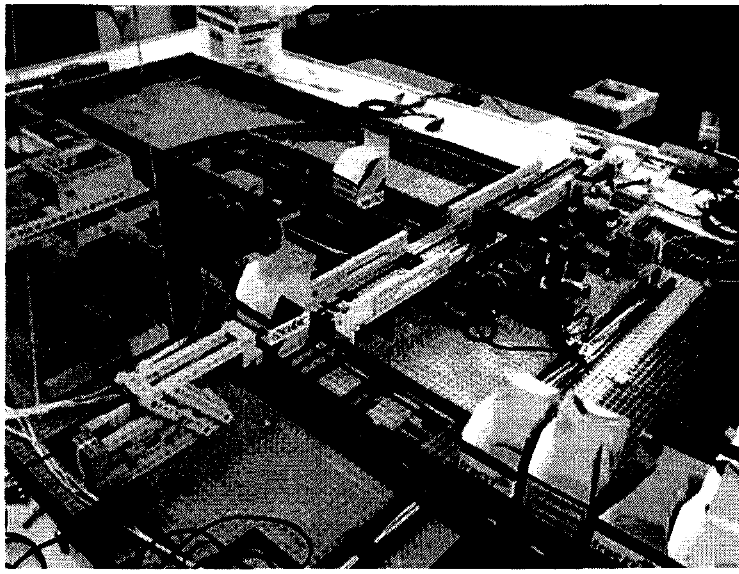


Figure C.1: 3-D Business Simulator

Participants (from different management levels and with varying skills background) can obtain a hands-on experience in applying different manufacturing and processing approaches, and can "see" the activities required in the order-fulfilment process. The "factory" itself is built with LEGO blocks, while industrial PLC's and communication interfaces are used to link to both an ERP system as well as asset utilisation and maintenance software.

The output is not only a simulation of the physical aspects of operating a manufacturing plant, but a visual performance measurement system that provides information on customers, suppliers, WIP and inventories, as well as the financial results of the processes or specific scenarios.

The ultimate aim is to give students and employees exposure to the application of concepts such as supply chain management, virtual enterprises, management by objectives, etc. and their building blocks, such as JIT, TOC, TPM etc. as well as observing the impact of their decisions on a company's bottom line. Through this they have a better understanding of the "business aspects" of operations and can provide immediate inputs into the work place. It is this integration of theory, available technology and business financials that provides the value of the simulator. Even relatively low-skilled and semi-literate employees can gain a basic understanding of the business environment, giving a tool for organisations to develop a learning environment. Ultimately, the creation of this learning environment along with tools such as the business simulator, will contribute towards the "knowledge worker".

C.3.2 Objectives of the 3-D Business Simulator

The 3-D Business Simulator is an applied learning opportunity to expose the trainees to real world issues. The ability to experience real application and practical integration makes the learning experience more realistic and interesting. The trainees will experience the dynamic nature of business through the simulation and will thus obtain an understanding of how all the components of a factory integrate. The simulator therefore is a system demonstrator. It shows not the working of individual components, but explicitly demonstrates integration layers. It should be an empowerment tool that will highlight the multiple levels of operation and management in an organisation. Financial statements, manufacturing data, process information and systems and control engineering data are shown in real-time on the system.

C.3.3 The different layers in the 3-D Business Simulator

Figure C.2 shows five layers within the simulator. These respond to the fields of education as stated previously, from the management level down to the physical instrumentation. By using the model in different configurations, different manufacturing facilities or manufacturing approaches can be demonstrated. It includes necessary components (e.g. off-the-shelf PLCs) to simulate a factory, all transactional data is generated by the integrated ERP system, and real-time asset management data is captured by the information system.

At the lowest level, the *Instrumentation Layer*, the model comprise of the field instruments. These could include valves, switches and pumps. These components are used to act as inputs to or receive outputs from the rest of the system.

The second layer, the *Control Layer*, consists of PLC's (programmable logic controllers) together with digital and analogue input and output devices. These devices control the inputs and outputs received from or sent to the instruments in the *Instrumentation Layer*.

The third or *Supervisory Layer*, consists of the supervisory control and data acquisition (SCADA) software. A SCADA system includes a graphical model of the factory floor. All the components (in the Instrumentation Layer) are shown in the model and movements or changes in e.g. stock levels are shown during the simulation. The SCADA software receives its inputs from the Control Layer.

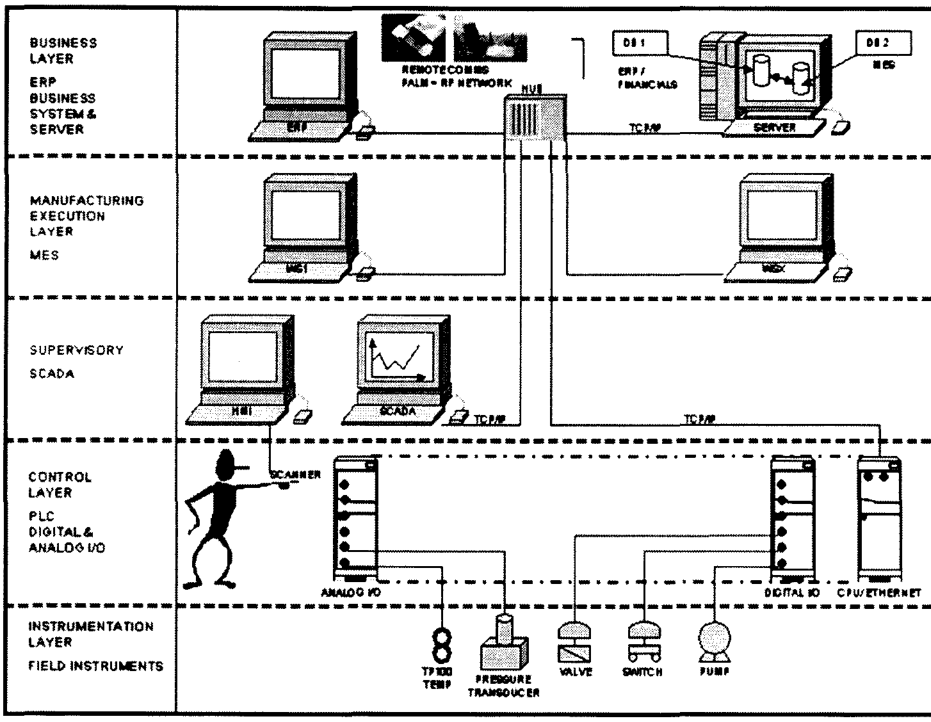


Figure C.2: Layers within 3-D Business Simulator

The fourth layer, the *Manufacturing Execution Layer*, comprises of a software application that controls all the operations on the shop floor. It uses the Supervisory Layer's information as input(s), decides on actions, and sends the output(s) back to the Supervisory Layer.

The top layer (*Business Layer*) consists of the ERP system. The ERP system communicates with the MES (manufacturing execution system) software and extracts data from the system to adjust stock levels by issuing or receiving stock, changing the financial statements and adjusting the business indicators.

All the components are linked via a network using the TCP/IP protocol. External communication, from the user of the factory, occur with the use of a handheld device linked to the rest of the network using a radio frequency (RF) network.

C.3.3 Process breakdown

To illustrate the complexity and integration involved in the mentioned business simulator, a short process breakdown is provided:

- A *customer order* is received via the means of a hand-held device/website;
- The *customer order* is registered on the ERP system;
- *MRP* create *production order* and *purchase orders* for shop floor and store requirements;

- *MES* transforms *production Order* to SCADA and PLC messages to start production process;
- PLC and SCADA trigger, control and monitor *goods receiving* into the *store*;
- PLC and SCADA trigger, control and monitor *production* on the shop floor;
- PLC and SCADA trigger, control and monitor *packaging* and *shipment* of *customer order* from the store;
- *MES* system monitor progress and provide business data back to the ERP system;
- *ERP* system tracks the business data on the highest level. I.e. *store movements*, *production order* completion, write journals, etc.

Figure C.3 graphically depicts this process.

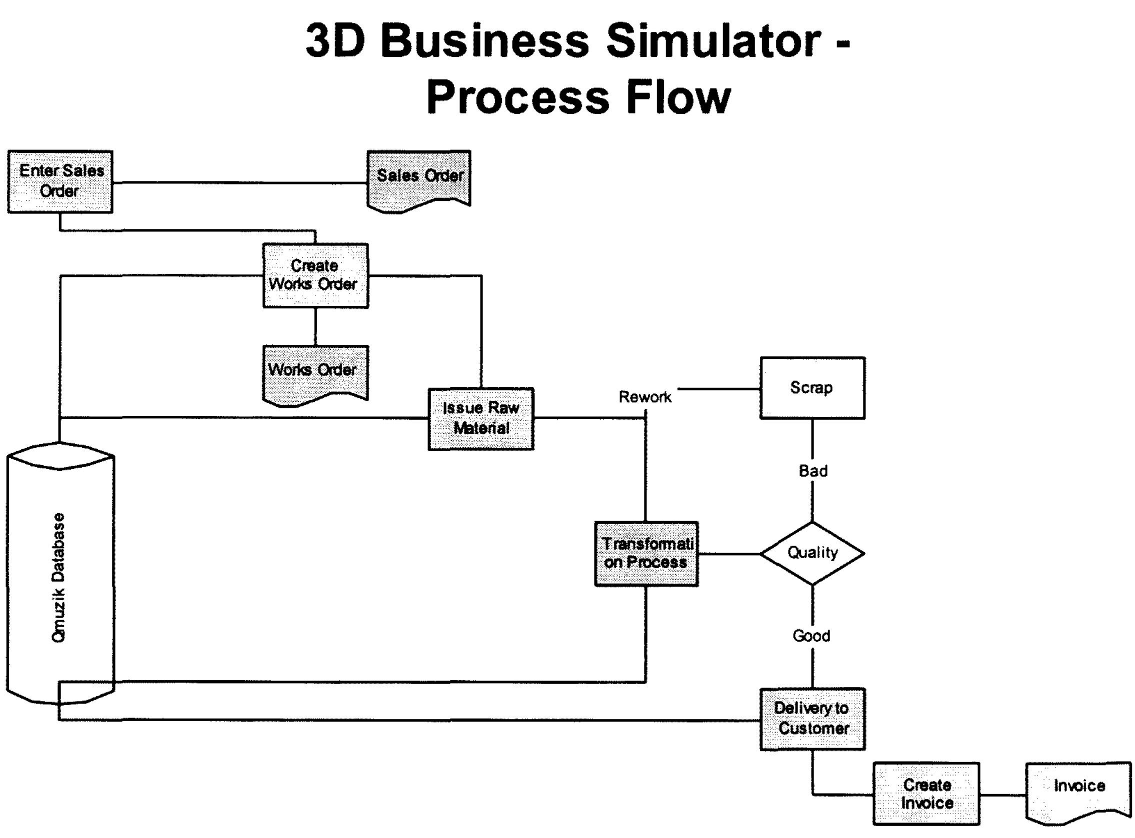


Figure C.3: Process flow for 3-D Business Simulator

This process breakdown indicates the complete business cycle as it occurs in a real production plant. This simulator can also be viewed as a virtual enterprise, since all the different aspects discussed previously in this thesis, is presented in this model. It is possible to simulate geographically dispersed business units through the use of the hand-held PDA. The PDA invoke Internet Explorer, and communicate all the customer order data through the Internet (in this model, all pc's have dedicated IP-addresses, including the PDA).

Integration issues between the e-commerce application and the ERP system, Qmuzik, are also addressed within the simulator. Many different software applications are used within the 3-D Business Simulator. All these applications need to be integrated to run the simulator efficiently and effectively, and are the same issues that need to be addressed within a virtual enterprise.

From this platform the GCC Training Centre can create a learning experience for students that is closely related to the real problems experienced in everyday working situations.

Appendix D

KPI structure requirements

D.1 Overview

The performance measurement structure proposed by the author will make use of key performance indicators to manage the enterprise. These KPIs will be used to indicate when specific identified aspects of the enterprise are not operating as planned. The Performance Tree will be presented in a graphical manner to assist in speedy intervention.

D.2 Requirements

The structure must be set up in such a manner that it will be possible to view the KPIs for data entered within the Qmuzik database. This entails that the Access reports must be linked to the active Qmuzik database that is used for the 3-D Business Simulator

It must be possible for the user to define the tolerances for each different element. It is possible that specifications will change over time, and tolerances differ for different companies as well. For this reason, it must be possible for the user to specify the specific tolerances applicable to his/her company. The tolerances must be specified according to section D.3.

D.3 The proposed interface

D.3.1 User settings

The interface will make use of forms within Microsoft Access to present the KPIs graphical. The first page will be company-specific settings, where it will be possible to set the specific tolerances for each KPI. The following figure illustrates the requirements for this form.

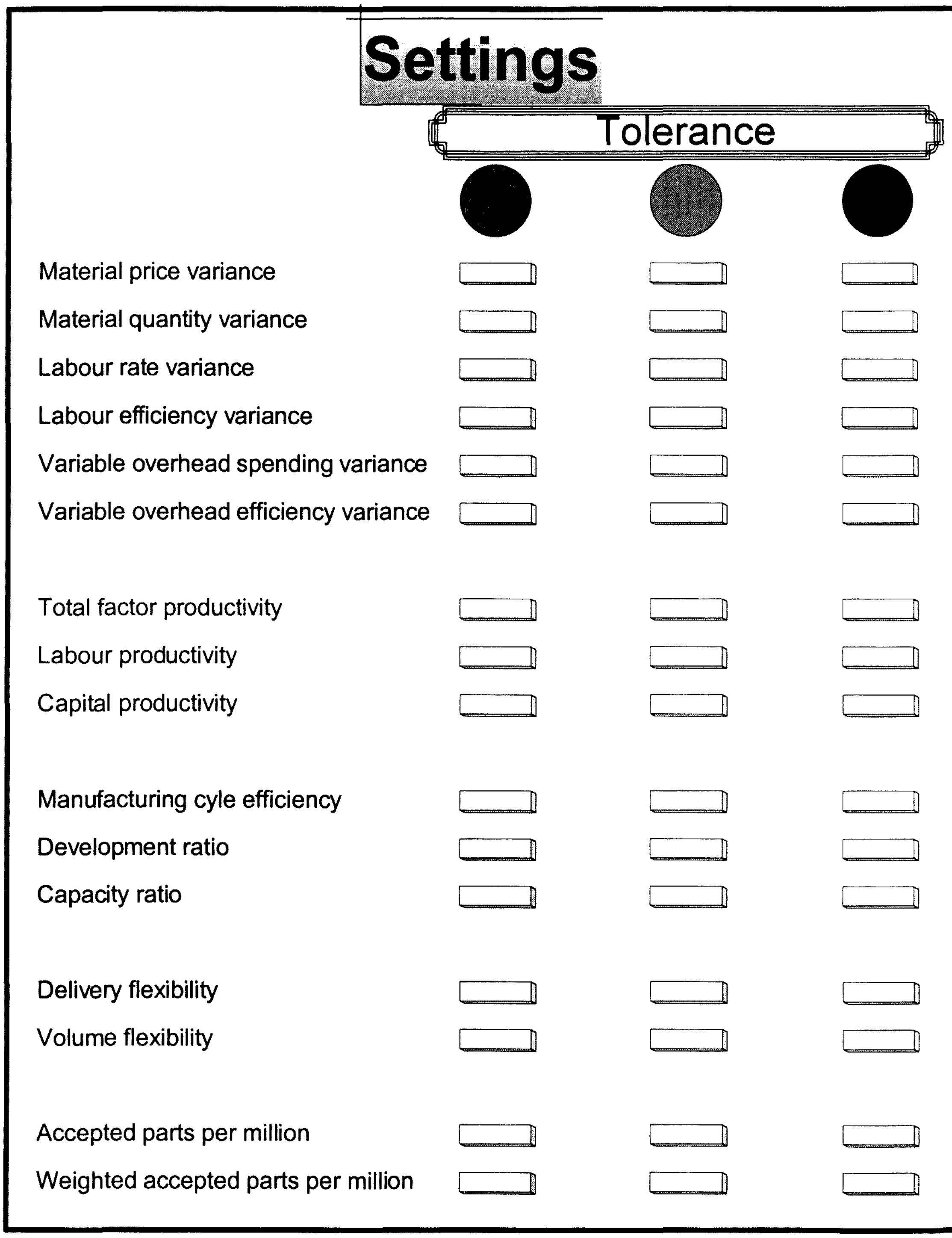


Figure D.1: User settings

The tolerances must be set up beforehand for the specific enterprise. The tolerances for each colour is as follows:

Table: D.1: Glossary of colours

Colour	Definition
Green	Operation within acceptable tolerance
Orange	Operation outside acceptable tolerance; needs investigation
Red	Operation outside acceptable tolerance; stop operation, identify problem and resolve

The KPI-structure will use these user-defined tolerances to notify the user of any problems with an operation. The tolerance is set up as a percentage of the deviation from the acceptable ideal.

D.3.2 Overview page

The first screen of the Performance Tree will be used when operations are within normal tolerances, or only need investigation. It will present the reader with the option to investigate any of the performance measure groups further if a problem is identified (any of the groups are orange). This form will not be seen when any of the KPIs is outside acceptable tolerance, and must be stopped for problem resolution (red). The final form, the specific suspect KPI, will then be displayed.

The requirement for the *Overview* page is as follows:

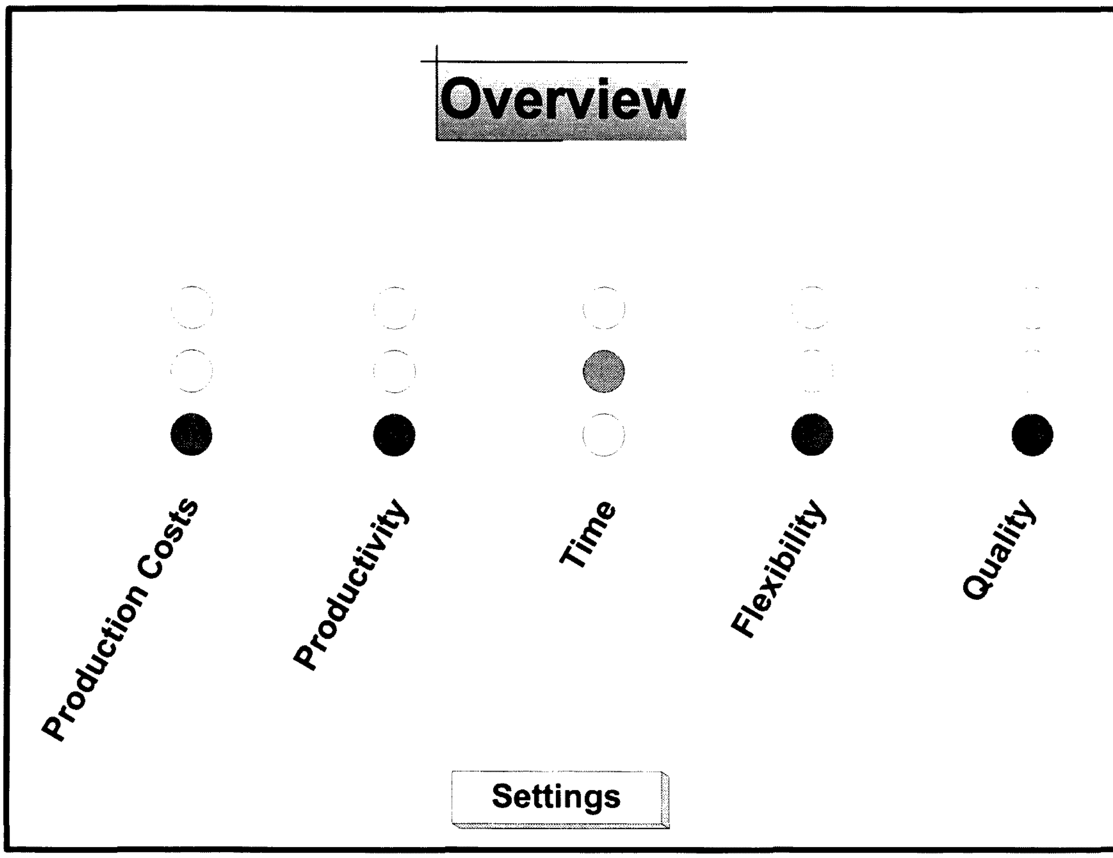


Figure D.2: Overview page

It must be possible for the user to click on the "out of tolerance" element as soon as it changes to orange. This will then take the user to the specific KPI that is outside the tolerance. (In the above example, it is the *Time* element that is out of tolerance. In this instance, when clicking on the orange button, the reader will be taken to the *Time*-screen, where the specific KPI can then be identified.)

There are five further pages that must be available to the user. This corresponds to the five elements in the Overview page. An example of one of these pages, the *Production costs*, is presented in the following figure.

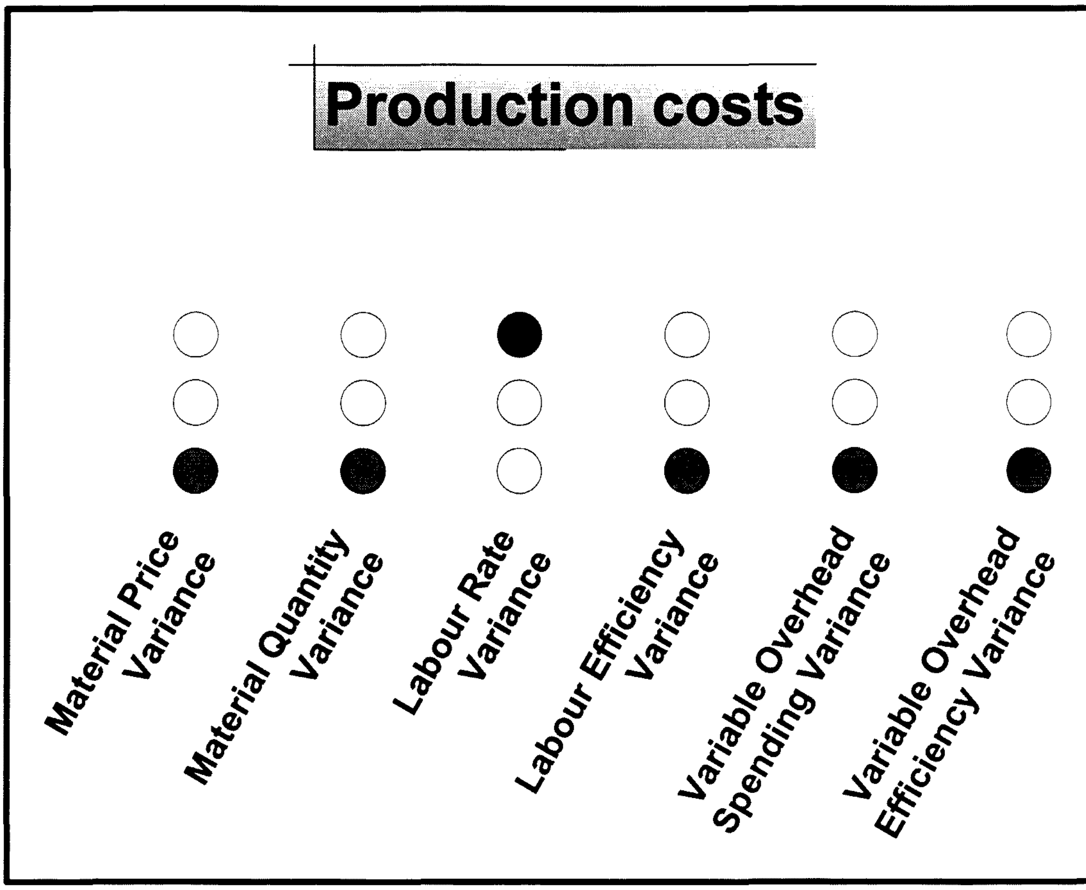


Figure D.3: Production costs page

As soon as one of the KPIs turns red, this will be the first page the user will view. Attention can then be focused on that specific indicator.

The same structure applies to the other four measures, namely:

- productivity;
- time;
- flexibility; and
- quality.

These are not represented here because the structure is the same as in Figure D.3.

Appendix E

Key performance indicators

E.1 Financial performance measures

The financial performance measures considers the following inputs:

- production costs;
- non-production costs; and
- productivity.

Each of these inputs is described in the paragraphs below.

E.1.1 Production costs

This section will make use of cost standards (or standard costing), because standard costing makes it possible to set objectives, and then to measure the difference relative to a standard – that is, what should have happened and what actually did happen. This is the method Dornier, Ernst, Fender & Kouvelis (1998:388) prefer for evaluating performance in global operations and logistics, a field that shares a lot of similarities with virtual enterprises. Cost standards can be used to determine the efficiency and effectiveness of the activities performed by the organisation. It is for this reason that the author decided on standard costing for evaluating the production costs. Although Neely et al. (1995) argue that this will result only in short-term control, it is the opinion of the author that long-term control and financial viability is not of concern to the virtual enterprise, but rather that of the individual companies of which the VE consist.

Another reason for choosing standard costing is the legal form of the virtual enterprise. Since there are no legal agreements between the different partners of the VE, there are no financial statements for the complete virtual enterprise. This excludes the extremely well documented and widely used financial ratios structure developed by the Du Pont Powder Company, the *Du Pont Pyramid of Financial Ratios.*

E.1.1.1 Cost of quality

Quality costs are categorised as (Angell & Chandra 2001: 112):

- the *price of conformance*, which includes both prevention and appraisal costs; and
- the *price of non-conformance*, which include internal and external failure costs.

Investment in *prevention costs* seek to eliminate the opportunity for quality defects by supporting activities such as quality programme management, training and education, quality promotion, process capability studies, failure mode and effect analysis, quality and function deployment, design of experiments, design for manufacturing, market research, internal and external customer surveys, quality planning, supplier certification programmes, preventative maintenance and cross-functional design teams.

The price of non-conformance includes *internal* and *external* failure costs. *Internal failure costs* are costs that occur when defective goods are still in the factory before shipment to customers. *External failure* costs appear when poor quality products are shipped to customers. These costs cover activities such as complaint adjustment, receipt and replacement of defective products, warranty charges and allowances or concessions made to customers for their trouble. Unfortunately, many external failure costs are unknown and unknowable, so that even with eventual perfect product quality, these intangible costs can linger due to the high multiplier effect of customer dissatisfaction (Angell & Chandra 2001:113)

E.1.1.2 Direct material costs

Direct materials are those materials that form an integral part of the finished product and that can be physically and conveniently traced into it.

The *material price variance* measures the difference between what is paid for a given quantity of materials and what should have been paid according to the standards that have been set. The formula for this variance is:

$$\begin{aligned} \textit{Material price variance} &= (AQ \times AP) - (AQ \times SP) \\ &= AQ(AP - SP) \end{aligned} \qquad \ldots(\text{E.1})$$

where

- ***AQ*** is the *actual quantity*;
- ***AP*** is the *actual price*; and
- ***SP*** is the *standard price.*

To normalise the measure for evaluating a product with a small price against a product with a larger one, and vice versa, the *material price variance* is divided by the *standard price* (***SP***):

$$\begin{aligned} \textit{Normalised material price variance} &= [(AQ \times AP) - (AQ \times SP)] / SP \\ &= [AQ(AP - SP)] / SP \end{aligned} \qquad \text{...(E.1b)}$$

There are many factors that influence the prices paid for raw materials: the size of the lots purchased, delivery method, quantity discount available, rush orders and the quality of materials purchased, to name a few.

The *material quantity variance* measures the difference between the quantity of materials used in production and the quantity that should have been used according to the standard that has been set. The formula for the materials quantity variance is as follows:

$$\begin{aligned} \textit{Material quantity variance} &= (AQ \times SP) - (SQ \times SP) \\ &= SP(AQ - SQ) \end{aligned} \qquad \text{...(E.2)}$$

where

- ***AQ*** is the *actual quantity*;
- ***SP*** is the *standard price*; and
- ***SQ*** is the *standard quantity allowed for output.*

The *normalised material quantity variance* is determined by dividing the *material quantity variance* by the *standard quantity* (***SQ***):

$$\begin{aligned} \textit{Normalised material quantity variance} &= [(AQ \times SP) - (SQ \times SP)] / SQ \\ &= [SP(AQ - SQ)] / SQ \end{aligned} \qquad \text{...(E.2b)}$$

The *material quantity variance* is best isolated at the time that materials are placed into production. Materials are drawn for the number of units to be produced, according to the standard bill of materials for each unit. The *material quantity variance* calls attention to the excessive use of materials while production is still in process and provides an opportunity for early control of any developing problem.

The excessive use of materials can result from many factors, including poor quality of inbound materials, faulty machinery, untrained workers or poor supervision. Generally speaking, it is the responsibility of the production department to see to it that the use of material is kept in line with standards. Quantity variance could also be ascribed to the purchasing department who might have bought inferior quality raw materials in order to economise on price, where these materials then proved unsuitable for production.

E.1.1.3 Direct labour costs

Direct labour costs are those labour costs that can be easily and conveniently be traced to products. It is also referred to as *touch labour*, since the direct labour workers typically touch the product while it is being made.

The price variance for direct labour is commonly termed a *labour rate variance*. The formula for labour rate variance is:

$$\begin{aligned} \text{Labour rate variance} &= (AH \times AR) - (AH \times SR) \\ &= AH(AR - SR) \end{aligned} \qquad \ldots(\text{E.3})$$

where

- ***AH*** is the a*ctual hours*;
- ***AC*** is the a*ctual rate*; and
- ***SR*** is the s*tandard rate.*

The *normalised labour rate variance* is determined by dividing the *labour rate variance* by the *standard rate* (***SR***):

$$\begin{aligned} \text{Normalised labour rate variance} &= [(AH \times AR) - (AH \times SR)] / SR \\ &= [AH(AR - SR)] / SR \end{aligned} \qquad \ldots(\text{E.3b})$$

In most organisations, the rates paid to workers are quite predictable; therefore rate variances, in terms of the amounts paid to workers, tend to be almost non-existent. Rate variances can arise, through the way labour is used. Skilled workers with high hourly rates of pay could be used for duties that require little or no skill and this could then call for low hourly rates of pay. This will result in unfavourable labour rate variances, since the rate paid for actual labour hours will exceed the standard rates authorised for the particular task being performed. A reverse situation can occur when unskilled or untrained workers are assigned to jobs that require some skill or training. The lower pay scale for these workers will result in favourable rate variances, although the workers could be highly inefficient in terms of output. It is also possible that unfavourable labour rates can arise from overtime work at premium rates if any portion of the overtime premium is added to the direct labour account.

The quantity variance for direct labour, more commonly referred to as the *labour efficiency variance*, measures the productivity of labour time. The formula for this measure is:

$$\begin{aligned} \textit{Labour efficiency variance} &= (AH \times SR) - (SH \times SR) \\ &= SR(AH - SH) \end{aligned} \qquad \ldots(\text{E.4})$$

where

- ***AH*** is the *actual hours*;
- ***SR*** is the *standard rate*; and
- ***SH*** is the *standard hours* allowed for output.

The *normalised labour efficiency variance* is determined by dividing the *labour efficiency variance* by the *standard hours* (***SH***):

$$\begin{aligned} \textit{Normalised labour efficiency variance} &= [(AH \times SR) - (SH \times SR)]/SH \\ &= [SR(AH - SH)]/SH \end{aligned} \qquad \ldots(\text{E.4b})$$

The possible causes for an unfavourable labour efficiency variance include poorly trained workers; poor quality materials, requiring more labour time in processing; faulty equipment, causing breakdowns and work interruptions and poor supervision of workers.

E.1.1.4 Manufacturing overheads

Manufacturing overheads include all costs of manufacturing, except direct materials and direct labour. It includes such items as indirect materials, indirect labour, maintenance and repair on production equipment, water and electricity, property tax, depreciation, etc. on manufacturing facilities. Water and electricity, property tax, depreciation and others are however associated with selling and administration functions and are therefore not included as part of manufacturing overheads.

The *variable overhead spending variance* measures deviations in the amounts spent for overhead inputs such as utilities. The formula for this variance can be expressed as follows:

$$\begin{aligned} \textit{Variable overhead spending variance} &= (AH \times AR) - (AH \times SR) \\ &= AH(AR - SR) \end{aligned} \qquad \ldots\text{(E.5)}$$

where

- ***AH*** is the *actual hours*;
- ***AR*** is the *actual rate*; and
- ***SR*** is the *standard rate*.

The *normalised variable overhead spending va*riance is determined by dividing the *variable overhead spending variance* by the *standard rate* (***SR***)

$$\begin{aligned} \textit{Normalised variable overhead spending variance} &= (AH \times AR) - (AH \times SR) \\ &= AH(AR - SR) \end{aligned} \qquad \ldots\text{(E.5b)}$$

Two things affect the overhead spending variance. First, a spending variance may occur simply because of price increases over and above what is shown in the flexible budget. This means that the prices paid for overhead items may have gone up during the year, resulting in unfavourable spending variances. Secondly, the overhead spending variance is affected by waste or excessive usage of overhead items.

The *variable overhead efficiency variance* is a measure of the difference between the actual activity in a specific period and the standard activity allowed, multiplied by the variable part of predetermined overhead rates. The formula for the measure can be expressed as:

$$\begin{aligned} \textit{Variable overhead efficiency variance} &= (AH \times SR) - (SH \times SR) \\ &= SR(AH - SH) \end{aligned} \qquad \ldots\text{(E.6)}$$

where

- ***AH*** is the *actual hours*;
- ***SR*** is the *standard rate*; and
- ***SH*** is the *standard hours* allowed for output.

The *normalised variable overhead efficiency variance* is determined by dividing the *variable overhead efficiency* by the *standard hours* (***SH***):

$$\textit{Normalised variable overhead efficiency variance} = [(AH \times SR) - (SH \times SR)]/SH = [SR(AH - SH)]/SH \quad \text{...(E.6b)}$$

The term *overhead efficiency variance* is a misnomer, since this variance has nothing to do with efficiency in the use of overhead. What the variance really measures, is how efficiently the base underlying the flexible budget is being utilised in production. If more hours are worked than are allowed at standard, then overhead efficiency variance will be unfavourable to reflect this inefficiency. As a practical matter, this inefficiency is not in the use of overheads, but rather in the use of the base itself. This measure is hardly ever used since flexible budgets are not frequently used by organisations.

E.1.1.5 Key performance indicators

The KPIs defined for the above production costs will make use of standard costing. The KPIs identified are:

- Direct materials price variance;
- Materials quantity variance;
- Labour efficiency variance; and
- Variable overhead spending variance.

These KPIs are easily measurable, and the data can be found through the standard ERP system. It is important to understand the ERP software in such a manner that the correct data are extracted.

E.1.2 Non-production costs

Generally, non-manufacturing costs are sub-classified into two sections:

- marketing and selling costs, and
- administrative costs.

Each of these sub-classifications is briefly explained.

E.1.2.1 Marketing and selling costs

Marketing and selling costs include all costs necessary to secure customer orders and to get the finished product in the hands of the customer. Examples of marketing costs include advertising, shipping, sales travel, sales commissions, sales salaries and costs regarding warehousing finished goods.

E.1.2.2 Administrative costs

Administrative costs include all executive, organisational and clerical costs associated with the general management of an organisation rather than those costs associated with manufacturing, marketing or selling. Examples of administrative costs include costs regarding executive compensation, general accounting, secretarial, public relations and similar costs involved in the general administration of the organisation as a whole.

E.1.3 Productivity

Productivity is conventionally defined as the ratio of total output to total input. Thus, productivity is a measure of how well resources are combined and used to accomplish specific, desirable results. Ruch (Neely et al. 1995) has pointed out that higher productivity can be achieved in a number of ways, including:

- increasing the level of output faster than that of the input (*managed growth*);
- producing more output with the same level of input (*working smarter*);
- producing more output with a reduced level of input (*the ideal*);
- maintaining the level of output while reducing the input (*greater efficiency*);
- decreasing the level of input, but decreasing the level of input even more (*managed decline*).

Productivity measurement is an important tool for evaluating a business unit's performance through production activities (Chen & Liaw 2001:1180).

Productivity measures are dived into:

- Total productivity; and
- Specific productivity.

E.1.3.1 Total productivity and specific productivity

Problems arise with the measurement of productivity, because it is difficult not only to define inputs and outputs, but also to quantify them. Craig and Harris (Neely et al. 1995) suggest that firms should seek to measure total, rather than partial, productivity. This point was later emphasised by Hayes et al. (Neely et al. 1995) when they described how firms could measure total factor productivity.

Total factor productivity (***TFP***) is defined as:

$$TFP = \frac{Value \quad added}{Labour\ inputs + capital\ inputs} \quad \ldots(E.7)$$

Value-added is the organisation's net contribution generated by production activities during a period. This model defines *labour inputs* (***L***) as expenses related to employees, including direct labour, indirect labour, marketing personnel, managers, etc. *Capital inputs* (***C***) are defined as both *fixed capital inputs* and *working capital inputs. Fixed capital assets* include depreciable assets (such as buildings, machinery, equipment and tools) and non-depreciable assets (such as land). The *working capital* includes the current assets on the balance sheet.

TFP can be reformulated to involve labour productivity (L_p) and capital productivity (C_p), which are partial indices measuring the value added per unit of labour input and per unit of capital input, respectively (Chen & Liaw 2001:1182). The *labour productivity* (L_p) can be defined as:

$$L_p = \frac{Value\ added}{Labour} = S_a \times V_r \quad \ldots(E.8)$$

where S_a represents the sales per employee (Sales(*S*)/Labour (# of employees)) and V_r the value-added ratio (***Value-added/Sales***). V_r is an index for measuring the percentage of value-added contribution by business sales, representing the profit per unit of sales. *Capital productivity* (C_p) can be defined as:

$$C_p = \frac{Value\ added}{Capital} = C_t \times V_r \quad \ldots(E.9)$$

where C_t is the capital-turnover ratio, which can be determined by ***Sales/Capital.***

E.1.3.2 Key performance indicators

The KPIs identified for productivity include the following:

- TFP (total factor productivity);
- C_p (capital productivity); and
- L_p (labour productivity).

All of the above are well-documented measures that are in use in a variety of leading-edge organisations that want to measure the performance of their productivity. It was for this reason that the author decided to include these KPIs in the structure.

E.2 Non-financial performance measures

Three non-financial performance measures have been identified by the author, namely:

- flexibility;
- time; and
- quality.

Each of these measures is explained below.

E.2.1 Flexibility

The dimensions of flexibility is range and response, where *range* refers to the issue of how far the manufacturing system can change and *response* focuses on the question of how rapidly and cheaply it can change (Neely et al. 1995).

Beamon (1999) gives a complete description of the four flexibility indicators. They are:

- volume flexibility;
- delivery flexibility;
- mix flexibility; and
- new product flexibility.

Each of these measures is described in more detail below.

E.2.1.1 Volume flexibility (F_v)

The *volume flexibility measure*, F_v, measures the proportion of demand that can be met (Beamon 1999:287). The first condition assumed, is that the demand volume, ***D***, is a random variable with an approximate normal distribution,

$$D \sim N\,(\mu_D, \sigma_D^2) \qquad \text{...(E.10)}$$

and which defines O_{min} and O_{max} as the break even and maximum profitable output (*resource limit*) volume during any period. Next it is assumed that sufficient data regarding demand volumes are available to the VE, and the parameters of the distribution for ***D*** corresponding to the mean demand and demand variance, can be effectively estimated as

$$\overline{D} = \frac{\sum_{t=1}^{T} d_t}{T} \qquad \text{...(E.11)}$$

$$S_D^2 = \frac{\sum_{t=1}^{T} (d_t - \overline{d})^2}{T - 1} \qquad \text{...(E.12)}$$

where d_t is the demand during period t, and T is the number of periods considered. The volume flexibility (F_v) can then be defined as:

$$F_v = P\,(\frac{O_{min} - \overline{D}}{S_D} \leq D \leq \frac{O_{max} - \overline{D}}{S_D}) \qquad \text{...(E.13)}$$

$$= \Phi\,(\frac{O_{max} - \overline{D}}{S_D}) - \Phi\,(\frac{O_{min} - \overline{D}}{S_D}) \qquad \text{...(E.14)}$$

where $F_v \in [0,1)$, and F_v represents the long-run proportion of demand that can be met.

E.2.1.2 Delivery flexibility (F_D)

The ability to move planned delivery dates forward to accommodate rush orders and special orders are described as *delivery flexibility* (Beamon 1999:288). *Delivery flexibility* is expressed as the percentage of slack time by which the delivery time can be reduced. The formula to define delivery flexibility needs t^* as the *current time period*, L_j as the *due date period* (or the latest time period during which the delivery can be made) for job j, and E_j as the earliest time period during which the delivery can be made for job j. If there are $j=1,\ldots,J$ jobs in the system, then the total slack time for all jobs j is represented by

$$\sum_{j=1}^{J} (L_j - t^*) \qquad \text{...(E.15)}$$

and the minimum delivery time for all jobs j is represented by

$$\sum_{j=1}^{J} (E_j - t^*) \qquad \text{...(E.16)}$$

Thus, F_D, the *instantaneous delivery flexibility*, may be measured as the percentage of excess slack across all jobs j, which can be formally defined as:

$$F_D = \frac{\sum_{j=1}^{J}((L_j - t^*) - (E_j - t^*))}{\sum_{j=1}^{J}(L_j - t^*)} \qquad \text{...(E.17)}$$

which simplifies to

$$F_D = \frac{\sum_{j=1}^{J}(L_j - E_j)}{\sum_{j=1}^{J}(L_j - t^*)} \qquad \text{...(E.18)}$$

E.2.1.3 Mix flexibility (F_m)

Mix flexibility is similar to, and often used interchangeably with *process* and *job flexibility*. *Mix flexibility* is a measure of the range of different product types that may be produced during a particular time period, or the response time between product mix changes (Beamon 1999:289). More specifically, Slack (Beamon 1999) define mix flexibility as:

- The number of different products that can be produced within a given time period (*product mix flexibility range*), or
- The time required to produce a new product mix (product mix flexibility response).

Formally, the product mix flexibility range is represented by:

$$F_m = N(t) \qquad \text{...(E.19)}$$

where $N(t)$ is the number of different product types that can be produced within the time period t. The product mix flexibility response may then be calculated as:

$$F_m = T_{ij} \qquad \text{...(E.20)}$$

where T_{ij} is the changeover time required from product mix i to product mix j, with $T_{ij} \geq 0$ for any i and j.

E.2.1.4 New product flexibility (F_n)

New product flexibility is defined as the ease with which new products are introduced (Beamon 1999:289). The introduction of new products will require a certain amount of time for development and set-up. Two different types of product flexibility can be measured:

- *time-based new product flexibility*, where the time is considered to introduce new products to existing operations; and
- *cost-based new product flexibility*, where the cost is considered to introduce new products to existing operations.

Time-based new product flexibility can be expressed as

$$F_n = T \qquad \text{...(E.21)}$$

where T is the time required to add new products, with $T \geq 0$. Similarly, cost-based new product flexibility may be expressed as

$$F_n = C \qquad \text{...(E.22)}$$

where C is the cost required to add new products, with $C \geq 0$.

E.2.1.5 Key performance indicators

The Key Performance Indicators defined for flexibility are:

- volume flexibility (F_v);
- delivery flexibility (F_D); and
- mix flexibility(F_M).

Volume flexibility is a measure of the percentage of demand that can be met, while *delivery flexibility* is a measure of the ability of the organisation to accommodate rush orders and special orders. The *mix flexibility* is an indicator that is very difficult to measure, but it gives an indication of a SME's agility within a virtual enterprise. All of these measures are of importance for the virtual enterprise, since they present the measures that are most important to customers, and the VE as a whole, with regard to flexibility. The volume flexibility and delivery flexibility are both measures that represent ratios of the customer's perceived view of flexibility.

E.2.2 Quality

This section will concentrate on performance measures that measure both the output and the process itself. The author identified three types of quality measures:

- produced quality;
- perceived quality; and
- inbound quality.

Each of these measures is explained briefly.

E.2.2.1 Produced quality

Produced quality can be measured through the effective use of statistical process control (SPC) and the number of defective goods returned during the warranty period. The purpose of the SPC is to control the scrap and the discards in the manufacturing process through the use of tools such as control charts, Pareto charts, process capability indices, etc.

A measure for produced quality is the number of defective parts per million. The measure for *defective parts per million* (DPPM) is normalised to a scale of 0 to 1 by means of the following transformation:

$$APPM = 1 - \frac{DPPM}{1{,}000{,}000} \qquad \ldots(E.23)$$

where APPM represents *acceptable parts per million*. An APPM of 1 corresponds to zero defects (DPPM=0), while an APPM value of 0 corresponds to all products being defective (DPPM=1,000,000).

E.2.2.2 Perceived quality

The *perceived quality* is the reputation, image, product capabilities, service, speed of delivery, dependability or other inferences regarding the attributes of a product as perceived by the customer. It is a very subjective measure since it is a measure that is extremely difficult to capture. Surveys need to be conducted to accumulate the necessary data required to make decisions based on the perception of customers about the quality of the product. After changes were made, it is necessary to conduct a complete new survey to evaluate these changes.

Perceived quality is used in determining value in the marketing field. *Value* is defined as the ratio of perceived quality to price: higher value is obtained when the customer gets greater perceived quality for a particular price, or the same perceived quality for a lower price (Meredith, McCutcheon & Hartley 1994:8).

E.2.2.3 Inbound quality

Inbound quality is the most important aspect of quality for the virtual enterprise. The VE's structure is made up of a variety of small firms, each producing that part of the final product for which that specific business unit is responsible. The quality of the component for which each individual business unit is responsible, interacts with the downstream operations in the other partner firms. The inbound quality is calculated so that different business units can be evaluated against one another.

The measure for produced quality is used in inbound quality through *data envelope analysis* (DEA), which is a linear-programming-based methodology that can evaluate multiple inputs and multiple outputs to calculate a ratio (*performance measure*) of total weighted output to total weighted input. This ratio is the relative efficiency of a decision-making unit (DMU). A DMU can be any economic agent with limited resources, aspiring to attain specified performance goals with as few inputs as possible (Forker & Mendez 2001:197).

The strength of this measure is that DEA calculates a combined index of overall performance using multipliers (weights) that maximise each DMU's efficiency score, relative to other DMUs (firms) in the comparison set. This means that the multipliers can vary from firm to firm, which allows the comparison of the account for structural differences among organisations.

The DEA rating is calculated for each supplier (or possible partner in the VE) as a measure of relative efficiency by calculating the maximum ratio of weighted APPM (*output*) to weighted TQM practices (*inputs*), subject to the conditions that similar ratios for every supplier be less that or equal to one and the weights chosen for the various outputs and inputs be greater than or equal to zero. These conditions can be formulated in mathematical terms as follows (Forker & Mendez 2001:202-203):

$$\max_{u_1, v_1, \ldots, v_8} \frac{u_1 APPM_k}{v_1 TM_k + v_2 PD_k + v_3 SM_k + v_4 QD_k + v_5 PM_k + v_6 QR_k + v_7 ER_k + v_8 T_k} \quad \ldots(E.24)$$

$$s.t. \quad \frac{u_1 APPM_i}{v_1 TM_i + v_2 PD_i + \ldots} \leq 1 \quad for \quad i = 1,2,\ldots\ldots,N$$

$$u_1, v_1, \ldots, v_8 \geq 0$$

In this equation, the abbreviations are as follows, measured on a scale from 1 to 5, to represent the responses *no extent* to *great extent.*

Table E.1: Abbreviations for TQM practices

Abbreviation	Variable
QD	Role of the quality department
TM	Role of top management and quality policy
PD	Product/Service design
ER	Employee relations
QR	Quality data and reporting
T	Training
PM	Process management/operating procedures
SM	Supplier quality management

It is also possible to define other measures with regard to quality. The measures presented in table E.1 are defined for the above equations. It is possible to include other variables as well, or disregard some of the mentioned ones if they are not applicable.

The representative solution is the one for which v_1 $TM_k + \ldots + v_8$ $T_k = 1$. Applying this transformation to the problem, the following linear programme can be obtained:

$$Max \quad u_1 APPM_k \qquad \text{...(E.25)}$$

s.t.

$$v_1 TM_k + v_2 PD_k + ... + v_8 T_8 = 1$$
$$u_1 APPM_i - v_1 TM_i - v_2 PD_i - ... \leq 0 \quad for \quad i=1,2,...,N$$
$$u_1, v_1, ..., v \geq_8 0$$

An optimal objective function value of 1 for the linear fraction programme represented above indicates that the supplier under consideration is *efficient* relative to its peer suppliers. A number less than 1 for the DEA rating also indicates that the supplier is *insufficient* relative to other suppliers (or possible partners) in the virtual enterprise.

E.2.2.4 Key performance indicators

The KPIs identified by the author for quality are:

- produced quality; and
- inbound quality.

The perceived quality is extremely difficult to measure (since it is very subjective), and is not included as a KPI. The other two indicators are of extreme importance to the VE's quality of its products, and must therefore be included.

E.2.3 Time

Time has been described as both a source of competitive advantage and as the fundamental measure of manufacturing performance (Neely et al. 1995). This statement can be justified by considering *just-in-time* (JIT) manufacturing and *optimised production technology* (OPT). Under the JIT manufacturing philosophy the production or delivery of goods just too early or just too late is seen as waste. Similarly, one of the objectives of OPT is the minimisation of throughput times.

The importance of time must never be underestimated. For all businesses, *profit* is a function of the time taken to respond to the needs of the market. This in turn means that profitability is inversely proportional to the level of inventory in the system, since the response time is itself a function of time. The rate at which a product contributes money determines the relative product profitability, and it is the rate at which a product contributes money compared to the rate at which the factory spends money that determines absolute profitability (Neely et al. 1995).

Time is categorised as either *internal time* or *external time.*

E.2.3.1 Internal times

There are two types of internal time:

- process time; and
- wait and move times.

Each of these sub-classifications is described in more detail below.

E.2.3.1.1 Process time

Process time is the amount of time in which work is actually done on the product.

E.2.3.1.2 Wait and move time

Wait time include *inspection time* and *queue time. Inspection time* is the amount of time spent to ensure that the product is not defective, while *queue time* is the amount of time a product spends waiting to be worked on, to be moved, to be inspected, or in storage waiting to be shipped.

Move time is the time required to move materials or partially completed products from workstation to workstation.

E.2.3.2 Key performance indicators

The internal times can be classified as *value-added time* and *non-value-added time.* The classification of the value-added and non-value-added times is given below, each with the types of activity times classified under it.

- Value-added time;
    - process time
- Non-value-added time
    - set-up time
    - wait time
    - inspection time
    - move time

- queue time

The *throughput time*, which is considered a key measure in delivery performance, can be evaluated by computing the *manufacturing cycle efficiency* (MCE) as follows:

$$MCE = \frac{Value\ added\ \ time}{Throughput\ \ (manufacturing\ \ cycle)\ \ time}$$
$$MCE = \frac{Total\ run\ time\ of\ all\ operations}{Time\ on\ production\ floor} \qquad \ldots(E.26)$$

The manufacturing cycle time includes all the value-adding and non-value-adding activities.

If the MCE is less than 1, then non-value-added time is present in the production process. An MCE of 0,5 would mean that half of the total production time consisted of inspection, moving, and similar non-value-added activities. An MCE of 0,1 (10%) means that 90% of the time a unit is in process is spent on activities that do not add value to the product.

E.2.3.3 External times

External times are classified according to the following sub-classifications:

- Time to market,
- Delivery speed and reliability, and
- System times, which are sub-classified into
    - supplier lead time;
    - manufacturing lead time; and
    - distribution lead time.

Each of these sub-classifications is described in more detail below.

E.2.3.3.1 Time to Market

Time to market is the time to engineer a product to order (see Figure E.1). In this environment, the following lead times should be considered:

- development lead time;
- procurement lead time;
- production lead time; and
- distribution lead time.

The opportunity for organisations in this environment to reduce total lead time begins with the reduction of product lead times.

E.2.3.3.2 Delivery Speed and Reliability

The *delivery speed* is the time required to carry out orders. The *delivery cycle time* is the time from receipt of an order from a customer to the shipment of the finished goods. This measure is called the *delivery time* (***DT***) (Bartezzaghi, Spina & Verganti 1994:5). This measure can be rewritten as the inventory turnover. *Inventory turnover* is the number of times the average inventory balance has been used (and thereby replaced) during a specified time period. Inventory turnover for a year is determined by the following ratio:

$$Inventory \quad turnover = \frac{Cost\ of\ goods\ sold}{Average\ inventory\ balance} \qquad \ldots(E.27)$$

Reliability is the respecting of due dates and the completeness of the order as required by the customer or promised to the customer.

E.2.3.3.3 System times

Lead times are divided into:

- development lead time (LT_e);
- procurement lead time (LT_p);
- production (manufacturing) lead time (LT_m); and
- distribution lead time (LT_d).

The interaction between the product stages and the product environment with regard to lead times is graphically represented in the following figure. It is important to note that some of the product stages can overlap (it is possible that production can start while the procurement of non-critical components is still being done, and the same with fabrication and assembly).

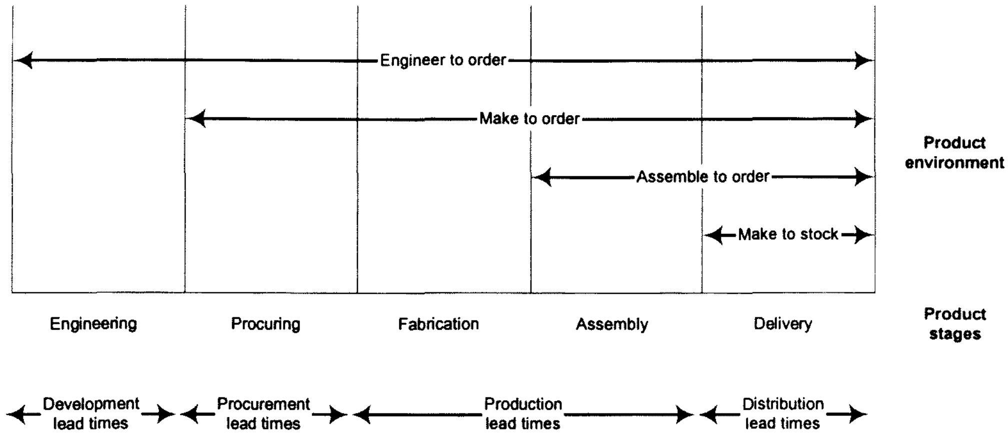


Figure E.1: Interaction between product environment and product stages w.r.t. lead time

Source: Tersine and Hummingbird (1995:12)

Development lead time

The *development lead time* (LT_e) is the time associated with conceptualising a new product.

Procurement lead time

Procurement lead time (LT_p) is the time associated with the procurement stage in a product. It is an external time since it is dependant upon suppliers and other external influences.

Manufacturing Lead Time

Manufacturing lead time (LT_m) is the time associated with fabrication and assembly (for assemble to order products).

Distribution Lead Time

Distribution lead time (LT_d) is the time associated with delivery of the final product, and is present in all products.

E.2.3.4 Key Performance Indicators

The *primary lead time* (***PLT***) can be calculated as:

$$PLT = LT_p + LT_m + LT_d + LT_e \qquad \text{...(E.28)}$$

It is important to note that LT_e is only present when new products are developed by the organisation. A measure for organisations that regularly develop new products, is the *development efficiency* (D_e):

$$D_e = 1 - \frac{LT_e}{PLT} \qquad \text{...(E.29)}$$

The closer the development efficiency tends to 1, the more efficient is the development stage. A development efficiency of 0,5 indicates that 50% of the primary lead time is spent on product development.

The *lead time* (***LT***) is determined as:

$$LT = PLT + WT \qquad \text{...(E.30)}$$

where ***WT*** represents the *wait time* from when a *customer order* (***CO***) is entered until it becomes a *works order* (***WO***). The *capacity ratio* (***CR***) is defined as:

$$CR = \frac{PLT}{LT} \qquad \text{...(E.31)}$$

The closer the ratio tends to 1, the more efficient the capacity planning is. A ratio of 1 means that work can start on a customer order as soon as it is loaded into the system (a customer order becomes a works order as soon as it is loaded). If the ratio is 0,6, it means that 40% of the time is not value-added time, since the customer is waiting 40% of the time from placing the order until receiving the product on non-primary lead time (***PLT***).

Appendix F

Material price variance and material quantity variance

F.1 Database investigation

The 3DBS database fields were investigated so as to ascertain which fields would be required so as to complete the calculations required for the KPI's.

It was found that the *material price variance* and *material quantity variance* KPIs were the only financial indictors that could be measured, as the remaining KPIs required values for which there were no fields in the ERP database. An example of this is the *labour rate variance.* This KPI requires the actual hours worked by an employee on a task. There is no field within the 3DBS ERP database that equals this value. The only manner in which this value can be obtained, is if the actual worker involved in this task were to fill in a form after the completion of the task and then this form would be used to enter the *completion time* into the ERP database. Another option will be to query the MES database for this value, and then integrate this database with the MES database to transfer the time stamp..

It was decided to use the first two KPIs as an example of implementing the Performance Tree. The remaining KPIs will be completed at a later stage when the different databases within the 3DBS are integrated.

F.2 Calculation development

This section makes reference to two KPI's, namely:

- Material price variance, and
- Material quantity variance.

These KPIs have been chosen for reasons specified in *Section F.1*.

F.2.1 Material price variance

Table F.1: Tables and fields used in the calculation of *material price variance*

Formula variable	Table	Field
SP (Standard Price)	Part financial year data	Material cost
AP (Actual Price)	Order line	Unit price Quantity complete Quantity rejected
AQ (Actual Quantity)	Order line	Quantity complete Quantity rejected

In order to determine the AP it was necessary to use the following formula:

$$Actual\ price\ (AP) = \frac{\sum(Unit\ price * Quantity\ complete)}{\sum(Quantity\ complete + Quantity\ rejected)} \qquad \ldots(F.1)$$

The summation occurs over the time period for which the unit price remains constant i.e. if the *Unit price* for item A changes from R6.00 to R7.25 after five days then the summation will occur over those five days for which the unit price was constant at R 6.00.

F.2.1.1 Filters

Filters were used within the SQL statements to eliminate data that was not relevant. The following filters were used:

- Only orders that have been completed are of interest. Therefore, a filter has been set so that all orders that are used have a completion date greater than zero and less than a date specified by the user.

- This KPI is focused on *purchase orders.* Purchase orders are indicated by the letters *PUR* in the *Order type* field of the table *Order line.* A SQL statement was used to filter these orders.

F.2.2 Material quantity variance

Table F.2: Tables and fields used in the calculation of *material quantity variance*

Formula variable	Table	Field
SP (Standard Price)	Part financial year data	Material cost
SQ (Standard Quantity)	Order line	Quantity ordered
AQ (Actual Quantity)	Order line	Quantity complete Quantity rejected

F.2.2.1 Filters

Filters were used within the SQL statements to eliminate data that was not relevant. The following filters were used:

- Only orders that have been completed are of interest. Therefore a filter has been set so that all orders that are used have a completion date greater than zero and less than a date specified by the user.
- This KPI is focused on *Production orders*. Production orders are indicated by the letters *PROD* in the *Order type* field of the table *Order line*. A SQL statement was used to filter these orders.

F.3 Example of material quantity variance

A specific KPI, the *material quantity variance*, was identified to illustrate the process of extracting a KPI from an ERP database, manipulating the relevant data and presenting it in a useful manner.

The Qmuzik system was used to create a *works order* with number *W79183*. The first step is to create the *Order Header* (Figure F.1) in the *Order Master* function. The information required in the *Order Header* is the *Order Number*, the *Type* (for *Works Orders* the *Type* is *Production*), the *Planner* and the *Division* (to which the order is assigned to).

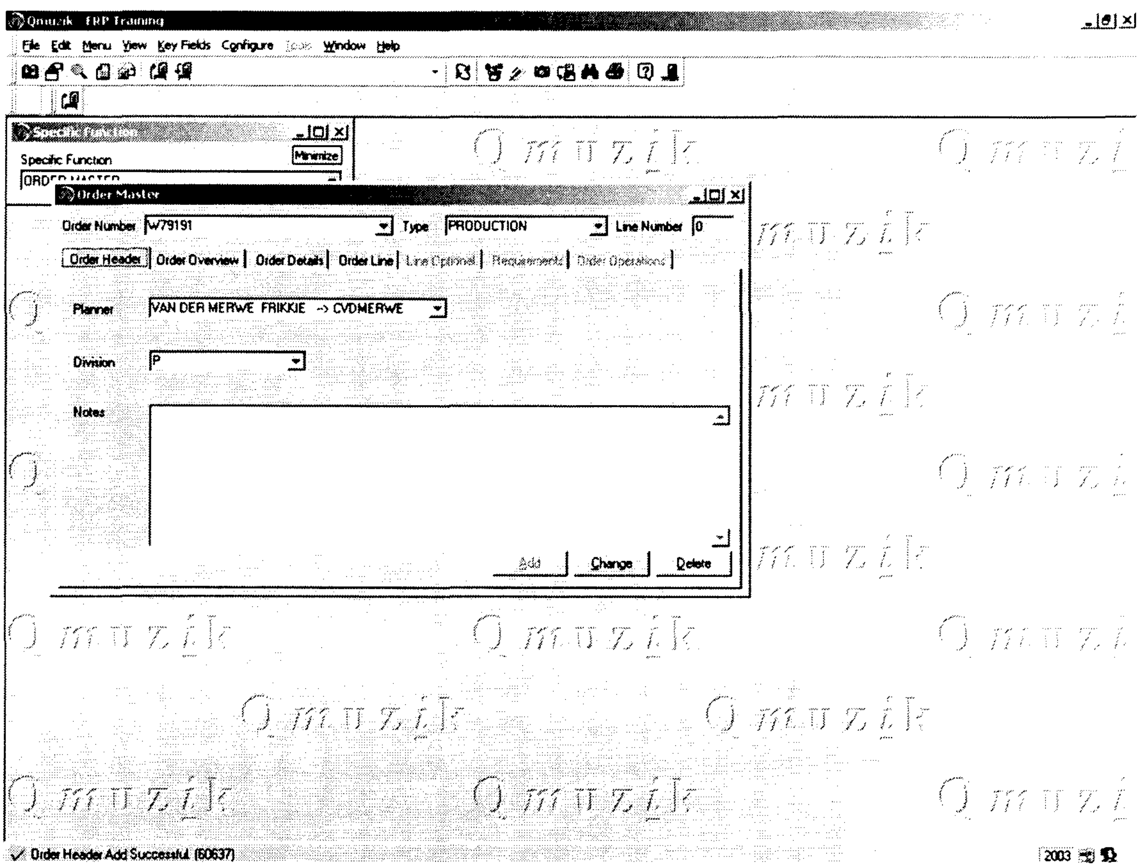


Figure F.1: Order Header in Qmuzik

On the *Order Line* tab, the required information is the *Line Number*, the *Part Number* (related to the division on the *Order Header* tab) of the parts that are to be manufactured, the *Start Date* and *Completion Date* of the order production, the *Status* of the order (*Released* means the order is released for production) and the *Quantity Ordered*. Figure F.2 shows this screen.

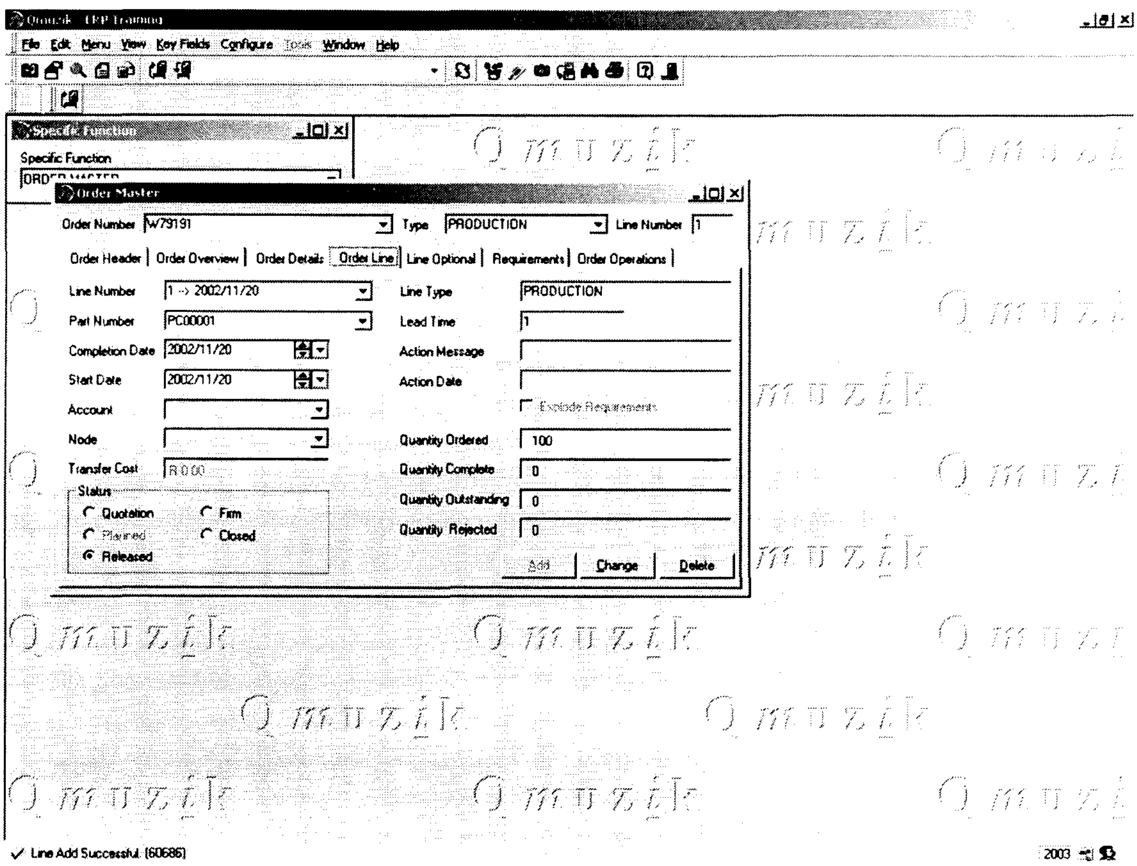
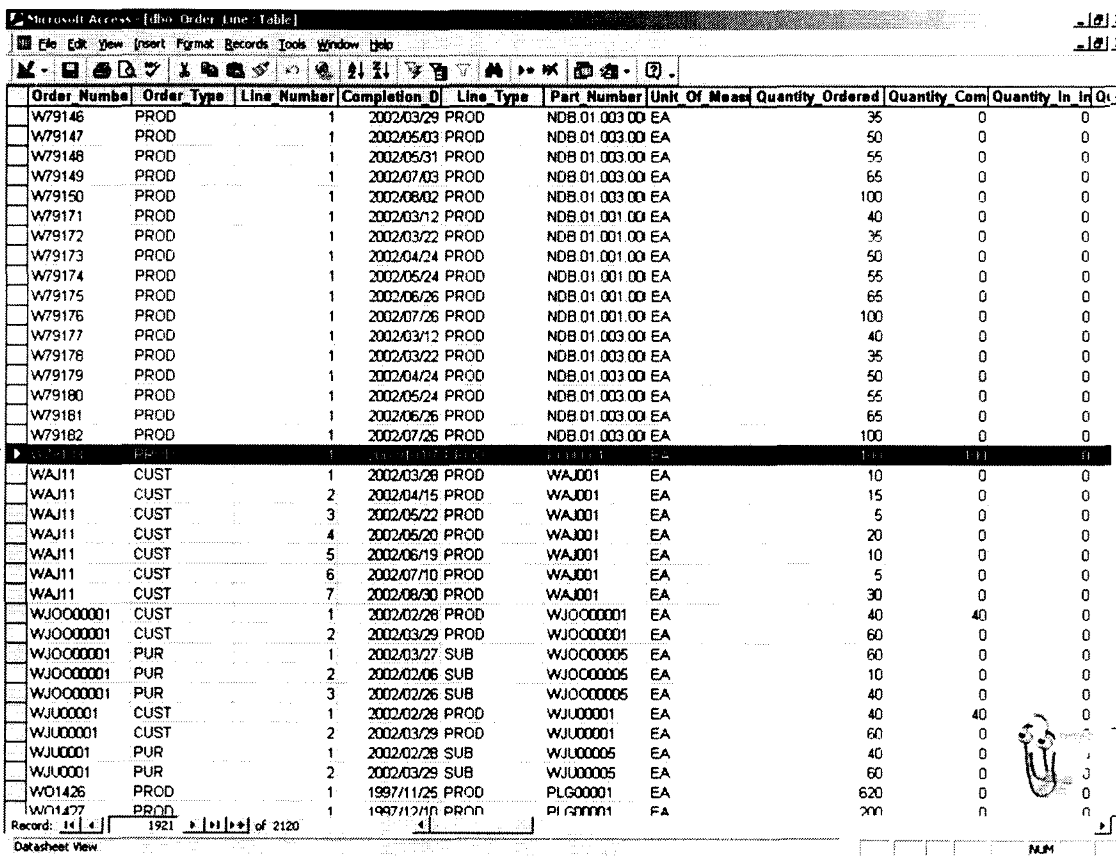


Figure F.2: Order Line in Qmuzik

In the *dbo_Order_Line* table of the Qmuzik database, it can be seen that the product that has been ordered was *PC00001*, and the quantity of products ordered were *100* (Figure F.3).



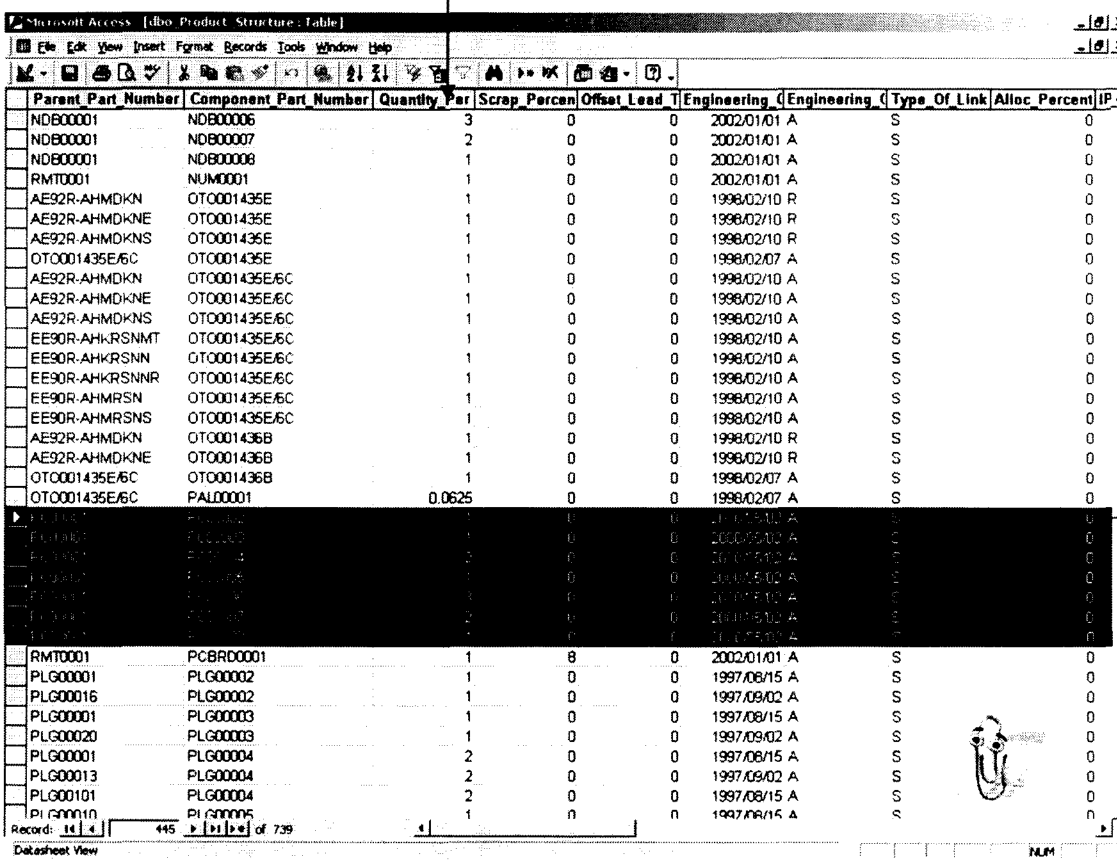
Order_Numbe	Order_Type	Line_Number	Completion_D	Line_Type	Part_Number	Unit_Of_Meas	Quantity_Ordered	Quantity_Com	Quantity_In_In
W79146	PROD	1	2002/03/29	PROD	NDB.01.003.00	EA	35	0	0
W79147	PROD	1	2002/05/03	PROD	NDB.01.003.00	EA	50	0	0
W79148	PROD	1	2002/05/31	PROD	NDB.01.003.00	EA	55	0	0
W79149	PROD	1	2002/07/03	PROD	NDB.01.003.00	EA	65	0	0
W79150	PROD	1	2002/08/02	PROD	NDB.01.003.00	EA	100	0	0
W79171	PROD	1	2002/03/12	PROD	NDB.01.001.00	EA	40	0	0
W79172	PROD	1	2002/03/22	PROD	NDB.01.001.00	EA	35	0	0
W79173	PROD	1	2002/04/24	PROD	NDB.01.001.00	EA	50	0	0
W79174	PROD	1	2002/05/24	PROD	NDB.01.001.00	EA	55	0	0
W79175	PROD	1	2002/06/26	PROD	NDB.01.001.00	EA	65	0	0
W79176	PROD	1	2002/07/26	PROD	NDB.01.001.00	EA	100	0	0
W79177	PROD	1	2002/03/12	PROD	NDB.01.003.00	EA	40	0	0
W79178	PROD	1	2002/03/22	PROD	NDB.01.003.00	EA	35	0	0
W79179	PROD	1	2002/04/24	PROD	NDB.01.003.00	EA	50	0	0
W79180	PROD	1	2002/05/24	PROD	NDB.01.003.00	EA	55	0	0
W79181	PROD	1	2002/06/26	PROD	NDB.01.003.00	EA	65	0	0
W79182	PROD	1	2002/07/26	PROD	NDB.01.003.00	EA	100	0	0
[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	EA	[illegible]	[illegible]	[illegible]
WAJ11	CUST	1	2002/03/28	PROD	WAJ001	EA	10	0	0
WAJ11	CUST	2	2002/04/15	PROD	WAJ001	EA	15	0	0
WAJ11	CUST	3	2002/05/22	PROD	WAJ001	EA	5	0	0
WAJ11	CUST	4	2002/05/20	PROD	WAJ001	EA	20	0	0
WAJ11	CUST	5	2002/06/19	PROD	WAJ001	EA	10	0	0
WAJ11	CUST	6	2002/07/10	PROD	WAJ001	EA	5	0	0
WAJ11	CUST	7	2002/08/30	PROD	WAJ001	EA	30	0	0
WJO000001	CUST	1	2002/02/28	PROD	WJO000001	EA	40	40	0
WJO000001	CUST	2	2002/03/29	PROD	WJO000001	EA	60	0	0
WJO000001	PUR	1	2002/03/27	SUB	WJO000005	EA	60	0	0
WJO000001	PUR	2	2002/02/06	SUB	WJO000005	EA	10	0	0
WJO000001	PUR	3	2002/02/26	SUB	WJO000005	EA	40	0	0
WJU00001	CUST	1	2002/02/28	PROD	WJU00001	EA	40	40	0
WJU00001	CUST	2	2002/03/29	PROD	WJU00001	EA	60	0	[illegible]
WJU0001	PUR	1	2002/02/28	SUB	WJU00005	EA	40	0	[illegible]
WJU0001	PUR	2	2002/03/29	SUB	WJU00005	EA	60	0	[illegible]
WO1426	PROD	1	1997/11/25	PROD	PLG00001	EA	620	0	0
WO1427	PROD	1	1997/12/10	PROD	PLG00001	EA	200	0	0

Record: 1921 of 2120

Datasheet View

Figure F.3: Quantity of products ordered

In the *dbo_Product_Structure* table (Figure F.4), it can be seen that the product PC00001 is manufactured by using 7 different parts. The quantity of parts needed for the manufacturing of every PC00001 product are also available in the *Quantity_Per* column.



Parent_Part_Number	Component_Part_Number	Quantity_Per	Scrap_Percen	Offset_Lead_T	Engineering_(	Engineering_(	Type_Of_Link	Alloc_Percent	IP
NDB00001	NDB00006	3	0	0	2002/01/01	A	S	0	
NDB00001	NDB00007	2	0	0	2002/01/01	A	S	0	
NDB00001	NDB00008	1	0	0	2002/01/01	A	S	0	
RMT0001	NUM0001	1	0	0	2002/01/01	A	S	0	
AE92R-AHMDKN	OTO001435E	1	0	0	1998/02/10	R	S	0	
AE92R-AHMDKNE	OTO001435E	1	0	0	1998/02/10	R	S	0	
AE92R-AHMDKNS	OTO001435E	1	0	0	1998/02/10	R	S	0	
OTO001435E/6C	OTO001435E	1	0	0	1998/02/07	A	S	0	
AE92R-AHMDKN	OTO001435E/6C	1	0	0	1998/02/10	A	S	0	
AE92R-AHMDKNE	OTO001435E/6C	1	0	0	1998/02/10	A	S	0	
AE92R-AHMDKNS	OTO001435E/6C	1	0	0	1998/02/10	A	S	0	
EE90R-AHKRSNMT	OTO001435E/6C	1	0	0	1998/02/10	A	S	0	
EE90R-AHKRSNN	OTO001435E/6C	1	0	0	1998/02/10	A	S	0	
EE90R-AHKRSNNR	OTO001435E/6C	1	0	0	1998/02/10	A	S	0	
EE90R-AHMRSN	OTO001435E/6C	1	0	0	1998/02/10	A	S	0	
EE90R-AHMRSNS	OTO001435E/6C	1	0	0	1998/02/10	A	S	0	
AE92R-AHMDKN	OTO001436B	1	0	0	1998/02/10	R	S	0	
AE92R-AHMDKNE	OTO001436B	1	0	0	1998/02/10	R	S	0	
OTO001435E/6C	OTO001436B	1	0	0	1998/02/07	A	S	0	
OTO001435E/6C	PAL00001	0.0625	0	0	1998/02/07	A	S	0	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	A	[illegible]	0	
[illegible]	[illegible]	[illegible]	0	0	[illegible]	A	[illegible]	0	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	A	[illegible]	0	
[illegible]	[illegible]	[illegible]	0	0	[illegible]	A	[illegible]	0	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	A	[illegible]	0	
[illegible]	[illegible]	2	[illegible]	[illegible]	[illegible]	A	[illegible]	0	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	A	[illegible]	0	
RMT0001	PCBRD0001	1	8	0	2002/01/01	A	S	0	
PLG00001	PLG00002	1	0	0	1997/08/15	A	S	0	
PLG00016	PLG00002	1	0	0	1997/09/02	A	S	0	
PLG00001	PLG00003	1	0	0	1997/08/15	A	S	0	
PLG00020	PLG00003	1	0	0	1997/09/02	A	S	0	
PLG00001	PLG00004	2	0	0	1997/08/15	A	S	0	
PLG00013	PLG00004	2	0	0	1997/09/02	A	S	0	
PLG00101	PLG00004	2	0	0	1997/08/15	A	S	0	
PLG00010	PLG00005	1	0	0	1997/08/15	A	S	0	

Figure F.4: Parts for product PC00001

Parts (components) of the final product are issued against the specific *Works Order*. The *Stores to Order Requirements* moves the components from the *Raw Materials Store* to *Production*, while all the components are booked against the *Works Order*. *Order Requirements to Scrap* movements are used to move damaged products from the production area to scrap. The components that were scrapped, needs to be reissued from the *Raw Materials Store* to complete the order. When all the products are finished, a movement is done from *Production to Stores* to place the finished products in the *Finished Goods Store*. The *Movements* screen is showed in Figure F.5.

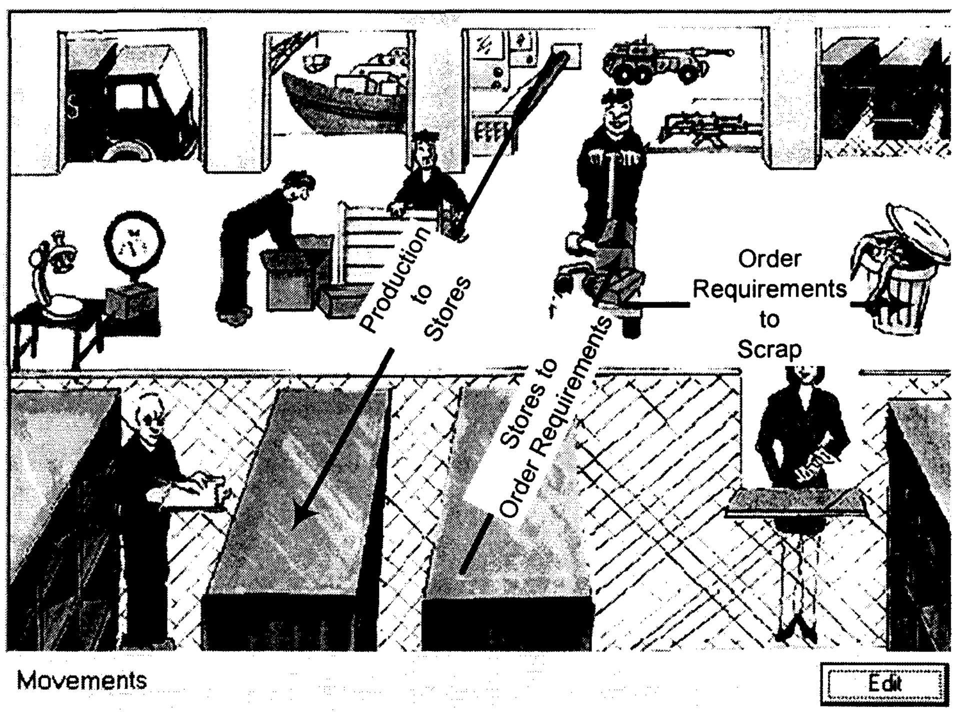


Figure F.5: Movements screen in Qmuzik

The movement screen for *Stores to Order Requirements* is showed in Figure F.6. The required fields for this function is the *Store* (the store from where the movement originates), the *Order Number* and *Order Line*, the *Mode* (for this example, *Part Only* is used, indicating that each part is moved independently from other parts), and the *Quantity*.

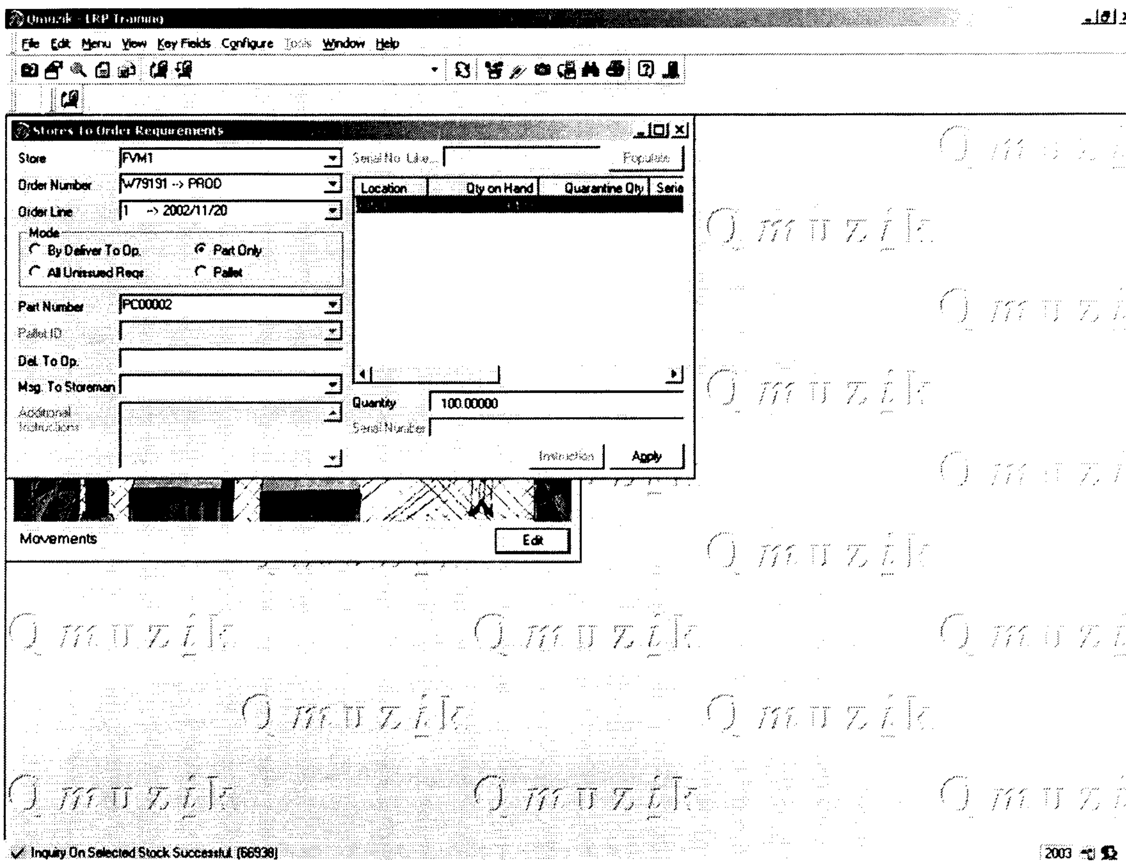
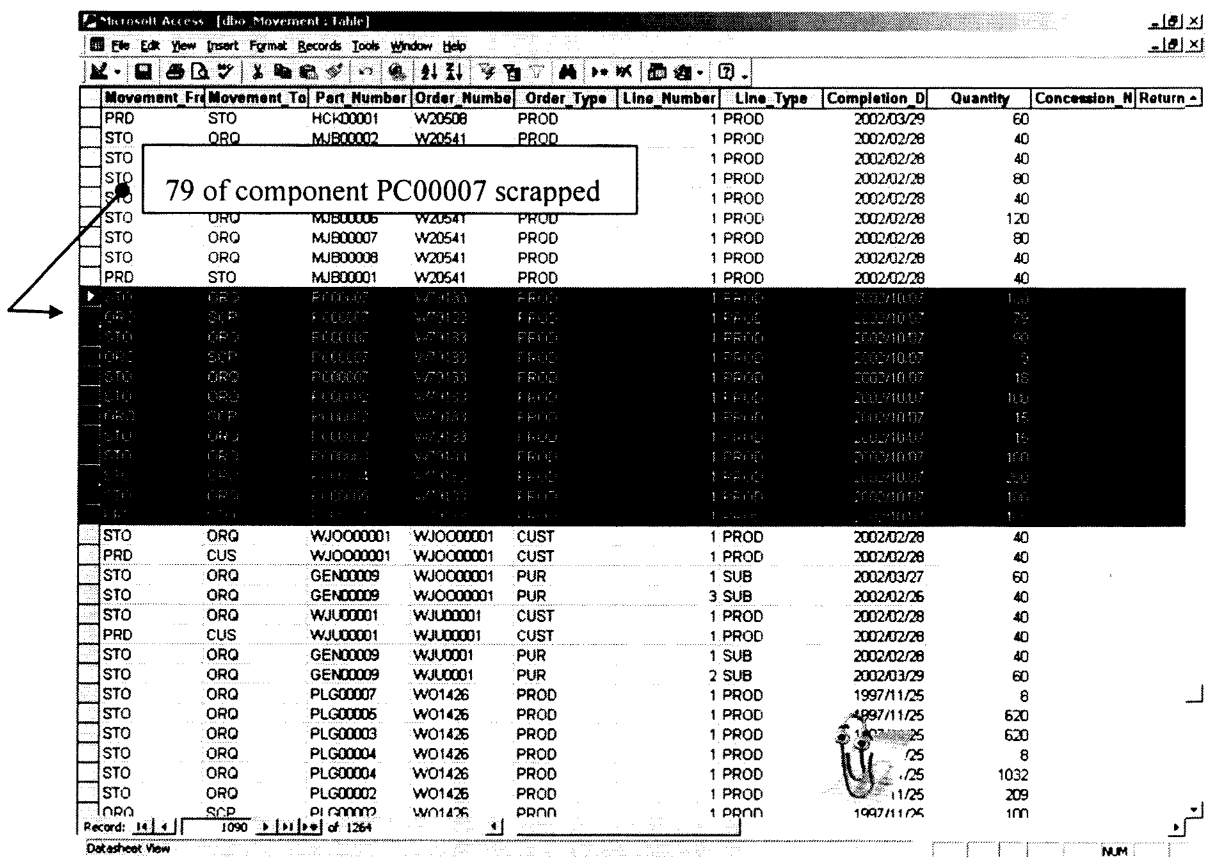


Figure F.6: Stores to Order Requirements screen in Qmuzik

Certain parts were then scrapped using the Qmuzik system. This included quantities of 79 and 9 of part *PC00007*, and 15 of part *PC00002*.

In the *dbo_Movement* table (Figure F.7) all the movements of the parts on the specific order are shown. It is important to note that no movement has been recorded for parts *PC00006* and *PC00008*. This is because these parts are floor stock, which is readily available on the production floor. These parts are thus ignored when the quantity variance is calculated.

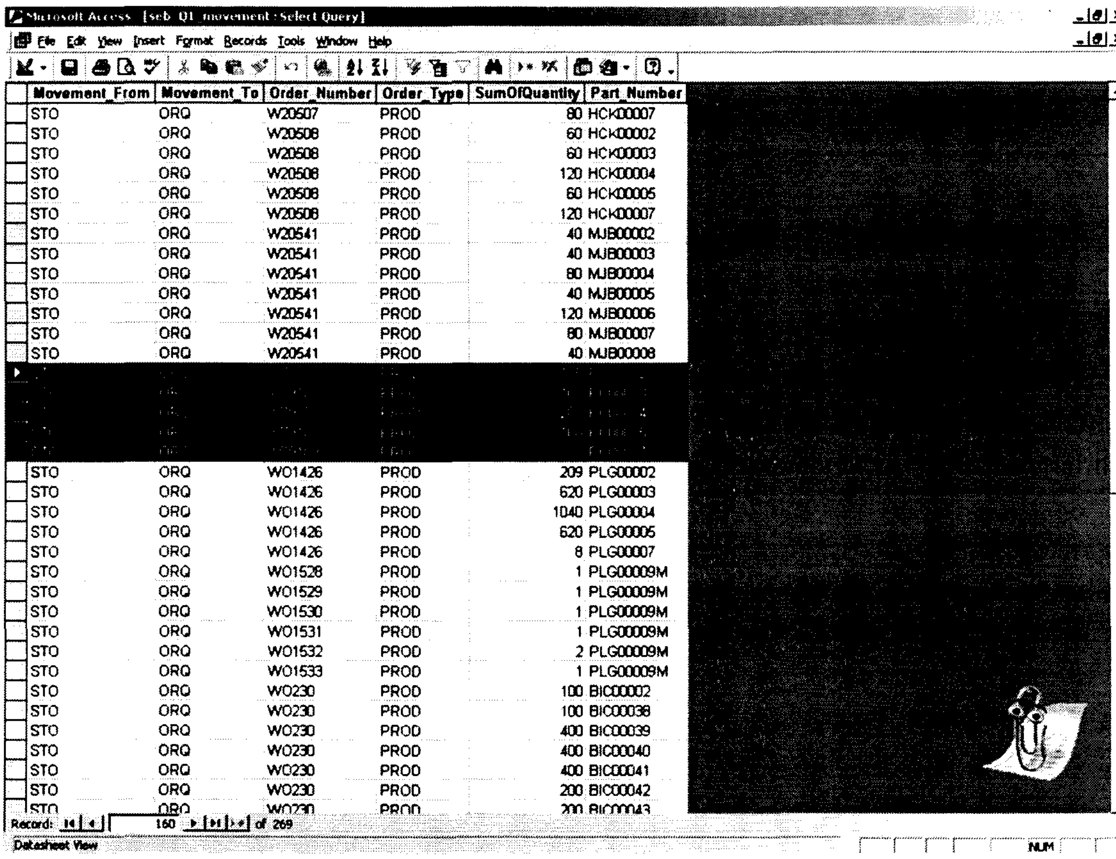
Extra movements had to be done to compensate for the components that were scrapped. This will cause the quantity variance.



Movement_Fr	Movement_To	Part_Number	Order_Numbe	Order_Type	Line_Number	Line_Type	Completion_D	Quantity	Concession_N	Return
PRD	STO	HCK00001	W20508	PROD	1	PROD	2002/03/29	60		
STO	ORQ	MJB00002	W20541	PROD	1	PROD	2002/02/28	40		
STO	[illegible]	[illegible]	[illegible]	[illegible]	1	PROD	2002/02/28	40		
STO	[illegible]	[illegible]	[illegible]	[illegible]	1	PROD	2002/02/28	80		
STO	[illegible]	[illegible]	[illegible]	[illegible]	1	PROD	2002/02/28	40		
STO	ORQ	MJB00006	W20541	PROD	1	PROD	2002/02/28	120		
STO	ORQ	MJB00007	W20541	PROD	1	PROD	2002/02/28	80		
STO	ORQ	MJB00008	W20541	PROD	1	PROD	2002/02/28	40		
PRD	STO	MJB00001	W20541	PROD	1	PROD	2002/02/28	40		
STO	ORQ	[illegible]	[illegible]	PROD	1	PROD	[illegible]	[illegible]		
ORQ	SCP	PC00007	[illegible]	PROD	1	PROD	2002/10/07	79		
STO	ORQ	PC00007	[illegible]	PROD	1	PROD	2002/10/07	90		
ORQ	SCP	PC00007	[illegible]	PROD	1	PROD	2002/10/07	9		
STO	ORQ	PC00007	[illegible]	PROD	1	PROD	2002/10/07	18		
STO	ORQ	[illegible]	[illegible]	PROD	1	PROD	2002/10/07	100		
ORQ	SCP	[illegible]	[illegible]	PROD	1	PROD	2002/10/07	15		
STO	ORQ	[illegible]	[illegible]	PROD	1	PROD	2002/10/07	15		
STO	ORQ	[illegible]	[illegible]	PROD	1	PROD	2002/10/07	100		
[illegible]	ORQ	[illegible]	[illegible]	PROD	1	PROD	2002/10/07	[illegible]		
[illegible]	ORQ	[illegible]	[illegible]	PROD	1	PROD	2002/10/07	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]		
STO	ORQ	WJO000001	WJO000001	CUST	1	PROD	2002/02/28	40		
PRD	CUS	WJO000001	WJO000001	CUST	1	PROD	2002/02/28	40		
STO	ORQ	GEN00009	WJO000001	PUR	1	SUB	2002/03/27	60		
STO	ORQ	GEN00009	WJO000001	PUR	3	SUB	2002/02/26	40		
STO	ORQ	WJU00001	WJU00001	CUST	1	PROD	2002/02/28	40		
PRD	CUS	WJU00001	WJU00001	CUST	1	PROD	2002/02/28	40		
STO	ORQ	GEN00009	WJU0001	PUR	1	SUB	2002/02/28	40		
STO	ORQ	GEN00009	WJU0001	PUR	2	SUB	2002/03/29	60		
STO	ORQ	PLG00007	W01426	PROD	1	PROD	1997/11/25	8		
STO	ORQ	PLG00005	W01426	PROD	1	PROD	1997/11/25	620		
STO	ORQ	PLG00003	W01426	PROD	1	PROD	[illegible]	620		
STO	ORQ	PLG00004	W01426	PROD	1	PROD	[illegible]	8		
STO	ORQ	PLG00004	W01426	PROD	1	PROD	[illegible]	1032		
STO	ORQ	PLG00002	W01426	PROD	1	PROD	[illegible]	209		
ORQ	SCP	PLG00002	W01426	PROD	1	PROD	1997/11/25	100		

Figure F.7: Movements table

A query is used to calculate the quantity of each part that has been moved from the *store* to the *order requirements* area (Figure F.8). This is the *actual quantity* (AQ) of material that was needed to manufacture the part.



Movement_From	Movement_To	Order_Number	Order_Type	SumOfQuantity	Part_Number
STO	ORQ	W20507	PROD	80	HCK00007
STO	ORQ	W20508	PROD	60	HCK00002
STO	ORQ	W20508	PROD	60	HCK00003
STO	ORQ	W20508	PROD	120	HCK00004
STO	ORQ	W20508	PROD	60	HCK00005
STO	ORQ	W20508	PROD	120	HCK00007
STO	ORQ	W20541	PROD	40	MJB00002
STO	ORQ	W20541	PROD	40	MJB00003
STO	ORQ	W20541	PROD	80	MJB00004
STO	ORQ	W20541	PROD	40	MJB00005
STO	ORQ	W20541	PROD	120	MJB00006
STO	ORQ	W20541	PROD	80	MJB00007
STO	ORQ	W20541	PROD	40	MJB00008
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STO	ORQ	W01426	PROD	209	PLG00002
STO	ORQ	W01426	PROD	620	PLG00003
STO	ORQ	W01426	PROD	1040	PLG00004
STO	ORQ	W01426	PROD	620	PLG00005
STO	ORQ	W01426	PROD	8	PLG00007
STO	ORQ	W01528	PROD	1	PLG00009M
STO	ORQ	W01529	PROD	1	PLG00009M
STO	ORQ	W01530	PROD	1	PLG00009M
STO	ORQ	W01531	PROD	1	PLG00009M
STO	ORQ	W01532	PROD	2	PLG00009M
STO	ORQ	W01533	PROD	1	PLG00009M
STO	ORQ	W0230	PROD	100	BIC00002
STO	ORQ	W0230	PROD	100	BIC00038
STO	ORQ	W0230	PROD	400	BIC00039
STO	ORQ	W0230	PROD	400	BIC00040
STO	ORQ	W0230	PROD	400	BIC00041
STO	ORQ	W0230	PROD	200	BIC00042
STO	ORQ	W0230	PROD	200	BIC00043

Record: 160 of 269

Datasheet View

Figure F.8: Movements from store to order requirements

The price of each part is calculated from the *dbo_Part_Financial_Year_Data* table by adding the different types of prices for each part together (Figure F.9).

Microsoft Access - [seb_02_part,year,price : Select Query]

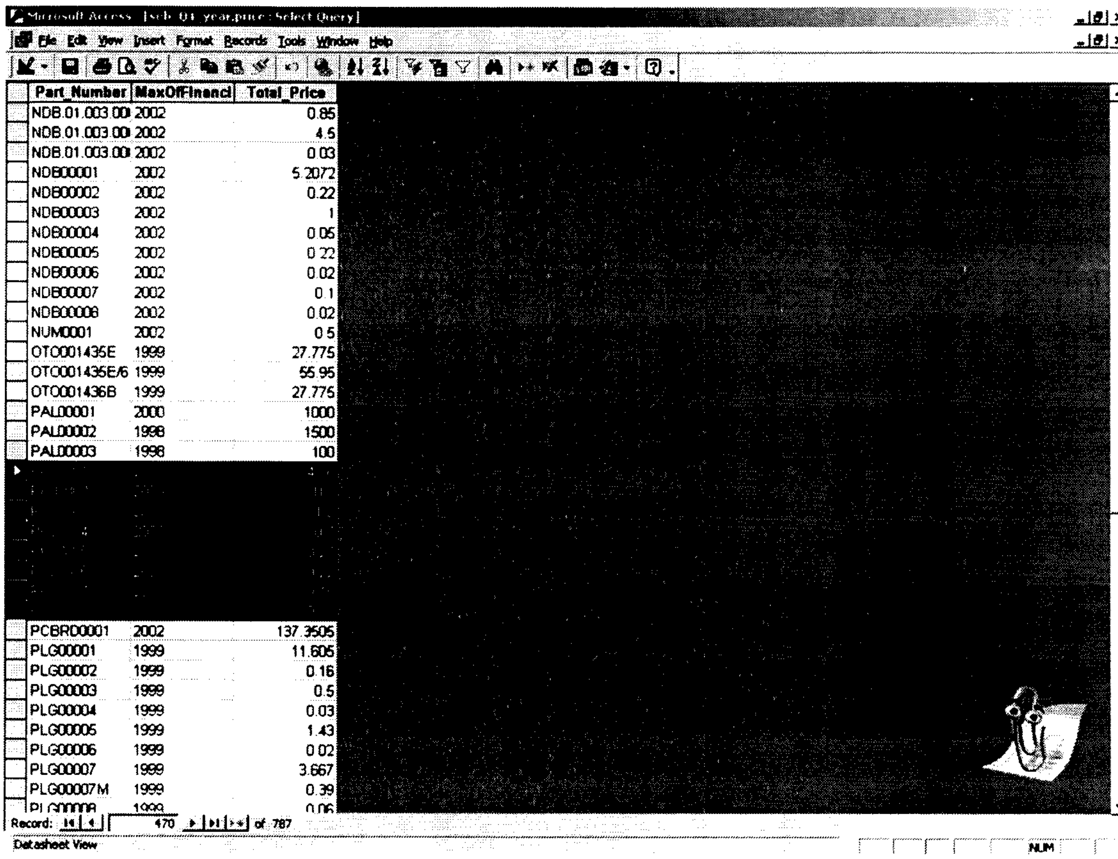
Part_Number	Financial_Yea	Material_Price	Labour_Price	Subcontract_F	Overhead_Pri	Fixed_Overhe	Transfer_Price	Total_Price
OTO001435E/6	1998	53.553	34.103	0	0	0	0	87.656
OTO001435E/6	1999	55.55	0.2	0	0.2	0	0	55.95
OTO001436B	1998	26.777	17.051	0	0	0	0	43.828
OTO001436B	1999	27.775	0	0	0	0	0	27.775
PAL00001	1998	1500	0	0	0	0	0	1500
PAL00001	2000	1000	0	0	0	0	0	1000
PAL00002	1998	1500	0	0	0	0	0	1500
PAL00003	1998	100	0	0	0	0	0	100
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	0	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]
PCBRD0001	2002	1.21	93.89	0	14.0835	28.167	0	137.3505
PLG00001	1998	0.554	7.334	0.2	3	0	0.2	11.288
PLG00001	1999	0.841	7.5	0.18	3.084	0	0	11.605
PLG00002	1998	0.15	0	0	0	0	0	0.15
PLG00002	1999	0.16	0	0	0	0	0	0.16
PLG00003	1998	0.5	0	0	0	0	0	0.5
PLG00003	1999	0.5	0	0	0	0	0	0.5
PLG00004	1998	0.03	0	0	0	0	0	0.03
PLG00004	1999	0.03	0	0	0	0	0	0.03
PLG00005	1998	0.003	0.667	0.2	0.333	0	0	1.203
PLG00005	1999	0	0.833	0.18	0.417	0	0	1.43
PLG00006	1998	0.22	0	0	0	0	0	0.22

Record: 586

Datasheet View

Figure F.9: Prices per parts

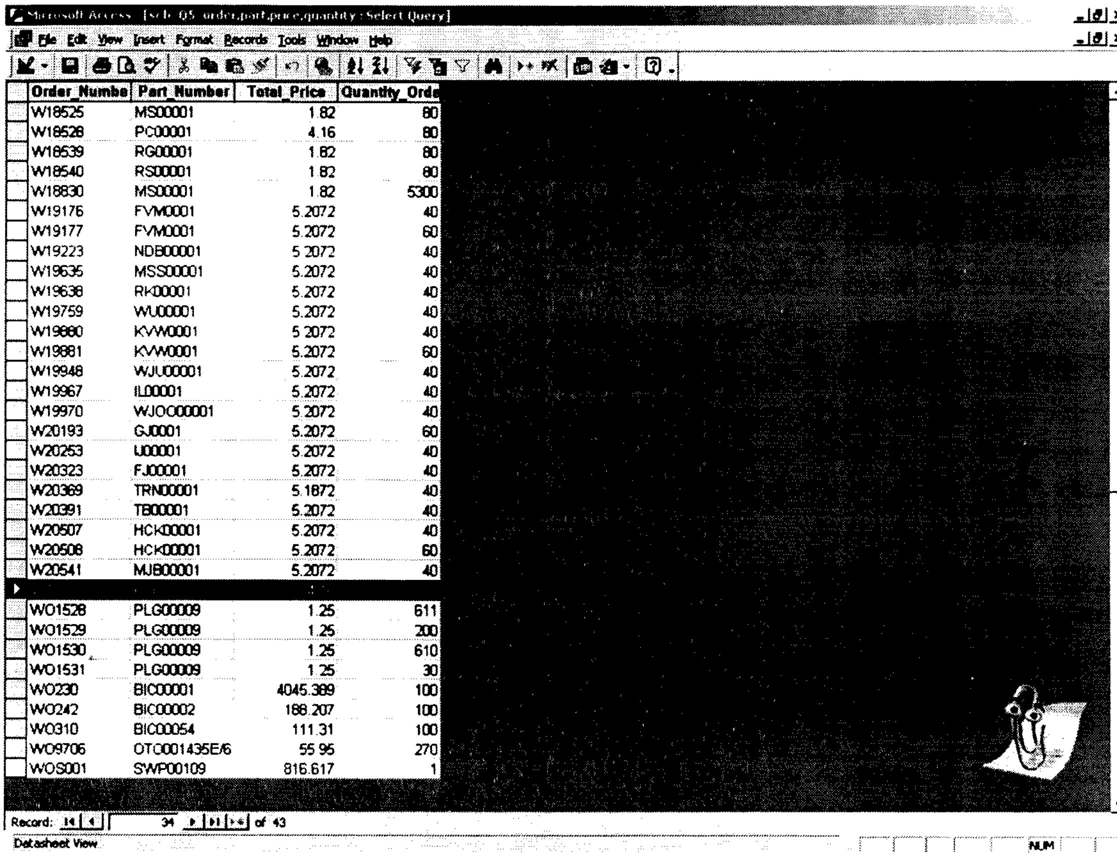
The most recent price (*actual price*) of each part is then extracted (Figure F.10).



Part_Number	MaxOfFinancl	Total_Price
NDB.01.003.00	2002	0.85
NDB.01.003.00	2002	4.5
NDB.01.003.00	2002	0.03
NDB00001	2002	5.2072
NDB00002	2002	0.22
NDB00003	2002	1
NDB00004	2002	0.05
NDB00005	2002	0.22
NDB00006	2002	0.02
NDB00007	2002	0.1
NDB00008	2002	0.02
NUM0001	2002	0.5
OTO001435E	1999	27.775
OTO001435E/6	1999	55.95
OTO001436B	1999	27.775
PAL00001	2000	1000
PAL00002	1998	1500
PAL00003	1998	100
PCBRD0001	2002	137.3505
PLG00001	1999	11.605
PLG00002	1999	0.16
PLG00003	1999	0.5
PLG00004	1999	0.03
PLG00005	1999	1.43
PLG00006	1999	0.02
PLG00007	1999	3.667
PLG00007M	1999	0.39
PLG00008	1999	0.06

Figure F.10: Actual prices

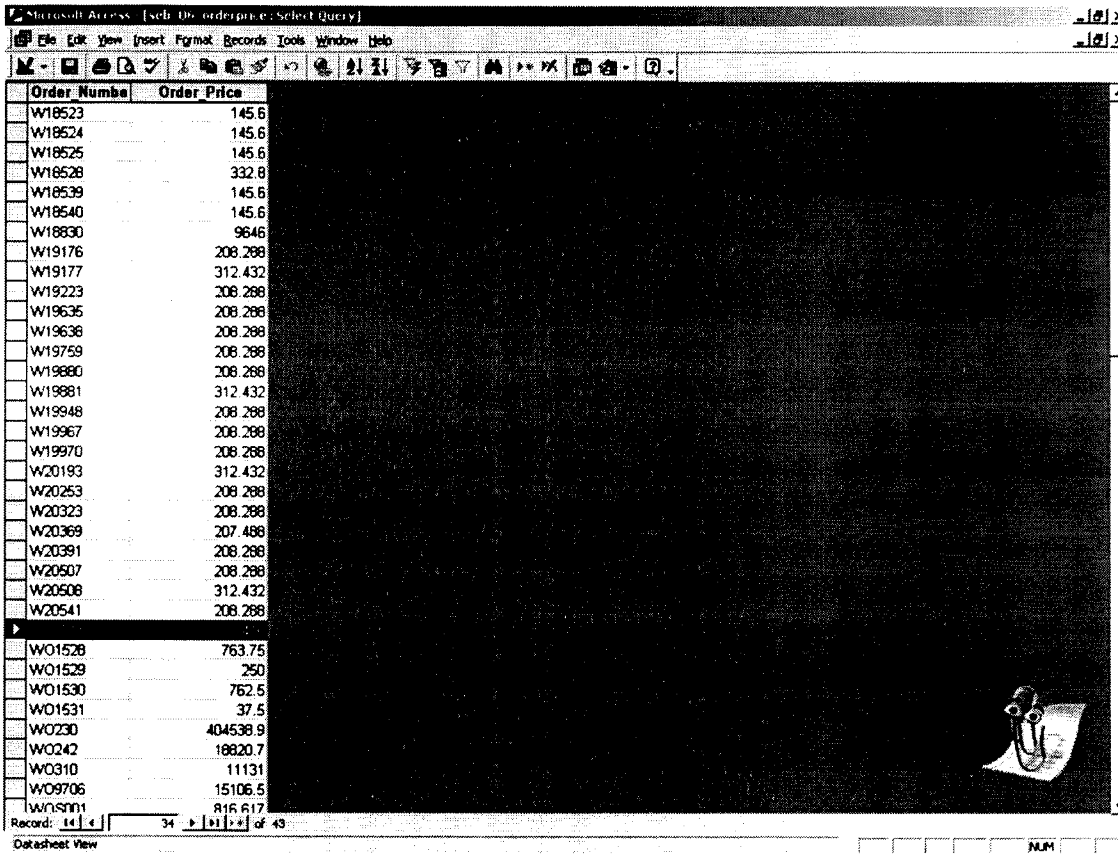
The *part number*, the *price* and the *quantity* of the order are now available (Figure F.11).



Order_Numbe	Part_Number	Total_Price	Quantity_Orde
W18525	MS00001	1.82	80
W18528	PC00001	4.16	80
W18539	RG00001	1.82	80
W18540	RS00001	1.82	80
W18830	MS00001	1.82	5300
W19176	FVM0001	5.2072	40
W19177	FVM0001	5.2072	60
W19223	NDB00001	5.2072	40
W19635	MSS00001	5.2072	40
W19638	RK00001	5.2072	40
W19759	WU00001	5.2072	40
W19880	KVW0001	5.2072	40
W19881	KVW0001	5.2072	60
W19948	WJU00001	5.2072	40
W19967	IL00001	5.2072	40
W19970	WJOC00001	5.2072	40
W20193	GJ0001	5.2072	60
W20253	IJ00001	5.2072	40
W20323	FJ00001	5.2072	40
W20369	TRN00001	5.1872	40
W20391	TB00001	5.2072	40
W20507	HCK00001	5.2072	40
W20508	HCK00001	5.2072	60
W20541	MJB00001	5.2072	40
WO1528	PLG00009	1.25	611
WO1529	PLG00009	1.25	200
WO1530	PLG00009	1.25	610
WO1531	PLG00009	1.25	30
WO230	BIC00001	4045.389	100
WO242	BIC00002	188.207	100
WO310	BIC00054	111.31	100
WO9706	OTC001435E/6	55.95	270
WOS001	SWP00109	816.617	1

Figure F.11: Summary of price and quantity per order

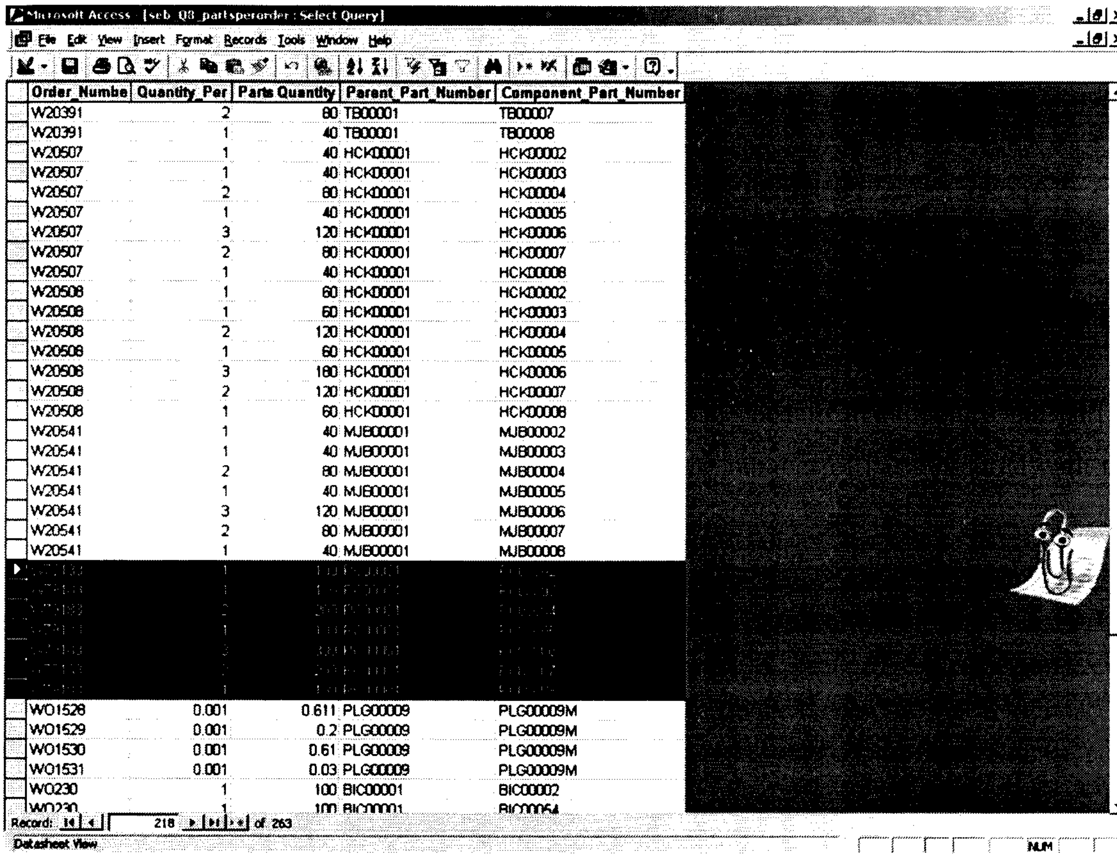
The *standard price* (SP) can now be calculated by multiplying the number of products ordered with the price of the product (Figure F.12).



Order Numbe	Order Price
W18523	145.6
W18524	145.6
W18525	145.6
W18528	332.8
W18539	145.6
W18540	145.6
W18830	9646
W19176	208.288
W19177	312.432
W19223	208.288
W19635	208.288
W19638	208.288
W19759	208.288
W19880	208.288
W19881	312.432
W19948	208.288
W19967	208.288
W19970	208.288
W20193	312.432
W20253	208.288
W20323	208.288
W20369	207.488
W20391	208.288
W20507	208.288
W20508	312.432
W20541	208.288
[illegible]	[illegible]
W01528	763.75
W01529	250
W01530	762.5
W01531	37.5
W0230	404538.9
W0242	18820.7
W0310	11131
W09706	15106.5
W0S001	816.617

Figure F.12: Standard price

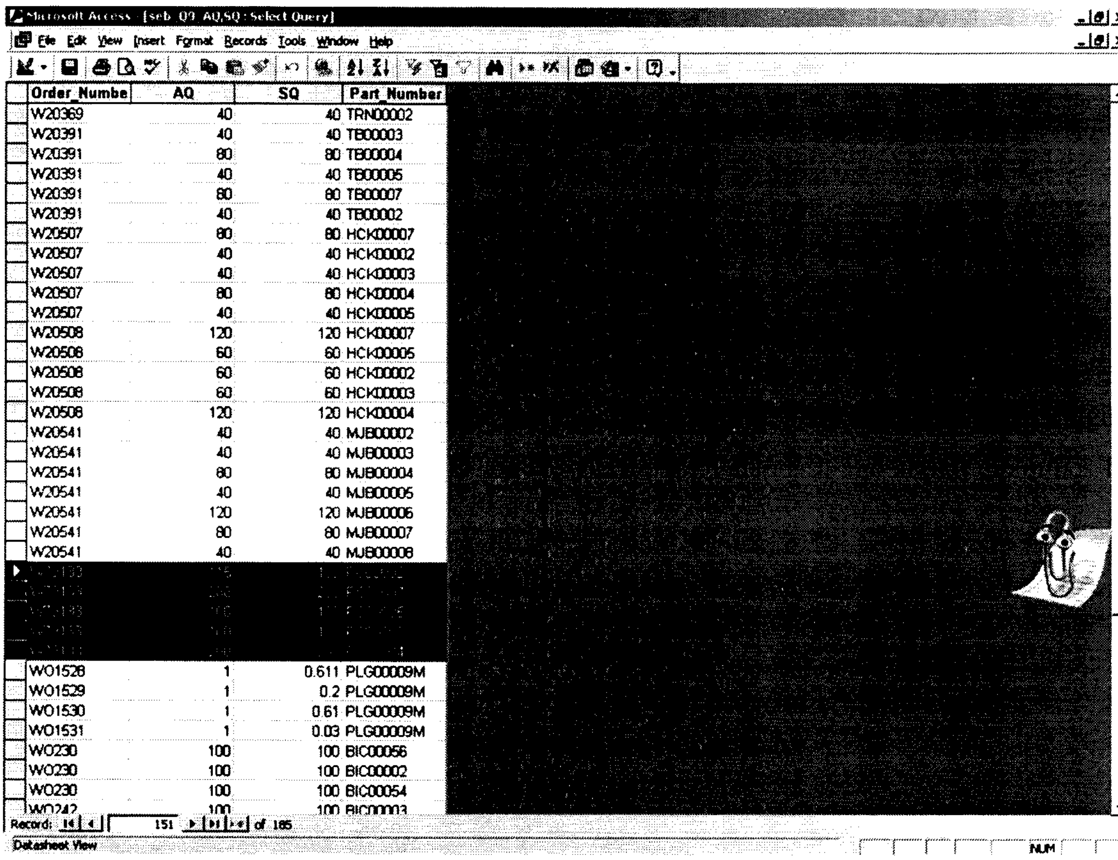
The *standard quantity* (SQ) of each component that is needed to manufacture the part is calculated (Figure F.13). This is done by multiplying the number of parts ordered with the number of components needed for each part.



Order_Numbe	Quantity_Per	Parts Quantity	Parent_Part_Number	Component_Part_Number
W20391	2	80	TB00001	TB00007
W20391	1	40	TB00001	TB00008
W20507	1	40	HCK00001	HCK00002
W20507	1	40	HCK00001	HCK00003
W20507	2	80	HCK00001	HCK00004
W20507	1	40	HCK00001	HCK00005
W20507	3	120	HCK00001	HCK00006
W20507	2	80	HCK00001	HCK00007
W20507	1	40	HCK00001	HCK00008
W20508	1	60	HCK00001	HCK00002
W20508	1	60	HCK00001	HCK00003
W20508	2	120	HCK00001	HCK00004
W20508	1	60	HCK00001	HCK00005
W20508	3	180	HCK00001	HCK00006
W20508	2	120	HCK00001	HCK00007
W20508	1	60	HCK00001	HCK00008
W20541	1	40	MJB00001	MJB00002
W20541	1	40	MJB00001	MJB00003
W20541	2	80	MJB00001	MJB00004
W20541	1	40	MJB00001	MJB00005
W20541	3	120	MJB00001	MJB00006
W20541	2	80	MJB00001	MJB00007
W20541	1	40	MJB00001	MJB00008
[illegible]	1	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]
[illegible]	2	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]
[illegible]	3	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]
WO1528	0.001	0.611	PLG00009	PLG00009M
WO1529	0.001	0.2	PLG00009	PLG00009M
WO1530	0.001	0.61	PLG00009	PLG00009M
WO1531	0.001	0.03	PLG00009	PLG00009M
WO230	1	100	BIC00001	BIC00002
WO230	1	100	BIC00001	BIC00054

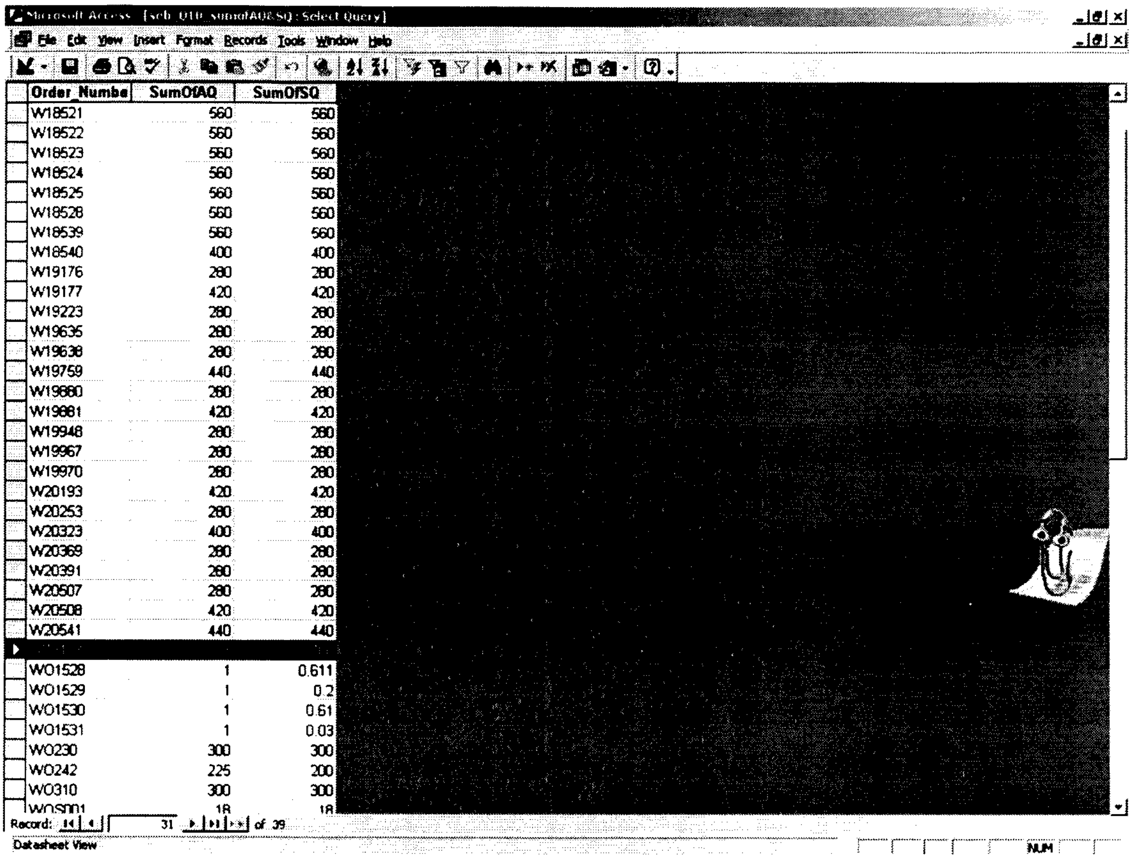
Figure F.13: Standard quantity

The *standard quantity* (SQ) and *actual quantity* (AQ) is now known for each part (Figure F.14). These quantities are added together to get the total standard and actual quantities for the order (Figure F.15).



Order_Numbe	AQ	SQ	Part_Number
W20369	40	40	TRN00002
W20391	40	40	TB00003
W20391	80	80	TB00004
W20391	40	40	TB00005
W20391	80	80	TB00007
W20391	40	40	TB00002
W20507	80	80	HCK00007
W20507	40	40	HCK00002
W20507	40	40	HCK00003
W20507	80	80	HCK00004
W20507	40	40	HCK00005
W20508	120	120	HCK00007
W20508	60	60	HCK00005
W20508	60	60	HCK00002
W20508	60	60	HCK00003
W20508	120	120	HCK00004
W20541	40	40	MJB00002
W20541	40	40	MJB00003
W20541	80	80	MJB00004
W20541	40	40	MJB00005
W20541	120	120	MJB00006
W20541	80	80	MJB00007
W20541	40	40	MJB00008
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
WO1528	1	0.611	PLG00009M
WO1529	1	0.2	PLG00009M
WO1530	1	0.61	PLG00009M
WO1531	1	0.03	PLG00009M
WO230	100	100	BIC00056
WO230	100	100	BIC00002
WO230	100	100	BIC00054
WO242	100	100	BIC00003

Figure F.14: Standard and actual quantities per part

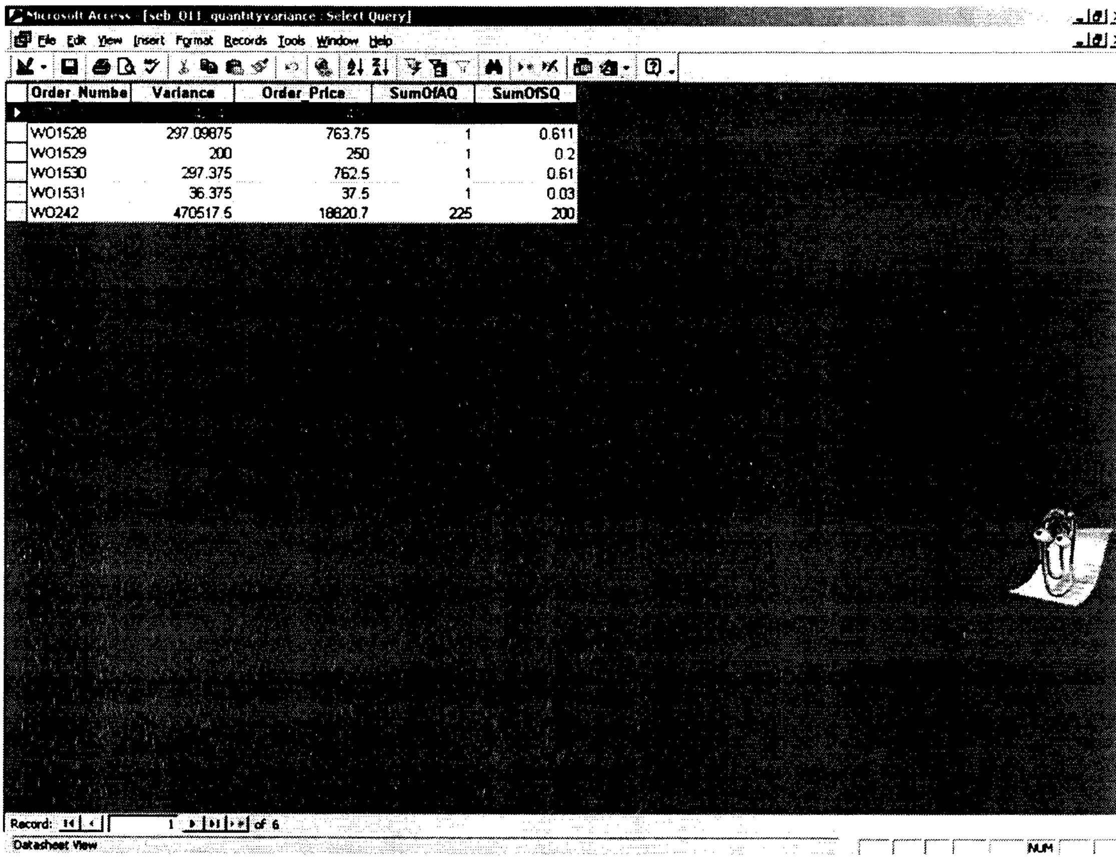


Order_Numbe	SumOfAQ	SumOfSQ
W18521	560	560
W18522	560	560
W18523	560	560
W18524	560	560
W18525	560	560
W18528	560	560
W18539	560	560
W18540	400	400
W19176	280	280
W19177	420	420
W19223	280	280
W19635	280	280
W19638	280	280
W19759	440	440
W19880	280	280
W19881	420	420
W19948	280	280
W19967	280	280
W19970	280	280
W20193	420	420
W20253	280	280
W20323	400	400
W20369	280	280
W20391	280	280
W20507	280	280
W20508	420	420
W20541	440	440
WO1528	1	0.611
WO1529	1	0.2
WO1530	1	0.61
WO1531	1	0.03
WO230	300	300
WO242	225	200
WO310	300	300
WOS001	18	18

Record: 31 of 39

Figure F.15: Total standard and actual quantities

All the necessary parameters (AQ, SQ and SP) are now known, and the *material quantity variance* can be calculated (Figure F.16).



Order_Numbe	Variance	Order_Price	SumOfAQ	SumOfSQ
WO1528	297.09875	763.75	1	0.611
WO1529	200	250	1	0.2
WO1530	297.375	762.5	1	0.61
WO1531	36.375	37.5	1	0.03
WO242	470517.5	18820.7	225	200

Figure F.16: Material quantity variance

The *normalised material quantity variance* (in terms of a percentage) can be calculated by dividing the *material quantity variance* into the *standard quantity* (Figure F.17).

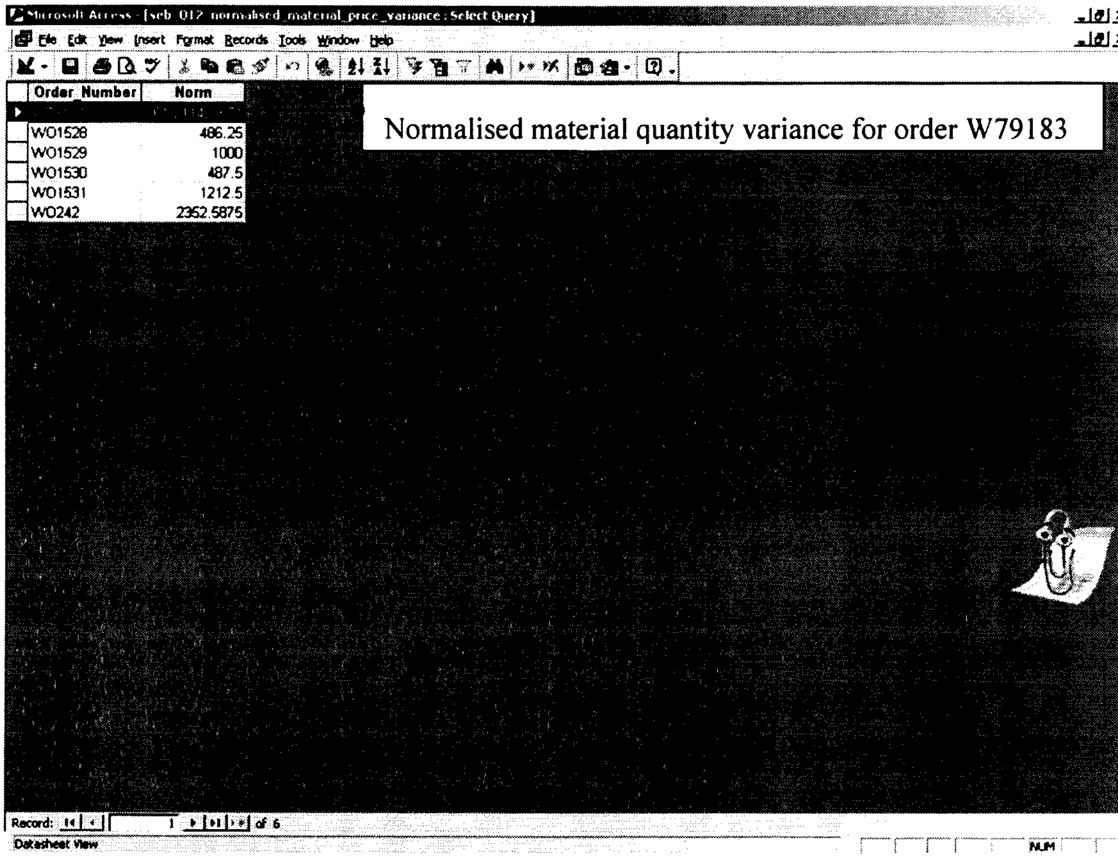


Figure F.17: Normalised material quantity variance

F.4 Discussion and Conclusion

The above example illustrated that it is possible to extract the relevant data to present the *material quantity variance.* This is the starting point for further development of the Performance Tree. The next step will be to investigate the ERP and MES databases to decide where the information for each KPI resides. The interactions between all the different systems on the business layer must then be taken into consideration.

After all the different KPIs in the Performance Tree are integrated, the physical interface can be designed. At that stage, the graphical presentation will be considered.