Analysing Product Development Best Practices and Improvement of Associated Activities with an Application to a South African Company

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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.

Abstract

The dynamic and highly competitive environment that most product development organisations find themselves in demands a method to constantly assess the maturity of the organisations' product development processes and systems. Many of these organisations are in the product development *business* and for this reason a need was identified for a method that can be used by managers to identify areas in need of improvement on a continual basis. This thesis included a literature study of product development best practices and organisational measurement techniques, as well as the application and evaluation of a tool that enables the business managers to assess the state of these product development activities against the benchmark of these said best practices.

The theoretical approach taken in this thesis, was to define the scope of the organisations and products to be included in the thesis, to investigate the current best practices within both the academic and industry arenas and identify the needs of product development organisations in terms of measuring their product development process maturity and then an evaluation of the tool that enables the identification of shortcomings in the organisations' development systems.

Included in the literature study were a variety of Business and Quality Philosophies, existing standards and measurement tools, as well as a brief look at Organisational culture and how it affects Product Development Activities. The results of this literature were then used to substantiate the tool that was used for the actual evaluation and case study. The literature provided a good basis of evaluation, particularly in the way that the tool employs measurements and scoring techniques to assess an organisation's position in terms of product development best practices.

The case study then took an existing tool that is currently used by DRM Associates (USA) in assessing the state of an organisation's Product Development Best Practices and used it to assess a Business Unit within a South African company. The results were analysed and the tool thus evaluated in terms of accuracy, user-friendliness and value for the South African market.

It was found that the tool is very accurate in terms of identifying areas of weakness both with respect to the strategic performance of the organisation as well as the individual best

practices. It is easy to understand, but the scoring system utilised is not that easily employed. It was felt that the scoring systems needed to be more generic as those of ISO 9004 and the South African Excellence Model. The idea is that managers do the assessment once in conjunction with a group of consultants and then again as part of a continuous improvement drive, on their own. Managers with limited knowledge of product development best practices and philosophies would find the assessment difficult to do on their own due to the ambiguous scoring criteria. It was felt that a generic system would be easier to use by non-technical people.

Once the assessment had been completed and the tool itself evaluated, the value of such a tool for South African product development organisations was also evaluated. In this evaluation it was found that the tool could be more valuable as a guide for future education (an educational roadmap) than as a benchmarking and assessment tool.

punte toekenning sisteem meer generies moes wees, soortgelyk aan diè van ISO 9004 en die 'South African Excellence Model'. Die idee is dat bestuurders die evaluering een keer saam met 'n groep konsultante moet doen en dan weer op hulle eie as deel van 'n deurlopende verbeterings-program. Bestuurders met 'n beperke kennis in beste praktyke en filosofië van produk ontwikkeling sou die evaluering moeilik gevind het as hulle dit op hulle eie gedoen het weens die dubbelsinnige punte toekenningskriteria. 'n Meer generiese sisteem sal makliker wees vir mense wat nie tegnies aangelê is nie.

Toe die gevallestudie voltooi was en die model self evalueer was, was die waarde van so 'n model vir Suid Afrikaanse produkontwikkelings-ondernemings terselfdetyd evalueer. Dit was gevind dat die model meer waardevol kon wees as 'n opleidingshulpmiddel vir ondernemings, in plaas van 'n evalueringsinstrument teenoor opgestelde grondslae.

Acknowledgements/Dedications

I would like to thank Prof Willie van Wijck, my study leader for his invaluable input, patience and encouragement, Kenneth Crow from DRM Associates for the guidance and assistance in the implementation of the software and to the members of the Communications Division of Tellumat (Pty) Ltd for their participation in the case study.

I would also like to dedicate this piece of work to my Grandfather without whom a Masters degree would have always been a dream.

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1. Introduction

With the advent of a global business environment, issues of global competitiveness are at the forefront of most companies' minds. Some of the issues that have come into play within the last decade or so that did not exist before are:

- A continual and dedicated search by managers for areas of competitive advantage
- the fact that more and more companies are 'closing the gap' by subscribing to programmes such as Total Quality Management
- the more complex environment in which product development now takes place due to the fact that there is more pressure to stabilise the Cost, Quality and Time triangle.

In order to maintain or further their positions in the race to be nationally and globally competitive, companies have been forced to adapt their business strategies to react quickly to changing customer needs. It is for this reason that the term "Continuous Improvement" has become so widespread. Continuous improvement within organisations provides a vehicle through which the changes in the market place can be handled and then embraced within the companies operating in this dynamic environment.

This in itself seems simple enough, but where does one start? Managers are now faced with the problem of how to determine what needs to change first and then an even more crucial challenge of managing change within the organisation to effect the changes needed.

This thesis describes the evaluation of an assessment tool designed specifically for use by organisations involved in product development, to enable the measurement of the maturity[1] of product development processes and enable the identification of the starting points for improvement efforts. It also embarks on a Case Study that identifies some of the inhibitors of product development best practices.

One certainly cannot predict future events exactly if one cannot even measure the present state of the universe precisely. – Stephen Hawking, A Brief History of Time

[1] The maturity of a process can be considered to be how close the process is to the accepted 'best practice'

Stephen Hawking's quote can be translated into the principle that Robert Kaplan and David Norton (1996) based their book "Translating Strategy into Action" on *"If you can't measure it, you can't manage it."* Organisations need to be able to develop a 'snap shot' of what the current state of affairs is and then use that 'picture' with the clues it may provide as a starting point for any improvement efforts in order to become truly 'excellent' or 'best-in-class'.

Although there has been much work around product development and the processes that it follows both in academic environments and industry, it is still an area that has much scope for improvement in many businesses. The advent of standards such as ISO 9004:2000 which covers product development activities more thoroughly has seen an increase in documentation of development activities and processes. However, the understanding of why these are necessary and how it affects the overall product development maturity in the company seems still not to have been grasped by many people. It was for this reason that the area of Product Development was chosen for this thesis.

Thus the goal of this thesis was to enable managers, specifically,

- to firstly understand the major elements of product development maturity, and
- secondly to be able to measure, improve and manage, thereby becoming more competitive in their relevant areas of industry

The thesis also aims to highlight the 'real world' problems that organisations face in trying to effect change.

> *You never had time to learn. They threw you in and told you the rules and the first time they caught you off base they killed you. - Ernest Hemingway*

Hemingway's statement is unfortunately particularly true within the product development arena. As Fleischer and Likes (Fleischer, 1997) stated "You have to do everything right when you introduce new products or you stand a significant chance of failure." For this reason improvement activities and learning from past mistakes increases the probability of the product being more successful after the next development cycle.

This is the reason that the case study in this thesis is directed at **managers** in a product development environment.

There are many philosophies and tools/models that encompass the entire organisation (e.g. South African Excellence Model, ISO 9004, and the Balanced Scorecard). There are probably even more that address Software Development process capability/maturity, but the literature studied and the personal experience of the author only revealed one measurement tool focused specifically on the area of product development. This tool was developed by Kenneth Crow at DRM Associates.

1.1 SCOPE

This thesis covers a literature study of the best practices currently employed by industries in the product development arena, the mapping of these best practices to DRM's model and a case study of a product development maturity assessment conducted using DRM's tool. It also looks at the effect of organisational culture on the product development process.

The scope of the thesis had to be defined for two areas:

- The lowest level of the product development cycle activities, and
- The managerial level where factors influencing the overall product development system come into play.

There are various schools of thought that have different views of the phases of the product life cycle. Typically the product life cycle can be illustrated as in Figure 1.

Because the focus of this thesis is on the product development cycle, the scope of the literature study was defined from the Concept phase up until and including the Industrialisation phase. The tool however, also includes a section on the methods and tools employed in the manufacturing of the product.

The scope was limited to product development environments and not manufacturing or services industries; immediately highlighting the fact that product development organisations face challenges different from those encountered elsewhere. Product development departments or companies have to deal with much longer process intervals, which vary from one development project to the next.

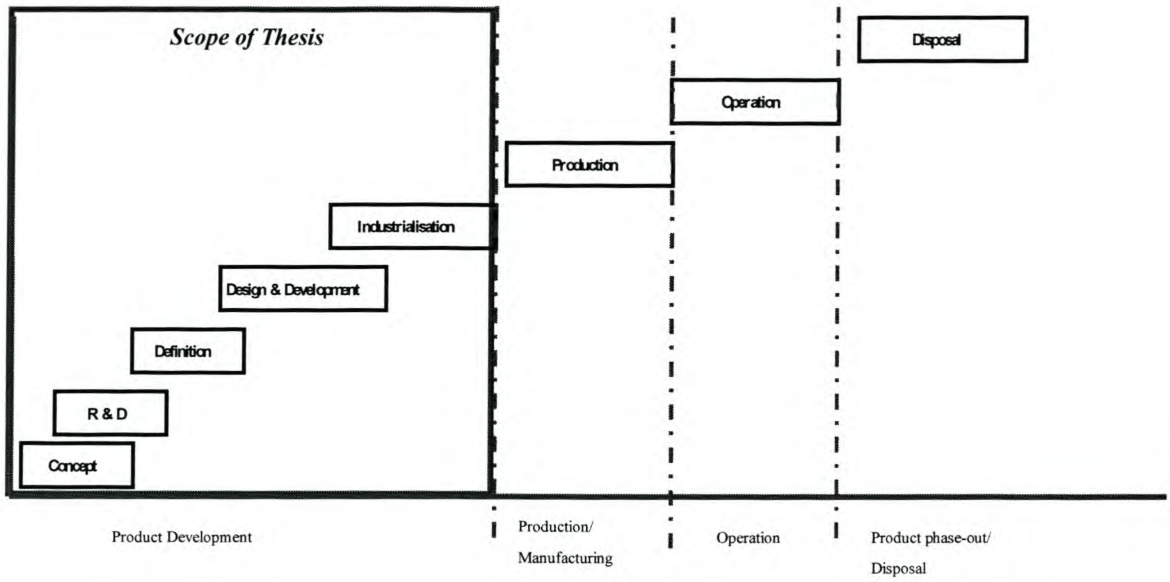


Figure 1: Diagrammatic representation of the traditional product life cycle

1.2 THESIS LAYOUT

With the focus of this thesis on Product Development Best Practices and the improvement of the associated activities, there were some basic requirements identified in order to do this.

Before any consideration can be given to improvement, the scope of Product Development needs to be understood: where it starts; where it ends; what the inputs and outputs are; the process phases and their sequence. An investigation into some Product Development methodologies that are currently employed was also necessary to inform the reader as to some of the ways in which all these phases with their various activities are put together in practice. These issues are addressed in Chapter 2.

Once the basic concepts of Product Development are understood, the next issue is that businesses need to know where their product development processes stand. Various methods of measurement need to be investigated in terms of what they measure and how they measure it. Chapter 3 deals with existing standards and measuring tools.

To begin the investigation into what to actually measure in order to improve, some business and quality philosophies were included in the literature study. The philosophies included in the study are all based on improving some aspect of an organisation. It was felt that basic principles included in these improvement philosophies could be used to identify measurable elements in the product development environment. Chapter 4 therefore investigates various general improvement philosophies.

Once the reader knows what general areas to focus on in a product development environment, the issue of the actual improvement arises. The question of how to improve continuously and not fall back into bad habits is one that all companies involved in any type of improvement activity faces. Chapter 5 therefore deals with Organisational Cultures and their 'fit' with Product Development Best Practices.

The tool that was employed in the assessment of a South African organisation brings all the above issues together. It highlights exactly what to measure by grouping product development activities into 28 categories that cover five main 'themes'. The tool also behaves as a standard against which to measure by employing an activity scoring system where an activity score of 10 is the standard against which the activity is measured (i.e. 10 is the ideal score). The tool also enables a prioritisation of improvement areas by analysing the assessment results and presenting an easy to understand gap analysis. Chapter 6 introduces the tool used.

Chapter 7 then deals with the actual assessment of a South African organisation using the tool. In this chapter the theoretical perspective of the case study is detailed. The background of the organisation is sketched and the results of the assessment are analysed.

The final chapter, includes an assessment of the tool used and also deals with why Product Development Best Practices are not more widely employed in South African organisations.

The layout of the thesis is graphically illustrated in Figure 2.

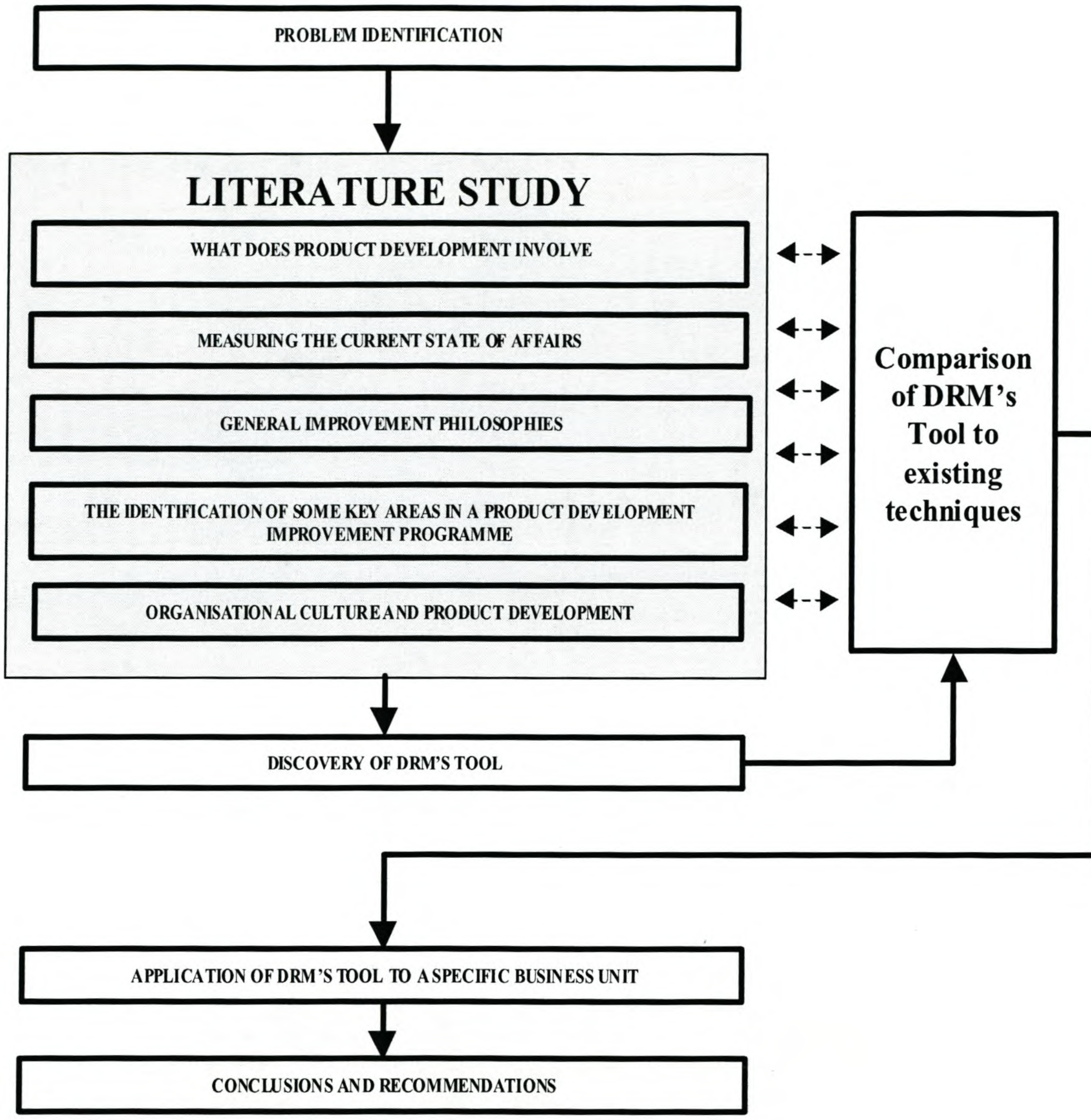


Figure 2: A diagrammatic flow of the approach taken in this thesis

2. What Does Product Development Involve?

2.1 INTRODUCTION

The success of the product depends on selecting the right projects, involving the customer throughout the process, and handling off the project in a smooth fashion to marketing and manufacturing. The timeliness and cost effectiveness of the New Product Development (NPD) process depend on how human resources are managed in a functional and cross-functional manner. Improvement in process cycle time occurs through intelligent bottleneck management of the project stream. [Dooley, 2001]

In order to give a reasonable indication of the maturity level of product development within a company, the content of any assessment tool needs to cover commonly accepted areas encompassed by product development activities. Literature was studied that included information on the elements that make up Product Development. The literature study undertaken also included a study of various Quality Philosophies, Quality Management Systems, Excellence Models and Best Practices.

With the focus in businesses leaning towards integrated organisations and concurrent engineering projects, efforts were made to classify the elements[2] and activities[3] that form the areas of focus[4] of an organisation. Standards such as ISO 9004, excellence models such as the South African Excellence Model, the Baldridge Model and the European Excellence Model illustrate these efforts. The contents of these models indicate that there are indeed various aspects to a business and a complex inter-connectivity between the individual activities identified. This train of thought was then used as a starting point in an effort to determine what organisational focus areas would form the basis for product development.

There were three phases to the literature study:

- Literature describing Product Development was consulted to determine what activities take place during product development phases and into which product development

[2] Elements of product development are the basic categories of activities

[3] Activities are detailed, specific actions or tasks that are performed

[4] An Area of Focus encompasses various Elements and therefore sets of Activities within product development processes

elements they can be categorised. The sequence of product development phases was also investigated.

- Various measurement techniques and standards were then investigated to show what to measure. This included methods already being used to measure organisational performance.

- The quality philosophies, business and excellence models noted previously were consulted in order to determine the areas and associated activities of organisations that these models cover; what elements they measure and how they measure them. It was felt that these models are valuable since the principles that they are based on may be transferred to a product development environment.

Once the 'What' of product development was defined, the 'How' of measuring it was addressed, as well as the issue of 'How to improve and maintain it'. A brief study of various types of organisational culture and their appropriateness to product development environments was then done.

2.2 ELEMENTS AND ACTIVITIES ASSOCIATED WITH PRODUCT DEVELOPMENT PHASES

At this point it is not necessary to identify the individual activities that occur during the product development life cycle phases, but rather to identify the various elements of an organisation that are required for each phase. To do this, the focus of the high level activities of each phase[5] need to be identified.

In their book "New Product Development, Managing and Forecasting for Strategic Success", Robert J.Thomas [Thomas, 1993] included a diagram (Figure 3) that illustrated the factors that, in their minds, affected the process of new product development.

[5] A phase of product development is a group of activities from one or more elements that are carried out during a particular time in the product's life cycle

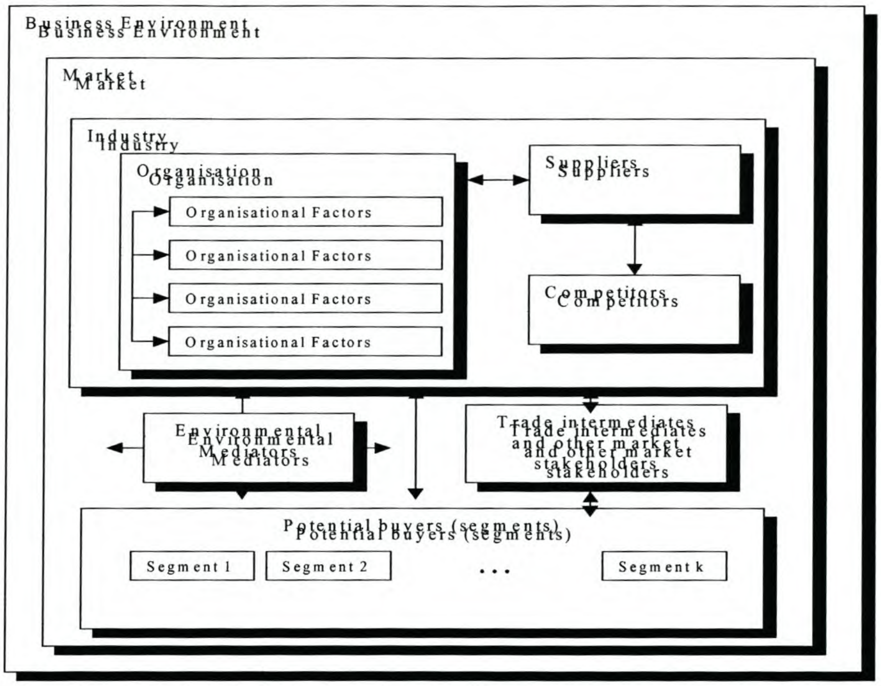


Figure 3: Factors affecting new product development [Thomas,1993]

Figure 3 gives an indication of the type of internal and external factors that are typically taken into account when embarking on a product development project. Organisational factors such as the quality paradigm or work culture and external factors such as governmental regulations would all have an effect on the progression of a product development project. Thus all factors need to be taken into account in any planning undertaken by the project team.

The phases that were defined in Chapter 1 (figure 1) and their focuses in terms of organisational elements are now elaborated on.

2.2.1 Conceptual Phase

According to Concurrent Engineering principles (activities taking place in parallel), the conceptual phase of a product's development includes a multitude of parties who all contribute their knowledge, ideas and needs in order to conceptualise a realistic vision of the product to be developed.

According to Crawford (1991) there are four stages in the Product Innovation Process[6]. Three of these stages are related to the generation and selection of a specific concept (i.e. the product that will ultimately be developed). These are:

1. Strategic planning stage
2. Ideation stage
3. Screening stage

The fourth stage is that of Development and is thus not covered in this section, but in section 2.2.4.

The three stages that Crawford elaborates on can be summarised as follows:

Table 1: Summary of Conceptual Phase. (Adapted from: [Crawford, 1991])

Stage of Conceptual Phase	Strategic Planning	Ideation	Screening
Focus of Stages	Sources of innovation Opportunity identification Screening of opportunities Guided by strategy	Find ways to capitalise on available resource or potential solutions Establish a team for the screening stage Identify and solve problems	Entry screening Customer screening Technical screening Final screening Assess feasibility with a Business Analysis
Input to stages	Ongoing marketing planning Special opportunity analysis Corporate planning	Area of opportunity Ideas that relate to the area of opportunity	Pool of concepts Team of 'experts' to react to ideas
Output of stages	Defined area of opportunity	Pool of new feasible concepts	One feasible concept
Organisational entities involved	Marketing Resources Management (strategy)	Employees Customers Management	Technical experts (engineering, manufacturing, suppliers) Marketing Voice of Customer

As one can see from the table above, this phase entails the skills of the following organisational entities, customers, engineering, manufacturing, suppliers, management and marketing.

The initial stage of Strategic Planning is 'guided by strategy'. The product strategy of an organisation should act as a filter for the choice or acceptance of concepts. Once a product

[6] Crawford refers to the Concept Phase as the Product Innovation Process

strategy has been determined by management, the above-mentioned people should all be involved in the concept selection (how candidate product concepts are screened and one concept is selected for further development) and preliminary concept design (how the selected concept is designed at a high level).

2.2.2 Research and Development (R&D) Phase

The main focus of this phase is to ensure that the appropriate technology is available to develop and manufacture the product. Activities found in the Research and Development phase can include:

1. Knowledge and understanding of various technologies and processes
2. Creating information systems to handle the product development and later maintenance information.
3. Development of the evaluation system to be used in the project, whereby the project progress as well as technical progress can be measured

With the focus of R&D activities being on the above areas, an aspect that deserves attention during this early phase is the availability and support of suppliers and the existence of the needed manufacturing techniques so as to facilitate easy industrialisation.

During the R&D phase of the product development life cycle, prototypes are often employed to enable the evaluation of many criteria such as ease of manufacture, appropriateness of technology, process maturity and marketability of the product.

The importance of information in product development cannot be underestimated. An excerpt from Robert Kaplan's book "The Balanced Scorecard" (1996) describes the importance of information very effectively

> *If employees are to be effective in today's competitive environment, they need excellent information – on customers, on internal processes, and of the financial consequences of their decisions– Robert Kaplan*

The concept of 'excellent' information is one that is becoming more and more important in many companies dealing with serious competitors. It is no longer enough to have access to data, it is now a necessity that the data makes sense, that it is correct and that it is available when, where and in the form it is needed.

This need is even more pronounced when product development is being considered. Design teams have integrated information needs that have a direct influence on the quality of the product design and any decisions that have to be made during the development phases. One of the main reasons for this need is the fact that many people and/or teams work on product sub-systems at a single point in time and the successful integration of those systems relies on correct and up-to-date data at all times.

Due to the nature of product development and the principles of Concurrent Engineering, a shallow organisational hierarchy is most likely the most effective way to ensure the quick and effective movement of information. The lack of 'red tape' commonly decreases the time it takes to respond to problems or innovative suggestions; it also seems to foster team spirit.

Problems in a product development environment are very often caused indirectly by miscommunication. However, a measurement of the quality of communication within a team or a business may be difficult. The direct cause of a failure in whatever area of the product's development should be analysed in order to determine if bad communication or a misunderstanding was the original cause of the problem. Only once this can be determined, can the quality of communication begin to be measured.

Technology and its management are increasingly playing a more important role in product development. The Research and Development phase of the product development life cycle should be focused on technologies available and management of these technologies relative to the product strategy for future developments.

In the Report of the Industrial Strategy Project published by UCT Press (1995) it was observed that *"... as a general rule, there is no denying the fact that, in an era of increasing technological complexity, no firm or economy can afford to produce across the board; selectivity is critical to economic efficiency."* For this reason it is a good starting point to affirm that the core of a company is what it knows and what it can do, rather than the products that it develops.

Technology strategy centres on this knowledge and these abilities. It consists of policies, plans and procedures for *acquiring* knowledge and ability, *managing* that knowledge and ability within the company and *exploiting* them for profit.

Many factors highlight the importance of technology strategy. Developing a technology strategy will force a company to step back from the analysis of its market position and the things it sells. Instead, it will force the company to analyse the product and production technologies on which its operations are based.

Most technologies only have a limited life span. It is for this reason why technology strategies and management are important. By keeping abreast of emerging technologies, the business can introduce new technologies into their products before the older technologies become obsolete and they lose their competitive advantage.

2.2.3 Definition Phase

In the Definition phase, the product is defined in terms of its functionality. Tools such as Quality Function Deployment are often utilised to marry the information that has been gathered from the Concept and R&D phases. Once the complete set of requirements is defined in a specification document, there needs to be a planning phase.

A detailed Product Life Cycle Plan (PLC Plan) should form part of the planning by management for product realisation. This plan should break down the product's development into various activities or tasks that need to be addressed over the entire development cycle. Activities to be included would typically be research, prototyping, engineering changes, testing, etc. The PLC Plan will focus the development team's attention on actions that occur over a 'long' time span, such as packaging and production considerations. The planning of a PLC includes the setting of milestones (in terms of the development activities, not timelines) that indicate the shift from one phase of the life cycle to another. The Concept and R&D phases of product development enable the managers to get a good picture of exactly what tasks would be required to develop the product. It is only once there is a good understanding of what the individual tasks are that the PLC Plan can be put together.

In order to negotiate these shifts, management should have various goals/objectives in place. A typical milestone that needs to be set, is that of the time at which a product baseline is defined. Engineers, by nature, want to design the best product possible, but 'windows of opportunity', customer demands and financial considerations place constraints on the development system that requires a definitive point of completion. It is therefore of utmost importance that the various phases of product development are defined in general and/or for each project.

Stage of Definition Phase	Requirements Specification
Focus of stage	Definition of user requirement statements (URS)
Input of stage	Concept Voice of customer Results of R&D phase
Output of stage	A defined set of high level requirements for the product
Organisational entities involved	Customer Marketing Engineering Manufacturing Suppliers Management

2.2.4 Design and Development Phase

During this phase of product development, the planning that took place in the Definition Phase is implemented and the relevant documentation and designs are generated for testing by the design engineers, in conjunction with the customers or the 'Voice of the Customer'.

Just as in the Conceptual Phase, there are various stages in the Design and Development phase. Each of these stages has a focus, inputs and outputs. The contents of Table 2 were gleaned from practical experience in a product development environment specifically for hardware. The stages of this phase were defined as a result of an analysis of the various documents that are typically generated in a practical hardware development environment as well as typical procedures that are followed in companies around South Africa and the world.

In order to ensure that there is a standard developed that can be improved upon in an organisation involved in product development, processes are vital in establishing a baseline against which all future activities can be measured.

It is essential that the developers, managers and any support staff that are involved in the product development environment are aware of the interactions between the various processes and are thus also aware of the fact that any changes made to one process, will more than likely affect other processes as well. This type of process network should thus always be at the forefront of all changes made to any particular part of the whole system.

Kenneth Crow describes the difference in the product development process as opposed to manufacturing processes in his article on "Characterising and Improving the Product Development Process". He states that a great deal of leverage is provided by improvement efforts in repetitive, high volume business and manufacturing processes, but highlights the fact that new product development is often one of the least repetitive, lowest volume processes in most organisations. There is also typically a high staff turnover in product development environments and a rapid pace of technology evolution therefore many development personnel have little understanding of or practical experience with any standard new product development process in their companies.

A development process that is not characterised and documented will result in difficulty in assuring and understanding what the process actually is.

> *Business processes are those through which we create, and deliver value to our customers...Business processes drive business results. The whole entity is defined by its business processes...We must redesign those business processes that were rooted in the functional organisation and align them with the crossfunctional requirements of the divisional structure.* - Xerox 2000 Leadership Through Quality: Strategy Briefing Book, February 1994

This excerpt from the Xerox strategy briefing book echoes the sentiment described in Robert Kaplan's "Balanced Scorecard": the processes whereby a customer receives value from a product or service need to be defined in terms of their ultimate output – customer satisfaction and quality products.

Table 2 contains a summary of the Design and Development Phase.

Table 2: Summary of Design and Development Phase

Stage of Design and Development Phase	Architectural Design	Detailed Design	Integration	Qualification	Release
Focus of stage	Developing the URS into high level functional requirements System view of the products various modules/elements	Translation of the high level functional specifications into lower level detail specifications and the implementation thereof	The integration of various modules of the product into a working system/product	Testing of the product against its stated requirements	Review of the product design Review of product information
Input of stage	URS System expertise Manufacturing	Architectural design	Detailed design modules	URS Testing specifications Test equipment Product data	Results of qualification testing
Output of stage	A high level work-breakdown structure of the functionality of the product	Detailed modular implementations of the specifications	Integrated product/system	Test results Updated testing procedures Updated datapack Field trial results	Functionally qualified product Qualified datapack
Organisational entities involved	System engineering	Engineering	Product design information Engineering System engineering Processes	Manufacturing Management Engineering Information systems Customer	Management Customers Marketing

2.2.5 Industrialisation Phase

The Industrialisation phase is the final phase of the product development life cycle that is covered by this thesis because it is seen as the last phase in a product development cycle. During this phase the designed product is prepared for production. An issue typically included here is preservation of product (packing materials and storage requirements) which is defined by the design engineers according to customer requirements and operating environments.

2.2.6 Summary of all Product Development Life Cycle Phases

It is important to note that the way in which the various product development phases have been set out in this thesis may seem to imply that each phase is separate from another and that 'over-the-wall' philosophies can be employed. In actual fact the exact opposite of this concept applies. The focus of each phase has been highlighted for ease of understanding, but the phases are very much interdependent. According to the principles of Concurrent Engineering, these phases should in fact occur as close to in parallel as possible to ensure a quality engineered and manufactured product as well as to shorten time to market.

The major organisational elements in the table below were extracted from the preceding sections by analysing those elements that were recurring.

Table 3: Summary of Product Development Phases and Associated Elements

PD Phase	***Focus of High Level Activities***	***Organisational Entities Involved***
Concept	Conceptualise a realistic vision of the product to be developed	Marketing Resources Management Employees Customers Technical Experts
R&D	To develop the technology needed to develop and manufacture the product. Information sharing Storage of new information Technology Management	Technical experts Product managers
Definition	Should break down the product's development into various activities or tasks that need to be addressed over the entire development cycle	Management Project Management principles Information sharing Customer

PD Phase	***Focus of High Level Activities***	***Organisational Entities Involved***
Design and Development	Implementation of defined requirements into a cohesive product Product design information Processes	Customer Marketing Engineering Manufacturing Suppliers Information systems Management
Industrialisation	Designed product is readied for production	Customer Engineers Manufacturing Standards (Internal and External)

2.3 INTEGRATED PRODUCT DEVELOPMENT / CONCURRENT ENGINEERING

Concurrent Engineering (CE) is based on the following philosophy: "the implementation of a process that integrates all functional disciplines associated with hardware systems design and development, by **systematically & simultaneously** employing a teaming of these disciplines, in order to integrate and concurrently apply all necessary processes required to produce an effective and efficient product that satisfies all customer requirements, at least cost and within a significantly reduced time frame." (Sterling, 1996)

The Engineering Department Management and Administration Report (EDMAR) (1997) summarises CE as follows:

2.3.1 Co-locate key functional disciplines

When teams are created allow them to sit in one location if possible

2.3.2 Organise cross-functional teams

CE sets up a new matrix-based organisational structure and lets the parallel teams work co-operatively. There are certain basic communication requirements when embarking on any product development project, but within each project the details thereof may differ.

Functions of communication were identified that were specific to a product development environment but could possibly also apply across the organisational spectrum by using various sources of literature. These sources ranged from those specifying product development information and the management of human resources through to the implementation of standards and excellence models such as ISO 9000 and the European Excellence Model. Some of the functions of communication are stated below:

- Ensuring a common understanding of the strategic alignment of the various product development projects undertaken
- Creating channels through which the identification and recording of customer wants and needs can occur
- To ensure common purpose within the development team
- To create an environment in which innovation and creativity can thrive
- To make information available with regards to performance of individuals, teams, equipment, suppliers etc. for the purpose of improvement, and
- To enable the passing of information between relevant parties in an effective manner allowing for informed decisions to be made.

With the functions of communication as listed above in mind, how to achieve these goals becomes an issue. There are possibly endless solutions to the problem of fulfilling these communication functions. Each solution however, will be specific to the business and its people due to the different 'organisational cultures' involved. The structure of the organisation, or in the case of PD, the product development teams and management play a huge role in how effective communication is to be achieved. Hierarchical structures of authority need a different approach to communication than an organisation that uses a very 'flat' organisational structure. What does remain the same is that communication must enable information to flow in the most economical manner possible between the people that need it and the people that supply it.

2.3.3 Use Computer Aided Design software

The use of software speeds up the design process and enables easier industrialisation of designed products due to the fact that the designs can be programmed directly into machinery such as CNC machines.

2.3.4 Conduct thorough design reviews at design concept and definition stages

In order to be able to improve from any point, one must have an understanding of where you stand at that point. ***An improvement can only be measured against something else*** For this reason, measurements of what is going on both in the actual product development as well as the processes that are playing a supporting role, are necessary. These measurements may be numerical or merely a review of the activities up until that point in the organisations existence (See Appendix C for an example of design review agendas.)

Reviews are the basis for any form of improvement and particularly for Continuous Improvement. Reviews are the mechanism of measurement, but eventually, standards against which we review or measure will also be required.

The most essential thing in order to truly improve on a continuous basis is not the review itself but the way in which the information revealed during a review, is used in the future. People should be actioned to fix things that have gone wrong, to look for areas to improve (e.g. in the area of customer satisfaction) and use the review as a platform for the exchange of ideas.

In order to improve, regular reviews are necessary that have to do with both the actual design of the product as well as the supporting documentation and processes. This may seem like a lot of time wasted, but in fact, these reviews save time since they stop mistakes from creeping into a design and propagating to a point where it is expensive to change. They allow for improvements to the product development support system that will allow things to happen faster and at lower costs. If the reviews action improvements or changes they will be worthwhile, on the other hand if they become merely a tabling of information then time will certainly be wasted.

A study done on the effects of best practices on product success (Dooley, 2001) revealed that *goals and metrics* had weak effects on product success and cycle time improvement. But the setting of goals and objectives allows the measurement of improvement and typically increases the motivation of the people involved.

The theme of measuring activities for the purpose of improving is covered in the last section of the ISO 9004 standard. This area of ISO 9004 includes the review of the validity and purpose of measurements and the intended use of data to ensure added value to the organisation.

2.3.5 Involve key disciplines, especially manufacturing, early in development

By involving all the players early in the development, information that has an effect on the product design is available during the early development phases and thus save time and money on reworking designs at a later stage.

What is different between a traditional (serial) and a concurrent product development process is the organisational set-up, management style and the manner in which scheduling of tasks and resources are accomplished. Engineers from different domains could work together (during any stage) to solve problems jointly. Although, in a traditional product development scenario, the respective life cycle engineers do their own work in phases and the information is passed in a serial manner on to the next department or group. The passing of information between two consecutive departments or groups is normally a one-time transfer. In a concurrent mode of product development, the workflow moves vertically among the workgroups (within its own phase), but also moves horizontally across its neighbouring phases. During the main activity for a phase, all members of the multi-disciplinary groups work together on tasks for that phase. In a concurrent workflow mode of product development, in addition to main-activity, two additional work activities take place simultaneously. They are named here as pre-activity and post-activity work for that phase. Pre-activity work is done before the main-activity, to support the requirements of some downstream activities or workgroups (including the main-activity) and to carry out some initial pre-works of its own. Post-activity work is done before completion of the main-activity work tasks, to support upstream activities (including the main-activity) and to carry out some of its post-activity tasks. A series of transfers may take place while the information is being built up during a main-activity phase.

Prasad et al (1998) refer to the 'X-abilities' (in terms of manufacturability, assemblability, maintainability, etc.) that are often used to describe the quality (one measure of performance) of a design in product development. There are many factors that influence a process's X-ability performance. They include integrated environment, supporting tools, design methodology, team organisation and process re-engineering. In order to get these factors to work together to enable concurrent engineering, Work Process Re-engineering is required.

This involves re-engineering the following:

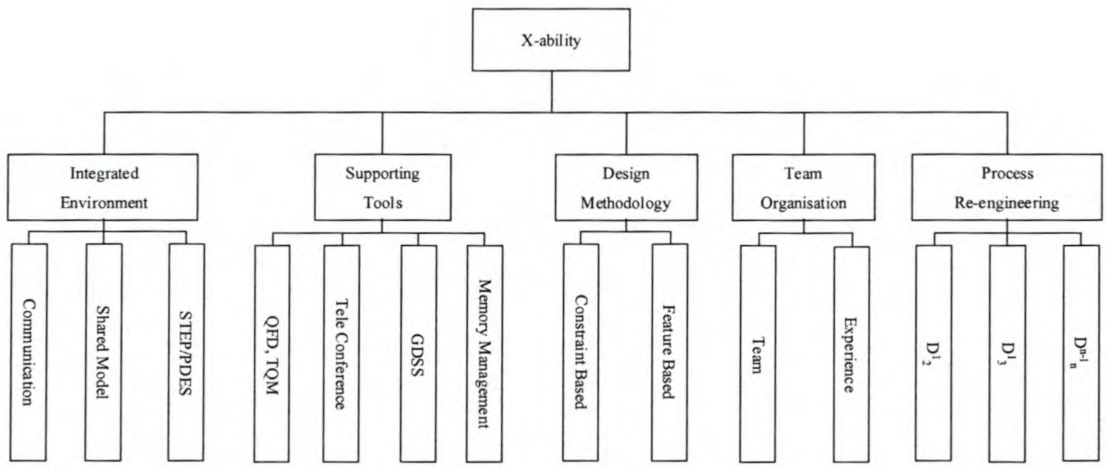


Figure 4: Factors influencing X-abilities (Source: Prasad et al, 1998)

Organisation: The traditional organisational structure is often hierarchical, which makes it almost impossible for the teams to consider many life-cycle aspects of product design and manufacturing whilst making concurrent decisions.

Resources: Existing resources need to be used as effectively as possible, the design environment needs to be improved with the aid of technology, new resources need to be employed for key tasks and new methods and tools need to be adopted as part of the product development process.

Workflow: The workflow needs to be redesigned so that team members can work together during each stage of product development. Employing the following strategies can do this: co-operation, co-ordination, group decisions, releasing results earlier, leveraging experience, pre-work and decomposing (Prasad et al, 1998).

2.4 RAPID PRODUCT DEVELOPMENT

Rapid Product Development has two sides to it. Firstly the technological side that offers organisations an opportunity to physically develop product prototypes etc. in a very short space of time using technologies such as stereo-lithography. The second is the management philosophy of enabling product development to take place faster. This section will deal with the philosophy of rapid product development rather than the technological side.

The ongoing ability to deliver a quality product or service quicker than the competition yields a sustainable competitive advantage. The bottom line is that when customers decide they want to buy, the first supplier who can fill that need with a quality product or service will flourish. These companies operate in Fast Cycle Time (FCT). Companies who are successful at reducing their development times secure the prime distribution channels, which create additional entry barriers for their competitors.

Christopher Meyer wrote an article entitled "A Six-Step Framework for Becoming a Fast-Cycle-Time Competitor" in which he describes six key steps to becoming a FCT competitor:

1. Understand what your end customer regards as added value, and reflect that in every job at every level within the organisation
2. Focus the entire organisation on work that adds value to the end customer
3. Redesign your organisation so that it is flat and based on multi-functional teams, with blurred boundaries inside and out
4. Pursue process development as actively as product or service development
5. Set "stretch" cycle time goals and measure processes publicly
6. Create an environment that stimulates and rewards continuous learning and action.

As techniques such as cross-functional development teams and concurrent engineering become widespread, these approaches to shortening development cycles lose their competitive edge (Smith & Reinertsen, 1992). Decisive advantage is likely to come from the techniques that the competitors are not using. There are still opportunities to accelerate the 'fuzzy, front end', in which half of a typical development cycle vanishes before the team even start work.

Smith and Reinertsen cover 10 such approaches in their article "Shortening the Product Development Cycle". These approaches are mentioned and briefly elaborated on below:

Be flexible about process: The most effective organisations have different systems available and are tuned to suit the objectives of managing both technical risk and development time. Without alternative processes, all projects tend to get sent through the same process, a common denominator that suits no objective well. In practice it usually errs on the side of minimising technical risk at the expense of speed.

Let economics be your guide: It is not unusual to discover that the product's development expense has far less impact on its life cycle profitability than development delay. When this is the case, managers who spend much of their time massaging the budget are concentrating on a low-leverage area.

Watch out for complexity: The degree of complexity in a project determines the effort needed and thus the length of the development cycle. The way to get new products out quickly is to minimise complexity by moving in short, simple steps, and sampling customer response along the way by selling intermediate models.

Manage the invention pipeline: Invention is a notoriously unpredictable activity. It cannot be scheduled into a normal project, much less an accelerated one. Many companies fail at managing invention because they try to integrate invention with product development. Product development should be tightly scheduled whereas invention is loosely scheduled.

Avoid the "thinking stage" trap: What we call the 'fuzzy front end' is frequently one of the largest and cheapest opportunities to shorten the development cycle. The front-end time is mostly a vacuum, largely because managers who haven't calculated a Rand value of development delay believe that time is free until people are assigned to the project.

Staff teams adequately

Staff with generalists: Specialists are difficult to keep fully occupied on a project. Good products require balance to provide value to the customer and a high degree of specialisation inhibits the manager's ability to redeploy people within a development team to match the workload.

Let the team manage the team

Manage both technical and market risk: Technical risk is the inability to satisfy the product specification, and market risk is the inability to sell the product assuming it meets specification.

Develop a reserve: There has to be some slack, because new product ideas will arise unexpectedly.

2.5 SUMMARY

The investigation of the phases of the Product Development Life Cycle identified the activities or best practices associated with each phase. Two product development methodologies i.e. Integrated Product Development and Rapid Product Development were also reviewed. At this point it is reasonable to assume that the reader now has a clear idea of what product development is and the types of activities. The activities that are described by all the preceding sections can be considered to be part of a pool of best practices with respect to product development.

In the effort to improve the product development processes within an organisation, these activities need to be measured. So, now that we know 'WHAT' we should be measuring, we need to investigate 'HOW' to measure it.

3. Measuring The Current State Of Affairs

In his article "The Performance Measurement Manifesto", 1998, Robert Eccles focuses on the fact that the leading indicators of business performance cannot be found in financial data alone. He summarises a performance measurement system into five essential activities:

1. Developing an information architecture
2. Putting technology in place to support this architecture
3. Aligning bonuses and other incentives with the new system
4. Drawing on outside resources, and
5. Designing an internal process to ensure that the other four activities occur.

Many companies 'track' activities, but Eccles says "What gets ***measured,*** gets ***attention***." This is the crux of why measurement is so vital. By giving attention to something, you can bring about improvements that are specific and whose impact is visible.

3.1 CAPABILITY MATURITY MODEL (CMM)

The Capability Maturity Model (CMM) is a model for judging the maturity of the software processes of an organisation and for identifying the key practices that are required to increase the maturity of these processes.

Although the scope of this thesis specifically excludes the development of software applications as stand-alone products, the principles on which CMM is based can also be modified to add value to an environment in which hardware products are developed.

The Capability Maturity Model for Software describes the principles and practices underlying software process maturity and is intended to help software organisations improve the maturity of their software processes in terms of an evolutionary path from ad hoc, chaotic processes to mature, disciplined software processes.

The CMM is organised into five maturity levels:

Table 4: CMM Basics (Source: http://www.cs.uofs.edu/~dmartin/process.html)

Maturity levels	*Key process areas*
1. Initial: The software process is characterised as ad hoc, and occasionally even as chaotic. Few processes are defined, and success depends on individual efforts and heroics.	▪ None
2. Repeatable: Basic project management processes are established to track costs, schedules and functionality. The necessary process discipline is in place to repeat earlier successes on projects with similar applications.	▪ Requirements management ▪ Project planning ▪ Project tracking and oversight ▪ Subcontract management ▪ Quality assurance ▪ Configuration management
3. Defined: The software process for both management and engineering activities is documented, standardised, and integrated into a standard software process for the organisation. All projects use an approved, tailored version of the organisations standard software process for developing and maintaining software.	▪ Organisation process focus ▪ Process definition ▪ Training programme ▪ Integrated software management ▪ Product engineering ▪ Intergroup co-ordination ▪ Peer reviews

4. Managed: Detailed measures of the software process and product quality are collected. Both the software process and products are quantitatively understood and controlled.	▪ Quantitative process management ▪ Quality management
5. Optimising: Continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative ideas and technologies.	▪ Defect prevention ▪ Technology change management ▪ Process change management

3.2 ISO 9004 SERIES: QUALITY MANAGEMENT SYSTEMS

In a study done on the effects of best practices on companies whose business is centred around product development it was shown that the presence of *quality certification* (such as ISO 9001) is a strong predictor of product success (the product achieves in the marketplace what is expected, or achieves more). On the other hand the presence of *quality awards* such as Malcom Baldridge National Quality Award, a State quality award, or supplier award, is a strong predictor of cycle time improvement. [Kevin Dooley, 2001]

The requirements for the ISO 9001 series are organised into four areas: (1) the Quality Management System, (2) Management Responsibilities, (3) Resource Management and (4) Measurement Analysis and Improvement. The fact that the entire organisation and all its facets are included in the standard meant that the ISO 9001 requirements could not be used 'As-Is'. This is due to the fact that the ISO 9001 series is set up to evaluate the four above-mentioned areas of business management, and not specifically product development activities. The goal of this thesis was to be able to use the information contained within the ISO 9001 series to aid in the choice of the Product Development Elements and then to ensure that the elements chosen cover all requirements stated within the ISO 9004 series Quality Management System Requirements.

The ISO 9000 series is made up of ISO 9001 and ISO 9004. There is only one distinct difference between the basic principle of the two standards and that is that the 9004 standard was developed to be used as a self-assessment tool within companies, whereas the 9001 standard is used as a standard which companies are certified against. In the latter case the method in which the company fulfils the standard is not the issue, but merely whether they comply. The 9004 standard, however, focuses heavily on the use of numeric scores to assess the position of a company in a way in which continuous improvement can be implemented and monitored with relative scores.

Specific features of the ISO 9004 self-assessment approach are that it can:

- *be applied to the entire quality management system, or to a part of the quality management system, or to any process*
- *be applied to the entire organisation or part of the organisation*
- *be completed quickly with internal resources*
- *be completed by a multi-discipline team, or by one person in the organisation who is supported by top management*
- *form an input to a more comprehensive quality management system self assessment process*
- *identify and facilitate the prioritisation of opportunities for improvement, and*
- *facilitate maturing of the quality management system towards worldclass performance.*

The ISO 9004 self-assessment approach is to evaluate the maturity of the quality management system for each major clause in ISO 9004 on a scale ranging from 1 (no formal system) to 5 (best-in-class performance).

> *Another advantage to this approach is that results monitored over time can be used to appraise the maturity of an organisation. This approach to self-assessment is neither a substitute for internal audit of the quality management system nor for the use of existing quality award models.*
>
> (Source: ISO 9004-4:1993, Quality management and quality system elements— Part 4: Guidelines for quality improvement.)

Documentation plays a vital role in the implementation of an ISO 9001 or 9004 programme.

As part of his conclusions in an article titled "Project Management and Communication of Product Development through Electronic Document Management", Mokhtar states that document management is a powerful approach for communicating and controlling product development. It is also the brain of many companies working in innovative and dynamic environments.

A typical answer to the problem of what to document would be to write everything down and then keep it all and use it where necessary. This is one of the major problems with many organisations trying to acquire ISO 9001 certification. The whole organisation and all its processes become bogged down in paperwork and valuable time and effort is lost. This is a particularly common problem in immature organisations. This approach seems to create a sense of security in the organisation that if they have forgotten about an element of a process it will have been written down somewhere.

In order to make any process repeatable, to be able to review activities accurately, to ensure design consistency and various other requirements with regard to product development, documentation is essential. But probably even more important is the quality of the of the documents.

If an interface control document between two systems is not controlled properly, the likelihood of the two systems being able to integrate is very slim. A decision needs to be made in terms of three types of documentation with regards to any organisation involved in product development. These are:

- What documents are needed to define how things are to be done (processes, review points etc.)

- What documents are needed to define what is to be done (levels of design documents, test results etc.), and finally
- What documents are needed to actually make the product (product datapack).

Documents provide an effective audit trail when reviews are held with the intent to improve. One must, however, be cautious of 'over-documentation'. Bad documentation is often far worse than no documentation.

3.2 EXCELLENCE MODELS

The Excellence Models consulted define the achievement of excellence in terms of organisational enablers and results. The table below shows the mapping of the three excellence models that were used as the basis for developing the graphical tool described in this thesis, against each other.

Table 5: A comparison of the Elements of Excellence Models studied

Baldridge Model	South African Excellence Foundation (SAEF) Model	European Excellence Foundation (EFQM) Model
Leadership	Leadership	Leadership
Customer focus and satisfaction	Customer satisfaction	Customer results
Business results	Business results	Key performance results
Process management	Processes	Processes
Human resource development & management	People management	People results
Strategic quality planning	Policy and strategy	Policy and strategy
Information and analysis	Resources and information management	
	Customer and market focus	
	Impact on society	Society results

Baldridge Model	South African Excellence Foundation (SAEF) Model	European Excellence Foundation (EFQM) Model
	People satisfaction	People
	Supplier and partnership performance	Partnerships and resources

The increased emphasis on the Customers, Processes and Business Results can be seen by the fact that these entities are worth more 'points' in the two excellence models lending one to believe that these three model components are certainly to be included in a Measurement Model.

3.3 BALANCED SCORECARD

The excerpt below is from the preface to the book "The Balanced Scorecard" written by David Norton and Robert Kaplan in 1996. It explains the origins of "The Balanced Scorecard".

> *The origins of this book can be traced back to 1990 when the Nolan Norton Institute, the research arm of KPMG, sponsored a one-year multicompany study, "Measuring Performance in the Organisation of the Future". The study was motivated by a belief that existing performance approaches, primarily relying on financial accounting measures, were becoming obsolete. The study participants believed that reliance on summary financial-performance measures were hindering organisations' abilities to create economic value.*

The idea of this new measurement system was to capture critical value-creation activities created by skilled, motivated organisational participants. While at the same time retaining, via the financial perspective, an interest in short-term performance, the Balanced Scorecard reveals the value drivers for superior long-term financial and competitive performance.

Although the Balanced Scorecard does not focus on product development, the principles in terms of measuring how effectively strategy has been implemented could be applied to any scenario.

The Balanced Scorecard is made up of four 'Perspectives':

- Financial Perspective
- Customer Perspective
- Internal-Business-Process Perspective
- Learning and Growth Perspective.

Each perspective has Objectives, Measurements, Targets and Initiatives that are all linked to the organisation's Vision and Strategy. The idea of the Balanced Scorecard is to start at the top – decide on a vision and strategy. The Balanced Scorecard methodology then enables organisations to work from the top down and align ALL business activities to the overall strategy. All measurements and objectives are focused towards one point: the strategy.

The fact that there are four perspectives means that the focus areas of improvement can be on the activities that have a cause and effect relationship to the financial results of the organisation.

Kaplan and Norton (1996) see the Balanced Scorecard as a 'Strategic Framework for Action'.

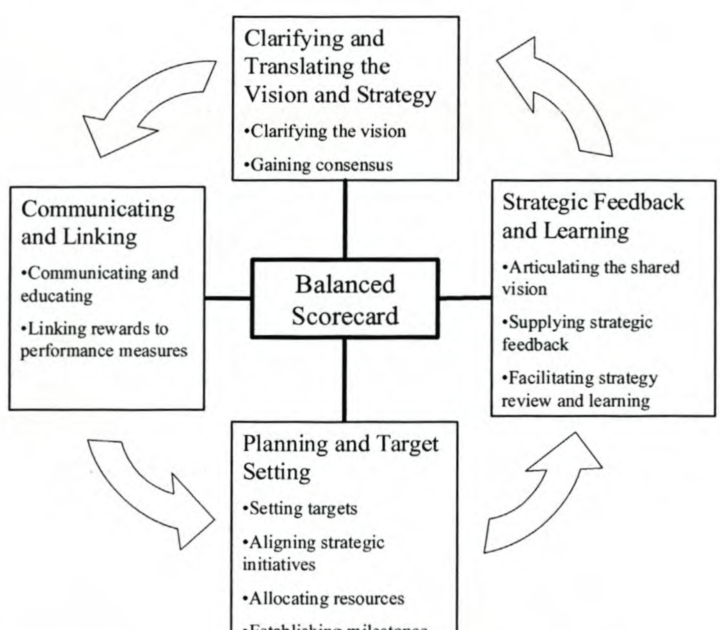


Figure 5: ***Source*** **Robert S Kaplan and David P. Norton, "Using the Balanced Scorecard as a Strategic Management System,"** ***Harvard Business Review*** **(January-February 1996)**

The Balanced Scorecard is one of the first performance measurement systems to focus on a number of non-financial aspects of performance and also highlights the need for focus within an organisation towards a common goal.

This idea can be applied to a product development environment where the strategy is to produce high quality products with reduced time-to-market. Thus the organisation will have to create objectives, implement measures, define targets and come up with and implement improvement initiatives in order to attain the goal of high quality products in reduced time-to-market.

3.4 SUMMARY OF ALL MEASUREMENT TOOLS

System	Goal	Main Focus Areas	Unit/Scale of Measurement	Comments
CMM	The Capability Maturity Model (CMM) is a model for judging the maturity of the software processes of an organisation and for identifying the key practices that are required to increase the maturity of these processes.	▪ Defining and managing requirements ▪ Planning ▪ Process ▪ Review ▪ Technology Management	1. Initial 2. Repeatable 3. Defined 4. Managed 5. Optimising	Although CMM was developed for software development processes, the manner in which process maturity is measured is most certainly applicable to a product development environment. It gives a defined level of measurement to indicate the maturity of an 'intangible'.
ISO 9004	Many models currently exist for the self-assessment of organisations to quality management system criteria.	▪ Quality Management System ▫ General requirements ▫ Documentation requirements ▪ Management Responsibility ▫ Management commitment ▫ Customer focus ▫ Quality policy ▫ Planning ▫ Responsibility, authority and communication ▫ Management review ▪ Resource management ▫ Provision of resources ▫ Human resources ▫ Infrastructure ▫ Work environment ▪ Product Realisation ▫ Planning of product realisation	For the Self Assessment in ISO 9004, the following scoring levels apply: 1. No formal approach 2. Reactive approach 3. Stable formal system approach 4. Continual improvement emphasised 5. Best in class performance	The requirements cover the entire spectrum of an organisation and don't focus exclusively on product development although the section on Product Realisation is a new addition and very valuable to companies due to the fact that it looks at the existence of typical "best practice" activities.

System	Goal	Main Focus Areas	Unit/Scale of Measurement	Comments
		▫ Customer-related processes ▫ Design and development ▫ Purchasing ▫ Production and service provision ▫ Control of monitoring and measuring devices ▪ Measurement Analysis and Improvement ▫ General ▫ Monitoring and measurement ▫ Control of non-conforming product ▫ Analysis of data ▫ Improvement		
SAEF	The Model enables an organisation to: ▪ Assess its performance objectively against a number of **internationally recognised criteria** ▪ Identify **strengths** of the organisation ▪ Single out **areas for improvement** ▪ Set **improvement plans in action** ▪ Repeat the process	▪ Enablers: ▫ Leadership ▫ Policy and Strategy ▫ Customer and Market focus ▫ People management ▫ Resources and Information Management ▫ Processes ▪ Results ▫ Impact on society ▫ Customer satisfaction ▫ People satisfaction ▫ Supplier and partnership performance ▫ Business results	Scores are assigned with regards to the degree of excellence attained. The full table of scoring levels can be seen in Appendix A.	▪ Pro's ▫ The element of continuous improvement is contained within the Model ▫ Singles out areas for improvement ▫ Not all elements are weighted the same thus implying some areas are more important than others ▪ Con's ▫ The SAEF Model concentrates on the whole organisation ▫ Scoring is not always objective
Balanced Scorecard	To capture critical value-creation activities created by skilled, motivated organisational;	▪ Financial ▪ Internal Business processes	▪ Objectives ▪ Measures	▪ Pro's ▫ The Balanced Scorecard looks

System	Goal	Main Focus Areas	Unit/Scale of Measurement	Comments
	participants. While at the same time retaining, via the financial perspective, an interest in short-term performance, the Balanced Scorecard reveals the value drivers for superior long-term financial and competitive performance. The aim is to align every action with the organisation's overall strategy.	▪ Learning and growth ▪ Customer	▪ Targets ▪ Initiatives	at how to integrate tools such as Total Quality Management, Just In Time activity-based cost management etc. into a measurement of the entire company. ▫ Con's ▫ There is no formal inclusion of Continuous Improvement into the basic principle of this model. The improvements made are merely as a result of more strategic focus throughout the company. ▫ There is no "final score" to compare after each iteration of improvement. Measurements are unique for each perspective and not indicative of the organisation as an entire entity.

4. General Improvement Philosophies

The paradigm shift of the last few decades towards an awareness of 'quality' has brought about numerous 'quality' philosophies. Many have come and gone but the truth of the matter is that the names of the programmes are often changed to reflect a change in emphasis, not a change in overall principles. All these programmes have evolved from the quality management philosophy espoused by Deming, Juran and others. (Westgard, 2000). The following section is dedicated to investigating some of the philosophies in an attempt to identify where they may play a role in product development.

There are four philosophies that have been included in this chapter: Total Quality Management (TQM), Continuous Improvement (CI) and Innovation, Six Sigma and Business Process Re-engineering (BPR). The reader should be aware of the fact that many academic groups feel that Continuous Improvement is part of Total Quality Management and therefore should not warrant a separate section in this literature. It was however the opinion of the author that the core concepts of Continuous Improvement can be implemented as a stand-alone project and thus still has merit enough to warrant a separate section.

It can also be argued that Six Sigma falls under the vast umbrella that is now 'Total Quality Management', but the focus of both Six Sigma and CI are different and therefore add value in different ways to the idea of using these general improvement philosophies in a product development environment.

4.1 TOTAL QUALITY MANAGEMENT

Total Quality was defined by a study group of the Total Quality Forum (1992) as:

...a people-focused management system that aims at continual increase in customer satisfaction at continually lower real cost. TQ is a total system approach (not a separate area or programme), and an integral part of high-level strategy. It works horizontally across functions and departments, involving all employees, top to bottom and extends backwards and forwards to include the supply chain and the customer chain... [Rampey and Roberts, 1992]

Bounds et.al [1994] state that *...the above definition is the most concise one available and agreeable to both business and academic leaders. It also separates the underlying principles* *from the tools and techniques that are often mistaken for the concept. This separation reveals an important insight into the reason that many managers fail to achieve their expectations with TQM.* The central idea of TQM is that *managers must think and act to improve organisational systems to provide superior customer value.* This idea is carried out by focusing on three themes:

1. **Customer Value Strategy**
2. **Organisational Systems**
3. **Continuous Improvement**

Each of these themes is summarised in the tables in Appendix B.

Bearing in mind that the concept of Total Quality Management is more of an overall culture than a programme, Schmidt and Finnigan (1992) suggest that TQM's roots include:

1. *Scientific management:* Finding the best way to do one job
2. *Group dynamics:* Enlisting and organising the power of group experience
3. *Training and Development:* Investing in human capital
4. *Achievement and motivation:* People get satisfaction from accomplishment
5. *Employee involvement:* Workers should have some influence in the organisation
6. *Sociotechnical Systems:* Organisations operate as open systems
7. *Organisational development:* Helping organisations to learn and change
8. *Corporate culture:* Beliefs, myths, and values that guide the behaviour of people throughout the organisation
9. *The new leadership theory:* Inspiring and empowering others to act
10. *The Linking-Pin concept of organisations:* Creating cross-functional teams
11. *Strategic planning:* Determining where to take the organisation, and how and when to get there

4.2 CONTINUOUS IMPROVEMENT AND INNOVATION

Imai (1986) suggests that Japanese managers are able to accomplish improvement through *kaizen*, which can be defined as a series of undramatic and subtle improvements that slowly and cumulatively raise the level of performance without interruption to activities. This contrasts to Juran's view of improvement by *breakthroughs*. The innovative one-shot deals that achieve dramatically better levels of performance (discontinuous jumps that are the focus of Business Process Re-engineering).

Bounds et al (1994) suggest that the most powerful mechanism to effect improvement is to combine Juran's *breakthroughs* and Imai's *kaizen*. They state that this combination of techniques would ensure no backsliding between the big innovation jumps because of the perpetual smaller improvements that are on-going. The diagram below illustrates the net result of this powerful combination.

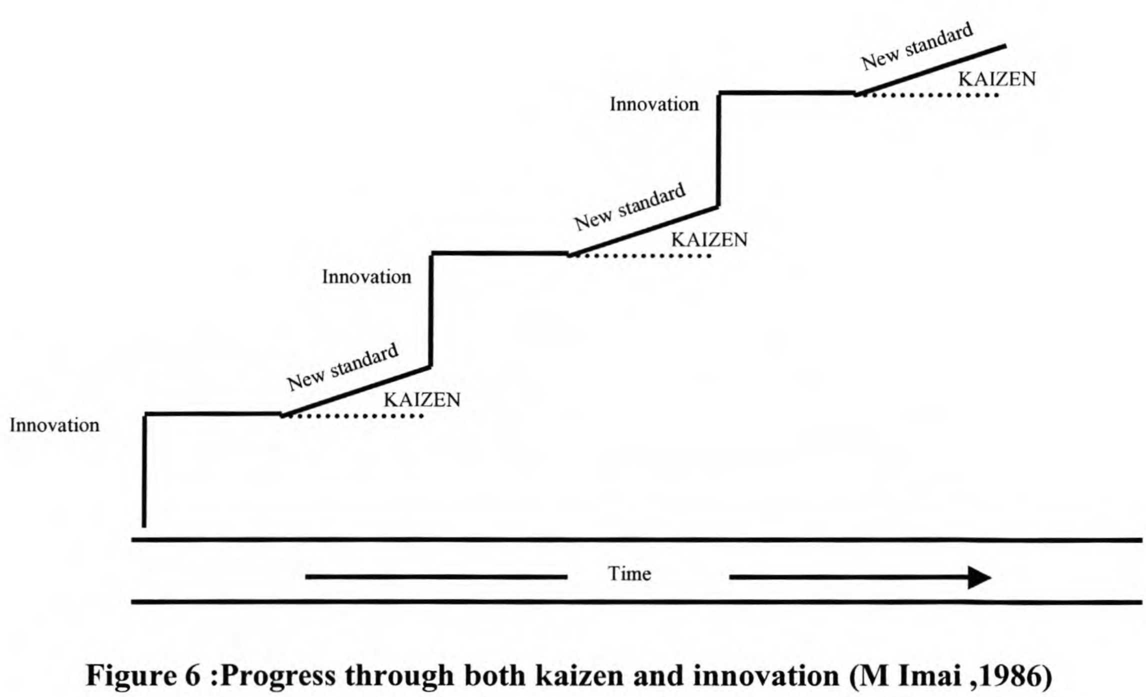


Figure 6 :Progress through both kaizen and innovation (M Imai ,1986)

Continuous improvement can only occur where there is a cycle that repeats itself. In other words the output of a cycle is the input for the next cycle. It is common in 'immature' organisations that management reviews, project meetings, target reviews, etc. are indeed part of the processes, but that these meetings are in fact just information sessions with no or very little action being taken as a result of the findings in these meetings. This is where measuring becomes a very powerful tool. It is not the measurements themselves that are important, but the actions towards improving the process based on the measurements.

Continuous Quality Improvement emphasises that quality is not static but needs to be improved on an ongoing basis. It provides problem solving methodology to support the identification and resolution of chronic problems, particularly those that occur across departments. Teamwork and group problem solving are important elements (Westgard, 2000).

In an article "How to carry out a Continuous Improvement project" Mike Hick defines the main steps involved in Continuous Improvement:

1. Set up the Project Team
2. Define the scope
3. Set the goals
4. Understand the process
5. Determine information needs
6. Identify the root causes
7. Develop solutions
8. Implement solutions
9. Review the results
10. Standardise the change

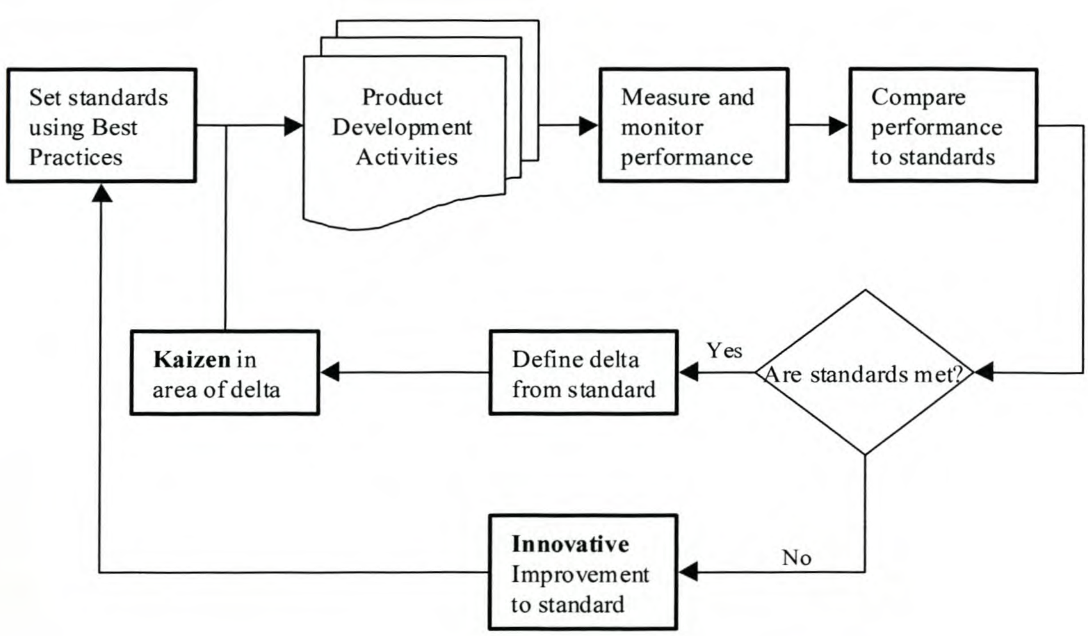


Figure 7: A diagrammatic representation of a CI approach

4.3 SIX SIGMA

In 1981, Bob Calvin, then chairman of Motorola, challenged his company to achieve a tenfold improvement in performance over a five-year period. This led to the work of the engineer, Bill Smith. In 1985 he presented a paper concluding that products that are assembled error free, rarely fail during early use by the customer. In the late eighties, early nineties, Motorola conceived the concept of Six Sigma. To Motorola, the term Six Sigma has become synonymous with quality.

DR Westgard of the University of Wisconsin states that Six Sigma is in fact a new marketing approach for TQM. This may be a controversial statement, but he justifies it by saying that the emphasis of Six Sigma is truly important for making quality management a more **quantitative** science.

Gary Cone published an article "Six Sigma Basics" in "The Global Compass" in which he summarises what six sigma is and is not:

What Six Sigma is:

- A philosophy
- A benchmarking metric
- A roadmap for improvement

What Six Sigma is not:

- A substitute for a good Quality System (reiterating Dr Westgard's view on Six Sigma)
- It is not to be used at the exclusion of other known improvement tools
- It is not a substitute for training your people in basic job skills
- ***It is not a substitute for having a disciplined product development process and rigorous management reviews***

There is a generally accepted five-step programme to implementing six sigma:

1. **D**efining an opportunity

2. **M**easuring performance

3. **A**nalysing the opportunity

4. **I**mproving performance

5. **C**ontrolling performance

These "DMAIC" structured protocols are needed to achieve the goals of a six sigma programme.

Each of these phases has been expanded on in Table 6 and their interaction with a product development environment.

Table 6: Based on Six Sigma DMAIC Roadmap (Source: isixsigma.com, 2002)

Phase	***Activities***	***Association to product development***	***General themes included in philosophy***
Define	▪ Define customers and requirements ▪ Develop problem statement, goals and benefits ▪ Identify champion, process owner and team ▪ Define resources ▪ Evaluate key organisational support ▪ Develop project plan and milestones	▪ Determination of customer requirements ▪ Form a product development team	▪ Teams ▪ Inclusion of customer input ▪ Review
Define Tollgate Review			
Measure	▪ Define defect, opportunity, unit and metrics ▪ Detailed process map of appropriate areas ▪ Develop data collection plan ▪ Validate measurement system ▪ Collect the data ▪ Begin developing Y=f(x) relationship ▪ Determine process capability and sigma baseline	▪ Review of past product design performance ▪ Determine how to proceed with product development, what information is needed, what you will measure	▪ Planning ▪ Measurement ▪ Review
Measure Tollgate Review			
Analyse	▪ Define performance objectives ▪ Identify Value/Non-value added process steps ▪ Identify sources of variation ▪ Determine root causes ▪ Determine vital few x's, Y=f(x) relationship	▪ Define points of review in the process in terms of what was expected and what was achieved	▪ Define objectives ▪ Review

Phase	*Activities*	*Association to product development*	*General themes included in philosophy*
Analyse Tollgate Review			
Improve	▪ Perform design of experiments ▪ Develop potential solutions ▪ Define operating tolerances of potential system ▪ Assess failure modes of potential solutions ▪ Validate potential improvement by pilot studies ▪ Correct/re-evaluate potential solution	▪ Methods of gathering customer requirements ▪ Methods of product concept generation ▪ Use of tools such as Quality Function Deployment to determine how best to implement customer requirements in a product ▪ Use prototypes to determine potential problems in the product	▪ Continuous improvement ▪ Review
Improve Tollgate review			
Control	▪ Define and validate monitoring and control system ▪ Develop standards and procedures ▪ Implement statistical process control ▪ Determine process capability ▪ Develop transfer plan, handoff to process owner ▪ Verify benefits, cost savings/avoidance, profit growth ▪ Close project, finalise documentation ▪ Communicate to business, celebrate successes	▪ Cost savings calculations ▪ Develop a process which is repeatable and improve on it in order to develop better products in shorter time ▪ Complete datapack	▪ Process standardisation ▪ Documentation ▪ Review
Control Tollgate Review			

4.4 BUSINESS PROCESS RE-ENGINEERING

> *"Continuous improvement is exactly the right idea if you are the world leader in everything you do. It is a terrible idea if you are lagging in the world leadership benchmark. It is probably a disastrous idea if you are far behind the world standard...we need rapid, quantum-leap improvement. We cannot be satisfied to lay out a plan that will move us toward the existing world standard over some protracted period of time – say 1996 or the year 2000 – because if we accept such a plan, we will never be the world leader"*- Paul O'Neill, Chairman ALCOA

Business Process Re-engineering is, by definition, the means by which an organisation can achieve radical change in performance as measured by cost, cycle time, service, and quality by the application of a variety of tools and techniques that focus on the business as a set or on related customer-oriented core business processes rather than a set of organisational functions (Johansson et al, 1993)

According to Johansson, there are 8 key enablers of BPR:

1. **People**: Employees should be able to move from one business process development team to another, who can take their skills and learning and enhance a team working on another project, and who can in turn increase skills and learning in each process-development assignment they undertake and take it with them to the next task. Thus adding huge volumes of value to the business efforts to gain on market leaders.

2. **Management and Leadership**: Leaders in companies that employ BPR must be technically knowledgeable in order to understand the implications of process-oriented operations. Leaders must also be able to manage the inherent resistance to change that exists in most business cultures.

3. **Organisational culture**: The combination of people and leadership/management style is the essence of organisational culture. Typical cultural attributes that constitute an environment for a successful BPR exercise are as follows:

- Leadership that can create a vision, articulate values, and create a climate in which business unit executives, managers and line personnel all work together and growth is encouraged
- Shared values
- Teamwork at and across all levels
- Constituency relationships, especially with shareholders, customers and suppliers
- Change and the desire to dominate the market

4. **Functional expertise**: BPR seeks as its ultimate goal the most complete defunctionalisation of the business possible consistent with corporate strategy. But even in the radically defunctionalised company, there will always be a need for expertise and knowledge of people from the former functions.

5. **Stockpiling**: A *BreakPoint* is the achievement of excellence in one or more value metrics where the market place clearly recognises the advantage, and where the ensuing result is a disproportionate and sustained increase in the supplier's market share (Johansson et al, 1993). **Stockpiling** is when a company finds two BreakPoints it can achieve, takes one now and puts the process capability for the other "on the shelf" to bring to bear when the marketplace reacts and catches up with the first BreakPoint.

6. **Instantaneous reaction**: The ultimate principle of this delayered, team-oriented, process-driven organisation is that simpler is better, that the more direct the contact between the marketplace and business operations the more immediate the reaction to marketplace stimuli can be.

7. **New assets and their management**: A new definition of assets occurs, no longer focusing on financial and physical assets. BPR redefines asset management as operating, people, brands, intellectual property, value-metric excellence and process technology. The business unit executive must take responsibility for developing, enhancing, renewing, and regenerating those assets.

8. **Performance indicators**: BPR requires only four business performance indicators:

- Quality
- Lead time
- Cost, and
- Service (as defined by the customer and the organisation)

The purpose in reducing the metrics to four simple ones is that everyone in an organisation can focus on them at all times: they can be easily displayed and understood.

4.5 SUMMARY OF BUSINESS AND QUALITY PHILOSOPHIES AND BEST PRACTICES

The value of these philosophies in terms of product development lies in their 'Focus Areas'. thereby teaching where to focus attention when implementing improvement programmes from them.

Table 7 summarises the Business and Quality Philosophies investigated.

Table 7 : Summary of the Business and Quality Philosophies

Philosophy/Practice	*What?*	*Focus Areas*	*Comments*
TQM	TQM is as much about the quality of processes as it is about quality products or results. It's a culture that combines many quality 'programmes' Themes: 1. Customer Value Strategy 2. Organisational systems 3. Continuous improvement	▪ Scientific management ▪ Group dynamics ▪ Training and Development ▪ Achievement and motivation ▪ Employee involvement ▪ Sociotechnical Systems ▪ Organisational development ▪ Corporate culture ▪ The new leadership theory ▪ The Linking-Pin concept of organisations ▪ Strategic planning	The focus on Customer Value Strategy is a focus that can be utilised in the formation of a product strategy as well as something to bear in mind when developing user requirements.
Continuous Improvement	Continuous Quality Improvement emphasises that quality isn't static but needs to be improved on an ongoing basis. It provides problem solving methodology to support the identification and resolution of chronic problems, particularly those that occur across departments. Teamwork and group problem solving are important elements.	▪ Teams ▪ Processes ▪ Information ▪ Review	Continuous Improvement is considered a basic part on any improvement programme that is currently used. It forms the basis of all forward movement in any organisation. CI is usually used in conjunction with other programmes that give the improvement projects more focus.
Six Sigma	1. Defining an opportunity 2. Measuring performance 3. Analysing the opportunity 4. Improving performance 5. Controlling performance	▪ Processes ▪ Measurement	Six Sigma has only recently expanded into areas of non-manufacturing. Although its principles can be utilised in any environment, there is not a large amount of data pertaining to Six Sigma in a development environment.

Philosophy/Practice	*What?*	*Focus Areas*	*Comments*
BPR	Business Process Reengineering is, by definition, the means by which an organisation can achieve radical change in performance as measured by cost, cycle time, service, and quality by the application of a variety of tools and techniques that focus on the business as a set or related customer-oriented core business processes rather than a set of organisational functions.	▪ People ▪ Management and Leadership ▪ Organisational culture ▪ Functional expertise ▪ Stockpiling ▪ Instantaneous reaction ▪ New assets and their management, and ▪ Performance indicators	BPR and TQM are premised upon the assumptions that change can be rationally measured, and evidence can be provided in order to judge the quality and progress of change. This is also the assumption on which the graphical tool development is based. Change and improvements within the product development areas of the organisation are tracked or 'measured' in order to judge the 'quality' of the development processes as a whole.

5. Organisational Culture And Product Development

5.1 INTRODUCTION

In the literature that deals with product development, innovation and teams, there are three recurring themes in terms of the organisation in which product development takes place:

1. Organisational strategy
2. Organisational culture (Leadership) and
3. Organisational structure

In a study to determine whether an organisation's strategic posture or organisational culture can improve their response time to industry change, Ozsomer et al. (1997) state that "*Strategy is a precursor to organisation structure".* The more proactive and aggressive a firm's strategic posture is, the more flexible its organisational structure would have to be.

John L. Thompson states in his book "Strategic Management" (1994) that "Culture is reflected in the way that people in an organisation perform tasks, set objectives and administer resources to achieve them. It affects the way that they make decisions, think, feel and act in response to opportunities and threats. Culture also influences the selection of people for particular jobs, which in turn affects the way that tasks are carried out and decisions are made. Culture is so fundamental that it affects behaviour unconsciously. Managers do things in particular ways because it is expected behaviour." This explains how organisational culture can have a direct effect on the way in which activities are performed (or not performed) within an organisation.

The terms 'paradigm' and 'culture' are often used interchangeably, but there is a distinction. Paradigm refers to the ways of thinking and acting prescribed by a professional field. Culture refers to the ways of thinking and acting that are characteristic of a particular social group or organisation.

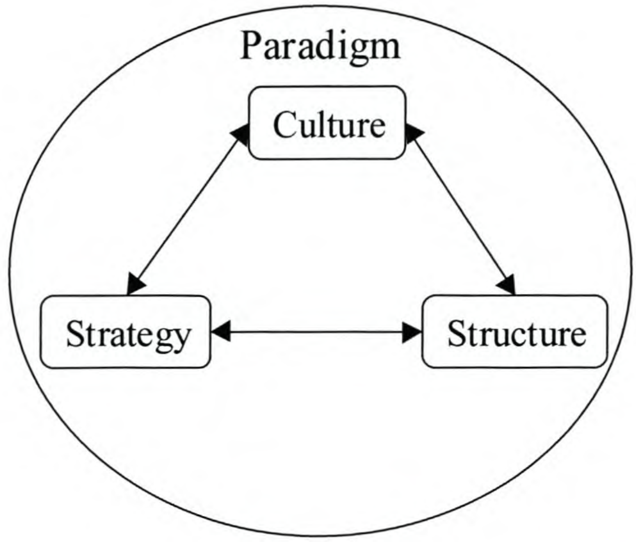


Figure 8: Relationship between Organisational Culture, Strategy, and Structure

There is a generally accepted awareness that there has been a quality paradigm shift in the world towards Total Quality Management which as stated in Chapter 4, has three themes:

1. *Customer value strategy*: the combination of benefits derived from using a product and the sacrifices required of the customer

2. *Organisational systems:* The means that provide customer value

3. *Continuous Improvement:* To keep pace with the changes in the external environment, managers have to change the organisation in different ways and more frequently.

This paradigm shift has caused the requirements for product development to shift and with this shift, organisational strategy, structure and culture have to also support a more customer oriented, continuously improving approach.

5.2. TYPES OF ORGANISATIONAL CULTURE AND PRODUCT DEVELOPMENT BEST PRACTICES

Charles Handy's book "Understanding Organisations" that was published in 1976 is still quoted in many recent articles and books when talking about organisational culture. In an extract from Thomson's book "Strategic Management" (1994) there is an adaptation of Handy's four cultures.

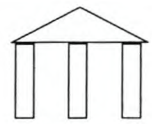
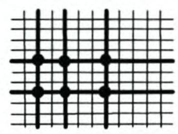
Culture	Diagrammatic Representation	Structure
Power or club		Web
Role		Greek temple
Task		Net
Person or existential		Cluster

Figure 9: Handy's Four Cultures. Adapted from Handy, C B (1976 *Understanding Organisations,* Penguin

Each type of culture and its relation to product development best practices is defined in sections 5.3 to 5.6.

5.3 THE POWER OR CLUB CULTURE

5.3.1 Introduction

Work is divided by function or product and a diagram of the organisation would be quite traditional. The lines radiating out from the center represent functions or departments, but the essential point is that there are also concentric lines representing communications and power. The further away from the center, the weaker the power and influence. Decisions can be taken quickly, but the quality of the decisions is very dependent upon the abilities of managers in the inner circle. A culture like this may prevent individual managers from speaking their minds, but decisions are unlikely to get lost in committees. Very little is formalised. Employees are rewarded for effort and change is very much led from the center in an entrepreneurial style. (Thomson, 1994)

5.3.2 Cultural impact on product development

The dominant influence of the center results in a structure that is able to move quickly and respond to change and outside threats. However, this is not gained by formal methods but by the selection of like-minded individuals who in key positions are able to 'guess what the Boss would do' without the need for conformist systems.

Attempts to implement a structured system into this culture are likely to be vigorously resisted both on the grounds of flexibility and unnecessary cost. Although due to the power of the 'center', if the 'boss' buys in to the importance of a structured system, and supports the principle of 'best practices' the implementation will be successful.

The ability to make decisions fast also means that there is inherent flexibility in the organisation to adapt. However, the need for empowered employees and open lines of communication as defined by product development best practices is not adequately catered for in this organisational culture.

5.4 THE ROLE CULTURE

5.4.1 Introduction

The culture is built around defined jobs, rules and procedures, and not personalities. Rationality and logic are at the heart of the culture, which is designed to be stable and predictable. Although the strength of the organisation is in the pillars, the power lies at the top. High efficiency is possible in stable environments, but the structure can be slow to change and is therefore less suitable for dynamic situations.

5.4.2 Cultural impact on product development

This type of organisational culture is ideally suited to the implementation of systems such as ISO 9000. However, its ability to react to changes in the marketplace is limited. This type of organisation adapts well to a structured, process-oriented environment. This may actually cause a problem though, when cross-departmental or functional processes need to be defined, as there is often a very 'territorial' approach to departments.

The multi-functional teams required by integrated product development might face difficulties that are compounded by this territorialism. Because of the focus on 'roles' in this culture, the organisation tends to be restrictive due to the 'packaging' of the tasks required by each job.

Typically, change is slow and usually brought about by fear. Therefore the open and innovative environment that product development requires in the new paradigm cannot flourish. Decisions on strategy would be slow and even worse to implement due to these VERY defined roles.

5.5 THE TASK CULTURE

5.5.1 Introduction

Management in the task culture is concerned with the continuous and successful solution of problems, and performance is judged by the success of the outcomes. The culture is shown as a net, because for particular problem situations people and other resources can be drawn from various parts of the organisation on a temporary basis. Discontinuity is a key element in this culture. In dynamic environments a major challenge for large organisations is the design of a structure and systems which allow for proper management and integration without losing the spirit and excitement typical of small entrepreneurial businesses.

5.5.2 Cultural impact on product development

A major positive in this culture is the fact that power and respect come from individual knowledge rather than rank or position. This is ideally suited to a multi-functional team that needs to have contributors from different areas to different degrees at different stages of development.

An organisation, which has a 'Task' culture, will typically be project oriented. This in turn means that in an environment such as the one required by product development – team-based - the 'Task' culture would enable the formation of multi-functional teams to occur without major changes to the status quo of the organisation.

5.6 THE PERSON OR EXISTENTIAL CULTURE

5.6.1 Introduction

The person culture is completely different from the other three cultures already mentioned. The organisation exists to help the individual rather than the other way around. Groups of professional people provide excellent examples (such as lawyers or doctors).

In his article "Building Effective product Development Teams/Integrated Product Teams" Kenneth Crow (1996), states that "Early involvement and parallel design are key objectives of integrated product development. The achievement of these objectives is dependent upon how people work together and organise product and process development activities. As a result, organisational approaches are critical to the success of integrated product development"

5.6.2 Cultural impact on product development

This organisational culture is not typically found in arena's where project work is required (except in the areas of technical or medical research). Typically, organisations who subscribe to the 'Person' or 'Existential' culture are more likely to accept a more philosophical approach to 'best practices' but will not fit into the structured environment that is required to develop products on time, with high quality and low cost. Although as previously stated, such organisations are usually involved in research based projects, rather than business developments.

5.7 ORGANISATIONAL CULTURE BEST SUITED TO PRODUCT DEVELOPMENT BEST PRACTICE IMPLEMENTATION

The requirements of the environment in which product development activities take place has a huge impact on the relative ease with which 'best practices' can be implemented and then maintained. The preceding paragraphs expanded on the effect of Handy's four organisational cultures in a product development environment. These findings are summarised in Table 8.

Table 8: 'Best Fit' of Organisation Culture to Product Development

Culture	***Cultural Fit***	***Challenges***	***Benefits***
Club	Poor/Fair	▪ Lack of innovation ▪ Executive dominance ▪ Lack of empowerment	▪ Strong leadership = quick change
Role	Poor	▪ Lack of innovation ▪ No team focus ▪ Change is slow	▪ Consistency
Task	Good	▪ Lack of structured processes	▪ Team focus ▪ Innovative ▪ Open communication ▪ Empowered employees
Existential	Very poor		▪ Typically not found in businesses involved in product development

As can be seen from the table above, the cultures that fit well with product development needs are the Club and the Task cultures. This means that after any assessment of the state of product development within an organisation, the improvement efforts need to focus on the culture of the organisation as well as the actual product development activities in order to improve in a way that can be maintained over a long period of time.

If the organisational culture is not conducive to fast changes, process improvement or information exchanges to name but a few issues, then any improvement will only be temporary. The organisation itself will not be able to sustain the requirements of product development that result in a competitive advantage.

6. An Introduction To the 'Product Development Best Practices And Assessment' Tool

As was stated in the introduction to this thesis, of all the literature that was studied in the area of product development and maturity measurement tools, only one tool was found that focused specifically on the area of product development. This is the 'Product Development Best Practices and Assessment tool' that was developed by Kenneth Crow and DRM Associates.

Kenneth A. Crow is President of DRM Associates, a management consulting and education firm focusing on integrated product development practices. He is a distinguished speaker and recognised expert in the field of integrated product development. He has over twenty years of experience consulting with major companies internationally in aerospace, capital equipment, defence, high technology, medical equipment, and transportation industries. He has provided guidance to executive management in formulating an integrated product development programme has reengineered the development process and has assisted product development teams in the application of integrated product development to specific projects.

6.1 PURPOSE OF THE TOOL

The "Product Development Best Practices and Assessment" tool was developed by DRM Associates in order to fulfil a need that has also been identified in this thesis. Managers need to be enabled to measure their product development performance against world class standards and then allow them to identify areas of improvement where improvement will allow them to leverage new areas of competitive advantage.

The tool has been designed to be used in an ongoing manner by the organisation itself. The initial assessment is traditionally conducted in conjunction with a team from DRM Associates during which the managers within the organisation gain enough experience to be able to do the assessment on their own.

The tool provides a graphical representation of the assessment results, which is easy to understand as well as to track improvement over time.

The tool has been developed using Microsoft Excel, which is commonly available and understood by a vast proportion of any organisation. This makes the navigation of the tool easy.

6.2 STRUCTURE

The tool is made up of five sheets. Each sheet tackles a different perspective of the assessment. Many of the following descriptions come directly from the tool itself.

Sheet 1: The first sheet of the workbook contains general information and instructions on the Product Development Best Practices and Assessment methodology. Each sheet's function is explained and the various user-input requirements are also highlighted and explained.

Sheet 2: The second sheet contains the best practices and assessment questions and the evaluation input form. There are 28 best practices that cover five focus areas: Strategy, Organisation, Process, Design Optimisation and Technology. These topics were also identified by the literature study conducted.

Each of the 28 categories of best practices has an evaluation scale specific to the criteria in order to make the assessment scores quantifiable. The evaluation scale describes four steps leading to the use of best practice (much like CMM). Each question that deals with an activity relating to the category is also rated by importance on a scale of 1 to 10.

Sheet 3: Sheet 3 deals with Strategic Alignment. This sheet summarises the best practices, importance ratings and performance. Each of the categories' activities are related to one or more of six product development strategies: time-to-market, minimum development cost, minimum product cost, innovation/performance, quality/reliability, and agility using a relationship factor of "0" to "3". A zero indicates this practice is not directly related to achieving this strategy while a three indicates that this practice is a strategic driver for that strategy. These practices and their weighted relationship are summarised at the bottom of this worksheet which results in a Weighted Average Performance By Strategy. The strategies with the highest levels of performance indicate that the enterprise has oriented its practices towards those particular strategies.

Sheet 4: Sheet 4 is the Summary. This sheet contains the Product Development Assessment Summary (resulting from the assessment on Sheet 2) including the gap analysis. The effectiveness ratings for each category on Sheet 2 are automatically picked up on the Summary worksheet on Sheet 4. Two weighting factors affect the summary effectiveness rating and the gap analysis: the assessment weight and the company weight. The assessment weight is pre-established by DRM Associates, based on the relative importance of each category of best practices on product development and the relative number of best practices in a category. The assessment weight cannot be modified. The company weight may be modified to reflect the critical success factors for product development in a specific business.

Sheet 5: Sheet 5 contains a streamlined version of this assessment methodology. It is based on a subset of the key best practices and is intended for the smaller enterprise and for a more rapid, less in-depth assessment. (This is similar to the South African Excellence Models self-assessment approach in that a scaled down version of the model can be used). Each practice is rated on a scale of one to ten. An average rating is computed. There is no formal gap analysis generated by the tool for this type of assessment. Practices with a rating below average are examined so as to identify areas on which to focus attention.

6.3 APPLICATION OF THE TOOL TO DIFFERENT ORGANISATIONS

One of the strengths of this tool is the fact that it can be tailored to any organisation that is involved with product development. The type of product developed is not a limiting factor in the use of the tool. In order for this tool to truly be an assessment against world class 'best practices' there also needs to be some standardisation for all organisations involved in product development. DRM's tool caters for this tailoring to a specific organisation by allowing importance allocations to the best practices and a prioritisation of product development strategies.

There are two areas where the tool can be tailored for a specific organisation (best practices and their associated categories and the organisation's product development strategy), but in both cases there are also industry/world standards that are maintained.

6.3.1 Relative importance of activities and product development categories

The tailoring to the specific requirements of the organisation occurs through each of the activities in each category being assigned an importance rating as well as a performance score. It is the importance rating that enables companies that develop high-volume products to place more importance on activities such as Design for Manufacture (DFM) rather than for example an organisation that develops customer-specific products who would place more importance on the recording and interpreting of customer requirements.

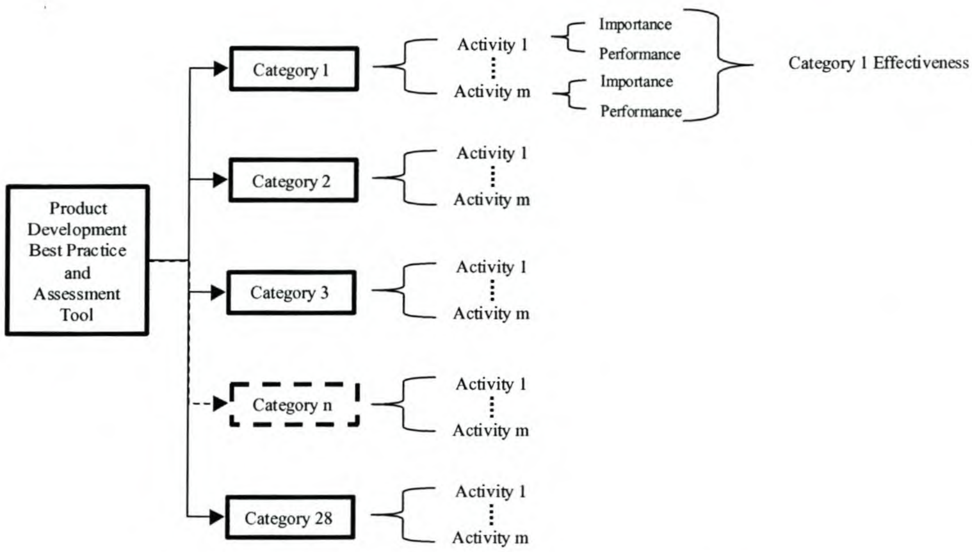


Figure 10: Illustration of how the Product Development Best Practices and Assessment Tool can be tailored to any product development organisation

Each category's effectiveness rating[7] is used in a gap analysis so as to enable the managers to prioritise improvement efforts.

The industry/world standard is included in the gap analysis of the 28 categories, where an "Assessment weight", which is predetermined by the tool is used in the assessment of the categories' performance. These predetermined weights are as a result of DRM Associate's research and experience.

Each category then has two weights that influence its overall assessment; an internal as well as an external rating. The internal rating is the "Company Weight" and the external weight is the "Assessment Weight"

The relationship between the best practices' importance ratings and scores, the categories' importance weighting and scores and the overall scores can be illustrated as Figure 11:

[7] The effectiveness rating of each category is a result of the sum of each activity's product of the importance rating and the activity performance score divided by the sum of all the activities' importance ratings

$$\sum_{activity\_1}^{activity\_n} \text{(importance rating)(performance score)}$$

Figure 11: Illustration of how internal and external ratings are used by the tool to ensure a 'world class' benchmarking tool

6.3.2 Relationship between product development activities and product development strategies

This is very important in terms of the fact that each organisation will seek out competitive advantage by pursuing slightly different strategies and focus areas in their particular markets and economic environments.

The tool identifies six product development strategies:

1. Time to market
2. Low development cost
3. Low product cost
4. High level of innovation and performance
5. Product quality, reliability and durability
6. Responsiveness to new opportunities and customer service needs

The industry standards can be seen in this area by the fact that the six strategies are already defined. The internal tailoring of the alignment of the best practices with the product development strategies, takes place by the organisation itself selecting the rank of each strategy. Therefore, Responsiveness to New Opportunities etc. may be ranked as the number one priority and the Time-to-Market as only priority number six.

The tool contains default values for the relationship factors between activities and the product development strategies. The relationship factor can be from "0" to "3". In this way, the organisation can align all its product development activities with the product development strategy (much like the approach taken in the Balanced Scorecard).

6.3.3 Adequacy of the tool's content

The literature study brought to light the fact that there are many tools that measure the maturity of organisations as a whole: ISO 9004, SAEF, and Balanced Scorecard are but a few. There are even more that aid the product development process such as QFD, TRIZ[8] and Product Data Management tools. However, only one tool was found that specifically focused on the area of product development. That is DRM's assessment tool.

Assessment tools such as South African Excellence Model (SAEM), look at the organisation as a whole. If one were to relate the elements of the SAEM to the areas that are of importance in product development (as highlighted from the literature), the model can be directly related to the area of product development. However, if one goes a level down, into the model, the criteria used for the actual assessment become too broad to adequately evaluate the activities that should take place in a product development environment.

This is also the case when looking at tools such as Six Sigma where it focuses on the detail of activities with respect to measurement and doesn't expressly look at best practices and the measurement thereof in terms of product development.

The actual content of the assessment tool can be qualified by a helicopter view of the literature available on product development. The tool's content includes all the topics that are handled by the literature that was presented in this thesis, and even some that were not. Figure 12 illustrates a theoretical mapping of the tool used in the thesis to the best practices that occur in the literature. Although it is impossible to state unequivocally that Crow's model covers every possible aspect that is important, the author could not find any gaps in the comparison with the literature.

[8] This is a method developed in order to aid the concept generation process and is used in conjunction with QFD.

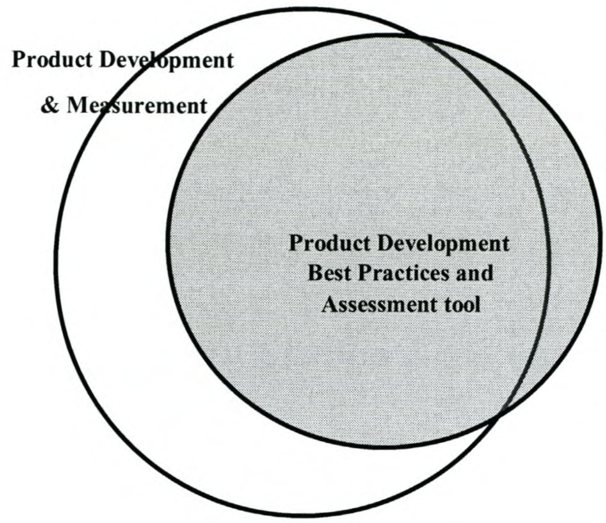


Figure 12: Mapping of tool to Product Development Best Practices and Measurement

The fact that the tool was developed by Kenneth Crow who is considered an expert in the field of product development processes, also adds confidence with regard to the content of the tool.

7. Case Study Introduction

7.1 INTRODUCTION

The case study was embarked upon in order to answer two questions:

1. Does the 'Product Development Best Practice Assessment' (PDBPA) model indeed highlight areas of strategic weakness in product development environments?
2. If 'best practices' are so beneficial, what are the obstacles that companies face that prevent them from actively embarking on programmes to implement these best practices?

7.2 THEORETICAL PERSPECTIVE

7.2.1 Type and Design of case study

The type of case study chosen to answer these questions was the 'Critical Instance' case study. These case studies examine one or more sites for either the purpose of examining a situation of unique interest with little or no interest in generalisations, or to call into question or challenge a highly generalised or universal assertion. This method is useful for answering cause and effect questions ('Writing Guides', Colorado State University, Appendix D).

This case study challenges the fact that the PDBPA tool can accurately predict the effect of product development activities on strategic alignments, it also investigates the cause-effect relationship between organisational culture and the implementation of best practices.

7.2.2 Data collection methods

A multi-modal approach was taken in the data collection, so as to gain a 'complete' picture of the situation in the organisation under investigation. The following methods were used:

- **Interviews**: The approach taken in gathering relevant information was that of an informal interview in which employees from all levels in the business unit were interviewed and asked to talk in general about their view on the 28 topics in the PDBPA model that were relevant to their specific roles in the organisation. The interviewee was guided by the content of the questionnaire, and activities were explained as necessary.

- **Participant observations**: The interviewees were encouraged to 'chat' about their feelings in terms of how things are currently done, and how they experience the status quo. They were also allowed to expand onto other topics during the interview in order to get as broad a picture of the organisational culture and the true product development process as possible.

- **Direct observations**: The interviewer also made observations during the study from a 'helicopter' perspective using her more academic approach and understanding of the concepts of best practices and their implementations.

7.3 CONTEXT

7.3.1 Business Unit Background

One business unit was chosen for the assessment using the tool. The business unit chosen develops PBXs and other PBX integrated products. Almost all of the products have a hardware and software / firmware element included in them.

The business unit in question forms one quarter of the Communications Division of Tellumat (Pty) Ltd. This is a South African based company with a long history in the PBX and Telecommunications industry.

There have been numerous retrenchments over the last few years and the business unit has seen a high staff turnover and therefore loss of intellectual property.

7.3.2 Organisational Structure

At present the organisational structure is quite hierarchical, although it is far less so than before the retrenchments and restructuring. The managers that are subordinate to the Switching General Manager are co-managers and act as a team.

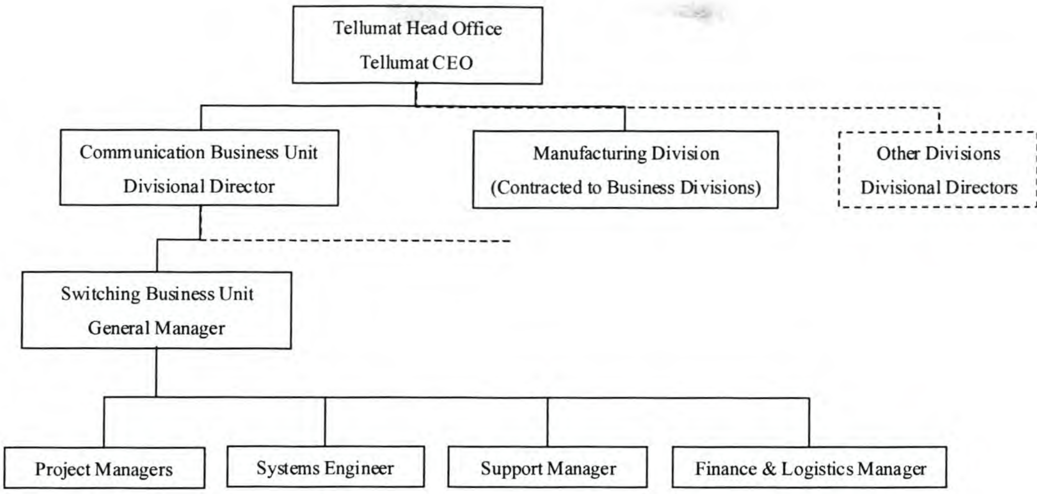


Table 9: Organogram of Tellumat Switching

7.3.2 Organisational Culture

The Switching Business Unit has elements of both the Role and the Club culture in it, although it possesses more attributes of the Role culture.

The 'power' lies in the top management and there are strict paths of communication to follow if information is shared up and down the chain of command. The Communications Managing Director at present has only been in his position for a few months and he practices an 'open door' policy. However, due to the legacy of these formal paths of communication, there is still reluctance from lower levels of employees to use the direct approach of communication to his level. There is again a formal communication route above the MD to the CEO. Very few employees have ever communicated with the CEO, however most if not all have been influenced by decisions that have been made at this level.

The culture has been built around jobs and rules (typical of the Role culture), but the rules themselves have been influenced by personalities of previous managers (Club culture). The processes that are enforced within the division are often changed to suit a particular manager's preferred way of doing things rather than changed because opportunities for improvement have been scientifically identified. There is also a lack of process discipline because the processes are not enforced and there are no repercussions for bad process discipline.

There is an overwhelming fear of change in this business unit, which has been exacerbated by the recent retrenchments and restructuring that have taken place. Change only occurs when there is a 'direct order' from 'the top' and is primarily due to fear of repercussions for not conforming to the new required standards.

7.3.3 Product History

The product range, which this business has, is actually one product with many sub-products. Therefore there are highly complex interactions between all the products. This has also resulted in testing difficulties and a high dependence of one product on another.

The majority of the products that are produced are mature and are considered to be in the 'cash cow' life cycle phase. This is a continuous source of frustration within the business unit due to the fact that contractual obligations to a customer who makes up the majority of sales, demands new development and enhanced functionality at this point in time.

The issues of component obsolescence have also required developments on 'old' products so as to ensure the continuation of the product series as a whole. This development is usually done as a cost saving exercise rather than a product enhancement.

The Switching business unit has a history of late deliveries and very long development cycles. New developments are very rarely on time and there is constant friction between the marketing and sales teams and the development teams for this reason.

7.3.4 Summary

The current state of affairs can be summarised as follows:

- Late deliveries due to scope creep and bad planning of projects
- High development costs
- Concerns in terms of leadership and employee empowerment
- Focus on one customer ('do or die' attitude).

7.4 ASSESSMENT OF STRATEGIC ALIGNMENT SUMMARY RESULTS

All the best practices are related to one of the six product development strategies using a relationship factor of "0" to "3". The strategies with the highest levels of performance indicate that the enterprise has oriented its practices towards those particular strategies.

The tool contains default relationship factors that link each best practice to the product development strategies that it affects. These default values were used in the assessment as the assessor felt that she did not have a deep enough understanding of how the best practices in the Switching business unit would affect the product development strategies. This is most definitely a shortcoming of the assessment and will be dealt with in more detail in Chapter 8. The ability, however, to rank the product development strategies means that the strategic gap analysis is still accurate based on DRM's default relationship factors.

The figure below is the gap analysis between intended strategies (based on ranking) vs. implied strategies (based on level of performance to the related best practices). An excerpt from the model itself explains: "Minimum gaps indicate strategic alignment. A positive gap indicates that additional effort is needed to bring up the level of performance for the practices related to this strategy. A negative gap indicates that, relatively speaking, there is an excessive level of performance for the practices related to this strategy."

	RANK PRIORITY OF STRATEGIES TO YOUR ORGANIZATION (1 to 6):	Rank	Perf.
6	Time to Market	1	5.1
5	Low Development Cost	2	5.2
4	Low Product Cost	6	5.0
3	High Level of Innovation & Performance	5	3.9
2	Product Quality, Reliability & Durability	4	4.7
1	Responsiveness to New Opportunities & Customer Service Needs	3	4.6

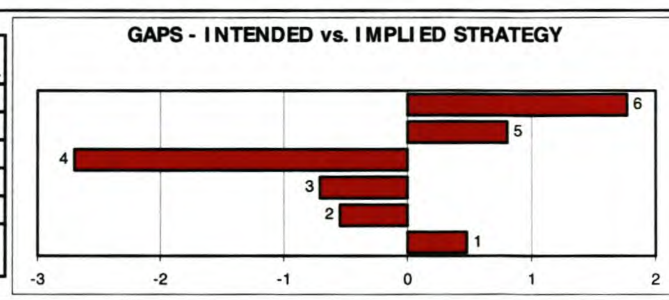


Figure 13: Weighted Average Performance By Strategy

The strategies were ranked from 1 to 6 as is seen in the figure above.

Figure 13 indicates that the business unit is under-performing on three of the general product development strategies: Time-to-Market, Low Development Costs, and Responsiveness to New Opportunities and Customer Service Needs. However, the business unit is 'over' performing in the strategic areas of Low Product Costs, High Level of Innovation and Performance and Product Quality, Reliability and Durability.

A 'perfect' organisation would achieve an 'empty' picture with no red bars in it to illustrate the fact that their performance is exactly on target with their strategies. The fact that there are gaps on both sides of the spectrum is indicative of the fact that too much energy is being spent on areas which do not have strategic importance to the organisation and too little attention is being given to other areas which have been deemed as strategically important by management.

This picture is very accurate in terms of describing the current state of affairs within Switching. As stated in section 7.3.3 (describing the background of Switching) it was stated that this business unit is notoriously bad at delivering on time. This can be seen from the fact that it is the number one focus of the organisation in terms of strategy, but it is also the poorest performer.

Switching also has one major customer who generates approximately 95% of the income and therefore there is an understanding within the business unit that "Whatever the customer wants, they get!" This is not so much a strategy as a necessity. Although the focus should be on the needs of the customer, the Switching business unit is under-performing with regards to this strategy.

7.5 GAP ANALYSIS OF ASSESSMENT RESULTS

In Figure 14 the results of the Best Practices and Assessment are shown. Each of the assessment categories has been weighted according to the importance of the various best practices contained within the input assessment sheets.

The 28 categories are summarised in terms of their importance and performance in an easy to understand bar graph. This particular set of results highlights areas for focus in terms of improvement activities. The weighted total for the organisation's product development is 4.9, which indicates that the organisation is only performing at about 50% of the levels which best practices require. This score is a summary score of the product development process as a whole. In order to utilise the gap analysis to prioritise improvement efforts, the individual categories need to be analysed.

Assessment Category	Assessment Weight	Company Weight	Effectiveness
Business & Product Strategy	0.5	2	4.9
Product & Pipeline Management	1	1	4.0
Technology Management	0.75	1	3.1
Management Leadership	1	1	4.4
Early Involvement	1	1	6.5
Product Development Teams	1.5	1	5.2
Organizational Environment	1	1	4.8
Process Management	1	1	5.6
Process Improvement	0.75	1	2.5
Understanding the Customer	1	1	3.7
Requirements & Specifications Mgt.	1.5	1	4.5
Development Process Integration	1	1	5.2
Supplier/Subcontractor Integration	1	1	3.1
Product Launch	1	1	3.0
Configuration Management	1	1	7.7
Design Assurance	0.75	1	6.1
Project & Resource Management	1.25	1	5.1
Design for Manufacturability	1	1	4.8
Product Cost Management	1	1	6.0
Robust Design	1	1	5.5
Integrated Test Design & Program	0.75	2	6.2
Design for Operation & Support	0.75	1	2.6
Product Data	1.25	1	6.8
Design Automation	1.25	1	5.9
Simulation and Analysis	1	1	4.6
Computer-Aided Manufacturing	0.75	1	5.9
Collaborative Tools & Technology	0.75	1	5.3
Knowledge Management	0.5	1	1.0
		Weighted Total	4.9

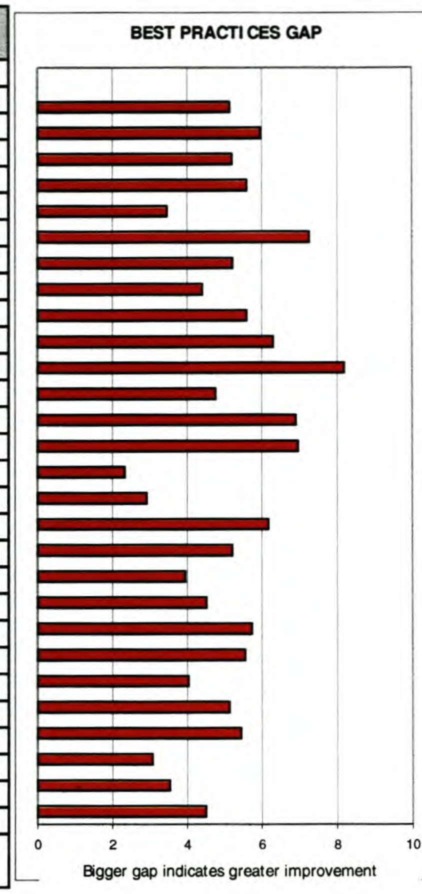


Figure 14: Product Development Assessment Summary (resulting from the assessment) including the gap analysis

The gap analysis is made up of a combination of three factors:

1. The Assessment Weight (pre-established based on the relative importance of each category of best practices on product development and the number of best practices in the category). This is an internal weighting factor.

2. The Company Weight (reflects critical success factors for product development in a specific business). This is an external weighting factor thus making the assessment relative to world class product development standards.

3. The Effectiveness Score (the average score for each criteria based on the importance and score for each activity) is also brought into the equation.

The comments that follow on the results of the Gap analysis only focus on those categories that had a gap of five or greater. The reason for this is that to focus on categories which at present are not 'underperforming' is not in alignment with the strategy of using the Gap analysis to focus on areas that need the most improvement.

The areas which have a Gap analysis that is above average (five and greater) are as follows:

Category number	***Description***	***Gap***	***Comments***	***Impact w.r.t Organisational Culture***
11	Requirements and Specification Management.	8.9	This result is reflected in the fact that the organisation completely 'over-performs' in terms of its customer strategy. The customer is allowed to change their requirements at any point in time without too much pressure. There are many serious instances of scope creep within the Switching product range.	
9	Process Improvement	8.5	The business unit in general thinks of processes in the manufacturing sense and has had little exposure to Development Processes and Life Cycles. Therefore there is also little to no drive for process improvement.	There is not a culture that is accepting of change unless it is 'demanded' from top management. People also feel that they are ignored when they come up with improvement suggestions (participant and direct observations).
6	Product Development Teams	7.2	Teams are highly under resourced and not multi-functional enough. Teams do not have authority. Very little training has been done in the dynamics of teams. There are not team building exercises that are focused specifically on the development teams. There are however, team building events that include the whole business unit.	Teams are expected to work well and 'produce the goods' yet the culture of the organisation still appraises the performance of individuals. Focus is still very much on the members of the team rather than the team as a whole.

Category number	***Description***	***Gap***	***Comments***	***Impact w.r.t Organisational Culture***
13	Supplier / Subcontractor Integration	6.9	Alternative suppliers are constantly being sourced 'in-case' the present supplier lets the unit down. Many of the components etc. that are supplied are electronic components which means that there is not a need for development in conjunction with the suppliers. In cases where product designs need to be subcontracted to manufacturers, the designs are developed internally and 'handed over the wall' to the manufacturer. There is interaction with these external subcontractors, but it is very reactive.	There is a culture of mistrust of suppliers and outsiders in general. If something goes wrong with a supplier, someone internally usually has fingers pointed at them. This instils a culture of paranoia, rather than active co-operation.
14	Product Launch	6.9	The fact that the set of products within Switching has been so stable for so long has resulted in the neglect of product launch activities. Therefore, new products are not planned properly and product launches are usually fraught with mishaps and activities that are forgotten until the last minute.	
10	Understanding the Customer	6.3	As previously stated, the "customer gets what the customer wants". But this is where things go wrong. There are often misinterpretations of customer requirements, which results in increased development time and costs. There are formal meetings with the customers to discuss requirements, but feedback from both parties tends to be slow.	There is a history of misunderstanding and 'sensitive' relationships with the business unit's main customer. There has not, until recently, been much personal relationship building with the customers except on a typically technical and formal level. The culture is very

Category number	*Description*	*Gap*	*Comments*	*Impact w.r.t Organisational Culture*
			from both parties tends to be slow.	formal and hierarchical, where only certain people have access to the customers
17	Project and Resource Management	6.2	The fact that there is no pressure on project managers to run projects to a defined Life Cycle and product-defined documentation, means that each project manager runs their projects differently. There is not a common format of data. Resources are spread over many projects	This is once again a result of the fact that there is a culture inherently against change. Very little improvements are initiated 'in case' they don't work and then someone gets blamed for spending money unnecessarily.
2	Product and Pipeline Management	5.9	The fact that there is little product planning at present stems from the fact that there is major uncertainty in terms of the customer moving forward with the product. The products have typically been developed solely around one specific customer's needs and thus have been neglecting many of the other available markets. With no focus being on 'other' product pipelines, they have not been developed and thus not managed.	
21	Integrated Test Design and Programme	5.7	Test jigs etc. are very expensive. If there is time to be chopped, it is usually in the testing of a product. Little planning is done in the early stages of the product. Most testing is done at the modular level and the integration testing is seen as part of the field trial as opposed to part of	Testing is commonly seen as an 'end-of-the-line' activity and is often forgotten until the development is nearly finished.

Category number	***Description***	***Gap***	***Comments***	***Impact w.r.t Organisational Culture***
			the product qualification.	
4	Management Leadership	5.6	The managers in this business unit are dedicated to their staff on a personal level. However, they do not empower their staff to take responsibility. It seems as if this is due to their own lack of empowerment.	The hierarchical structure that exists within this business unit and the manner in which it relates to the organisation as a whole has a tremendous impact on how managers can support improvements, teams etc. within their environment. Managers do not have much 'power' to employ resources or change the status quo. All change must come from 'the top' and be justified by financial benefits.
22	Design for Operation and Support	5.5	The fact that most of the customers' product install base is serviced by their own technicians and the fact that Switching uses the Customer Services[9] department has meant that the developers themselves do not often deal with field support problems. There may be more to gain by actively involving the developers with the Tellumat 'in-house' support team as well as giving them more exposure to the customers' support teams.	
25	Simulation and Analysis	5.4	From the interviews conducted, the main reason for not doing more simulation was firstly COST: the packages that would be required for the type of product are very expensive. The second reason was	

[9] Customer Services handles all the product repairs

Category number	*Description*	*Gap*	*Comments*	*Impact w.r.t Organisational Culture*
			lack of training: there were only two people that were trained to use the available simulation packages and of those two only one was actively using it.	
24	Design Automation	5.3	The fact that the products are all electronic in nature excludes much of the physical modelling etc. with CAD/CAM tools that would exist in a more mechanical environment. However, it was felt that tools that model from the top-down in terms of simulating the modular inputs and outputs would certainly be valuable. Tools that have PCB design standards built in etc. would also be beneficial.	
7	Organisational Environment	5.2	There were two quite distinct perceptions on this topic – one from top management and one from the employees. Open-book management seems to only include information. There is a very good communication system whereby information gets spread downwards, but the personnel development requirements, supportive accounting policies, and training are definitely lacking.	There is a negative culture within this organisation in terms of the way in which they perceive the 'company' to value the individuals. Employees at lower levels feel 'expendable' and are thus not highly motivated.
18	Design for Manufacturability	5.2	This is a typical case of 'talk the talk' but not 'walking the walk'. There are DFM standards, but they are brushed off by developers. The developers stated in the interviews	Once again the use of standards and procedures is not enforced by managers. Process discipline is again

Category number	*Description*	*Gap*	*Comments*	*Impact w.r.t Organisational Culture*
			developers stated in the interviews that the DFM standard is too broad and is used more as a guide than as a development standard. Developers insist that they do develop with Design For Manufacturing in mind (this can actually be seen by the fact that the success rate of first type boards working has increased over the last few years), but the designs are inconsistent amongst developers themselves due to the fact that they did not work to a specific standard.	lacking
1	Business & Product Strategy	5.1	This is an area, which has already been identified as weak by the Managing Director. There is no benchmarking done in terms of competitors' products and other product development industries. The product strategies and business plans that have been produced up to date have been informal and often unrealistic.	Managers need to take strategies and their implementation seriously. By doing this, activities and all development projects can be aligned to the strategy. At present, there is no drive to employ this 'Balanced Scorecard' type approach.

8. Conclusions

This chapter aims to answer the two questions posed at the beginning of Chapter 7:

1. Does the 'Product Development Best Practice Assessment' (PDBPA) model indeed highlight areas of strategic weakness in product development environments?
2. If 'best practices' are so beneficial, what are the obstacles that companies face that prevent them from actively embarking on programmes to implement these best practices?

The first question was answered by evaluating the accuracy of the tool's results with regard to the Switching Business Unit. Factors affecting the assessment results are also highlighted and explained.

The second question is answered by some general observations as encountered in the case study and evaluates the value of such a tool in the South African environment.

8.1 DOES THE "PRODUCT DEVELOPMENT BEST PRACTICE ASSESSMENT" MODEL INDEED HIGHLIGHT AREAS OF STRATEGIC WEAKNESS IN PRODUCT DEVELOPMENT ENVIRONMENTS?

Table 10: Evaluation of the accuracy of the tool's results

Summarised state of affairs	***Tool's Result***
Late deliveries due to scope creep and bad planning of projects	Poor performance in terms of the Time-to-Market strategy was indicated. The Gap analysis revealed a gap of 8.2 on the Requirements and Specification Management criteria (the worst result of the 28 criteria). Project and Resource Management was seventh on the list of 'worst gaps'. The other criteria that were 'worse' than this also play a

Summarised state of affairs	***Tool's Result***
	direct role in planning due to the fact that many of them see functions (external to the developers) becoming involved early in the development stages, thus allowing an initial free flow of information into the project. In this way good planning is then easily facilitated.
High development costs	This was indicated by a poor performance against the strategy of "low Development Cost" where it was the second worst performer – although the Product Cost Criteria scored a 3.9 in the Gap analysis.
Concerns in terms of leadership and employee empowerment	Three of the 28 criteria included in the tool directly address the organisation, its leadership approach and its people. In all three of these criteria, there was a gap of 5.2 or greater. This gives a clear indication of the fact that the general perception on the value of people within the organisation and their level of empowerment are far below 'world class'.
Focus on one customer ('do or die' attitude)	This is clearly illustrated by the Strategic Alignment summary where major 'over-performance' is illustrated. The implication is that there is too much effort put into trying to satisfy the customer, for not enough benefit.

The above table clearly demonstrates that DRM's Product Development Best Practices and Assessment tool in fact identifies the areas of weakness in the product development arena accurately. In terms of 'strategic weaknesses', this business unit needs to re-assess its strategies in terms of product development. Perhaps with a re-alignment of its strategic position the situation could look better, but at this point in time, the result of product development activities is not moving the unit in the desired strategic direction.

8.1.1 Factors affecting the assessment results

There were various factors that may have affected the results that the tool produced. The number of assessors and the method of assessment could have had an influence on the information that was actually obtained from the interviews. The weights that were assigned as 'Assessment Weights' (indicating industry standards) could also have been invalid for this particular business unit. The interpretation of the evaluation scale by the interviewer would play a major role in the outcome of the tool as this would directly affect the performance scores allocated to the various activities. Finally, the mathematical integrity of the model itself would obviously influence the results of the assessment.

Number of assessors

It was found that conducting the assessment with only one person was advantageous in that the assessor was exposed to all the information, but that was the only advantage. The assessment requires a team of people with different focuses and knowledge to fully understand the workings of the business unit.

Although the assessor has done much research in the area of product development and the associated activities and best practices, it was felt that this knowledge was not sufficient to adequately lead the interviewees in the direction that would highlight all the areas that should have been investigated. The assessor often felt as though there was more to the information given, but due to lack of experience was unsure of how to pursue it further.

Therefore, from a view of knowledge and experience, a team of assessors is definitely the best way in which to get the most from the assessment in a short space of time.

Method of Assessment

There were three methods of assessment used: Interviews, Direct Observations and Participant Observations.

The interview method of assessment was combined with the participant observations by keeping the interviews informal and allowing the participants to comment where they felt that they had information to offer. This method of information collection had various advantages. All levels of employees could be approached on a one-to-one basis to gain information about the activities that actually occur in the organisation with respect to the various best practice criteria. This method of assessment revealed that many of the employees felt more at ease and spoke freely about their opinions of what is done well, what needs improvement and how they feel about the way in which the development project is run.

This freedom granted to the interviewees allowed various new key factors to emerge where, had the interviews been conducted in a formal manner where only the questions included in the model itself were posed, many of the cultural issues that are affecting the way in which things get done, would not have emerged.

The method of Direct Observation by the interviewer also highlighted various advantages. The interviewer's previous exposure to product development theories and principles enabled a 'helicopter view' to be developed of the activities and their various levels of maturity within the Switching department.

The "Assessment Weights" which indicate industry standards

The Assessment Weights that were selected as default values for each category in the Gap analysis by DRM, have a resolution of 0.25. The explanation included in the tool states that these weights were based on the relative importance of each category of best practices on product development and the relative number of best practices in the category. The tool itself offers no scientific evidence for the weights that are assigned to each category and for the purposes of the assessment they must be accepted. A more scientific evaluation of the tool however, highlights the need for these weights to be clarified by some sort of historical data or investigation.

The resolution as well as the weights themselves could warrant further investigation.

Mathematical Integrity of the Tool's Calculations

In order to check the integrity of the mathematical basis of the tool and to determine how it calculates the assessment results, two scenarios were tested. The first was where all the best practices were given an importance of 10 as well as a performance score of 10. The second scenario utilised the tool's default importance ratings of each best practice and then applied a score of 10 to all of them. The reason for the two different scenarios was to ensure that the importance that an assessment team assigns to the various activities does not influence the outcome of the assessment in a negative way. This means that it is important that the activities that are rated as less important by the assessment do not actually count as much as the other best practices in the overall calculations.

The result of these 'tests' indicated that there were two issues that cast doubt on the overall mathematical integrity of the tool:

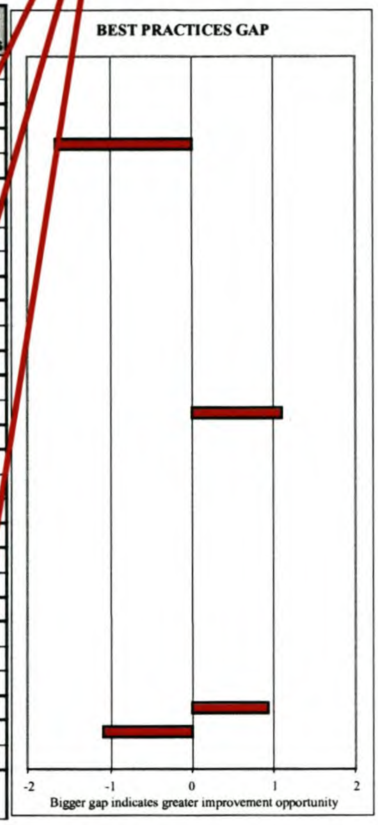
1. The results of the Gap analysis showed that there were **four** categories whose effectiveness ratings were incorrectly calculated.

2. The sum of the weighting factors that are used in the Gap analysis does not add up to 28, but 27. This is important because if the entire weight of all the categories is to be considered as 100%, then the weight over the 28 categories must be 28 to ensure that all the total tool weight has been dispersed over the categories in a statistically sound manner.

However, a positive finding was that the importance given to the individual best practices do not negatively affect the overall score of the assessment.

With the scores of all best practices being 10, one would expect an Effectiveness score of 10 for all categories, this is not the case for four categories

Assessment Category	Assessment Weight	Company Weight	Effectiveness
Business & Product Strategy	0.5	1	10.0
Product & Pipeline Management	1	1	10.0
Technology Management	0.75	1	12.2
Management Leadership	1	1	10.0
Early Involvement	1	1	10.0
Product Development Teams	1.5	1	10.0
Organizational Environment	1	1	10.0
Process Management	1	1	10.0
Process Improvement	0.75	1	10.0
Understanding the Customer	1	1	10.0
Requirements & Specifications Mgt.	1.5	1	10.0
Development Process Integration	1	1	10.0
Supplier/Subcontractor Integration	1	1	10.0
Product Launch	1	1	8.9
Configuration Management	1	1	10.0
Design Assurance	0.75	1	10.0
Project & Resource Management	1.25	1	10.0
Design for Manufacturability	1	1	10.0
Product Cost Management	1	1	10.0
Robust Design	1	1	10.0
Integrated Test Design & Program	0.75	1	10.0
Design for Operation & Support	0.75	1	10.0
Product Data	1.25	1	10.0
Design Automation	1.25	1	10.0
Simulation and Analysis	1	1	10.0
Computer-Aided Manufacturing	0.75	1	8.8
Collaborative Tools & Technology	0.75	1	11.4
Knowledge Management	0.5	1	10.0
		Weighted Total	10.0



The sum of the Assessment Weights is 27 not 28

Figure 15: Illustration of where there are mathematical inaccuracies

The major focus of this section of the tool is to perform a Gap analysis whereby priorities for improvement can be determined for the organisation's future. The accuracy of the Gap analysis itself is therefore crucial to the organisation. If the Gap analysis is incorrect, the organisation may again be spending energy on the wrong things.

The Gap analysis itself takes into consideration the present state of the category relative to the 'perfect' score of 10 of each category as well as the importance of the category to the company overall.

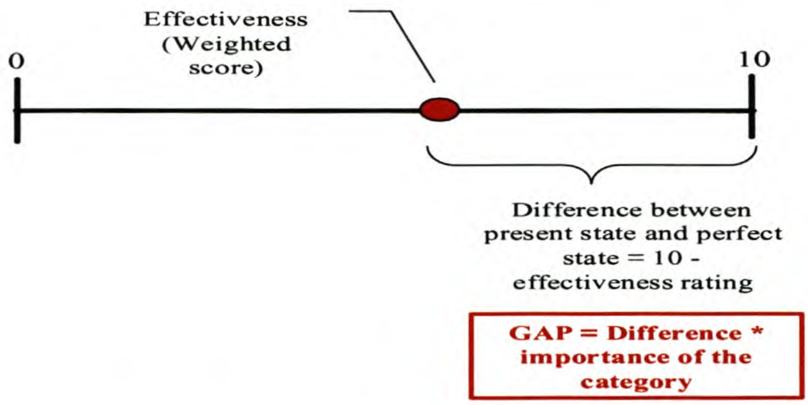


Figure 16 : Diagrammatic representation of the Gap analysis method

The Gap analysis is done by determining how far the category still has to go before it achieves the 'perfect' score of 10 and then multiplies this 'difference' with the relative importance of the category which is determined by both the industry weighting and the company weighting of the category.

Evaluation Scale

The tool utilises an evaluation scale that is specific to each of the 28 criteria included in the model. It was found that this scale was very difficult to use to score each of the best practices due to the fact that it is so specific.

It was felt that an example would best demonstrate the difficulties that were experienced.

Figure 17 is taken from the tool itself. The topic is 'Management and Leadership'. As can be seen, the evaluation scale used for this topic is made up of very specific activities of management with regards to Integrated Product Development, resources, leadership and organisational structures. Although this type of detail enables the assessor to get a good idea of the various levels of maturity, it is also very difficult to use the scale (top of each category's page) to assess the maturity of each individual best practice. This is commonly due to the fact that many organisations, including the Switching business unit, do some of the activities at one level and others at another.

For example, question 4.3: *Communicate management objectives for improving product development. Has executive management clearly communicated objectives for improving the product development process to the rest of the organisation? Is management actively reviewing and monitoring the achievement of these objectives?*

This question does not deal directly with any of the topics covered by the evaluation scale i.e. Integrated Product Development, resources, leadership and organisational structures. It is therefore difficult to assign a score that 'fits' well.

4.0 MANAGEMENT AND LEADERSHIP

EVALUATION SCALE

Traditional (0)	**Developing (3)**	**Committed (7)**	**Best Practice (10)**
Executive management is unaware of integrated product development (IPD) concepts or new product development best practices. No formal action is planned. A hierarchical, authoritative management structure is in place with excessive layers of management.	Management is aware of IPD, but lacks training or in-depth knowledge. Management has directed that IPD elements be implemented. Limited resources have been provided, but formal planning, active leadership & visible commitment are lacking.	Management is knowledgeable about IPD. They are involved in planning the implementation of IPD and have publicly stated a commitment to IPD. Resources have been provided, but active leadership is lacking. Managers verbally support empowerment. Management layers are being reduced and manager roles redefined. The culture is being improved.	Management is very knowledgeable about IPD. They are actively involved in planning, leading and monitoring the results of IPD. They provide sufficient resources & help overcome impediments. Flat organization structure created. Managers actively support empowerment. A supportive culture has been established.

		Importance	Performance
4.1	**Develop management understanding and commitment.** Does management understand the concepts and practices of integrated product development (IPD) and time-to-market? Is there a strong executive management interest in improving the product development process and accelerating time-to-market?	5	5
4.2	**Establish and support product development process owner/sponsor.** Is there an active, visible, committed leader recognized as owning the product development process or a "sponsor" of an initiative to improve the product development process? Does this individual have the support of other executives responsible for the functions involved in product development, or is there a steering committee of executives guiding the effort to improve the product development process?	7	7
4.3	**Communicate management objectives for improving product development.** Has executive management clearly communicated objectives for improving the product development process to the rest of the organization? Is management actively reviewing and monitoring the achievement of these objectives?	5	3
4.4	**Establish supportive culture.** Has management established or are they actively working to establish a supportive culture based on teamwork, cooperation, open communication, overcoming the "not invented here" syndrome, continuous improvement, driving out fear, entrepreneurship, participative management, etc. When a problem occurs, does management focus on lessons learned and corrective action rather than punishing the guilty?	7	7
4.5	**Value and reward creativity and risk-taking.** Does management create and support an environment and culture conducive to creativity, risk-taking and "out-of-the-box" or divergent thinking? Is there formal training on creative thinking? Are methods such as TRIZ/theory of inventive problem solving used? Are these traits valued and rewarded or is there a conservative, risk-averse culture?	6	6
4.6	**Support improvements proactively.** Has management provided resources to support improving the development process? Is management involved in establishing appropriate policies to support concurrent engineering/integrated product development and time-to-market? Is management helping to overcome impediments to change and improvement?	5	4
4.7	**Empower development personnel.** Have executive and middle management empowered development personnel? Has sufficient authority been delegated to support assigned responsibilities? Has decision-making been pushed down to the lowest competent level?	10	2
4.8	**Re-define manager's roles with empowerment.** Do managers understand their roles as development personnel are empowered? Do managers have the skills required to undertake their new roles? Have performance criteria and rewards been re-aligned to facilitate these new roles? These new roles emphasize personnel development, process improvement, resource management, being a technical resource to support teams, and sharing information across teams.	5	3
4.9	**Accept responsibilities of empowerment.** Do development personnel and teams accept their responsibilities under empowerment? Has the organization created a culture that eliminates fear of failure which inhibits accepting responsibility under empowerment?	10	5
4.10	**Flatten the organization structure.** Has the organization reduced the number of levels of management and increased the span of control (flat organization structure or the "horizontal organization") consistent with empowerment, improved communication and reduced non-value-added effort? Have alternate career paths been established to move managers into roles as performers while still providing rewards and career advancement?	7	4
4.11	**Avoid over-committing personnel.** Does management balance work with resources available? Are they realistic in making commitments? Development personnel should not be over-committed, and, in particular, the best people should not be overloaded.	5	2
	Management and Leadership Effectiveness Rating		4

Figure 17: An example from the tools to illustrate evaluation scale

The study of the Existing Standards and Measurement Tools in Chapter 4 revealed measurement systems that were generic in nature. It was found that ISO 9004 (Self-Assessment), SAEM and CMM all use generic scoring systems. (See Appendix A.)

These generic scoring systems are easier to apply to any type of 'question'. It was also felt that the questions themselves are very specific thus a complex evaluation scale reduces the user friendliness of the model quite considerably.

This may not be of great consequence when the assessments are being conducted by a team of experts, but as soon as the organisation tries to do another assessment on their own, it may cause confusion and thus scores that may not be true reflections of the state of affairs in the organisation may be assigned to the best practices.

8.2 IF 'BEST PRACTICES' ARE SO BENEFICIAL, WHAT OBSTACLES ARE COMPANIES FACED WITH THAT PREVENT THEM FROM ACTIVELY EMBARKING ON PROGRAMMES TO IMPLEMENT THESE BEST PRACTICES?

8.2.1 General Observations

Having interviewed various levels of management within the Switching business unit the following became clear:

1. Business is about money and therefore, before embarking on any programme of improvement, managers want to know how the programme is going to improve their **bottom line**.

2. It is all too common that the understanding of process maturity and discipline is equated with inflexibility and time wasting. The common perception is that by being forced to follow various steps in a process prevents products from being introduced to the market-place quickly.

3. The successful implementation of any improvement programme has proved to be a result of motivated leaders who 'practice what they preach'. The interviews with the Communications General Managers revealed the fact that they were open to ideas of improvement, but were waiting for one of the staff members 'down the ladder' to initialise

the improvements. There is not a lack of willingness to improve, but rather a lack of initiative that would find ways to improve.

4. Finally, and probably the most common reason for managers not employing 'Best Practices' is that many South African and possibly global businesses run on a fire-fighting basis. There is rarely a time when reflection and review of past mistakes is possible. Businesses constantly find themselves late on projects and without time to plan for the future, thus they also find themselves perpetuating a cycle of 'state of chaos'.

In any business, managers are most concerned with **money**. The mere fact that any implementation of 'Best Practices' will entail a level of financial as well as time investment makes many managers sceptical of introducing programmes to improve the current state of product development.

8.2.2 Supplier and Subcontractor Integration

Section 13 of the tool deals explicitly with the integration of suppliers and subcontractors into the development of products. This is quite difficult in the South African context due to the fact that many South African companies still feel that by sharing intellectual property with outsiders they are putting themselves at risk. In a developing world, there is a mentality that money is the driving factor and the more you make in the short term the better off you are. For this reason companies are hesitant to invest in partnerships that will only see returns in the future.

The concept of minimising suppliers is also seen as High Risk in many South African organisations. This is commonly seen as 'Putting all your eggs in one basket'. This mentality goes back to the fact that money is the overriding feature in most companies in a developing world market – the risk of one supplier taking shortcuts to cut costs is often too high for companies to afford not to have an alternate supplier at short notice.

Recently in the Switching business unit, there have been numerous issues with suppliers delivering sub-standard parts/components. There is not enough money in the unit at the moment to 'grow' partnerships, therefore alternative suppliers is a quick and 'effective' alternative.

8.2.3 Impact of Organisational Culture

It was found that many managers presume that the people working under them comply to predefined processes or best practices and that this is not always the case. The "Show Me!" approach highlighted many areas in which there were process non-compliances, as well as differences in perceptions of how things are being done and in their inherent importance to the business, even among team members. This seems due to a lack of open communication and understanding of process value and discipline. This can be seen with the Management and Leadership effectiveness rating of 4 in Figure 17.

The perception of the existing organisational culture is one of "The business unit first, people second". This has resulted in various 'destructive' attitudes. The first and most prevalent is that of "Why should I do extra?". There are a few more phrases that have crept into many of the interviews, which can be summed up by the following statements:

- Very few people within this organisation feel vaguely motivated to improve things for fear of 'rocking the boat' and also for not being supported by management,
- There is an overriding awareness of trying to cut costs at every corner, with the result that people do not do what they think will result in a better product, but what will result in a product that is not late and that is not running over budget.

There is a great awareness of the hierarchy in which everyone must work and the 'open door' policy of the Managing Director is yet to filter through to the product developers themselves. There is great reluctance to move over their direct bosses' head for fear of repercussions from either their boss or their bosses boss etc. The combination of the Role and Club cultures needs to be changed towards a Task oriented culture, but for this to occur there needs to be a huge shift in focus from management – who at present are also Role oriented. This is substantiated by the fact that the culture is built around defined jobs, rules and procedures, and not personalities. High efficiency is possible, but the structure can be slow to change and is therefore less suitable for dynamic situations.

8.3 VALUE OF ASSESSMENT FOR SOUTH AFRICAN COMPANIES

South African companies involved in new product development face many unique challenges that are not experienced by companies that are based in the first world. In an article by Gideon de Wet entitled "Emerging from the Technology Colony: A view from the South",. De Wet describes a technology colony (e.g. South Africa) as follows:

- *The predominant industrial business activity in the colony is at the manufacture and "trade-in-final-products" end of the product life cycle, while activities in the industrialised country tend towards a continuum over the whole life cycle*

- *There is a small group of activities at the research end of the life cycle in the colony, representing the R&D activities of tertiary education institutions, some R&D done in local industry and some government funded R&D*

- *There is a large flow of technology from the developed world into the colony, in the form of licensed product designs, processes, sub assemblies and final products, often implemented in the colony in the form of a subsidiary of a multi-national corporation*

- *There is an almost insignificant flow of technology from the local R&D community to the local industrial sector, mainly because the relevant R&D is done "back home"; but there is some communication between the local and foreign R&D communities.*

In the case of South Africa, more than 80% of the value in industrial business activity is done under (foreign) license, and more than 50% of this activity is subject to market constraints.

Reading between the lines there are some very serious implications in the above statement in terms of South African companies' abilities to implement best practices in the product development environment.

Of the five major dimensions classified in DRM's tool (Strategy, Organisation, Process, Design Optimisation and Technology), three are affected by the fact that South Africa is a technology colony. Processes, Design Optimisation and Technology all depend on information being fed through from Research organisations to local industry.

The effect of this weak technology transfer means a few things for South African companies:

- They are not aware of and do not fully understand the implications of development processes that cover the entire product life cycle.

- Product development that does take place from concept to grave is often more expensive than their foreign counterparts due to the fact that South African companies often do not have access to the latest design technologies and tools, are not aware of the tools that are available, or usually cannot afford them because of the scale of economy.

- Companies that do their own product development frequently have to compete with already licensed foreign products that are brought into the country by their competitors. This forces companies to focus mainly on the 'time-to-market' development strategy rather than all six that DRM's tool focuses on: time-to-market, minimum development cost, minimum product cost, innovation/performance, quality/reliability, and agility.

These points were seen in the business unit assessed.

- Many of the people spoken to were unaware of the principles of a product development life cycle and the activities that should take place within one. Most of the more technically oriented people focused solely on their job, and had little or no idea of how they fit into the 'bigger picture' of developing a product. The concepts that were present in the form of best practices were seen as either completely new or only seen in terms of the person's specific work environment.

- In terms of the tools and methodologies that are available to aid product development activities, the South African market seems very far behind. Of all the people interviewed as a part of the assessment, very few knew of QFD, and not one person had ever used it. It is especially in this area where the disconnect between academic research and industry is most clearly seen.

- The focus in the business unit is to "get the product out". The basic understanding of the need to get the product into the marketplace quickly is to do whatever it takes, including spending large amounts of money. The quality or reliability of the product is not the priority. Many employees feel that one should first get the product into the marketplace and then make it work properly. This obviously has huge impacts on design costs as much rework is usually required at a very late stage of the product life cycle.

For all of these reasons, the value of a tool such as the 'Product Development Best Practice and Assessment' tool can be almost immediately seen. In the South African context the tool may not so much be a powerful benchmarking and assessment tool as a tool to educate all levels of employees and management about product development best practices and the sorts of things that South African product development companies should be aware of if they want to successfully compete in a global market.

The author feels that the assessment that was conducted within the Switching business unit will not find its value in terms of the results that it presented. The value is rather in the fact that the people that were interviewed were exposed to new information and have a slightly better understanding of the product development activities as they stand in a 'best practice environment'.

The tool would be better utilised in South Africa as a basis from which to begin a long-term improvement process that starts with EDUCATION.

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Appendix A: Measuring/Scoring Systems

Table A 1: CMM Scoring System

Maturity Levels	*Key Process Areas*
Initial: The software process is characterised as ad hoc, and occasionally even as chaotic. Few processes are defined, and success depends on individual efforts and heroics	▪ None
Repeatable: Basic project management processes are established to track costs, schedule and functionality. The necessary process discipline is in place to repeat earlier successes on projects with similar applications	▪ Requirements Management ▪ Project Planning ▪ Project tracking and Oversight ▪ Subcontract management ▪ Quality Assurance ▪ Configuration Management
Defined: The software process for both management and engineering activities is documented, standardised, and integrated into a standard software process for the organisation. All projects use an approved, a tailored version of the organisations standard software process for developing and maintaining software	▪ Organisation process focus ▪ Process definition ▪ Training programme ▪ Integrated software management ▪ Product engineering ▪ Intergroup co-ordination ▪ Peer reviews
Managed: Detailed measures of the software process and product quality are collected. Both the software process and products are quantitatively understood and controlled	▪ Quantitative process management ▪ Quality management
Optimising: Continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative ideas and technologies.	▪ Defect prevention ▪ Technology change management ▪ Process change management

Table A 2 : ISO 9004 Self Assessment Scoring Systems

Maturity Level	*Performance Level*	*Guidance*
1	No formal approach	No systematic approach evident, no results, poor results or unpredictable results
2	Reactive approach	Problem- or corrective-based systematic approach, minimum data on improvement results available
3	Stable formal system approach	Systematic process-based approach, early stage of systematic improvements, data available on conformance to objectives and existence of improvement trends
4	Continual improvement emphasised	Improvement process in use, good results and sustained improvement trends
5	Best-in-class performance	Strongly integrated improvement process, best-in-class benchmarked results demonstrated

Table A 3: Enablers Scoring Guidelines (SAEF, Level1 Criteria for Organisation Performance Excellence)

Approach	*Score*	*Deployment*
▫ Anecdotal or non-value adding	0%	▫ Little effective usage
▫ Some evidence of soundly based approaches and prevention based systems ▫ Subject to occasional review ▫ Some areas of integration into normal operations	25%	▫ Applied to about **one-quarter** of the potential when considering all relevant areas and activities
▫ Evidence of soundly based systematic approaches and prevention based systems ▫ Subject to regular review with respect to business effectiveness ▫ Integration into normal operations and planning well established	50%	▫ Applied to about **half** the potential when considering all relevant areas and activities

Approach	*Score*	*Deployment*
▫ Clear evidence of soundly based systematic approaches and prevention based systems ▫ Clear evidence of refinement and improvement business effectiveness through review cycles ▫ Good integration of approach into normal operations and planning	75%	▫ Applied to about **three quarters** of the potential when considering all relevant areas and activities
▫ Clear evidence of soundly based systematic approaches and prevention based systems ▫ Clear evidence of refinement and improvement business effectiveness through review cycles ▫ Approach has become totally integrated into normal working patterns ▫ Could be used as a role model for other organisations	100%	▫ Applied to about **full** potential in all relevant areas and activities

Table A 4: Results Scoring Guidelines (SAEF, Level1 Criteria for Organisation Performance Excellence,

Results	*Score*	*Scope*
▫ Anecdotal	0%	▫ Results address **few** relevant areas and activities
▫ Some results show positive trends and/or satisfactory performance ▫ Some favourable comparisons with own targets	25%	▫ Results address **some** relevant areas and activities
▫ Many areas show strongly positive trends and/or sustained good performance over at least 3 years ▫ Favourable comparisons with own targets in many areas ▫ Some comparisons with external organisations ▫ Some results caused by approach	50%	▫ Results address **many** relevant areas and activities

Results	*Score*	*Scope*
▫ Most results show strongly positive trends and/or sustained excellent performance over at least 3 years ▫ Favourable comparisons with own targets in most areas ▫ Favourable comparisons with external organisations in many areas. Many results are caused by approach	75%	▫ Results address **most** relevant areas and activities
▫ Strongly positive trends and/or sustained excellent performance over at least 5 years ▫ Excellent comparisons with own targets and external organisations in most areas ▫ "**Best in Class**" in many areas of activity ▫ Results are clearly caused by approach ▫ Positive indication that leading position will be maintained	100%	▫ Results address **all** relevant areas and activities

Appendix B: General Improvement Philosophies

Table B-11 Description of old paradigm and new (emerging) paradigm on topics for the theme of customer value strategy [Bounds et al, 1994]

Topics	Old Paradigm	New (emerging) paradigm
Quality	Meeting specifications, inspected into product, make tradeoffs among quality, cost, schedule	One component of customer value, managed into process, seek synergy among quality, cost schedule
Measurement	Internal measures of efficiency, productivity, costs, and profitability, not necessarily linked to customers	All measures linked to customer value
Positioning	Competition	Customer segments
Key stakeholder	Key stakeholder, boss (other stakeholders are pawns)	Customer (other stakeholders are beneficiaries)
Product design	Internal, sell what we can build	External, build what customers need

Table B-12 Description of old paradigm and new (emerging) paradigm on topics for the theme of organisational systems [Bounds et al, 1994]

Topics	Old Paradigm	New (emerging) paradigm
Cross-functional approach	Negotiation across functional interfaces to obtain co-operation	Cross-functional systems defined, owned, and optimised
Technology	To deal with complexity, to eliminate people problems	To reduce complexity, source of optimisation for customer value
Employee involvement	Focused on hygiene factors	Focused on strategic factors
Human resource management	Regarded as a staff responsibility, administration of personnel hiring, firing, and handling complaints	Regarded as a critical resource, managed as system input
Role definition	Task and job descriptions set limits	Vision inspires flexibility
Culture	Social and emotional issues are suppressed, politics and power dominate	Connect with individual sense of purpose, emotions, and social meaning
Structure	Specialisation, tall hierarchy with functional emphasis	Integration, flat hierarchy with team emphasis

Table B-13 Description of old paradigm and new (emerging) paradigm on topics for the theme of continuous improvement [Bounds et al, 1994]

Topics	Old Paradigm	New (emerging) paradigm
Occasion	Focused new product development, episodic, relative to problems, big breakthoughs only	Focused on broader systems, unending, proative to opportunities, big breakthroughs and small steps
Approach	Trial and error	Scientific method
Response to error	Punish, fear, cover-up, seek people fix, employees are responsible	Learning, openness, seek process/system fix, management is responsible
Decision-making perspective	Individual political expediency, short term	Strategic, long-term, purposeful for organisation
Managerial roles	Administer and maintain status quo, control others	Challenge status quo, prompt strategic improvement
Authority	Top driven via rules and policies	Customer-driven through vision, enablement, and empowerment
Focus	Business results through quotas and targets	Business results through capable systems, means tied to results
Control	Scoring, reporting, evaluating	Statistical study of variation to understand causes
Means	Delegated by managers to staff and subordinates	Owned by managers who lead staff and subordinates

Appendix C: Phase Gates

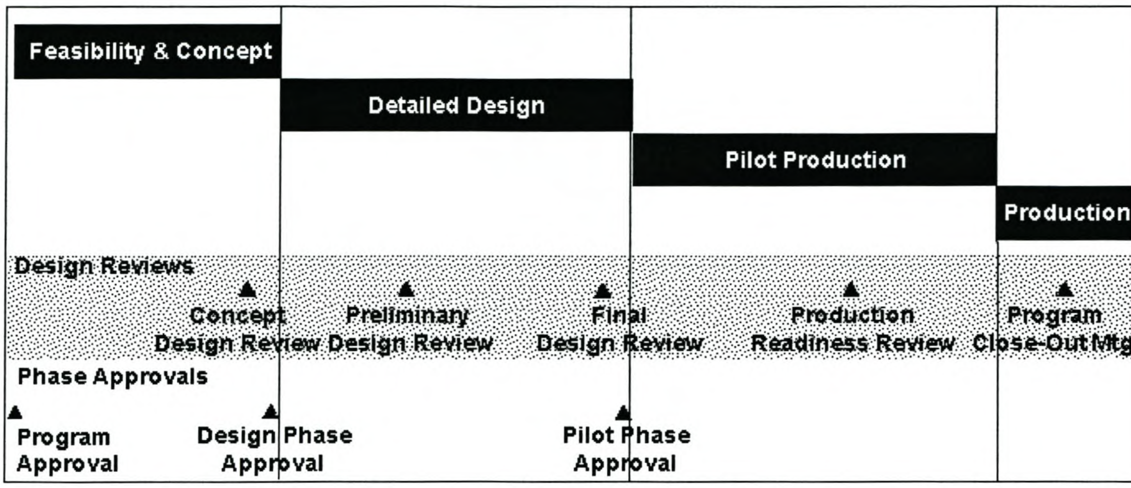

Figure C-18: Phase Gate and Design Review Timing

Table C- 2: Control your process with phase gates and design reviews (Source: Kenneth Crow 1998)

Meeting Title	Programme Approval Meeting	Design Phase Approval Meeting	Pilot Phase Approval Meeting
Timing	Prior to the Feasibility & Concept Phase	At the end of Feasibility and Concept Phase	At the end of the Prototype Phase
Phase Approved	The Programme and the Feasibility and Concept Phase	Design Phase	Pilot Phase
Entry Criteria or Prerequisites	Project Definition	Successful Concept Design Review	Successful Final Design Review
Meeting Required Before:	Resources can be applied to programme	Quote delivered to the Customer and Design Phase can begin	Pilot Phase can begin and production tooling ordered
Agenda	- Programme overview - Basic customer requirements - Key programme milestone dates - Product and tooling cost targets - Quality targets - Programme risk issues - Proposed NPD process deviations	- System architecture - Degree of new invention & technical development - Manufacturing sourcing - Concept Design Review issues & proposed resolution - Cost targets vs. estimates - Internal quality targets - Programme budget & preliminary investment requirements - Programme breakeven time - Proposed customer quotation - Updated programme schedule - Programme staffing issues - Programme risk issues - NPD process deviations	- Final Design Review issues and proposed resolution - Customer satisfaction & issues - Cost targets vs. estimates - Programme budget - Tooling & equipment investment and budget approval - Programme breakeven time - Updated programme schedule and status - Programme risk issues - NPD process deviations

Appendix D: Case Study Theory

The literature presented below has been taken from the web site of Colorado State University

(http://writing.colostate.edu/references/research/casestudy/printFormat.cfm)

It was used as a guide in the development of the Case Study in the Tellumat, Switching Department. There is a copy right on this text (1997-2002)

Selected text has been extracted from the literature.

1. INTRODUCTION AND DEFINITION OF CASE STUDIES

Case study refers to the collection and presentation of detailed information about a particular participant or small group, frequently including the accounts of subjects themselves. Researchers do not focus on the discovery of a universal, generalisable truth, nor do they typically look for cause-effect relationships; instead emphasis is placed on exploration and description.

The type of comprehensive understanding that is acquired in a case study is arrived at through a process known as thick description, which involves an in-depth description of the entity being evaluated, the circumstances under which it is used, the characteristics of t he people involved in it, the nature of the community in which it is located. Thick description also involves interpreting the meaning of demographic and descriptive data such as cultural norms and mores, community values, ingrained attitudes, and motives.

Case studies are the preferred strategy when how or why questions are asked. Case studies require a problem that seeks a holistic understanding of the event or situation in question using inductive logic – reasoning from specific to more general terms. It strives for a more holistic interpretation of the event or situation under study.

The goal of a case study is to offer new variables and questions for further research.

2. TYPES AND DESIGN

Types of Case Studies

Illustrative Case Studies: These are primarily descriptive studies. They typically utilise one or two instances of an event to show what a situation is like.

Exploratory (or pilot) Case Studies: These are condensed case studies performed before implementing a large scale investigation. Their basic function is to help identify questions and select types of measurement prior to the main investigation.

Cumulative Studies: These serve to aggregate information from several sites collected at different times. The idea behind these studies is the collection of past studies will allow for greater generalisation without additional cost or time being expended on new, possibly repetitive studies.

Critical Instance Case Studies: These call into question or challenge a highly generalised or universal assertion. This method is useful for answering cause and effect questions.

Identifying a Theoretical Perspective

In designing the study, researchers need to make explicit the questions to be explored and the theoretical perspective from which they will approach the case. The three most commonly adopted theories are listed below:

Individual Theories: These focus primarily on the individual development, cognitive behaviour, personality, learning and disability, and interpersonal interactions of a particular subject.

Organisational Theories: These focus ion bureaucracies, institutions, organisational structure and functions, or excellence in organisational performance.

Social Theories: These focus on urban development, group behaviour, cultural institutions, or marketplace functions.

Designing a Case Study

Typically research designs deal with at least four problems:

- What questions to study
- What data are relevant
- What data to collect
- How to analyse that data

In other words, a research design is basically a blueprint for getting from the beginning to the end of a study.

Robert K. Yin (1993) does offer five basic components of a research design:

1. A study's questions
2. A study's propositions (if any)
3. A study's units of analysis
4. The logic linking of the data to the propositions
5. The criteria for interpreting the findings.

Yin also stresses the importance of clearly articulating one's theoretical perspective, determining the goals of the study, selecting one's subject(s), selecting the appropriate method(s) of collecting data, and providing some considerations to the composition of the final report.

3. CONDUCTING CASE STUDIES

To obtain as complete a picture of the participant as possible, case study researchers can employ a variety of approaches and methods.

Single or Multi-modal?

To obtain as complete a picture of the participant as possible, case study researchers can employ a variety of methods. Some common methods include interviews, protocol analyses, filed studies, and participant-observations. Some studies have come under heavy fire in the past for only using one method.

Participant Selection

It is important that he participant pool remain relatively small. Often a brief "case history" is done on the participants of the study in order to provide researchers with a clearer understanding of their participants, as well as some insight as to how their own personal histories might affect the outcome of the study.

Data Collection

There are six types of data collected in case studies:

1. Documents
2. Archival records
3. Interviews
4. Direct observations
5. Participant observation
6. Artifacts

Protocols, that is, transcriptions of participants talking aloud about what they are doing as they are doing it, have been particularly common in composition case studies.

Case studies are likely to be far more convincing and accurate if they are based on several different sources of information, following a corroborating mode. Cynthia Selfe (1985) argues that because "methods of indirect observation provide only an incomplete reflection of the complex set of processes involved in composing, a combination of several such methods should be used to gather data in any one study."

It is important to note that in case studies, as in any qualitative descriptive research, while researchers begin their studies with one or several questions driving the inquiry (which influence the key factors the researcher will be looking for during data collection), a researcher may find new key factors emerging during data collection. This will link possible further research.

Data Analysis

Generally, researchers interpret their data in one of two ways: holistically or through coding. Holistic analysis does not attempt to break the evidence into parts, but rather to draw conclusions based on the text as a whole. Sharan Merriam (1988) suggests seven analytic frameworks for the organisation and presentation of data:

1. The role of participants
2. The network analysis of formal and informal exchanges among groups
3. Historical
4. Thematical
5. Resources
6. Ritual and symbolism
7. Critical incidents that challenge or reinforce fundamental beliefs, practices, and values

There are two purposes of these frameworks: to look for patterns among the data and to look for patterns that give meaning to the case study.

Composing of the Report

In the many forms that it can take, "a case study is generically a story; it presents the concrete narrative detail of actual, or at least realistic events, it has a plot, exposition, characters, and sometimes even dialogue" (Boehrer, 1990). Typically authors address each step of the research process, and attempt to give the reader as much content as possible for the decisions made in the research design and for the conclusions drawn.

This contextualisation usually includes a detailed explanation of the researchers' theoretical positions, of how those theories drove the inquiry or led to the guiding research questions, of the participant's backgrounds, of the process of data collection, of the training and limitations of the coders, along with a strong attempt to make connections between the data and the conclusions evident.

Sharan Merriam (1985) also offers several suggestions for alternative presentations of data:

1. Prepare specialised condensations for appropriate groups
2. Replace narrative sections with a series of answers to open-ended questions
3. Present "skimmer's" summaries at beginning of each section
4. Incorporate headlines that encapsulate information from text
5. Prepare analytic summaries with supportive data appendixes

4. COMMENTRY ON CASE STUDIES

Most case study advocates point out that case studies produce much more detailed information that what is available through statistical analysis. Advocates will also hold that while statistical methods might be able to deal with situations where behaviour is homogenous and routine, case studies are needed to deal with creativity, innovation, and context. Detractors argue that case studies are difficult to generalise because of the inherent subjectivity and because they are based on qualitative subjective data, generalisable only to a particular context.

Appendix E: Product Development Best Practice Assessment Tool

1.0 BUSINESS AND PRODUCT STRATEGY

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
There is no explicit business nor product development strategy and business planning is not formally done. Product development programs are reactive to opportunities. No formal competitive evaluation (e.g. product benchmarking, tear-downs, etc.) nor analysis are performed. Critical success factors & core competencies are not known.	Some business planning is done, but there is no formal product development strategy. Competitor and competitor product strengths and weaknesses are informally identified. Product/program planning is done in isolation of business planning based on perceptions of the company's strategy.	Business planning is done considering competitor capabilities. Critical success factors are understood and considered in planning. Business & product development strategies are used to guide product planning and product development. Formal competitive evaluations are performed, however, core competencies and the basis of competitive advantage are not formally defined.	A well-defined business planning process exists resulting in a well-defined product development strategy and product plan(s). Competitive evaluation and market analysis are weighed against company strengths & weaknesses. Critical success factors and core competencies are understood and considered in product planning. Business and product development strategy are used to drive product planning.

		Importance	Performance
1.1	**Develop a business strategy as a basis for a product development strategy.** Does the company have a formal business strategy and plan which defines markets, customers, technologies and products that the company will pursue? Does this plan provide a sufficient framework for deriving a product development strategy and preparing product plans?	7	5
1.2	**Evaluate the competition and the external environment.** Does the company evaluate the products (e.g., product benchmarking, product tear-downs, etc.), capabilities, and strengths and weaknesses of its competitors? Has market analysis been performed to understand market segments and determine opportunities for product development?	8	2
1.3	**Determine strengths and weaknesses and core competencies.** Has the company determined it's strengths and weaknesses, it's core competencies, and it's basis for competitive advantage?	8	6
1.4	**Derive a product development strategy and use it as the basis for product planning and development.** Has a clear product development strategy been determined (e.g., first to market, innovative technology, low-cost products, high quality/reliability products, etc.)? Is the business and product development strategy and business plan used as the basis for formal product plans and technology or R&D plans?	7	4
1.5	**Communicate and apply the business and product development strategy.** Is this business plan and product development strategy shared and communicated outside of executive management? Is it generally understood by managers, key development personnel, and technologists, and do they use it as a framework and guide for their development activities? Do development projects take advantage of core competencies and the company's basis for competition?	7	5
1.6	**Develop a product plan.** Does the company develop a multi-year, multi-generational plan for each product line, product family or platform? Are the product plans regularly updated based on market research, the identification of specific customer needs, or new product concepts or ideas?	7	5
1.7	**Plan based on product family/platform.** Are product plans prepared for product families or product platforms to coordinate development of individual products? Are the product development strategy and product planning based on using a common product core design or platform to maximize product variety and design re-use with a minimum of development effort?	6	5
1.8	**Plan new product development projects as a portfolio.** Is product mapping or portfolio analysis performed to properly position products relative to appropriate product planning parameters such as market segment, price, competitors, performance, technical risk, development complexity, product life cycles, etc.?	7	5
1.9	**Manage development portfolio risks.** Are development projects managed as a portfolio – some higher risk break-through projects; some moderate risk development projects; and some lower risk product enhancements, derivatives or product line extensions? Is the company's product development portfolio consistent with its business objectives and the level of risk that it is willing to tolerate?	7	7
	Business and Product Strategy Effectiveness Rating		5

2.0 PRODUCT & PIPELINE MANAGEMENT

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
Product plans are not prepared and development projects are undertaken at management direction without any business case (justification) being prepared. Development budgets, if prepared, do not necessarily correspond to the annual budget. Projects are not prioritized and resources are overloaded during the year.	A limited product plan may be developed for some product lines. A business case (justification or profit plan) is prepared for any significant development effort before development proceeds. Development budgets correspond to the business plan, but projects are not prioritized and resources are overloaded during the year. An ad-hoc process exists for identifying, screening and prioritizing new development opportunities.	Product plans are prepared for covering all significant development efforts. A disciplined approach to product planning and business planning exists where development budgets correspond to the business plan. A evolving process exists for identifying and screening new development opportunities and managing the pipeline. Projects are prioritized and development is initiated only when resources become available.	A well-integrated process of product and business planning exists. Plans are maintained through periodic business and product planning reviews which provide flexibility to respond to opportunities. A robust process exists for identifying and screening new development opportunities against the business strategy and managing the pipeline. Development risks are assessed and steps taken to mitigate them. Projects are managed as a portfolio with balanced risks & rewards.

		Importance	Performance
2.1	**Establish a process for identifying new product opportunities.** Is there a formalized process and supporting systems to identify new product ideas, concepts and opportunities from both internal and external sources? Are these ideas, concepts and opportunities reviewed and screened in a regular and timely way as a basis for new product development plans and decisions?	7	3
2.2	**Screen and prioritize development projects.** Are new product ideas, concepts and opportunities screened against the company's business and product strategy? Are business and product plans and strategy used to guide investments in developing new products and the priority of specific development projects? Is there an executive-level product steering committee in place to review and prioritize product development opportunities?	6	4
2.3	**Reconcile development funding requirements with the business plan.** Do the funding requirements of the product plans correspond to the overall investment and the resource levels dictated by the business plan and annual budget? Is there a mechanism in place to resolve differences between product plan funding requirements and the business plan/annual budget?	5	3
2.4	**Respond properly to new opportunities.** If a good opportunity presents itself for developing a new product or a product derivative not addressed in the product plan, is the plan updated in response to this opportunity and the resources required considered in the context of the overall business plan (budget added or priorities changed in order to hit market windows) ? Does the company have contingency development funding to react to immediate development opportunities?	6	5
2.5	**Staff to the plan.** Are the business plan and product plans used as the basis for staffing the functional disciplines supporting product development? Are resources at a sufficient level to support development projects dictated by the product plan?	7	3
2.6	**Balance project priority, resources and opportunity.** Does the decision to undertake a new product development effort adequately balance the priority of specific development projects (based on the product plans), the availability of resources to support development, and the business opportunity? Does management avoid starting too many projects and spreading resources too thinly, thereby delaying time-to-market?	5	5
2.7	**Prepare a business case.** Is a business case or business justification prepared early in the development cycle that identifies target cost, price, sales volume, revenue, and non-recurring development costs? Is this thoroughly reviewed and considered before development proceeds further?	10	5
2.8	**Assess and mitigate risks.** Are business risks and technical risks identified, assessed and documented? Are specific actions identified and taken to mitigate these risks or provide a fallback approach?	5	4
	Product and Pipeline Management Effectiveness Rating		4

3.0 TECHNOLOGY MANAGEMENT

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
Technology is developed based on R&D's perception of the company's and customers needs. Deployment to new product development projects is difficult. Very little attention is focused on developing new manufacturing processes.	Key required technologies are identified and plans are established to develop or acquire them. As these technologies are developed they are deployed to new product development projects, but are "thrown over the wall" rather than any cross involvement. Investment in new process capabilities is reactive (based after the fact on new product needs).	Required technologies identified based on strategy & long-term product plans. R&D projects regularly reviewed against objectives. R&D personnel clearly understand customer needs and facilitate transfer of new technology to projects. Technology "pulled" based on market need. Increasing emphasis focused on process technology. Process investments driven by development requirements.	There is effective coordination of R&D across business units based on business unit & corporate strategy and product plans. Mechanisms are in place to survey new technology developed outside and acquire this when appropriate. Equal emphasis placed on process technology. Process investments driven by business/technology plan.

		Importance	Performance
3.1	**Identify required technologies to support product development.** Does the business planning or technology planning process identify specific technologies required to support sustained competitive advantage based on product plans, core competencies, business objectives, and technology deficiencies? Are technology roadmaps or forecasts developed to identify technical directions?	5	2
3.2	**Plan sourcing of technologies.** Is there any formal process to determine which technologies will be acquired from the outside (e.g., licensing, joint ventures, subcontracting) versus developed internally (make/buy decision)?	7	2
3.3	**Base R&D plans on the business plan.** Are internal research and development projects based on the business plan and technology plan: technologies required to support new products and technologies that are to be internally developed? Are technology development projects clearly tied to business objectives?	10	7
3.4	**Develop technology independently of new product development.** Is technology developed independently of individual product development projects and deployed to these projects when it is reasonably mature in order to minimize development cycle time? Is this technology developed based on business and technology plans so that its is available sooner to support development projects?	5	1
3.5	**Establish and communicate clear R&D objectives.** Are clear objectives established for research and development projects and are these projects regularly reviewed relative to these objectives? Does management believe they are getting a good return on the R&D investments?	2	1
3.6	**Establish mechanisms to effectively deploy new technology to development projects.** Are there effective mechanisms for communicating the results of technology development efforts and deploying new technologies to development projects? These mechanisms include meetings between R&D and product development personnel, technology training/briefings, rotation of personnel, etc. Is there an assessment of technology maturity and risk before new technology is deployed to product development projects?	10	3
3.7	**Coordinate R&D across business units.** In a multi-division / multi-business unit environment, are there effective mechanisms for coordinating and communicating research and development results from other business units or corporate so that technology can be leveraged throughout the enterprise?	5	1
3.8	**Survey and acquire useful technology.** Are functions in place to survey and collect information on external technology development efforts and appropriately disseminate this information internally? Does the company aggressively acquire or license relevant technology when it fits company needs (versus a "not invented here" or "head in the sand" culture prevailing)?	5	1
3.9	**Don't "push" unneeded technology.** Do new product development efforts effectively balance "technology push" versus "market pull" in deciding what technology to deploy to new product development efforts?	5	4
3.10	**Develop new process technology.** Is adequate effort and investment given to developing new process technologies? Best in class companies are spending 30% to 50% of their R&D budgets on process technology development versus product technology development.	5	1
3.11	**Leverage R&D investments.** Does management emphasize maximizing the re-use of both product and process technology as well as product designs to maximize R&D leverage? Does the company effectively leverage its investments in R&D and product development?	5	0
	Technology Management Effectiveness Rating		3

4.0	MANAGEMENT AND LEADERSHIP		
EVALUATION SCALE			
Traditional (0) Executive management is unaware of integrated product development (IPD) concepts or new product development best practices. No formal action is planned. A hierarchical, authoritative management structure is in place with excessive layers of management.	**Developing (3)** Management is aware of IPD, but lacks training or in-depth knowledge. Management has directed that IPD elements be implemented. Limited resources have been provided, but formal planning, active leadership & visible commitment are lacking.	**Committed (7)** Management is knowledgeable about IPD. They are involved in planning the implementation of IPD and have publicly stated a commitment to IPD. Resources have been provided, but active leadership is lacking. Managers verbally support empowerment. Management layers are being reduced and manager roles redefined. The culture is being improved.	**Best Practice (10)** Management is very knowledgeable about IPD. They are actively involved in planning, leading and monitoring the results of IPD. They provide sufficient resources & help overcome impediments. Flat organization structure created. Managers actively support empowerment. A supportive culture has been established.

		Importance	Performance
4.1	**Develop management understanding and commitment.** Does management understand the concepts and practices of integrated product development (IPD) and time-to-market? Is there a strong executive management interest in improving the product development process and accelerating time-to-market?	5	5
4.2	**Establish and support product development process owner/sponsor.** Is there an active, visible, committed leader recognized as owning the product development process or a "sponsor" of an initiative to improve the product development process? Does this individual have the support of other executives responsible for the functions involved in product development, or is there a steering committee of executives guiding the effort to improve the product development process?	7	7
4.3	**Communicate management objectives for improving product development.** Has executive management clearly communicated objectives for improving the product development process to the rest of the organization? Is management actively reviewing and monitoring the achievement of these objectives?	5	3
4.4	**Establish supportive culture.** Has management established or are they actively working to establish a supportive culture based on teamwork, cooperation, open communication, overcoming the "not invented here" syndrome, continuous improvement, driving out fear, entrepreneurship, participative management, etc. When a problem occurs, does management focus on lessons learned and corrective action rather than punishing the guilty?	7	7
4.5	**Value and reward creativity and risk-taking.** Does management create and support an environment and culture conducive to creativity, risk-taking and "out-of-the-box" or divergent thinking? Is there formal training on creative thinking? Are methods such as TRIZ/theory of inventive problem solving used? Are these traits valued and rewarded or is there a conservative, risk-averse culture?	6	6
4.6	**Support improvements proactively.** Has management provided resources to support improving the development process? Is management involved in establishing appropriate policies to support concurrent engineering/integrated product development and time-to-market? Is management helping to overcome impediments to change and improvement?	5	4
4.7	**Empower development personnel.** Have executive and middle management empowered development personnel? Has sufficient authority been delegated to support assigned responsibilities? Has decision-making been pushed down to the lowest competent level?	10	2
4.8	**Re-define manager's roles with empowerment.** Do managers understand their roles as development personnel are empowered? Do managers have the skills required to undertake their new roles? Have performance criteria and rewards been re-aligned to facilitate these new roles? These new roles emphasize personnel development, process improvement, resource management, being a technical resource to support teams, and sharing information across teams.	5	3
4.9	**Accept responsibilities of empowerment.** Do development personnel and teams accept their responsibilities under empowerment? Has the organization created a culture that eliminates fear of failure which inhibits accepting responsibility under empowerment?	10	5
4.10	**Flatten the organization structure.** Has the organization reduced the number of levels of management and increased the span of control (flat organization structure or the "horizontal organization") consistent with empowerment, improved communication and reduced non-value-added effort? Have alternate career paths been established to move managers into roles as performers while still providing rewards and career advancement?	7	4
4.11	**Avoid over-committing personnel.** Does management balance work with resources available? Are they realistic in making commitments? Development personnel should not be over-committed, and, in particular, the best people should not be overloaded.	5	2
	Management and Leadership Effectiveness Rating		4

5.0 EARLY INVOLVEMENT

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
There is minimal, if any, involvement of functions outside of Engineering until drawings have been developed. Functional sign-off on drawings is a rubber stamp. Significant problems (e.g., producibility) are addressed after pilot/low-rate production begins.	Marketing and Engineering collaborate during the concept development stage. Product development teams may be established on a limited basis once development begins. Manufacturing becomes involved during development and has an active role in reviewing designs and suggesting changes before release.	Key functions are involved in concept development stage and feasibility exploration. Product development teams are established once development begins. Most functional disciplines are involved in resolving problems or concerns during development. Attempts are made to assign personnel full time to projects.	All necessary functions are involved from the concept development stage. Teams are formed for concept development and stay in place until product effectively transitioned into production. There is consensus related to development by affected functional disciplines and problems or concerns are addressed early.

		Importance	Performance
5.1	**Involve core disciplines at the start of the project.** Are core disciplines such as Engineering, Marketing/Program Office, and Manufacturing assigned to a development project at its inception (once approved by management or the customer)? Are all core disciplines actively involved in project start-up? Do core disciplines have a meaningful role and sufficient level of effort?	8	5
5.2	**Assign all disciplines at the start of the project.** Are all disciplines involved in product development (including non-core disciplines) assigned to a development project at its inception (once the project is approved by management or the customer) and do they have a meaningful role and level of effort? Other disciplines can include product support/field service, test engineering, reliability engineering, purchasing, finance, quality, tool engineering, component/material engineering, subcontracts, etc.	7	8
5.3	**Involve all disciplines with project planning.** Are these disciplines involved in project planning and the preparation of a management or customer proposal/business case to undertake the development of a new product. Do they have an active say in the preparation of initial the work definition, budgets and schedules to support product development?	8	8
5.4	**Rapidly staff the project to get off to a good start.** Is the development project staffed as planned to get the project off to a good start? Avoid developing a schedule based on optimistic assumptions of personnel availability only to find that personnel are unavailable to begin the project when needed.	7	7
5.5	**Maintain continuity of personnel on the project.** Are personnel assigned to a development project for the life of the project? Is there a policy or conscious effort to avoid transferring people to other projects and replacing them with another person before their work is done? Is turnover monitored for development projects and are actions taken to reduce or minimize turnover if it becomes to high?	9	8
5.6	**Establish meaningful non-Engineering roles with product development.** Do development personnel from disciplines other than Engineering have an active say in planning and design decisions? Do they sign-off on project and design documents or have a meaningful voice in the decision-making process? Are issues or concerns raised by non-Engineering personnel considered and addressed early in the process?	8	6
5.7	**Provide sufficient level of early involvement.** Is there a sufficient level of involvement from all functional disciplines early in the development cycle to adequately address development issues, minimize time-to-market and minimize engineering changes? Are staffing ratios or other staffing guidelines used to insure that there is an adequate level of involvement from needed functional disciplines?	8	8
5.8	**Maximize full-time assignment of personnel.** Are core development personnel assigned to the project on a full-time basis? If people are assigned on a part-time basis, is there an adequate justification for this? Part time assignment places conflicting demands on people's time and causes delays in accomplishing project tasks. Full-time assignment shouldn't be limited to only the Engineering disciplines; this may indicate that the organization does not have sufficient involvement of other disciplines.	10	5
5.9	**Maintain Engineering involvement into production.** Do core disciplines such as Engineering, Manufacturing, Test, Purchasing, etc. continue to stay involved at an adequate level until the new product has effectively transitioned to production? A point should be defined where development personnel stay involved to resolve production and test issues. This point might be based on a certain number of units produced, achieving a certain production rate, achieving a certain production yield, etc.	5	3
	Early Involvement Effectiveness Rating		7

6.0	PRODUCT DEVELOPMENT TEAMS		
EVALUATION SCALE			
Traditional (0) Product development teams (PDT's)/integrated product teams (IPT's) are not used, and little collaboration between functional disciplines exists. Development is based on "throw it over the wall". Teams are perceived as "design by committee".	**Developing (3)** Management believes that teams are beneficial to improve development. PDT's/IPT's have formed on a pilot basis, but no management guidance on roles, responsibilities and reporting relationships has been provided. Middle management is uncertain or threatened. No training or team building is provided. Teams are not collocated. Team leaders focus on "managing".	**Committed (7)** Management has concluded that teams are necessary for competitive product development. Collocated PDT's/IPT's are used for most projects. Management has defined roles, responsibilities and reporting relationships. Middle management is supportive and beginning to move toward empowerment. Team building training is provided. Team leader's role in transition.	**Best Practice (10)** Multi-function PDT's/IPT's and integration teams are consistently used for product development. The team leader's role is to facilitate the team. Teams are collocated and empowered. Training and facilitators are provided. Teams are cohesive and collaborative. Teams are self-directed and committed. Managers are supportive.

		Importance	Performance
6.1	**Use product development teams/integrated product teams.** Are cross-functional teams of product development personnel formed at the start of the development cycle to support product development as the norm? These teams should include key disciplines including engineering, manufacturing, test, product support, etc.	10	3
6.2	**Organize appropriate size teams.** Are development personnel organized into appropriately-sized, cross-functional product development teams? The ideal size is in the range of six to ten core members and no more than fifteen. On a larger development project, the entire "project team" would not be considered a product development team/integrated product team.	5	6
6.3	**Work together regularly as a true team.** Do product development teams/integrated product teams operate as true teams? Do they work together on a daily basis rather than meeting periodically? Do functional disciplines other than Engineering actively participate rather than being informed about the design?	10	8
6.4	**Use a team(s) for coordination.** On a larger project requiring multiple product development teams/integrated product teams, is there a multi-function program management team, product team, or system integration team to coordinate development activities and assure effective integration? Are critical dependencies and interfaces understood and worked between multiple team?	5	4
6.5	**Emphasize teamwork and collaboration.** Do the teams consistently exhibit a high degree of teamwork? Do teams exhibit a common purpose? Have the teams developed a charter or mission statement as a basis for a common purpose? Do the teams collaborate effectively? Do they spend some time focusing on the process of maintaining effective teamwork?	10	6
6.6	**Establish effective team leader role.** Do team leaders help guide and facilitate (versus manage and direct) the operation of the team? Do they avoid the role of the ultimate decision-maker on the team? (An indicator of this is whether the team leader is held responsible for the teams results or the team is held jointly responsible for its results.) Are they selected based on their interpersonal skills, their leadership skills and their broad business perspective rather than just their technical skills? Do they receive specific team leader training to help them in this role?	10	5
6.7	**Provide resources to develop teamwork.** Is there a defined process for initiating a new product development team/integrated product team and developing their teamwork? Are resources committed to helping team develop teamwork? This includes team-building training and exercises, time spent in meetings focusing on the development of teamwork, and the services and support of facilitators in the early stages of team development.	5	3
6.8	**Support team operation.** Is executive management, functional management, and program/project/ product management truly committed to and support the operation of the teams? Often, middle management feels threatened by empowered teams collocated outside their areas. They may state verbal support, but they are not comfortable with or truly committed to teams.	2	2
6.9	**Collocate development personnel.** Are product development team members physically collocated in a common area within a building? On a program with multiple product development teams, are individual teams collocated together in a logical way? If development personnel are located in different sites, cities or countries, does the company use virtual collocation (periodic face-to-face meetings supported by extensive collaborative computing and video-conferencing) to maintain a high degree on communication and interchange among team members? Note: rate extensive use of virtual collocation in conjunction with periodic face-to-face meetings in place of physical collocation no higher than a 7.	10	7
6.10	**Emphasize self-direction and commitment.** Are the teams self-directed and committed? Do they plan their work? Do they buy-in and commit to higher-level schedules, budgets, and performance targets developed by management? Do team members understand and accept their responsibilities and feel committed to deliver results on schedule? Do the teams exhibit a high energy level?	10	6
6.11	**Strive for consensus decisions.** Do teams strive for consensus decisions on key issues? Do the teams attempt to refine the designs to satisfy concerns of the team members? Does the team effectively collaborate in an effort to achieve consensus?	5	3
6.12	**Establish effective communication & coordination mechanisms.** Are there well-defined mechanisms for communicating among team members, between teams, and with functional and project management? Is this communication effective? Are there effective mechanisms for coordinating team and program activities on a day-by-day basis?	5	3
	Product Development Team Effectiveness Rating		5

7.0	ORGANIZATIONAL ENVIRONMENT		
EVALUATION SCALE			
Traditional (0) Performance appraisal oriented toward traditional individual & functional criteria. No project input to appraisal. Functional managers have control over project expenditures. Traditional cost system. No attempt to re-orient policies. Minimal training; less than .5% of payroll.	**Developing (3)** Performance appraisal criteria expanded to consider teamwork & traditional functionally-oriented goals de-emphasized. Informal project input to appraisal. Increasing program & team control over project expenditures. Traditional cost system. Little recognition of need to re-orient policies. Training susceptible to budget cuts. Training 1-2% of payroll.	**Committed (7)** Performance appraisal modified to consider and better support teamwork. Project/program mgrs. provide input to appraisal. "Open book" management practiced. Team responsible for budget & schedule. Shortcomings in accounting system recognized. Company policies are partially realigned to fully support CE/IPD. Stable training budgets at 2-5% of payroll.	**Best Practice (10)** Emphasis on performance of team vs. individuals. Recognition of a good job. Team and project provide input to performance appraisal. Appraisal criteria address enterprise & customer factors. Team empowered to spend money within budget. Accounting system provides meaningful information. Policies compatible with CE/IPD. Importance of training recognized. Training >5% of payroll.

		Importance	Performance
7.1	**Practice "open book" management.** Does the company practice "open book" management? Do development personnel have access to information such as business strategy and plans, product plans, business results, competitive assessments, project plans, etc. which establish a framework for product development efforts?	7	7
7.2	**Provide access to needed data.** Do development personnel have access to company plans, R&D data, cost accounting data, pricing data and other company data to support product development decision-making? Do personnel have access to all needed project, product, and process data for their projects?	8	7
7.3	**Understand project objectives and plans.** Do development personnel clearly understand project objectives, specifications, assigned tasks, interdependencies, budgets and schedules? Are they aware of which tasks are on the critical path? Are they aware of critical design parameters of other disciplines that are on the project (e.g., controls, electronic packaging, structure, analysis and simulation, etc.)?	10	7
7.4	**Communicate and coordinate issues and changes.** Are changes to requirements, product designs, process designs, etc. clearly communicated to all affected development personnel in a timely manner? Is there effective coordination of changes and issue resolution?	8	7
7.5	**Maintain functional focal point to share and provide information.** Do functional managers share information and lessons learned across projects? Do they conduct periodic departmental meetings to maintain expertise within the discipline, maintain relationships between personnel within the discipline, and share information? Do they serve as a functional discipline resource to draw upon as personnel face issues?	6	5
7.6	**Establish supportive performance appraisal system.** Are the performance appraisal, compensation and reward systems supportive of teams and functional cooperation? Performance criteria should not focus exclusively on functionally-oriented performance measures, but should be broadened to include team-oriented measures. Multiple inputs to performance appraisals should be obtained (e.g., functional manager, program/project/product manager, and the team members) to avoid narrow functional bias. Compensation and rewards should be based on a combination of individual and team performance.	8	4
7.7	**Provide recognition and fair bonuses/incentives.** Are special efforts and outstanding work recognized? Are bonuses, incentives and special recognition set-up in away to avoid resentment among team members and between teams? Giving a bonus or special recognition to one team member for efforts related to the team can create resentment among team members.	9	5
7.8	**Establish supportive accounting policies.** Are budgeting and cost accounting systems set-up so they facilitate proper application of resources and support empowerment? If development personnel's time is charged to overhead, the budgeting process may prevent functional managers from having enough people to adequately support development projects. If accounting policy requires functional manager approval for budgeted expenses such as travel, prototype materials, and other direct costs, the product development team is not truly empowered.	5	0
7.9	**Provide technical information resources.** Does the organization maintain a library of technical publications, relevant books, and technical papers to provide development personnel with information to keep themselves up-to-date? Does the organization provide access to other information sources, the Internet, an intranet, and online databases for development personnel?	5	3
7.10	**Plan personnel development requirements.** Do manager's identify future workforce requirements and support personnel development to insure a highly skilled workforce to support development needs now and in the future? Are career paths defined? Are knowledge and experience requirements defined? Are personnel development plans maintained?	5	1
7.11	**Train development personnel.** Does the organization provide training to develop and maintain their people's skills and knowledge? Best in class companies are providing in excess of 100 hours per year (5% of people's time) for training. Do product development personnel receive training in skills and knowledge related to their functional discipline, cross-functional knowledge, team-building, problem-solving, project management, development methodologies (e.g., DFMA, QFD, DOE, etc.), and new or updated design automation systems and tools?	5	1
	Organizational Environment Effectiveness Rating		5

8.0	PROCESS MANAGEMENT		
EVALUATION SCALE			
Traditional (0) The development process is not standardized - different processes used on projects. The process is not documented, documentation is out of date and/or the process is not understood by personnel. The process is recognized as inefficient & time-consuming.	**Developing (3)** The development process is partially documented and generally standardized (some deviations exist across projects). Development personnel have a good understanding of this process. Initial attempts have been made to improve this process. SEI level 2.	**Committed (7)** The development process is standardized & mostly documented. ISO 9001 certification achieved. Development personnel have a good understanding of project phases, activities, deliverables, & milestones. Process owners have taken responsibility for the process. Process implications considered when design automation is planned. SEI level 3.	**Best Practice (10)** The development process is standardized & documented with well-defined gates between project phases. Development personnel have been trained to understand this process & they adhere to it. Process owners manage the process. Redundancies have been eliminated and information flow streamlined. Process improvement drives consideration of design automation. SEI level 4 or 5.

		Importance	Performance
8.1	**Establish a common development process.** Is there either a common or a "baseline" product development process? A baseline process has a common core approach but allows flexibility to be adapted to meet the particular requirements of an individual development project.	9	4
8.2	**Document the development process.** Is this process documented? Is the documentation up-to-date? Does the documentation describe the tasks and activities to be performed, responsibilities, information flows, process outputs, design reviews, and phase-gate reviews? (Things to look for: ISO-9000 or QS-9000 certification, Baldrige award application, and SEI CMM evaluation would indicate a certain level of documentation and compliance related to the product development process.)	7	7
8.3	**Document the project-specific development process.** If a baseline process is adapted or modified to the specific needs of an individual project or there is no general product development process documented, is a product/software/system development plan or a modified process description prepared which describes the process for that project?	7	3
8.4	**Communicate and follow the process.** Is the intended product development process commonly understood by development personnel? Is process documentation accessible to development personnel? Is the intended development process consistently followed?	9	8
8.5	**Establish process responsibility.** Are there process owners identified who are responsible for defining development process activities and maintaining the process documentation? Is the product/software/system development plan prepared for an individual project reviewed by the process owner to assure compliance with policy, standards, and minimum requirements and to assure consistency with a common baseline process?	6	7
8.6	**Understand design automation impact on the process.** Are process improvements and benefits defined and considered when new or updated tools and design automation systems are evaluated? Are process improvements made when new or updated tools and design automation systems are deployed? When new or updated tools and design automation systems are introduced, is adequate training provided covering both the tools and the new process? Is the process monitored to determine if the benefits are achieved or to identify corrective action?	6	7
8.7	**Understand process improvement goals and process performance.** Are the goals for the development process (related to time, cost, and quality) clearly articulated? Is the current level of process performance known (e.g., development cycle time, design iterations, etc.) Are policies and practices aligned to support development goals?	8	2
8.8	**Streamline the development process information flow.** Is the flow of information in the development process streamlined? Have redundant databases and re-entry of data been minimized or avoided? Is there an orientation to communicating electronically rather than by paper? Have unnecessary document copies and redundant filing systems been eliminated? Does the organization avoid a "paper alibi" culture or a tendency for departments to maintain their own files or databases?	8	2
8.9	**Emphasize design re-use to minimize development cost and schedule.** Is there an emphasis on design re-use (e.g., modules, parts, cores, cells, part models, requirements documents, plans, technical documentation, simulation models, fixtures, tooling, etc.) to minimize development content and streamline the development process?	9	8
8.10	**Establish and control the project with stage gates.** Do the development phases or stages have clearly defined requirements which must be satisfied before completing the current phase or stage? Are management reviews used as gates to assure requirements have been satisfied? Is there reasonable balance between assuring that all process steps and requirements have been completed, but preventing unnecessary delays to the development cycle?	8	8
	Process Management Effectiveness Rating		6

9.0	PROCESS IMPROVEMENT		
EVALUATION SCALE			
Traditional (0) There is no awareness of nor formal mechanisms to identify and share best practices. "Not invented here" syndrome is very evident. Personnel are resistant to change. Metrics are lacking. There is no improvement program in place. Personnel react to competitive problems by assuming the competition is producing at a loss.	**Developing (3)** Increasing focus on improving the development process by examining what has gone well and not well in the past. Informal review of lessons learned. Initial efforts to identify and communicate best practices. Initial efforts to review what other companies are doing. Limited metrics exist to measure performance (primarily budget & schedule/time-to-market).	**Committed (7)** Initial process re-engineering efforts are underway. Lessons learned. Guidance is provided on best practices. Development programs focus on improving the development process. Formal benchmarking of the development process provides a sounder external perspective. Basic metrics in place to measure the development process.	**Best Practice (10)** A vibrant, continuous improvement program based on process reengineering & best practices is in place. Lessons learned are formally identified and used to improve development. Formal benchmarking is extensively used to identify best practices & improve business processes. Extensive metrics exist to measure process performance & guide improvement. A change-oriented culture exists.

		Importance	Performance
9.1	**Improve the development process continuously.** Is there an on-going, proactive effort to improve the product development process? Are improvement objectives clearly defined and communicated to management and personnel involved in product development?	10	4
9.2	**Create a positive culture of change.** Is the company culture oriented to continuous improvement, learning new ways, and making positive changes (versus "not invented here" and resistance to change)?	5	2
9.3	**Involve personnel in making improvements.** Are development personnel as well as managers and process owners involved in identifying and making improvements to the development process? Are process improvement teams used to identify opportunities and improve the development process? Are customers and suppliers (internal and external) of each process step involved in improving the process? Are ideas for improving the development process actively solicited from development personnel?	10	4
9.4	**Provide process improvement training and tools.** Are personnel involved in defining and improving the development process provided with any formal training of best practices, problem solving, and process mapping and analysis? Are formal methodologies used to document current processes and identify opportunities for improvement?	5	3
9.5	**Understand best practices as a basis for identifying improvements.** Are best practices related to concurrent engineering, integrated product development and time-to-market understood by management? Are they understood by development personnel?	10	2
9.6	**Establish meaningful performance metrics.** Are metrics for measuring the performance of the product development process defined and performance data regularly collected and reported? Are the metrics meaningful and useful? Do both management and development personnel review product development performance? Is this information used to further improve the development process?	10	1
9.7	**Benchmark product development.** Is formal benchmarking with "best in class" product development organizations used to assess the company's current product development practices and identify improvements? Are metrics used to compare performance and identify "gaps" for follow-up action?	5	1
9.8	**Capture and disseminate lessons learned.** Are lessons learned related to the product development process documented? Are they communicated or made available to development personnel? Are they used to improve the development process?	5	3
9.9	**Manage the product/software development process.** Is the product or software development process well-managed and optimized? Characteristics of a managed and optimized process include the use of metrics to monitor and improve the process, the process is very predictable, business process defects or shortcomings are studied and acted upon, lessons learned are captured, and there is an on-going effort to improve the process. (A Software Engineering Institute (SEI) CMM process maturity level of 5 would fully satisfy this criteria. Otherwise, scale the response to this question based on the process maturity level.)	5	2
	Process Improvement Effectiveness Rating		3

10.0	UNDERSTANDING THE CUSTOMER		
	EVALUATION SCALE		
Traditional (0) Products are developed based on management's and engineering's perceptions of what the marketplace/customer needs. Customer contact is limited to the marketing or program office. There are no formal mechanisms to identify customer needs or obtain feedback from the marketplace.	**Developing (3)** Marketing/program management is responsible for identifying customer needs. Other functions have limited customer contact. Meetings, surveys or other data collection methods help identify customer needs. Feedback on significant customer problems is eventually considered in developing new products.	**Committed (7)** There is a significant focus on understanding the needs of current and potential customers. Significant effort invested in meetings, focus groups, market research and other mechanisms to determine needs. Customer feedback is actively considered. Some early customer involvement on programs.	**Best Practice (10)** Satisfying customer needs is one of the primary missions of the organization. There are numerous mechanisms to determine the "voice of the customer". Company personnel regularly visit customers to gain insights. Web-based tools are used to gather ideas and feedback from customers. There is active early customer involvement to resolve questions/issues or provide feedback to improve new products.

		Importance	Performance
10.1	**Identify a new product's customers.** Do development personnel have a clear understanding of who the customers (market segment) are for every new product development effort? Are a new product's customers formally defined in a product plan, statement of work, team charter, or marketing requirement specification?	7	3
10.2	**Understand customer needs.** Are the company processes, policies, and culture truly oriented toward understanding customer needs and satisfying those needs (versus trying to build a better mousetrap regardless of need)? Is the company oriented toward understanding and satisfying the needs of both intermediate customers (subcontractors, prime contractors/OEM's, distributors, retailers) as well as the end-user? Does the company focus on understanding the needs of both current customers as well as potential customers?	10	5
10.3	**Promote understanding of customers through multi-level contacts.** Is contact and communication with the customer emphasized? Does the company avoid limiting contact to just the marketing/sales or program office functions? Do development personnel in most functions have contact or exposure to customers? Does the company promote customer contact through programs such as rotation through sales/marketing or customer support functions or by visiting customers or going out to the field and observing how products are actually used and maintained by customers?	7	5
10.4	**Formalize gathering of customer needs.** Are formal mechanisms such as market research, customer meetings, focus groups, surveys, ethnographic studies, web-based focus group/customer feedback tools, or customer requirements documents used to capture customer needs or requirements? Is the relative importance of customer needs assessed? Is sufficient information captured to define customer needs? Is this information openly shared with development personnel or is it filtered through a marketing requirements specification?	10	4
10.5	**Gather and consider customer feedback.** Does the company emphasize the value of post-sales feedback from customers for product development? This can be through warranty/survey cards, warranty data, hotlines or customer complaint numbers, web-based customer feedback systems, post-sale surveys, customer support feedback, and feedback solicited by sales/marketing personnel. Is this data formally accumulated and summarized into useful information? Is this information made available to and considered by development personnel?	10	3
10.6	**Involve customers in development.** Are customers involved in the development process to provide input, guidance and feedback either through focus groups, customer reviews, customer panels, or direct participation? Are customers involved throughout the development cycle to provide input and feedback rather than only providing initial input? If customer representatives are directly involved in development, are they considered part of the product development team? Is information openly shared with them? Is their input actively considered?	5	1
	Understanding the Customer Effectiveness Rating		4

11.0 REQUIREMENTS AND SPECIFICATIONS MANAGEMENT

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
No formal methodology or process exists to determine customer requirements or establish specifications. Requirement & specification documents may not be created or if they are, the content is not standardized. Specifications are not maintained as requirements change. Requirements are not tracked.	A formal requirements document is prepared, but requirements are not tracked after the project starts. A structured, standardized specification is prepared & distributed to key personnel. However, the process for considering changes to requirements and specifications is not well-defined and managed. QFD used on a pilot basis to help define requirements.	The process of gathering & documenting requirements is formalized. QFD is regularly used. Specifications are developed based on a formal methodology. Development milestones require approval of requirements and specifications before development activities continue. Major changes are evaluated before approval given to proceed.	A formal process exists for gathering, documenting and tracking requirements. QFD is used extensively. A standard specification format is used. Requirements and specifications are updated as needs change only when determined by a rigorous management process. Systems exist to support requirements tracking and allocation.

		Importance	Performance
11.1	**Understand competitor strengths and weaknesses.** Are competitor's products analyzed or benchmarked to understand customer needs, strengths and weaknesses, and positioning in the marketplace? Is this information made available to and considered by development personnel?	10	5
11.2	**Capture internal and certification requirements.** Are internal management requirements for a new product (based on company strategy and definition of target markets) formally captured? Are compliance or certification requirements identified at the start of the development cycle?	10	5
11.3	**Use QFD or a formal requirements definition process.** Is quality function deployment (QFD), a formal requirements database, or a similar technique used to organize customer needs and priorities and translate them into specific product requirements at the start of the project? Is this process used to develop an agreed upon set of product requirements and objectives? Are multiple functional disciplines involved in defining the product requirements and objectives?	7	5
11.4	**Document requirements and specifications completely.** Is a formal requirements document, QFD house of quality/product planning matrix, marketing specification, functional specification, and/or product specification prepared? Is this communicated to development personnel? Is this reviewed and agreed to by development personnel prior to start of development? Are requirements thoroughly reviewed to determine missing, infeasible or ambiguous requirements?	10	5
11.5	**Address trade-off's and life cycle requirements.** Does the requirements definition and specification process adequately consider trade-off's not only in product performance and features, but also in terms of cost, quality, schedule, and risk? Are the requirements realistic and achievable within the cost targets and development schedule? Do requirements and specifications address the broader life cycle requirements rather than just product performance?	10	5
11.6	**Use a formal systems engineering process to flowdown requirements.** In the development of complex products or systems, is there an effective systems engineering function in place responsible for partitioning the system into logical subsystems or modules and allocating requirements to subsystems and to hardware versus software? Are physical and functional interfaces defined and documented early in the development process?	10	4
11.7	**Provide management review of product requirements and significant changes.** Is management involved in reviewing and signing-off on product requirements before development proceeds? Is management involved in reviewing significant changes or deviations to requirements as they occur or at milestone points?	10	4
11.8	**Tightly manage requirements.** Once requirements and specifications are approved, are they tightly managed to avoid requirements creep or "creeping elegance"? If any changes are made to product requirements or specifications, are the cost, schedule and risk impacts balanced against the benefits of the change? Are the development budgets, schedules, and cost targets updated to fully reflect these impacts when requirements or specification changes are made?	10	4
11.9	**Track and reconcile requirements.** Are requirements formally tracked during the development process? Is there traceability from the functional specification to the documented and approved requirements and vice versa? Are the capabilities of the product as designed compared against the list of requirements and the functional specification and any deviations identified?	10	4
	Requirements & Specifications Management Effectiveness Rating		5

12.0	DEVELOPMENT PROCESS INTEGRATION		
EVALUATION SCALE			
Traditional (0) Development activities performed by individual functional disciplines occur sequentially. Information is passed on to the next discipline after an activity is essentially complete. Collaboration occurs after an activity is complete and a problem is recognized. Concurrent development activities perceived as risky.	**Developing (3)** The benefits of time-to-market have been recognized and the company is exploring how to perform development activities concurrently. The organization is learning to work with partial information. Development activities are not tightly synchronized. No formal assessment of how to reduce development schedules has occurred.	**Committed (7)** The development process has been studied and efforts made to improve to move toward a more concurrent development process. Some reductions to development cycle times have been achieved. Improvements have been made in synchronizing development activities. Multi-team development effectively coordinated. Significant early evaluation of product concepts.	**Best Practice (10)** A highly concurrent development process is in place. The organization recognizes the opportunities to reduce development cycle times and appropriately balances these strategies with risks. Development activities are tightly synchronized. Multi-team development effectively coordinated. Significant early evaluation of product concepts.

		Importance	Performance
12.1	**Spend sufficient time developing and evaluating product concepts.** Are sufficient architectural studies performed, product concepts developed, and analysis and trade studies performed early in the development cycle to select the most optimal product concept? Do development personnel consider trade-off's in product technology, system architecture, manufacturing processes, risk, functionality cost and schedule?	8	6
12.2	**Track critical parameters and interactions.** Are critical parameter such as weight, speed, power requirements, floorspace, etc. closely tracked during the development cycle? Are critical interactions such as heat and reliability understood and managed?	6	4
12.3	**Use an appropriate degree of concurrency in development activities.** Is the product development plan and schedule based on an appropriate degree of concurrent activities balancing time-to-market with development risks? Is this plan supported by sufficient early involvement of the functional disciplines? Is there any formal assessment of the risks vs. the benefits of greater concurrency of development activities?	5	3
12.4	**Learn to work with partial information.** Are development activities undertaken based on preliminary or "partial" information to allow the activity to be conducted more in parallel? Have functional boundaries been minimized to allow information to be readily passed back and forth as development proceeds? As preliminary information is refined, is this readily made available in a timely way to users of that information?	8	6
12.5	**Tightly synchronize development activities.** Are development activities tightly synchronized? Do development personnel understand the critical path? Are the critical path activities adequately resourced to avoid delays?	8	4
12.6	**Coordinate inter-team activities, interfaces and dependencies.** On larger development projects with multiple product development teams, is the development workscope, critical dependencies, and interfaces for each team clearly defined? Does a well-defined process exist for multiple teams/ development personnel to coordinate and manage development activities related to various subsystems and to electrical, mechanical and software design?	9	7
	Development Process Integration Effectiveness Rating		5

13.0 SUPPLIER/SUBCONTRACTOR INTEGRATION			
EVALUATION SCALE			
Traditional (0)	**Developing (3)**	**Committed (7)**	**Best Practice (10)**
Suppliers and subcontractors quote to drawings and technical data packages after design developed. Company believes in benefits of competition and multiple suppliers for each item. Arms length relationship with suppliers and a minimum of information exchanged.	Efforts to reduce number of suppliers and subcontractors, but concern over competition and being taken advantage of dominates. Some early supplier involvement and feedback. Closer working relationship developing with handful of suppliers. Occasional exchange of digital product models.	Active efforts to identify best performing suppliers and reduce number of suppliers and subcontractors to a minimum. Supplier capabilities cataloged. Developing closer working relationship. Suppliers normally involved early with teams. Expectation of supplier feedback. Capabilities being established to regularly exchange digital product models. Some use of collaborative tools and web access.	Small number of suppliers and subcontractors (one supplier per commodity ideal). True partnership. Suppliers treated as team members and proactively provide input. Integrated supplier/company development processes & schedules. Trading partner relationship with maximum exchange of information including digital data & use of collaborative technologies.

		Importance	Performance
13.1	**Effectively involve suppliers and subcontractors early in development.** Are make/buy decisions made early in the development cycle so that suppliers can be effectively involved early in the development process? Are suppliers and subcontractors in fact involved at an early stage to discuss concepts and options prior to a design being developed?	10	5
13.2	**Identify and select suppliers/subcontractors early.** Is the company able to easily identify a supplier or subcontractor to invite to participate early in the development process? Does the company have a database of suppliers' and subcontractors' capabilities and the type of items they can provide to aid in selecting a supplier or subcontractor early? Are preferred suppliers picked on a comprehensive and objective basis that considers performance, process capability, quality, management, etc.?	5	4
13.3	**Achieve a high level of information interchange with suppliers/subcontractors.** Is there a sufficient level of supplier and subcontractor involvement? Is there a high level of information interchange? Are points of contact known within each organization? Is there regular exchange of digital product data (vs. paper documents)? Are extranets, web-based tools, and collaborative systems used to facilitate access to and exchange of information?	10	5
13.4	**Maximize supplier and subcontractor collaboration.** Do supplier and subcontractor personnel actively participate on product development teams or in team meetings? Are collaborative technology tools used to facilitate communication and collaboration with suppliers and subcontractors? Do suppliers and subcontractors have open access to development personnel (rather than dealing only with purchasing or subcontract management personnel)? Do supplier and subcontractor personnel spend considerable time collaborating with development personnel? Are supplier and subcontractor inputs considered and generally acted on?	10	1
13.5	**Minimize suppliers to incentivize early involvement.** Has the company minimized the number of suppliers to incentivize supplier involvement in new product development? Does the company invite a very small number of suppliers to get involved in development for each item (the ideal number is generally one)?	5	1
13.6	**Build long-term partnerships.** Is the relationship with suppliers and subcontractors truly a long-term, partnership with a win-win attitude with both parties? When a supplier or subcontractor gets involved up-front during development, does that supplier or subcontractor generally stay involved for the life of the program? Do both parties regularly share information such as business plans, product plans, technology plans/roadmaps, sales projections, etc.?	5	1
13.7	**Continuously improve buy items.** Do suppliers and subcontractors continue to work closely with the company after the design has been released to further reduce the costs and improve their items? Do suppliers get regular feedback on their performance?	5	3
	Supplier/Subcontractor Integration Effectiveness Rating		3

14.0	PRODUCT LAUNCH		
	EVALUATION SCALE		
Traditional (0) Product launch & transition to production addressed when drawings are released. No pre-planning exists. New equipment, tooling & process documentation acquired or developed after release. Engineering personnel move on to other projects, delaying resolution of open issues.	**Developing (3)** Manufacturing involved prior to release to plan transition, but transition not actively managed. The need for potential new process equipment not recognized until after release. Tooling commitments made after design released. Engineering personnel still tend to move on to other projects prior to stable production.	**Committed (7)** Transition plans & schedules developed, but still not actively managed. New process equipment acquired to support product requirements - some delays caused. Some risks taken with tooling to support rapid transition. Early manufacturing involvement & continuing engineering support to resolve issues.	**Best Practice (10)** Extensive planning, scheduling and monitoring of transition activities. New process development & equipment acquisition made based on technology plans to support production schedules. Tooling decisions made to manage risk & schedule. Early manufacturing involvement & continuing engineering support to resolve issues.

		Importance	Performance
14.1	**Prepare a product launch plan.** Are formal plans and schedules developed for launching new products, transitioning new products into production, or ramping up production? Are facility, production equipment, tooling, computer system, manpower, and training requirements adequately identified and acted upon early in the process to avoid impacting scheduled production/launch dates?	10	2
14.2	**Plan and coordinate production/launch requirements.** Are formal systems such as MRP II / ERP used to construct a manufacturing bill of material, plan production, schedule material requirements and acquire materials for both prototype/pilot product and regular production? For services, are resource planning systems used to determine manpower, training, facility and equipment requirements and coordinate their acquisition? Are realistic forecasts provided to plan requirements considering production ramp-up or launch? Is there close coordination with material and production planning to plan requirements? Are there efficient procurement processes for acquisition of prototype, pilot production, and initial production parts and materials?	5	7
14.3	**Verify process design in realistic setting.** Are pre-production prototypes and pilot/low rate production/process validation runs used to verify manufacturability, process plans, tooling, and costs? Are production status parts used to demonstrate production readiness and support reliability testing? Is intended production equipment and processes used for this purpose? Are manufacturing personnel (versus engineering technicians) involved in the building of pre-production prototypes, pilot production or process validation builds? Are problems or feedback during prototype, pilot production or process validation builds captured and corrective action taken?	7	2
14.4	**Prepare instructions and manufacturing programs thoroughly** . Are adequate process plans, work instructions, or procedures prepared? Is training provided to manufacturing/service personnel? Are computer-aided manufacturing programs (e.g., NC programs, insertion programs, robotic programs, test vectors, dimensional inspection programs, etc.) effectively debugged and tested before production start-up?	10	2
14.5	**Coordinate product launch with Manufacturing and other functions.** Is there effective coordination with manufacturing management regarding transition to production/ramp-up and the impact on existing products? Is there adequate communication, coordination and involvement with remote manufacturing locations?	10	5
14.6	**Resolve product launch problems quickly.** Are problems quickly identified and acted upon? Are yields, defects, documentation or equipment programming errors, service problems, and manufacturing "squawks" formally tracked and closed out? Is there a sufficient level of engineering/product development support to address product launch problems?	10	5
14.7	**Prepare to roll-out the product early.** Is a marketing plan prepared to coordinate all pre-launch and launch activities? Are activities to roll the product out to the market (package design, advertising programs, establishing sales channels, planning distribution, setting inventory levels, etc.) done in parallel with the development of the product to minimize time-to-market? Are the functional disciplines such as marketing, sales, advertising, distribution, logistics, etc. effectively involved early to support these activities? Is early customer testing done and adjustments made in a way to minimize impact on product launch?	10	4
14.8	**Test market the product.** Is the product or service test marketed to gauge customer reaction? Are results analyzed to determine market acceptance and validate or adjust sales forecasts? Are results analyzed to determine what changes may need to be made to the product or service? Are results analyzed to determine what changes may need to be made to market strategy, sales channels, advertising, packaging, related services, etc.?	10	5
14.9	**Prepare to sell and support the product.** Are sales, customer service and product support personnel trained to support the product in advance of its launch? Are they prepared to support a rapid ramp-up?	10	1
	Product Launch Effectiveness Rating		3

15.0	CONFIGURATION MANAGEMENT		
EVALUATION SCALE			
Traditional (0) Occasional problems with version & configuration control. Requires significant manual effort to manage. Poor part numbering practices undermine CM. Long engineering release and engineering change cycle times (>2 months) with cumbersome review and approval process.	**Developing (3)** Basic version control in individual systems for digital product data. Good configuration control, but based on control of physical documents. Effective engineering change control, but process is cumbersome. Configuration status can be readily determined. Good part numbering practices facilitate CM.	**Committed (7)** Product data management (PDM) systems in place for basic product data and used for configuration control. CM focus has shifted to digital data. Engineering change control process has been streamlined. Effective CM systems in place with subcontractors.	**Best Practice (10)** Product data management systems in place for all product data with good version & configuration control of digital data. An efficient release and engineering change process has been established (cycle time <5 days). There is effective CM of in-process design data. Subcontractor CM process tied into company's PDM system.

		Importance	Performance
15.1	**Manage product configuration.** Is there an effective configuration management system in place? Are there physical or software controls over all approved and released design documentation and files? Is there a single source (physical vault, electronic vault, repository, or library) recognized as the master for design documentation and files?	10	9
15.2	**Establish a comprehensive release process.** Is there a well-controlled, comprehensive release process in place? Does the release process focus broadly on all product and process documentation or data to support production of a new product (rather than focusing just on drawings and parts lists)? Do appropriate parties or systems get needed information in a timely manner?	10	9
15.3	**Maintain file and document relationships.** Is there a system in place to associate the various design documentation and files to the product model to help maintain overall the configuration? Do drawings, parts lists, net lists, test programs, CAE analysis, NC programs, process plans, etc. have versioning and linkages to properly associate these documents/files to the product and underlying product model?	5	3
15.4	**Manage in-process design configuration.** On larger programs, is there a check pointing system in place to periodically designate the most current version of the design for other teams or development personnel to access? Are there effective controls to prevent personnel from working with old or out-dated design documentation, files, or product configurations?	5	6
15.5	**Identify version and configuration status.** Is the most current, approved version of design documentation and files clearly identified. Is the status of other versions of design documentation and files clearly identified? Can the company determine the release status and configuration status of all items under development or in production at any time?	5	6
15.6	**Use good part numbering practices.** Are there good configuration practices in terms of part numbering and revision identification? Are changes to fit, form or function identified with a new part or item number? Is a common part numbering system used in Engineering, manufacturing and Product Support?	5	9
15.7	**Establish effective change controls.** Is there an effective change control process in place? Is this process understood and followed consistently? Are engineering changes tracked and their status clearly identified? Are the costs of engineering changes versus the value of the change determined? Is the effectivity of changes clearly identified?	5	8
15/8	**Streamline review and approval process.** Are the release process and engineering change process efficient? Is there a minimum of review and approval steps? Are they performed in a minimum amount of time? Is there a prioritization system to act on high priority changes even more quickly?	10	9
15.9	**Establish effective subcontractor/supplier CM system.** Is there an effective configuration management and engineering change system in place for subcontractors and suppliers? Do supplier's and subcontractor's configuration management systems conform the company's systems and policies?	5	6
	Configuration Management Effectiveness Rating		8

16.0 DESIGN ASSURANCE

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
Ad-hoc design reviews called at last minute. There may not be a standard approach or a policy to guide them. Design reviews focus on technical issues. Little focus on design assurance during development or significant after-the-fact effort to review designs for errors or deficiencies. Design issues not effectively tracked and may get overlooked.	Policy requires design reviews at designated points in development cycle. Design reviews are addressing more of the substantive issues - producibility, reliability, maintainability, testability, safety, cost, risk, etc. Design review action items are tracked. A disciplined process of design checking by separate functional group exists. Design verification and validation is performed, but not consistently nor with design-intent parts or production-intent processes.	Critical to Quality characteristics are understood and controlled. Design verification and validation is consistently performed with design-intent parts or production-intent processes. An effective design review process exists that involves the right people and addresses all substantive issues. Design review action items and open development issues are tracked to resolution. Development personnel recognize and accept their responsibility for design assurance.	Plans are developed to proactively counter past development problems and defects. As development personnel internalize the design assurance function and integrate design checking into the design process, the need for outside reviews and separate checking functions is reduced and the process is streamlined.

		Importance	Performance
16.1	**Plan to counter prior defects.** Does the project team meet at the beginning of the project to review product defect statistics from prior projects and plan defect prevention activities or countermeasures? Is an advance quality plan (AQP) prepared? Do development personnel review product defect metrics during and at the conclusion of the project?	6	2
16.2	**Identify and control critical to quality (CTQ) characteristics.** Are CTQ characteristics identified in a logical manner based on customer needs? Is there a way to flow these critical/significant characteristics down to the design or specification of an individual part, assembly, software module, or service element (e.g., QFD deployment, process planning and process control matrices)? Is a control plan prepared to define process controls and inspection steps for controlling these critical/significant parameters in production or procurement?	6	2
16.3	**Track and analyze development problems.** Are development issues and problems formally captured and tracked until problems are resolved? Are action items from design reviews formally tracked (e.g., action item list) until closure? Are causes for engineering changes identified? Are the root causes of development problems, design review action items, and engineering changes identified and analyzed? Is corrective action taken to reduce these problems?	8	7
16.4	**Establish responsibility for design assurance.** Do development personnel and product development teams feel a strong sense of responsibility for design assurance? Do development personnel and product development teams conduct thorough drawing reviews or code walk-through's prior to any formal design reviews?	8	7
16.5	**Integrate design checking with design.** Is design checking done? Is it done by designers and CAD operators (versus a separate functional group)? Are there relatively few drawing, documentation, or file errors on released documents or files?	4	5
16.6	**Perform formal design verification.** Does the process include formal steps for design verification? Design verification may include activities such as: performing alternate calculations; simulation and analysis; design reviews; testing, demonstration and qualification; and review of design documents before release. Is design verification consistently performed on all aspects of the design before release? Is there clear evidence of design verification?	9	7
16.7	**Establish a common design review process.** Are there well-defined milestone points at which design reviews are conducted? Are design reviews consistently performed? Are the required inputs or documentation for the review clearly defined? Are there guidelines or an agenda for conducting design reviews? Are they effective? Are they followed?	8	6
16.8	**Facilitate proper participation in design reviews.** Are the participants in the design reviews clearly identified? Are design reviews staffed with senior, experienced, objective personnel who can provide valuable perspectives? Do design reviews include personnel from disciplines other than just engineering and program/project/product management? Are design reviews scheduled far enough in advance so that the appropriate personnel can attend?	7	7
16.9	**Address all substantive issues in design reviews.** Do design reviews address substantive issues and not serve as a project briefing? Do design reviews address factors such as producibility, reliability, maintainability, testability, safety, cost, risk, compliance with standards, etc. in additional to technical performance? Are the design reviews performed in a positive manner (rather than as a witch hunt or in an overly critical way)?	9	8
16.10	**Internalize design assurance.** As development personnel and product development teams/integrated product teams take responsibility for design assurance and quality, are outside reviews, design checking, and approval steps kept to a minimum to avoid project delays and unnecessary bureaucracy?	2	7
16.11	**Perform product, process and service validation.** Are the product and process or service formally validated to assure that it meets its requirements or specifications? Is this validation performed with design-intent parts and production-intent processes? Is it performed with the production personnel or service personnel that will produce the product or provide the service? Are discrepancies formally identified and resolved?	8	7
	Design Assurance Effectiveness Rating		6

17.0 PROJECT AND RESOURCE MANAGEMENT

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
Formal project management methods are not used. Projects are planned on an ad-hoc basis. Project management system tools are lacking or not readily accessible. No attempt is made to plan required development resources. Personnel are assigned as available. Periods of significant over- & under-utilization exist, and many projects are delayed.	Project management systems are used to plan & manage significant projects, but systems and processes may not be standardized. Resources for major projects are planned & committed based on the project plan, but overall resource management is lacking. Where required, a good cost/schedule discipline exists. Periods of over- & under-utilization exist, and some projects are delayed.	Common PM system used to plan all significant development efforts. Teams are involved in the planning process. Resources are planned & committed based on the project plan and a resource plan. Resources are still over-committed, and management "spreads" resources to address multiple needs. Activities are monitored based on this plan and a good cost/schedule discipline exists.	Teams rigorously plan, monitor & maintain project plans. Planning templates are used to aid & standardize planning. Critical chain method used. Plans reflect a parallel mode of development. Project & department resource requirements identified & capacity managed. Project priorities determined & over-committing avoided. Projects adequately resourced considering time-to-market requirements.

		Importance	Performance
17.1	**Prepare a development plan considering prior performance.** Does the company prepare a development budget and schedule for the project? Is a standard project template available and used to facilitate project planning? Are prior projects budgets and actual's, schedules, problems, and lessons learned used as the basis for developing the current project plan?	5	4
17.2	**Create a comprehensive, realistic plan.** Are the development budgets and schedules integrated, comprehensive and realistic? Do they reflect an adequate level of early involvement from the necessary functional disciplines?	10	5
17.3	**Use critical chain method.** Is the critical chain method (CCM) of project management used? The critica chain method removes padding from individual tasks and instead establishes buffers. It focuses on understanding the critical chain and addressing bottlenecks. Has schedule performance been improved with the use of CCM?	10	5
17.4	**Obtain personnel's commitment to the plan.** Do development personnel or product development teams prepare or assist in the preparation of the budget and schedule? On a larger project, do development personnel or product development teams review and buy into the higher level development schedule and budget? Do they then prepare lower level budgets and detailed schedules based on the higher level budgets and schedules?	10	4
17.5	**Communicate plans and responsibilities.** Is the project plan communicated to all involved development personnel? Does each person involved in the development project have access to the project plan? Is there a clear understanding of who has responsibility for each task and deliverable required by the project?	10	8
17.6	**Identify project staffing requirements.** Does the development plan include a time-phased manpower or staffing plan with estimates of the number of design engineers, designers, CAD operators, manufacturing engineers, test engineers, purchasing representatives, marketing personnel, etc., that the project requires including identification of skill levels, special skills, and experience requirements?	5	3
17.7	**Plan development resource requirements.** Is a resource plan or manpower loading prepared which identifies the requirements for manpower across all product development projects and other functional department requirements and compares these requirements with manpower available by time period? Does the company plan support resources such as facility space, workstations, computers, software licenses, meeting/project rooms, etc.?	10	6
17.8	**Allocate and manage resources.** Does functional management effectively use the resource plan to manage, allocate and assign manpower or make decisions about outsourcing/ contracting for development resources? Do program/ project/ product managers and executive management effectively prioritize projects, coordinate resources across projects, and make the tough decisions about deferring projects or acquiring additional resources when not enough resources are available?	10	7
17.9	**Integrate subcontractor/supplier plans.** Does the company review and approve subcontractor project plans? Are these plans integrated into the overall project plan? Does subcontract management and program/project/product management regularly review subcontractor costs, schedules, and technical performance?	5	2
17.10	**Assess project progress regularly.** Is there a regular (monthly is ideal) assessment of costs incurred against the budget? Is there a regular assessment of costs against earned value? Is there a regular (at least quarterly) assessment of estimate to complete and estimated cost at completion? Is there a regular assessment of actual progress against scheduled progress? Of technical performance against cost and schedule?	5	3
17.11	**Update plans and manage the project.** Is product development project's progress and performance used to manage the project and take corrective action when necessary? Is the development plan regularly updated to reflect actual progress, available resources, and plan changes?	5	4
	Project & Resource Management Effectiveness Rating		5

18.0	DESIGN FOR MANUFACTURABILITY		
	EVALUATION SCALE		
Traditional (0) Drawings reviewed for producibility just prior to or after release. EC's requested for major problems. Minimal understanding of DFM principles and producibility guidelines lacking. Training non-existent. DFM not a company objective.	**Developing (3)** Awareness of DFM is developing. Some initial training provided. Initial producibility guidelines being developed. Pilot efforts with DFM analysis. Some standardization. Preferred parts list used. Critical processes being identified to determine capabilities. DFM not perceived as a management- level issue.	**Committed (7)** Importance of DFM generally recognized. Training provided. DFM principles commonly understood. More comprehensive producibility guidelines developed. Active standardization efforts. Significant component library. Some DFM analysis tools regularly used. Most process capabilities understood.	**Best Practice (10)** DFM is an accepted management objective. Training provided. DFM principles commonly understood. Designs are highly producible. High degree of standardization and modular design. Producibility guidelines regularly maintained. Guidelines embedded in design systems. Appropriate DFM tools used. Process capabilities well-understood.

		Importance	Performance
18.1	**Apply design for manufacturability.** Is design for manufacturability/assembly (DFM/A) recognized by all development personnel as an important objective? Is there a formal effort to incorporate DFM/A in development projects? Does management assess the use of DFM/A or the DFM/A results during development?	10	9
18.2	**Develop DFM/A expertise.** Do development personnel have a sufficient level of expertise in manufacturing processes and tooling to address manufacturability? Do development personnel have a sufficient level of knowledge in DFM/A principles and application? Has there been formal training in DFM/A for development personnel?	5	3
18.3	**Establish manufacturability guidelines.** Are there guidelines, rules or design standards related to manufacturability or producibility? Are they comprehensive and complete? Are they understood? Are they consistently applied? Are they regularly reviewed, maintained and updated as processes, materials, components, and technology changes? Has training been provided in the application of producibility guidelines, rules or design standards? Have DFM/A design rules been built into design automation systems (e.g., PCB layout, etc.)?	5	3
18.4	**Develop understanding of process capabilities.** Are manufacturing process capabilities understood and documented? Are development personnel familiar with manufacturing facilities, equipment, and process capabilities? Is there any type of job rotation program for engineering personnel to spend time in Manufacturing and become familiar with manufacturing processes, capabilities and issues?	5	3
18.5	**Use DFM/A analysis tools.** Are any DFM/A analysis tools (manual or computerized) used as a normal part of the development process to assess manufacturability of part, assembly and product designs? Are tools available to assess manufacturability of the major fabrication processes (e.g., sheet metal, machining, injection molding, etc.) used by the company? Are tools available to assess manufacturability of the major assembly processes (e.g., manual assembly, automated assembly, PCB assembly, etc.) used by the company?	5	3
18.6	**Establish DFM/A metrics.** Are DFM/A metrics (e.g., parts count, labor time, cost, "design efficiency", etc.) used by development personnel to assess manufacturability and compare design approaches? Are specific DFM/A targets established and monitored during development? Are projected labor times, machines times, and costs compared with actual experience and used to validate DFMA guidelines and analysis tools?	3	0
18.7	**Invest sufficient effort in manufacturability.** Is there a sufficient level of effort to assess and improve manufacturability during the development of a new product? In addition to any manufacturing engineering or tool engineering involvement in development, are shop floor personnel involved to provide first-hand feedback on product, process and tool designs?	10	5
18.8	**Achieve DFM/A improvements.** Have tangible DFM/A results been achieved to date? Have part counts been reduced in later generation products? Have labor and machine times been reduced? Have recurring production costs been reduced? Have tooling costs been reduced? Has "design efficiency" improved? Have engineering changes related to producibility been declining?	5	3
18.9	**Use modular design approach.** Does the company utilize a modular design approach for hardware and software? Are core modules utilized for new designs to reduce design effort, standardize, and reduce manufacturing costs?	5	5
18.10	**Standardize parts and materials.** Is there an effective effort to standardize materials, parts and components? Is there a management emphasis and supporting policy on standardization and use of preferred parts? Is there a preferred parts list? Is there a materials/parts catalog to identify standard parts/materials and like parts? Is there a group technology coding and classification systems to aid in identification of like parts and part families or catalog?	10	9
18.11	**Establish a common component library.** Is there a single, company-wide standard materials/parts/components/cell library? Does the library provide information for all disciplines (e.g., physical properties; geometry; functional characteristics; performance; reliability data; test data, procurement sources, costs, leadtimes and availability; etc.)? Is the library linked to applications and decision support systems to facilitate the selection and use of materials/parts/components/ cells? Is there a standard library for tooling and fixtures?	5	3
18.12	**Design for environmental production.** Is there a formalized program to design for environmental production? Is the program proactive instead of reactive? Is there an active effort to reduce energy consumption with production processes? Is the company identifying and reducing toxic or polluting production materials (e.g., CFC's, heavy metals, solvent emissions, etc.)? Is the company minimizing the environmental impact of packaging?	5	1
	Design for Manufacturability Effectiveness Rating		5

19.0	PRODUCT COST MANAGEMENT		
EVALUATION SCALE			
Traditional (0) Cost targets are not established. Development personnel do not have access to cost data. Costs are not used as a decision criteria during development. Cost estimates established after the design is developed; major problems cause significant redesign.	**Developing (3)** Target costs established but not used to guide development decisions. Team access to cost data limited. Typically, one team member focuses on product costs, and cost models are used to accumulate estimates, but not until later in the development cycle. Better models are being developed & improved.	**Committed (7)** Target costs established and used to guide team decisions. Management focuses attention on achieving cost targets. Team is sensitive to customer affordability. Team not always able to access timely & meaningful cost data. Capable product & life cycle cost models are being used regularly to track design-to-cost performance. Existing models are being improved. Managing cost still reactive.	**Best Practice (10)** Strong management emphasis on designing to cost target. Entire team is sensitive to affordability. Strong focus on customer value, function analysis, & exploring design alternatives. Team has full access to timely & meaningful cost data. Robust product & LCC models exist & have been validated with actual experience. Costs actively managed. On-going effort to reduce costs with value engineering.

		Importance	Performance
19.1	**Establish a sound basis for cost estimates.** In preparing customer proposals or developing a business case for a new product, is there a sound basis for developing product cost estimates? Is a formal cost estimating system used? Are appropriate disciplines involved in the development of the cost estimates, are they committed to the product cost estimates, and do they sign off on the proposal or cost estimate?	5	5
19.2	**Establish target costs to guide product development.** Are target costs or design to cost objectives established based on customer affordability and competitive product costs? Are target costs allocated down to subsystems, assemblies, component parts, or service elements to support a target cost or design to cost approach? Is cost treated as an independent variable to be achieved along with other customer requirements rather than as dependent on the product design?	7	6
19.3	**Create awareness of affordability requirements.** Are development personnel aware of and sensitive to customer affordability requirements and competitive pressures? Are they involved in establishing target costs and are they committed to achieving target costs?	7	8
19.4	**Provide full access to cost data.** Do development personnel have full access to cost data to support estimating and costing? Is historical cost data maintained in a manner that is easily accessible? Is cost data organized in a useful manner?	7	9
19.5	**Develop and use comprehensive cost models.** Are product cost models or cost estimating systems used to project product costs from an early point in the development cycle? Are the cost models able to project costs based on characteristics of the product (parametric) rather than merely accumulate estimated costs? Are these cost models comprehensive? Do they consider all significant cost elements? Do they cover the various fabrication and assembly processes used to build the product?	6	5
19.6	**Evaluate life cycle costs or cost of ownership when appropriate.** If appropriate, are life cycle cost or cost of ownership models used to project product acquisition costs, operating costs, support costs and disposal costs? Is the life cycle costs or cost of ownership model comprehensive? Does it address all significant cost elements? Is the company able to accumulate reasonable data to support life cycle costing or cost of ownership (e.g., operation and support costs, etc.)?	5	4
19.7	**Insure valid, consistent cost projections.** Are the cost model projections periodically validated against actual experience? Is the basis for handling allocated costs in the costs models consistent with accounting practice?	7	7
19.8	**Determine and understand cost drivers.** Do development personnel understand the product's or system's cost drivers? Is there sufficient consideration of the cost drivers in initially establishing requirements and during the development cycle?	6	6
19.9	**Evaluate the costs of design alternatives.** Do development personnel regularly perform cost studies or develop cost estimates to assess alternate design approaches to best meet cost targets? Do they regularly use product or life cycle cost models to explore design alternatives? Are different fabrication and assembly options adequately considered? Do development personnel proactively consider product and life cycle costs in making decisions during the development cycle?	7	4
19.10	**Monitor target cost achievement.** Does executive management and program/ project/ product management monitor the achievement of target costs or design to cost objectives? Do development personnel track the progress in achieving costs targets?	7	7
19.11	**Improve indirect cost allocation.** Does the company use activity based costing (ABC) to provide a sounder basis for allocating indirect costs to products for both estimating and accounting purposes? Is the company satisfied with the allocation of indirect costs to products? Do development personnel understand the indirect cost drivers and their relationship to design decisions?	7	8
19.12	**Use value engineering/analysis.** Are value engineering or value analysis techniques commonly used to analyze function vs. cost and support cost reduction or value improvement?	8	3
19.13	**Reduce product costs continually.** Have product costs in terms of real monetary units (e.g., dollars, yen, pounds, francs, etc.) been declining relative to product capability and complexity? Have engineering changes related to after-the-fact cost reduction (vs. proactive cost reduction during development) been declining?	7	6
	Product Cost Management Effectiveness Rating		6

20.0 ROBUST DESIGN

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
No formal methodologies to develop a robust design. Quality and reliability analysis, when done treated as a compliance requirement. Strategy is added design margins, de-rated components, and tighter tolerances. Minimal reliability/stress testing.	Initial efforts to gather quality and reliability data from the field, but formal systems lacking and only major problems acted upon . DOE used in Manufacturing to solve process problems. Reliability methods minimally used when not required. Reliability/ stress testing performed for critical items.	Systems being developed to gather quality and reliability data from the field and regularly act on problems. DOE used some during development to solve problems. Reliability predictions developed. Initial use of reliability analysis tools. Moderate reliability/stress testing. Early efforts to mistake-proof design. Good focus on safety.	Robust design is a recognized objective. Quality and reliability data gathered from the field and problems acted upon (FRACAS). DOE actively used during development to optimize critical parameters. Actual reliability compared to predictions to improve models. FTA, FMECA, and other analysis tools used. Extensive reliability/stress testing. Strong focus on safety.

		Importance	Performance
20.1	**Understand the product's or service's operating environment.** Is there an adequate understanding of the operating environment in which the product will be used (or even mis-used) or the service performed? Are the operating environment and the reliability requirements of the product addressed in the product specifications? Are counter-measures for potential product mis-use considered? Is the full operating environment addressed in the design of the product or service?	10	7
20.2	**Establish capable processes.** Are capable production, software development or service processes in place. Process capability is the repeatability and consistency of a manufacturing, software development, or service process relative to the customer requirements in terms of specification limits of a product or service parameter. Has process capability been statistically determined?	10	8
20.3	**Control critical to quality (CTQ) characteristics.** Do development personnel understand what product characteristics or parameters are critical to the successful operation of the product? Are the required CTQ characteristics within the process capabilities of the organization or its suppliers? Have control plans been established to monitor these CTQ characteristics?	10	7
20.4	**Use analysis, design of experiments, or Taguchi Methods to optimize product parameters and minimize variability.** Are analysis, design of experiments (DOE), or Taguchi Methods regularly used to optimize product, process, quality and reliability parameters and minimize the effects of variability? Is continuing attention focused on optimizing these critical parameters throughout the development cycle?	5	3
20.5	**Establish realistic tolerances.** Do development personnel establish realistic tolerances that balance the cost of achieving the tolerance with the requirements of the design (rather than over specify tolerances to protect themselves)? Are tolerances within the organization's process capabilities? Are statistical tolerancing, tolerance modeling, and tolerance analysis tools used to focus attention on critical tolerances in terms of "fit"?	5	3
20.6	**Mistake-proof the product or service.** Do development personnel focus on mistake-proofing the fabrication, assembly or coding of the product? Do development personnel focus on mistake-proofing the operation/performance of the product or service? Do development personnel work at making operating instructions and manuals, product markings, and warnings clear, easy to understand, and robust?	5	3
20.7	**Design for reliability.** Is there a sufficient level of effort to assess and improve reliability during the development of a new product? Are reliability engineers involved in product development at an early stage and at a sufficient level? Are they able to adequately influence reliability considerations?	10	7
20.8	**Measure reliability results.** Are specific reliability targets established and results monitored during development? Is a reliability growth program in place? Does management assess reliability results during development? Is projected reliability compared with actual experience?	5	3
20.9	**Establish reliability guidelines.** Are there guidelines, rules, or design standards related to reliability? Are there guidelines for de-rating components? Are guidelines, rules, or design standards understood? Are they consistently applied? Are they regularly reviewed and maintained? Are there efforts to study the physics of failure and use this information to improve how parts and materials are used for product development?	5	2
20.10	**Use reliability analysis tools.** Are reliability prediction programs/models used to assess the reliability of the design during the development cycle? Are other reliability analysis tools used to support product development?	5	2
20.11	**Use reliability techniques to analyze faults/failures and enhance reliability.** Are techniques such as fault tree analysis (FTA), failure mode and effects analysis (FMEA), failure modes, effects, and criticality analysis (FMECA), or anticipatory failure determination used to identify and mitigate sources of reliability problems? Are these results used to proactively improve reliability versus jut complying with customer or regulatory requirements? Are these tools used to analyze and mitigate failures with both the product and process?	5	1
20.12	**Use testing to improve reliability.** Is environmental stress testing (EST), accelerated life cycle testing, or strife testing used to identify and correct reliability problems in the product design?	10	9
20.13	**Track failures and take corrective action.** Are production failures tracked and analyzed? Is warranty data related to failures maintained and analyzed? Is the company able to capture and analyze in-service/field reliability data (beyond the warranty period for the entire product life cycle)? Is there a failure reporting and corrective action system (FRACAS) to report and track failures in the field and track corrective actions? Is this reliability and failure information analyzed and used to improve the design of new products?	10	6
20.14	**Design for product safety.** Is sufficient attention paid to product safety? Are there guidelines and design standards related to safety? Are safety engineers involved at an early point in the development cycle? Where appropriate, is hazard analysis performed? Is there sufficient safety testing?	5	5
20.15	**Achieve reliable and safe designs.** Have there been tangible improvements in robustness, reliability and safety for new products? Has mean time between failures (MTBF), failure rates, and accident rates improved? Have engineering changes related to reliability and safety been declining?	5	5
	Robust Design Effectiveness Rating		5

21.0	INTEGRATED TEST DESIGN AND PROGRAM		
	EVALUATION SCALE		
Traditional (0) Test engineering is involved late in the development process. As a result designs are difficult & expensive to test. Few tools exist to support test development & test is a relatively expensive development activity. Minimal developmental testing is performed and problems are identified during acceptance testing or in the field.	**Developing (3)** Customer requirements forcing more focus on test. Role of test engineering improving. Some involvement working with designers to improve testability. Initial tools to take functional design data to generate test programs. Test plans developed early in cycle. Minimal developmental testing is performed and problems are identified during qualification or acceptance testing.	**Committed (7)** Test engineering becoming actively involved in development. Well defined DFT approaches, but not as well understood outside test engineering. Economics of DFT not considered. Moderate degree of test coverage achieved. Efforts to utilize standards under way. Better tools to develop test programs. Early test plans. More developmental testing performed.	**Best Practice (10)** Test requirements are resolved upfront. Test participates on the team & actively influences the design balancing cost, functional requirements, & quality objectives. High degrees of coverage achieved. Test results used to identify process problems. DFT practices well-understood. Tools integrated with CAD/CASE support test (e.g., ATPG). Test standards commonly used.

		Importance	Performance
21.1	**Develop a test strategy.** Is there a clearly defined strategy and overall plan for developmental testing, certification/qualification testing, acceptance testing, field testing, self-test, etc.? Do development personnel understand this strategy and plan?	5	8
21.2	**Consider economics in developing the test plan.** Is economic analysis performed to determine an optimum test strategy, level of testing, and test coverage? Is this analysis used to resolve trade-off's in test strategy (test effort; floorspace requirements to support test on boards and semiconductors; use of built-in self test; dedicated custom test equipment and fixtures vs. standard test equipment and fixtures, etc.) and develop a test plan?	5	8
21.3	**Establish testability targets.** Is there a well-defined process for identifying test requirements (e.g., quality function deployment, requirements matrix, analysis of critical functions, etc.)? Are test requirements defined in the product specification? Are specific testability targets (e.g., percent fault coverage, etc.) established and test metrics and results monitored during development? Does management assess testability results during development?	5	9
21.4	**Prepare test plan early.** Is a test plan developed early in the project based on customer requirements and company strategy? Is the test plan comprehensive? Is the test plan reviewed and understood by development personnel? Is it reviewed and approved by program/ project/ product management Are customers involved in defining test requirements and reviewing test plans and procedures?	10	8
21.5	**Develop test procedures and equipment in parallel with product.** Are test procedures developed in parallel with the product? Are they thorough and complete? Is test equipment designed, specified, acquired, and/or constructed in parallel with the development of the product to avoid delaying product testing?	5	9
21.6	**Assess product testability.** Is there a sufficient level of effort to assess and improve testability during the development of a new product? Are test engineers involved in product development at an early stage and at a sufficient level? Are they able to adequately influence testability considerations?	10	5
21.7	**Establish testability design guidelines.** Are there guidelines, rules, or design standards related to testability? Are they understood? Are they consistently applied? Are they regularly reviewed and maintained? Are industry standards for test (e.g., boundary scan - IEEE 1149.1, etc.) regularly used?	5	9
21.8	**Develop testability expertise.** Are development personnel familiar with testability principles (e.g., accessibility, partitioning, control, visibility, etc.)? Are development personnel familiar with testability guidelines rules and design standards? Have development personnel received any formal training related to design for testability?	5	8
21.9	**Use test results to improve the product & process.** Is development testing done when the product, subsystem or item can't be readily simulated to mature the product design as soon as possible? Is performance/certification or qualification testing done to ensure the product meets design specifications? Are acceptance testing results used not only for product assurance, but to monitor and improve the production process and improve the product design?	10	1
21.10	**Automate testing where appropriate.** Is there an effective use on built-in self test where that is appropriate? Is there an adequate level of test automation? Is there a sufficient level of automated test pattern generation or use of automated test cases?	5	7
21.11	**Perform software quality assurance.** Is there an effective software quality assurance (SQA) program in place? Consider the Software Engineering Institute's process maturity assessment relative to SQA if one has been performed.	5	4
21.12	**Involve customers in testing when appropriate.** Are customers effectively involved in testing (operational evaluation and testing, acceptance testing, beta testing, field evaluation, etc.) where appropriate? Is there effective planning, coordination, communication and feedback from customer test involvement? Is customer feedback effectively utilized to improve the product?	5	7
21.13	**Balance testing and time-to-market considerations.** Are time-to-market considerations properly balanced out with sufficient testing and evaluation? Is a sufficient level of developmental testing done or is qualification and acceptance testing used inappropriately to identify design problems? Testing should be thorough and necessary fixes to the product or process should be acted upon quickly. This should be balanced out with a streamlined approach to testing that minimizes delays while getting a product to market quickly.	5	8
21.14	**Improve testability and testing.** Have there been tangible improvements in testability and test coverage for new products? Have test costs relative to product complexity, product capability, regulatory requirements, and customer test requirements declined? Have engineering changes related to testability been declining?	5	0
	Integrated Test Design and Program Effectiveness Rating		6

22.0	DESIGN FOR OPERATION AND SUPPORT		
EVALUATION SCALE			
Traditional (0) Product service/support/ maintainability not considered as part of the design cycle. Separate functional discipline assesses spares requirements & maintenance procedures after design. No guidelines, analysis tools or models used.	**Developing (3)** Product support function(s) is a member of the team, but supportability analysis & documentation still developed later in the development cycle. Maintainability principles understood, but no formal guidelines exist. Basic analysis tools & models used for compliance purposes only.	**Committed (7)** Product support function(s) is an active member of the team. Maintainability principles understood and guidelines documented. No formal support strategy exists; team works to an implied strategy. Analysis tools & models beginning to be used to assess & influence the design. Automated logistics analysis.	**Best Practice (10)** Product support function(s) is an active member of the team. Maintainability principles commonly understood. Product support strategy well-defined & customer, company or support organization capabilities known. Maintainability guidelines exist; training provided. Analysis tools & models used. Metrics used to guide decision-making.

		Importance	Performance
22.1	**Design for product support.** Is there a clearly defined strategy and policy for product support and maintainability/serviceability (e.g., what types of repairs and maintenance will be performed by customers, modularity, etc.)? Do development personnel understand this strategy or policy?	5	3
22.2	**Establish maintainability/serviceability targets and measure results.** Are maintainability/ serviceability requirements defined in the product specification? Are specific maintainability/ serviceability targets established and projected results monitored during development? Does management assess maintainability/ serviceability projected results during development? Are projected results compared with actual experience?	3	1
22.3	**Invest sufficient effort in maintainability/serviceability.** Is there a sufficient level of effort to assess and improve maintainability/ serviceability during the development of a new product? Are maintainability, product support or service engineers involved in product development at an early stage and at a sufficient level? Are they adequately able to influence maintainability/ serviceability considerations?	6	5
22.4	**Establish maintainability/serviceability design guidelines.** Are there guidelines, rules, or design standards related to maintainability/ serviceability? Are they understood? Are they consistently applied? Are they regularly reviewed and maintained?	5	2
22.5	**Develop maintainability/serviceability expertise.** Are development personnel familiar with maintainability/ serviceability principles (e.g., accessibility, modularity, ease of disassembly, common hand tools, etc.)? Are development personnel familiar with maintainability/ serviceability guidelines rules and design standards? Have development personnel received any formal training related to design for maintainability/ serviceability?	5	2
22.6	**Apply customer input to enhance maintainability/serviceability.** Do customer maintenance/ service personnel provide input to product development or are they involved in product development? Is customer feedback used to improve maintainability/serviceability?	5	2
22.7	**Use analysis tools.** Are analysis tools (e.g., human factors modeling, maintenance/service simulation, design for disassembly analysis tools, level of repair analysis, life cycle cost models, etc.) used to support product development? Are maintenance/service procedures modeled or simulated? Are logistics analysis and spares modeling tools used to support product development, to establish a sufficient maintenance/ field service capability, and to establish appropriate spare parts inventories?	3	1
22.8	**Address human factors in design.** Are human factors related to operation and support of a product adequately considered in the development of a new product? Are there guidelines, rules, or design standards related to human factors? Are they understood? Are they consistently applied? Are human factors engineers effectively involved early in the development cycle?	3	2
22.9	**Begin developing product documentation early.** Is product documentation (operating instructions, operating manuals, maintenance manuals, etc.) and training developed in parallel with the product? Are technical writers and trainers effectively involved on product development teams?	5	4
22.10	**Design for environmental operation.** Is there adequate consideration of environmental operation objectives (e.g., minimize energy consumption, minimize emissions, etc.) during product development? Is there a proactive effort to minimize toxic materials and maximize recyclability? Are there guidelines, rules, or design standards related to environmental design and recyclability? Are environmental considerations and disposal costs factored into a life cycle model?	5	2
	Design for Operation and Support Effectiveness Rating		3

23.0 PRODUCT DATA

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
Paper is used as the primary medium for communicating product data. "Sneaker-net" used to move data among systems with proprietary formats. Delays in getting needed data. No data management. No product data standards.	A variety of digital product data is created, but it is output to paper as the design authority. Translators used to move data between application systems, but are cumbersome. Data redundancy. Basic version control in individual systems for digital product data.	Most product data is captured in digital form. The digital product model is sometimes the sole design authority. Translators used to move data between application systems smoothly. Some data redundancy. Product data management systems in place to manage product data.	All product data is captured in digital form and the digital product model is the sole design authority. Systems are tightly integrated to work with a common model. Heavy use of product data standards with efforts to use STEP. Product data management systems in place for all product data with good version control.

		Importance	Performance
23.1	**Maintain product information in digital form.** Is a major portion of product and process data stored and managed in digital or electronic format? Has most legacy data (data created by past "systems" such as drawings and other documents) been translated to a digital format (rasterized or translated to vector or object representations)?	5	6
23.2	**Use digital product model and data as the master record.** Are the company's product design "documents" of record in the form of digital product models or electronic databases rather than paper documents or drawings? Are these records considered as the basis for release for the product design, the basis for inspection and testing, and the basis for certification or regulatory approval? If there's a discrepancy between the "master" drawing and the digital product model, is the digital product model considered correct?	10	9
23.3	**Ensure availability of digital product data.** Is product data created by the product development team available to all team members and project personnel online? Is product data available online to all non-development personnel who have a need (e.g., manufacturing, product support, procurement), avoiding the use of paper drawings and other documents as the means of communication? Is there minimal use of paper for communicating product and technical information inside the company?	10	8
23.4	**Provide effective systems environment.** Is there an effective systems environment that provides rapid access to product information? Can product data be accessed without time-consuming file translation steps or relying on paper documents? Are there sufficient terminals and workstations to provide access without waiting?	5	7
23.5	**Maintain a common product database.** Is product development data stored and managed in a common logical database? Is there a common database for embedded software or software products? Can this data be accessed and used directly without re-entry of data into a separate database or without cumbersome translation steps?	5	5
23.6	**Maintain a complete digital product model.** Does the "digital product model" for new products generally contain most product and process data? This would include specifications, functional information (e.g., weight, performance, schematics, logic models, etc.), geometric information, product structure and configuration information, analysis information, administrative information, manufacturing process information, testing information, and product support information?	5	6
23.7	**Manage digital product data with a PDM system.** Is a product data management system used to manage access and changes to product data, relationships among product data, versioning, and the approval process through workflow capabilities? Is there an effective data management and configuration control system for embedded software and software products?	10	3
23.8	**Use common product data standards.** Does the company use a common CAD system and CAE/CAM applications that can directly work with this data format. Do company applications work with a common modeling kernel (e.g., ACIS, Parasolids, etc.) or framework? Is a direct translator used between applications? Are product data and data exchange standards such as IGES, EDIF, SET or VDA used? Does the company have an effort underway to transition to future product data standards such as STEP (ISO 10303)? Order of preference for rating is: common CAD/CAE/CAM system, common CAD modeling kernel or framework, direct translator, STEP data exchange, or other data exchange standard such as IGES or EDIF.	5	7
23.9	**Use electronic interchange with suppliers/subcontractors.** Does the company regularly exchange product and technical information with suppliers and subcontractors electronically? Is supplier and subcontractor technical data which is provided to the company, provided in an electronic format? Does the company have a strategy and business arrangement to facilitate interchange of data? Order of preference for rating is: common CAD system, common CAD modeling kernel (e.g., ACIS, Parasolids, etc.) or framework, direct translator, or data exchange standard such as IGES, STEP or EDIF.	5	9
23.10	**Provide digital product data to customers.** Where appropriate, is product information provided to customers in digital form (e.g., drawings, parts lists, technical manuals, etc.)? Do customers have direct access to the company's technical database (e.g., CITIS) subject to access control, business arrangements, and ownership of data rights?	5	8
	Product Data Effectiveness Rating		7

24.0	DESIGN AUTOMATION		
EVALUATION SCALE			
Traditional (0) Minimal design automation or multiple systems. First generation tools (e.g., 2D CAD, schematic capture, etc.). Tools used by a separate drafting group. No CASE tools.	**Developing (3)** Partially integrated second generation (3D wireframe, integrated EDA) CAD/CAE tools. Front-end CASE tools, but not fully embraced. Move toward common design automation systems. Use of data standards (IGES, EDIF) to communicate data. Constraints on availability of tools to users.	**Committed (7)** Integrated third generation (solids, EDA frameworks) CAD/CAE tools. Front-end and back-end CASE used. Feature-based, parametric solid modeling and electronic mock-up used. Data standards (STEP, IGES, EDIF) to communicate data.	**Best Practice (10)** Integrated 3rd generation tools based on common digital product model. Tools oriented to design optimization. Tools support top-down design, full assembly modeling & electronic mock-up, & front to back CASE. Tools are readily accessible & used by all team members through development cycle.

		Importance	Performance
24.1	**Determine needed design automation capabilities.** Is there a sufficient understanding of the development process, its bottlenecks and improvement opportunities to serve as a basis for determining design automation requirements? Has the company determined how its wants to build and represent components and products (e.g., wireframes, surfaces, solids, assemblies, schematic capture, hardware description language, etc.)? Is there consensus on design automation requirements?	7	8
24.2	**Provide sufficient CAD/CAE/CAM resources.** Is there sufficient availability of CAD/ CAE/ CAM resources to ensure that personnel performing critical development activities don't have to wait for workstations and applications? (Consider the number of workstations versus the number of users who directly access the digital product model.) Does the company's hardware and network provide sufficient performance to effectively use CAD /CAE/ CAM across the enterprise?	5	10
24.3	**Use solids modeling and assembly modeling for mechanical design.** Is the digital product model based on solids modeling? Does the company develop or have a complete 3-D solids model of all the parts that go into the product? Are parts designed in the context of assemblies? Is assembly modeling regularly used to capture a design, represent part relationships, and evaluate the design?	8	6
24.4	**Create electronic mock-up of the product.** Are solid models used to provide an electronic mock-up of the product to evaluate fit, alignment, interference, clearance, etc.? Does the modeler manage product structure relationships as the basis for electronic mock-up? Is interference detection automated? Is interference detection used in conjunction with kinematic analysis?	6	7
24.5	**Use a features-based, hybrid modeler.** Is the solids modeler feature-based? Does the solids modeler support both constraint-based and parametric or variational modeling (hybrid modeler)? Are these capabilities used appropriately? Does the modeler support complex, sculpted surfaces if this capability is needed? Does the CAD system have associative capabilities where a change in the model will update the various representations based on the model (e.g., drawings, tool designs, NC programs, etc.)?	7	5
24.6	**Use visualization capabilities.** Are rendering and visualization systems commonly used to support industrial design and evaluate products, complex shapes, styling or packaging? Is animation used to visualize the operation of the product?	8	8
24.7	**Automate with electronic design tools.** Are electronic design automation tools available to capture schematics and to layout and route a printed circuit board? Can these tools support automatic placement of components and routing of more complex, multi-layer boards without a high degree of manual intervention (manual component placement and manual routing)?	5	5
24.8	**Support system level design.** For more complex systems, are system level design or electronic system design automation (ESDA) tools used to model overall systems, partition the system into subsystems, allocate functions to hardware and software, and model and simulate the overall system operation?	5	4
24.9	**Use top-down design when appropriate.** For more complex electronic designs, are there top-down design tools which use a hardware description language to describe a behavioral model of the product, perform behavioral simulation, synthesize a design, and simulate the operation considering the physical design? Are adequate tools available to fully support this top-down design methodology?	7	3
24.10	**Automate software engineering.** For products involving software development, are computer-aided software engineering (CASE) tools used? Does this include both front-end tools for systems analysis and design as well as back-end tools for database and screen design and code	5	3
24.11	**Establish common systems and a framework environment.** Are common design automation systems used or are the systems able to work with a common digital product model? Is a framework used to integrate best-in-class design automation tools into a common user interface and share information between applications?	6	5
24.12	**Insure effective use of design automation.** Do the design automation tools balance ease of use with the level of capabilities needed? Has adequate training been provided? Is the casual user able to use the tools or is use limited to a core group of power users? Is there an adequate degree of utilization of the full capabilities of the tools given the specific needs of each user?	7	6
	Design Automation Effectiveness Rating		6

25.0 ANALYSIS AND SIMULATION

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
Minimal, if any, simulation and analysis tools. Reliance on handbooks/guidelines, rough calculations, outside assistance, and significant design margins.	Moderate simulation & analysis. Simulation done primarily after the design has been completed to verify it. Internal specialists to support simulation and analysis. Tight integration lacking; requires translation from design automation systems.	Moderate simulation and analysis with more done earlier in the development cycle before design is completed. More and easier to use tools. More engineers are able to use the simulation and analysis tools without calling upon specialists. Tighter integration with design automation tools (can work directly with product model or translation transparent).	Extensive use of simulation and analysis from beginning to end to minimize design iterations and building/testing prototypes. Simulation at the overall system level as well as component level. Effective optimization tools in place. Easy to use tools are directly used by engineers. Manufacturing processes simulated. Tight integration with product model.

		Importance	Performance
25.1	**Simulate and analyze overall product performance.** Is overall product performance adequately and effectively simulated and analyzed with mathematical models, computer-aided engineering (CAE) tools, or virtual reality (to simulate operation of the product by the customer or user)? Is this analysis and simulation effectively used during development to improve the product or primarily to verify the design after the fact?	7	0
25.2	**Simulate and analyze part, assembly and subsystem performance.** Is part, assembly and subsystem performance adequately and effectively simulated and analyzed with mathematical models or computer-aided engineering (CAE) tools (e.g., logic simulation to verify functionality, fault simulation to determine detectability of a failure, finite element analysis to determine mechanical or thermal performance, computational fluid dynamics to determine aerodynamics, etc.)? Is this analysis and simulation effectively used during development to improve the part, assembly and subsystem design or primarily to verify the design after the fact?	9	7
25.3	**Simulate and analyze product designs early to minimize late iteration and physical prototypes.** Are simulation and analysis tools used at an early point in the development cycle to develop the design with a minimum of changes and iteration? Have the number of design iterations, engineering change orders, and physical prototypes been reduced as a result of this early analysis and simulation?	9	7
25.4	**Use appropriate, easy-to-use CAE tools.** Is there an extensive range of CAE tools to support the various analyses necessary to effectively develop the company's products? Are the analysis and simulation tools easy to use (minimizing the need for specialists and allowing direct use by team members)? Do the tools facilitate and automate the process of creating a model (e.g., automatic mesh generation in finite element analysis) and performing the simulation and analysis, thereby reducing manpower and cycle time? Are more sophisticated tools available to support the professional analyst?	5	7
25.5	**Use CAE to mature and optimize the design.** Are these tools used extensively to explore options and develop a mature design (analysis driven design), thereby reducing design, build and test iterations? Do the CAE tools support design optimization by describing the design objective and design constraints and having the software seek its goal?	5	3
25.6	**Tightly integrate analysis & simulation with design.** Can simulation and analysis tools directly work with the digital product model without recreation or re-entry of the model or translation of the model file. If analysis results in changes to the model, are associative capabilities available to directly update the model?	8	7
25.7	**Simulate the logical and physical design.** Is the design of an electronic product or system simulated prior to the physical design based on a schematic or hardware description language model (behavioral simulation)? Is information extracted from the physical design of an electronic product (back annotated) or is the physical design directly used to perform more detailed analysis of product performance (considering timing delays and parasitics) to verify and optimize the physical design?	5	1
25.8	**Simulate manufacturing processes and process design.** Is analysis and simulation used to model and understand manufacturing processes and complex material behaviors (e.g., molding, metal cutting, etc.) Are manufacturing process designs simulated (e.g., NC programs, work cells, factory flow and layout, etc.)?	5	0
25.9	**Validate the analysis and simulation.** Is actual performance compared to the results of the analysis and simulation to validate the models and algorithms? Are validation tests performed?	5	0
25.10	**Re-use analysis and simulation models.** Does the company re-use analysis and simulation models that have been properly documented and validated? Are models created that can be parametrically modified to perform design sensitivity studies, analyze design alternatives, and analyze families of parts? Is a library of successful analysis models maintained and made accessible to development personnel?	5	10
	Analysis and Simulation Effectiveness Rating		5

26.0 COMPUTER-AIDED MANUFACTURING

EVALUATION SCALE

Traditional (0)	Developing (3)	Committed (7)	Best Practice (10)
No CAM integration. Design data re-entered or re-created to support part programming or testing.	Partial CAM integration. Some design data re-entered or re-created to support part programming and testing. Data transfer to CAM requires a cumbersome translation procedure.	Moderate CAM integration. Minimal design data re-entered or re-created to support part programming and testing. Data transfer to CAM requires a translation procedure. CAPP initiated. Some rapid prototyping primarily for visualization and mock-ups	Integrated 3rd generation tools based on common digital product model used to generate part programs, insertion programs, inspection programs and test programs (automatic test pattern generation). Sophisticated and broad CAM capabilities. Extensive rapid prototyping for visualization, prototypes and soft tooling.

		Importance	Performance
26.1	**Use rapid prototyping and tooling technologies.** Are rapid prototyping and tooling technologies such as stereolithography, selective laser sintering, etc. used to create a physical part to further evaluate a part or product design, to communicate design intent, to build prototypes, or to create tooling? Is rapid prototyping used for electronics design with technologies such as field programmable gate arrays (FPGA) to flexibly prototype and build low-volume board and system designs?	8	8
26.2	**Use CAM for part programming.** Are computer-aided manufacturing (CAM) systems commonly used to develop parts programs to drive production equipment (e.g., NC programs, insertion programs, etc.) or create work products such as photomasks with a minimum of manual effort, errors and time?	6	6
26.3	**Develop tooling and fixturing based on part model.** Are CAM systems used to develop tool and fixture designs directly from the digital product model?	8	8
26.4	**Use computer-aided tools for plant and process design.** Are computer-aided design tools used for the design of new plants, production facilities and processes. Are these 3D/solids modeling tools? Ae there visualization and fly-through tools to inspect and assess the elements of the design? Are modeling and simulation tools used to analyze production flow and identify potential bottlenecks?	0	0
26.5	**Use CAPP to optimize process planning and reduce effort.** Are computer-aided process planning (CAPP) systems commonly used to develop process plans or work instructions? Is a rule-based (generative) CAPP system used (vs. a variational CAPP system with a standardized process plan for a part family)? Does the knowledge base of the CAPP system cover most of the fabrication and assembly processes used by the company?	5	5
26.5	**Drive CAI from part/product model.** Are computer-aided inspection systems commonly used which derive inspection programs directly from the part geometry? Can these systems handle geometric dimensioning and tolerancing (GD&T) representation in assessing a part/product?	0	0
26.6	**Drive CAT from the product model.** Are computer-aided test systems commonly used which derive test vectors (e.g., automatic test pattern generation), probing locations, or other functional information from the product model?	0	0
	Computer-Aided Manufacturing Effectiveness Rating		6

27.0	COLLABORATIVE TOOLS & TECHNOLOGY		
EVALUATION SCALE			
Traditional (0) Network in place to support maintaining files in a central directory on a server. Different project management tools used by individual project managers. Little use of collaborative tools.	**Developing (3)** Video-conferencing introduced and used for critical meetings. Intranet used to maintain basic project or product development information. Standard project management systems, but not used in a distributed way for reporting status. Some initial use of view & mark-up and workflow tools.	**Committed (7)** Some use of video-conferencing, collaborative meeting, and collaborative CAD tools to support virtual collocation and customer & supplier communication. Use of an intranet and basic workflow tools to maintain and communicate project information. Common project management used consistently to plan & manage projects.	**Best Practice (10)** Extensive use of video-conferencing, collaborative meeting, and collaborative CAD tools to support virtual collocation and customer & supplier communication. Use of an intranet, product development portal, workflow, distributed project management, and NPD automation tools to maintain and communicate project information.

		Importance	Performance
27.1	**Provide infrastructure to facilitate communication, knowledge-sharing & collaboration.** Are all development personnel connected via a local area network (LAN)? Is there sufficient capacity and bandwidth to enable development personnel to effectively use the network for communication & collaboration? Is there a sufficient bandwidth to support communication and collaboration outside the organization's site(s)? Is there an adequate balance between security and access to the corporate network and corporate data? Are secure web sites or VPN technology used to provide secure links to proprietary corporate data for collaboration?	10	8
27.2	**Use technology to support collaboration.** Is video conferencing used to improve communication with customers, suppliers, subcontractors, and development personnel at other sites? Are collaborative computing tools such as electronic white boards and computer-based meeting tools used? Are web-based tools used to support collaboration with remote team members, customers and suppliers?	10	6
27.3	**Use collaborative CAD tools.** Are collaborative CAD tools available to support a collaborative design and review process? Are people able to view a product model as part of an online meeting? Can more than one user manipulate the model at a time? Are view and mark-up tools available to support this collaborative environment? Is product data readily available to all people who need access through simple view and mark-up or web browser software? Are these tools effective and are they readily used?	5	3
27.4	**Provide sufficient IT resources to support product development.** Are the sufficient information technology personnel available to support software applications for product development? To support the network, workstations, PC's and servers? To support development or implementation of new applications or technology needed by product development personnel? To develop needed codes for analysis?	5	4
27.5	**Use workflow tools to coordinate activities.** Are workflow and groupware applications used to improve the flow of information between functions and help automate development process activities?	5	1
27.6	**Use a common, distributed project management system.** Are there effective computerized project estimating and pricing systems? Are computerized project management systems used for planning, scheduling, recording status, and monitoring project progress for all development projects? Is a common project management system used for all development projects? Do development personnel have access to project estimates, plans and schedules? Do team members have tools and access to report and update the status of their respective project tasks?	10	5
27.7	**Provide a product development intranet & portal to maintain and communicate project information.** Is a product development intranet and portal used to maintain and communicate information to support product development? Is it used for lessons learned and general technical information? Guidelines, design rules and checklists? Project information such as team charter(s), project organization, project plan(s), status, and other project information? Are there portals where development personnel can readily access needed information? Is the intranet/portal regularly used by development personnel as a useful source of information? Is this information well-organized and easy to use?	10	3
27.8	**Automate the NPD process.** Are tools used to automate the NPD process? Do these tools allow the process to be defined, e.g., stages, gates, activities, deliverables and responsibilities? Do they allow tracking of projects against this NPD process? Do they provide a repository for project deliverables and documents with check-in and check-out capability? Do they track status for supporting design reviews and stage-gate or phase-gate reviews? Do they provide a different view for project personnel (e.g., responsibilities and status), team leaders (e.g., project status and team member responsibilities), and management (e.g., cross project view and project status)?	5	1
	Collaborative Tools & Technology Effectiveness Rating		5

28.0	KNOWLEDGE MANAGEMENT		
EVALUATION SCALE			
Traditional (0) Development personnel may maintain separate project notebooks. There is no formal enterprise record of development decisions & supporting analysis. Guidelines & lessons learned are not documented.	**Developing (3)** Development decisions are documented in project notebooks. Lessons learned are documented in project memos & informally accumulated by managers. Some formal design guidelines exist.	**Committed (7)** Formalized systems are established to capture lessons learned, but domain limited. Extensive formal design guidelines exist for key areas. Initial efforts to develop knowledge-based engineering systems or embed guidelines.	**Best Practice (10)** Development decisions are well-documented in electronic project notebooks. Extensive sharing of information across projects through design repositories. Lessons learned are accumulated in a formalized system with extensive retrieval capabilities. Extensive guidelines are available through online systems. Knowledge-based engineering & expert systems widely used.

		Importance	Performance
28.1	**Maintain design repositories.** Are project notebooks maintained by development personnel? Are major design decisions and their rationale captured in project notebooks? Are project notebooks maintained in digital format? Is the information in digital project notebooks effectively organized in design repositories and available for reference by all development personnel? Is information in design repositories related to past development projects used to support current development projects?	5	1
28.2	**Maintain guidelines digitally.** Are there formal design guidelines, standards and design rules? Are these rules and guidelines comprehensive and complete? Are these maintained in an digital format? Are these rules used by design automation systems to create and represent designs that comply with these rules?	5	2
28.3	**Establish lessons learned system.** Are there formal systems to capture lessons learned? Are lessons being effectively captured either as they occur or at project milestones? Is this information categorized and organized? Does the lessons learned system facilitate organization, access and cross-referencing of the lessons (e.g., hypertext with links, search engines, intranet, etc.)? Are lessons learned valued and the system effectively used by the organization?	10	1
28.4	**Assess and maintain knowledge.** Is there a regular effort to assess, catalog and maintain knowledge related to product development. Is this knowledge proactively disseminated and used for training and developing personnel?	5	0
28.5	**Use knowledge-based engineering systems.** Are knowledge-based engineering systems and expert systems being investigated or used on a pilot project? Are they utilized to support normal development efforts? Is the knowledge base to support these systems comprehensive (versus limited to a single point solution)? Are there on-going efforts to further develop and apply expert systems or knowledge-based systems technology?	5	0
	Knowledge Organization Effectiveness Rating		1