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Enterprise Wide Business Management

Using EDEN™ as a Platform

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Assignment presented in partial fulfilment of the requirements for the degree of Masters of Industrial Engineering at the University of Stellenbosch.

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Declaration

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

Ek, die ondergetekende verklaar hiermee dat die werk gedoen in hierdie projek my eie oorspronklike werk is wat nog nie voorheen gedeeltelik of volledig by enige universiteit vir 'n graad aangebied is nie.

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Date:

Synopsis

The Rapid Product Development Division (RPD) of the Global Competitiveness Centre (GCC) identified the need to automate and integrate their organisational business processes and to share common data and practices across the entire enterprise in a real-time environment.

Different software applications such as Microsoft® Excel, Microsoft® Access, the University's Financial System and others, are used to complete a single project. A system was therefore needed to provide the capabilities to integrate all of these applications into one workable system.

The most perceived technology to create such an environment, namely Enterprise Resource Planning (ERP), was found to be too sophisticated and expensive. The Knowledge Management Software Solution, called EDEN™, was identified as the most appropriate technology that could fulfil the needs of the RPD.

Different modern management approaches, such as Theory of Constraints (TOC) and Customer Relationship Management (CRM), and process modelling tools were combined to build three roadmaps on the EDEN™ (Enterprise Design Navigator) platform to provide an enterprise wide business solution. A roadmap will aid as a guide that leads the user through a series of steps in order to create an understanding of the methods to be used when starting a new project or product design. The three roadmaps developed are Project Management, Product Development and Business Functions.

The Project Management Roadmap was developed because all the RPD's work for clients is managed in the form of a project. This Roadmap should provide the necessary guidance and support to manage any project.

The most important processes of the RPD are without doubt the product development processes. The Product Development Roadmap was developed with detailed procedures to assist with any product design.

The business functions of the RPD are functions, such as finance and management information, that support the organisation's operations and the project management processes. The Business Functions identified for the RPD was combined into the Business Functions Roadmap.

The main objective of the thesis was to integrate the business processes and all the software applications into one workable system and to share common data in a real-time environment. This was successfully accomplished by making use of the roadmaps and of the EDEN™ Environment.

OPSOMMING

Die Rapid Product Development Division (RPD) van die Global Competitiveness Centre (GCC) het die nood om hul besigheid prosesse te outomatiseer en te integreer geïdentifiseer asook om hul data en beste praktyke met die hele besigheid te deel in 'n "real-time" omgewing.

Verskillende sagteware toepassings soos Microsoft® Excel, Microsoft® Access, die Universiteit se Finansiële Sisteem en ander, word gebruik om een projek uit te voer. 'n Sisteem was dus benodig om al hierdie verskillende sagteware toepassings in een werkbare sisteem te integreer.

Die mees toepasbare tegnologie om so 'n omgewing te skep, genaamd "Enterprise Resource Planning" (ERP), was gevind as te duur en te kompleks. Die "Knowledge Management Software Solution", genaamd EDEN™, was geïdentifiseer as die mees toepasbare tegnologie.

Verskillende moderne bestuur benaderings, soos "Theory of Constraints" (TOC) en "Customer Relationship Management" (CRM), asook prosesse modelleer tegnieke was gesamentlik gebruik om drie "roadmaps" te bou op die EDEN™ platform. A "roadmap" dien as 'n riglyn wat die gebruikers sal ly deur 'n reeks van stappe met die doel om 'n beter verstaanbaarheid te kry van die tegnieke wat gebruik word wanneer 'n nuwe projek begin word. Die drie "Roadmaps" is Projekbestuur, Produk Ontwikkeling en Besigheid Funksies.

Die Projekbestuur "Roadmap" was ontwikkel omdat alle werk wat gedoen word deur die RPD bestuur word in die vorm van 'n projek. Hierdie "Roadmap" sal die nodige leiding en ondersteuning bied vir die bestuur van enige projek.

Die belangrikste prosesse van die RPD is sonder twyfel die produk ontwikkeling prosesse. Die Produk Ontwikkelings "Roadmap" is ontwikkel met gedetailleerde prosedures om bystand te bied met enige nuwe produk ontwikkeling.

Die besigheid funksies van die RPD is funksies, soos finansies en informasie bestuur, wat ondersteuning bied aan die besigheid se operasionele en projekbestuur prosesse. Die geïdentifiseerde besigheid prosesse van die RPD was gekombineer om die Besigheid Funksies “Roadmap” te ontwikkel.

Die hoof doel van die tesis was om die besigheid prosesse en al die sagteware toepassing te integreer in een werkbare sisteem asook om data te deel in ‘n “real-time” omgewing. Dit was suksesvol bereik deur gebruik te maak van die “roadmaps” en die EDEN™ omgewing.

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GLOSSARY

RPD	Rapid Product Development
CAD	Computer Aided Design
CNC	Computer Numerical Control
EDEN™	Enterprise Design Navigator
ERP	Enterprise Resource Planning
BPM	Business Process Modelling
BPR	Business Process Re-engineering
JMS	Job Management System
CRM	Customer Relationship Management
TOC	Theory of Constraints
DFA	Data Flow Analysis
DFD	Data Flow Diagrams
SME	Small/Medium Enterprise
ICOM	Input, outputs, control and Mechanism
IEM	Integrated Enterprise Modelling
OOA	Object-oriented analysis
GCC	Global Competitiveness Centre
IPK	Institute for Production Systems and Design Technology
CMS	Customer Management System
TVC	True Variable Cost
RE	Reverse Engineering
RP	Rapid Prototyping

1. Introduction

1.1 Project Brief

The RPD identified the need to automate and integrate their organisational business processes and to share common data and practices across the entire enterprise in a real-time environment.

Different software applications such as Microsoft® Excel, Microsoft® Access, the University's Financial System, etc., are used to complete a single project. A system was therefore needed to provide the capabilities to integrate all of these applications into one workable system.

The most perceived technology to create such an environment, namely Enterprise Resource Planning (ERP), was found to be too sophisticated and expensive. The Knowledge Management Software Solution, called EDEN™, was identified as the most appropriate technology that could fulfil the needs of the RPD.

1.2 Background of the RPD

The ability of the RPD, which form part of the Global Competitiveness Centre, to present a full rapid product development process chain is the single most important distinguishing factor between this Centre and many other activities in and around South Africa. The Centre has spent over three years developing its expertise in the fields of CAD/CAM/CAE, Reverse Engineering, Rapid Prototyping and tooling, CNC Machining and Quality Control.

It deploys leading edge equipment to educate students and perform technology transfer. Furthermore, the Centre provides small and medium enterprises with state-of-the-art services they would not ordinarily be able to acquire.

Rapid Product Development Equipment and Services available through the GCC:

□ **CAD / CAM and CAE**

High end CAD workstations - CAD workstations that run the full suite of Pro/ENGINEER, Pro/MANUFACTURING, PowerShape, and EdgeCAM. The workstations are situated in an open plan room, which is ideal for training. The CAD systems are used for training as well as performing complex engineering design and analysis. Figure 1 illustrates models designed with three different CAD applications.

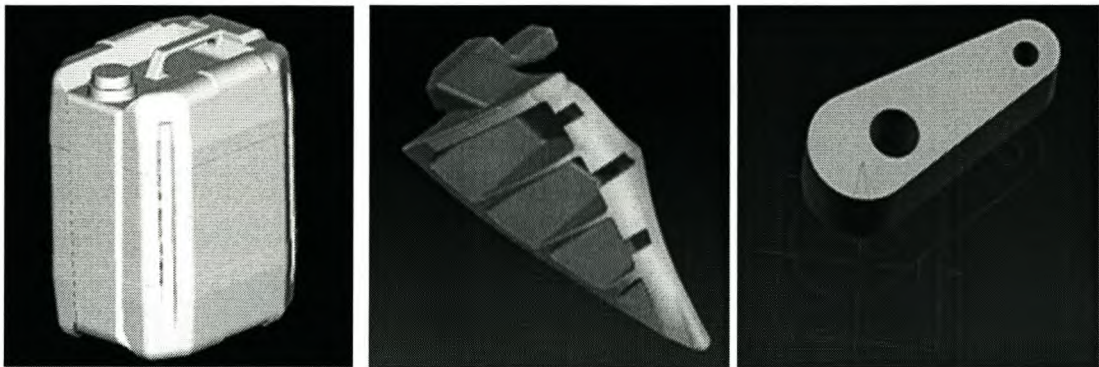


Figure 1: Pro/Engineer

PowerShape

Unigraphics

□ **Reverse Engineering**

Renishaw Cyclone - A dedicated continuous touch probe digitiser that can rapidly scan physical objects, as well as controlling software able to generate CAM and STL outputs. These outputs can further be refined to produce full 3D CAD models. Figure 2 illustrates the Renishaw Cyclone scanning machine.



Figure 2: Renishaw Cyclone

□ Rapid Prototyping

Z Corporation 3D Rapid Prototyping System - The Z Corp 3D printer is the fastest and one of the cheapest to operate rapid prototyping systems in the world. It is capable of growing models that are ideal for conceptualisation, design verification, marketing as well as patterns for investment casting. Figure 3 shows an example of a grown part.

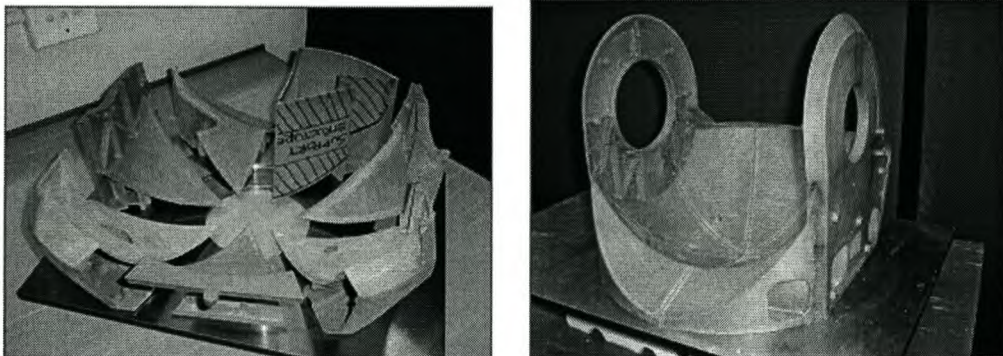


Figure 3: Part grown by Z Corp 3D Printer

□ Rapid Tooling

MCP-HEK Vacuum Casting System MCP 4/04 - Using silicon rubber as mould material the system is capable of producing high quality dimensionally exact prototypes in polyurethane with properties very close to those of the end-use material, within 12 hours. This is approximately 3% of the cost and time required for steel tooling. In combination with the 3D printer this system becomes a powerful tool for product development. Figure 4 shows examples of moulds and prototypes.

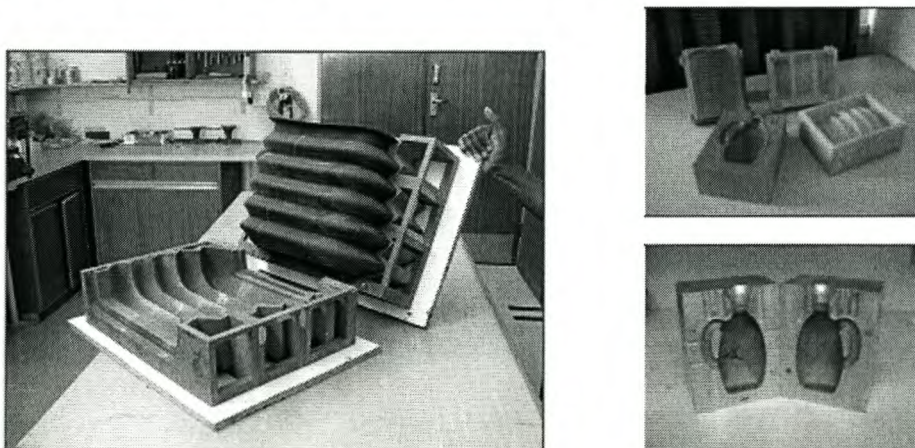


Figure 4: Rapid Tooling Products

□ CNC Machining

Leadwell 4 Axis CNC Milling Machine & Leadwell Lathe - The GCC has access to these machines, which can be used for academic research and industrial projects. Figure 5 shows typical CNC Milling machine.

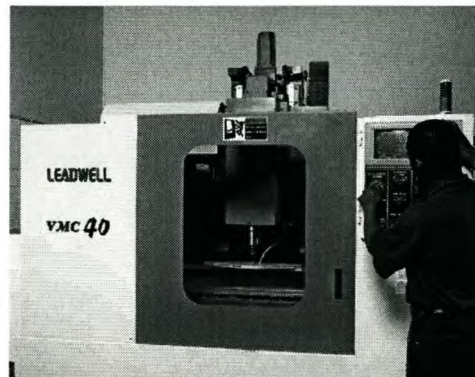


Figure 5: CNC Milling Machine

□ Quality Control

Mitutoyo Bright 710 CMM – The Co-ordinate Measuring Machine is capable of performing 3D mechanical measurements accurate to 6 microns. The machine is used for part inspection including 3D form accuracy, as well as for reverse engineering. Figure 6 illustrates the CMM in action.

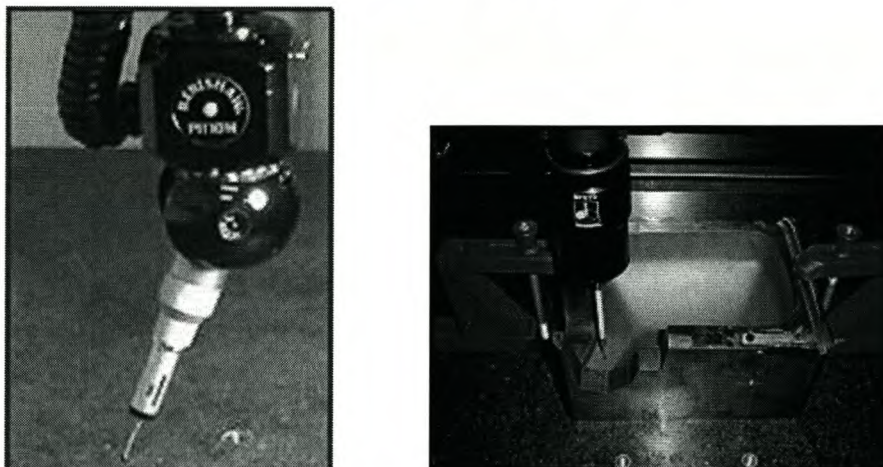


Figure 6: Co-ordinate Measuring Machine

1.3 The Project Goals

The primary goal of this project was to develop an EDEN™ Environment for the RPD Enterprise that would fulfil their needs. The primary goal was divided into more manageable goals, which are listed below:

- Goal 1:** Re-engineer RPD business processes by means of Business Process Modelling and Re-engineering (BPR)
- Goal 2:** Develop Roadmaps for the RPD EDEN™ Environment.
- Goal 3:** Populate Roadmaps with relevant documents and information.
- Goal 4:** Train end users
- Goal 5:** Implement EDEN™ at the RPD

1.4 Project Methodology

In order to achieve the above-mentioned goals of, a project methodology was developed. The methodology is summarized in figure 7. Each phase of the methodology is explained in more detail in the following chapters.

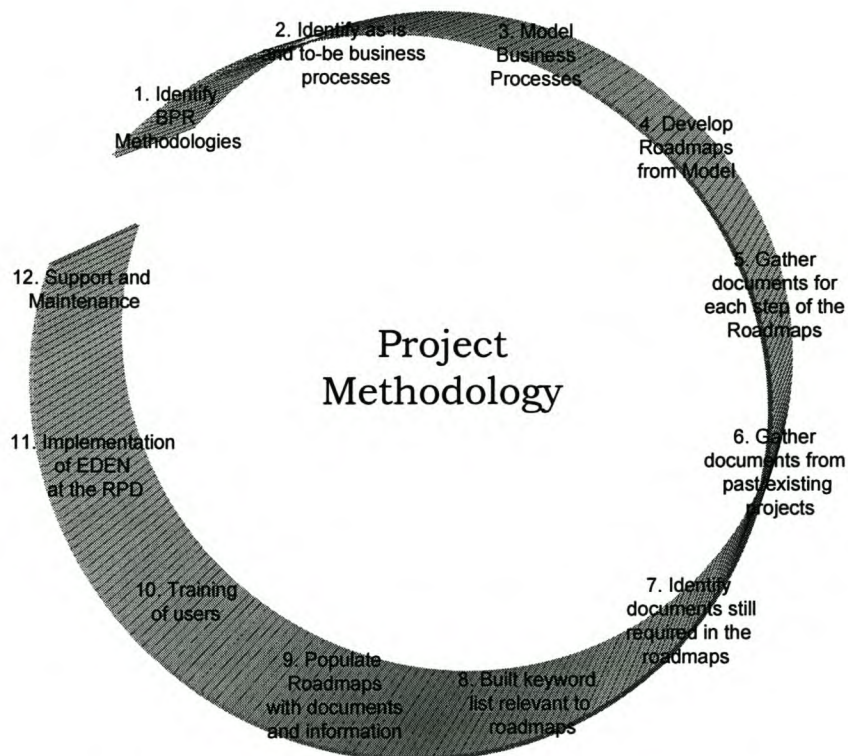


Figure 7: Phases of the Project Methodology

This report is structured according to the phases of the methodology. Firstly, in chapter 2, it describes the identified Business Process Re-engineering (BPR) methodologies. In chapter 3 the TO-BE business processes of the RPD and how it was modelled are explained. The main features of EDEN™ are described in chapter 4 and in chapter 5, 6 and 7 the Roadmaps for the EDEN™ Environment are introduced. Chapter 8 includes phases 5 to 9 of the project methodology. These phases all form part of the preparation of the EDEN™ Environment. The training of the end users is addressed in Chapter 9. Chapter 10 explains the implementation methodology that was used. The Job Management System developed for the RPD is described in chapter 11. In Chapter 12 a marketing strategy for the RPD is summarised.

The duration of the project is outlined in the table 1. The total duration of the project was 115 man-days.

Table 1: Duration of Project Phases

Duration of the Project Phases	Man-Days
Define scope of thesis	3
Identify BPR methodologies	10
Identify AS-IS and develop TO-BE business processes	16
Model business processes	5
Develop roadmaps from models	4
Gather documents for each step of the roadmaps	10
Gather documents from past/existing projects	1
Identify documents still required in the roadmaps	2
Built keyword list relevant to roadmaps	3
Populate roadmaps with documents and information	6
Training of user	7
Implementation of EDEN at the RPD	3
Support and Maintenance	7
Development of Job Management System (JMS)	10
Identify Marketing Strategy for the RPD	3
Writing of thesis document	25

1.5 What is EDEN™

EDEN™ is a Windows® based *software environment* that supports a *multi-disciplinary team* through a variety of *change projects* within a company. EDEN™ allows the team to follow a *pre-defined structure*, which acts as a roadmap for a project. EDEN™ provides the team with relevant, *good practice information* that is easily assessable and easy to share. The EDEN™ software environment will capture the *experiences and knowledge gained* by team members, thereby ensuring repeatability and a learning culture. EDEN™ provides management with *high-level control* over a project.

1.6 How EDEN™ is used to fulfil the Needs of the RPD

The EDEN™ *software environment* enables managers and any other personnel of a business to function and operate in a more efficient manner. The software environment is easy to master and it integrates with other software applications such as Microsoft® Access, Microsoft® Word, Microsoft® Excel, etc. EDEN™ is easily installed on individual PCs or networks and has a familiar Windows® interface.

All the RPD's work for clients is managed in the form of different projects. EDEN™ allows a multi-disciplinary team, such as the RPD, to co-operate and manage all their projects on a company wide basis. Project outcomes are therefore integrated throughout the company. Each employee of the RPD is able to focus on his or her area of expertise. All their contributions are combined and managed within the EDEN™ environment.

EDEN™ allows a team or business to follow a *pre-defined structure*, which acts as a roadmap for a project as mentioned in section 1.5. The structures or roadmaps are normally determined during the initial phases of a project. However, the need of the RPD was not to determine a roadmap for every single project undertaken. Three roadmaps were therefore formulated specifically for the RPD to firstly assist them with the management of any project and secondly to integrate all their business processes.

The three roadmaps formulated are the Project Management Roadmap, Product Development Roadmap and Business Functions Roadmap. These roadmaps enable the RPD to move forward in a structured and organised way. Goals and project outcomes are clearly defined and visible to all employees.

Each roadmap consists of a certain number of steps and sub-steps. Relevant examples, templates and information of good practices are stored at a specific step or sub-step of a roadmap. This allows the RPD to share information and knowledge throughout the enterprise on a real-time basis. Improvements to information can also be captured and stored.

Information is gathered, captured and stored in the relevant steps of the roadmap as a project progresses. Typical information gathered and stored for a specific project is customer details, quotations, project plan and schedules, job information, material usage, procedures, financial details, shipping and delivery notification.

By doing the above EDEN™ automatically captures and preserves the knowledge, expertise and experience of RPD's key personnel, which is the most valuable (and vulnerable) asset of the enterprise.

These business processes of the RPD are further integrated by making use of the checklist feature of EDEN™. Checklists of the procedures were developed for most of the steps and sub-steps of the roadmaps. These checklists are firstly used to guide the management and personnel with the execution of any project. Secondly, it is used to monitor the progress of any project by ticking-off each completed task.

The key features of EDEN™ are explained in chapter 4 in more detail.

2. Identify Business Process Modelling and Re-Engineering Methodologies

2.1 Introduction

Numerous modelling tools of diagrammatic nature are available today, whether for incremental or radical enterprise improvement. Data flow diagrams (DFD), IDEFØ and Object-oriented Modelling are the most commonly used methods to support companies with the modelling of business processes. A thorough study of each of the mentioned methodologies was conducted to obtain a better understanding of the working of each methodology. Strengths and weaknesses were also identified during the study. The study was also the starting point of the Project Methodology Cycle as shown in figure 8.

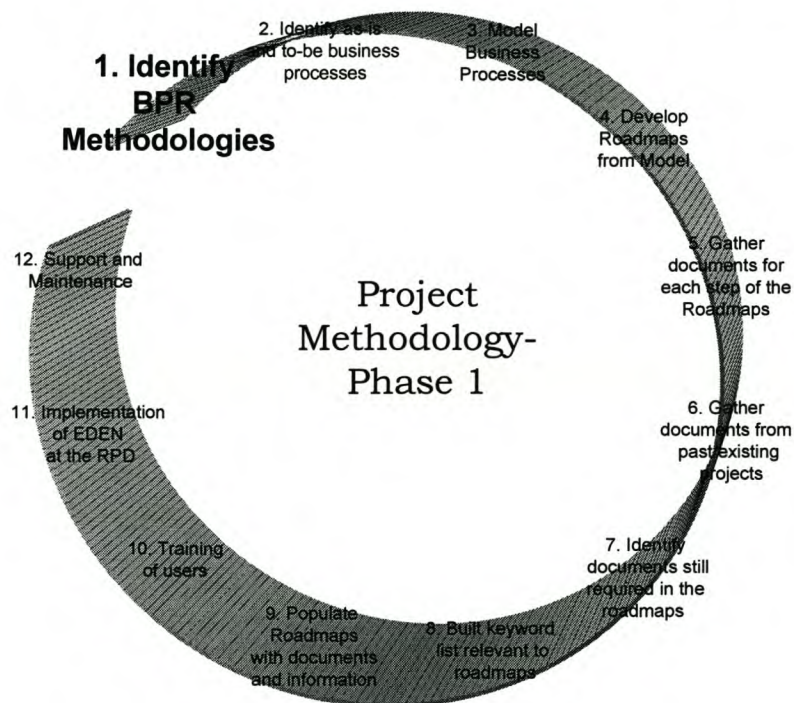


Figure 8: Phase 1 – Identify BPR Methodologies

2.2 Introduction to Business Process Modelling and Re-engineering

Worldwide competition is getting fiercer every day and requires companies to strictly orient their operations towards the market. Constantly changing markets require a high speed of response and high degree of flexibility. To survive in a competitive climate, companies also need to place great emphasis on customer orientation. Cost pressure and customer orientation call for an improvement of the quality and efficiency of business processes and for quick adjustments to shifts in the market.

To attain the objectives, companies often analyse processes. Information on the quality, control, optimisation, costs and the comparison (process benchmarking) of processes as well as on responsibilities and environmental aspects may be obtained with different methods. The required data and structures, such as models of the organisational structure and the process organisation (process structure, process chain), are often similar or are based on similar basic structures. Methods to model and analyse business processes need to take these different model views into consideration. The objective of these models is to introduce process models as a basis to easily record, process and store information in a company.

Quality management and business process modelling are already available in many companies. The development of methods to optimise business processes remains to be one of the core tasks of corporate planning and business engineering. Furthermore, in view of dynamic markets and changing basic conditions such as laws, the policy environment and new technologies, a business has to be able to analyse and adjust business processes on an ongoing basis. It is therefore very important that methods are developed in such a way that it allows the businesses to continuously use business process models and the appropriate tools. The process of "Continuous Engineering" is required to continually trace market requirements and to continually use new technologies in the field of business processes.

2.3 Defining Business Process Modelling and Re-engineering (BPR)

A much-quoted definition of BPR comes from Hammer and Champy (1993), as "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measurements of performance, such as cost,

quality, service and speed." Hence, BPR is a process-oriented approach. Other commentators suggest BPR should be evolutionary rather than revolutionary for change to be successful [1][2].

2.4 Supporting Tools for BPR

Since BPR is about dramatic improvement, at some point almost everyone has to be involved in it. Hence, there is a need to communicate to every level of the business throughout the initiative. This is important, particularly where the team and business are geographically or locally dispersed [1]. Additionally, there is a need for stimulating and supporting communication about the changes to be made between the team and the business, and between the business and its partners i.e. the customers and suppliers [2].

One solution for facilitating such communication is a descriptive model in which business processes are represented "as-is" or "to-be". Since the business environment is such a dynamic environment, change often overtakes models before delivering any significant results [1]. Non-information technology (IT) experts must be able to develop or extend the model. Hence, a tool is required which facilitates non-expert computer user communication via a descriptive model, capturing their vision and insights towards the re-engineered enterprise.

Many BPR software tools are available on the market. The tools can be classified by the facilitating BPR project life cycle, and by purpose. Project lifecycle tools include strategic initialisation [3] with direction identification and opportunity searching; implementation with "to-be" model building, and exploitation with further improvement. The purpose of the tools includes [4]: project management; co-ordination; modelling; business process analysis; human resource analysis and systems development.

Many tools are available to stimulate, simulate and support these approaches, based on different methodologies and frameworks [5].

2.4.1 Data Flow Analysis

Data Flow Analysis (DFA) can form a fundamental starting point for performing BPM in general, and this is also a good starting point for applications in small- to medium-sized enterprises. In terms of business efficiency, DFA offers the distinct advantage in that it is relatively simple to apply and the time taken to undertake a business process re-design project is not excessive. Furthermore, DFA is a popular procedure in the information systems profession in general and has a wide area of application.

There are three stages in the DFA methodology [6] as follows:

1. **Information acquisition** - questionnaire needs to be established and put to key respondents during interviews;
2. **Analysis** - using DFA techniques; and
3. **Report** - the report should specify the immediate and future re-engineering solutions.

For the information requirement analysis, the principle of "5W+1H" rule is normally used. The "5W" stands for Who, What, When, Where and Why; and "1H" stands for How. The guidelines for an analyst are listed as follows:

- **Who** is involved in the situation we are analysing?
- **What** is the current situation?
- **When** must the new system be in place?
- **Where** will the new system fit within the old environment?
- **Why** is a new system being sought?
- **How** will the new system function?

Two approaches are normally used to collect information for the DFA exercise. They are: information collection through group meetings, and information collection through interviews. Information collection by group meetings requires the forming of groups of people from the enterprise. The groups continue discussion until they reach a consensus view, which forms the basis for model development. This approach usually consumes a lot of time and, because of the high number of people involved can be costly. Companies are normally reluctant to allow highly paid employees to consume time in

such meetings, particularly companies that fall into the SME category. This type of group discussion is therefore very difficult to arrange in the business environment of SME's.

The other method of collecting information is through individual interviews. This requires experienced consultant analysts, who are assigned to the enterprise for the collection of user descriptions and samples of the documents/data used directly in the operations. In comparison with group discussions, this method requires less time and is generally less costly, but tends to provide less exposure with model users, and may lead to sub-optimal solutions.

The second approach tends to produce results of nearly the same quality as the first and in a much shorter period of time. Increasing the number of expert consultants will certainly increase cost, but may not proportionately increase the reliability of the information after a certain point.

DFA [6] is in fact a structured systems analysis and design methodology. It uses a data flow diagram (DFD) to model or analyse the current system and to find solutions for an improved system. It is principally based on:

- the purposes of the application: its functions or processes; and
- the treatment of the problem in a top-down manner. A top-down analysis is performed to determine the external interfaces of the application first, then high level functions, and finally, lower level functions.

2.4.1.1 The DFA procedure

1. Context Diagram

The context diagram is the highest-level diagram of a set of DFD's, and reveals an external picture of the information system. It consists of the three components of input and output, terminators, and general functions.

2. Event List

The event list is a simple textual listing of the events in the environment to which the system must respond. A DFD uses symbols including external entity, process, data store and data flow.

3. Current physical DFD

The formation of the current physical DFD involves the re-organisation of a context diagram or several context diagrams. The current physical DFD shows the flow of data amongst entities such as persons and departments within the system. The current physical DFD is then transformed to the current logical DFD.

4. Current Logical DFD

The current logical DFD is derived from the context diagram and event list. The current logical DFD shows the flow of data along the essential functions of the system. Furthermore, a complex system can be modelled, as a levelled DFD by the processes of abstraction and decomposition, which describes different levels of DFD's to allow refinement of the modelling process (see figure 9).

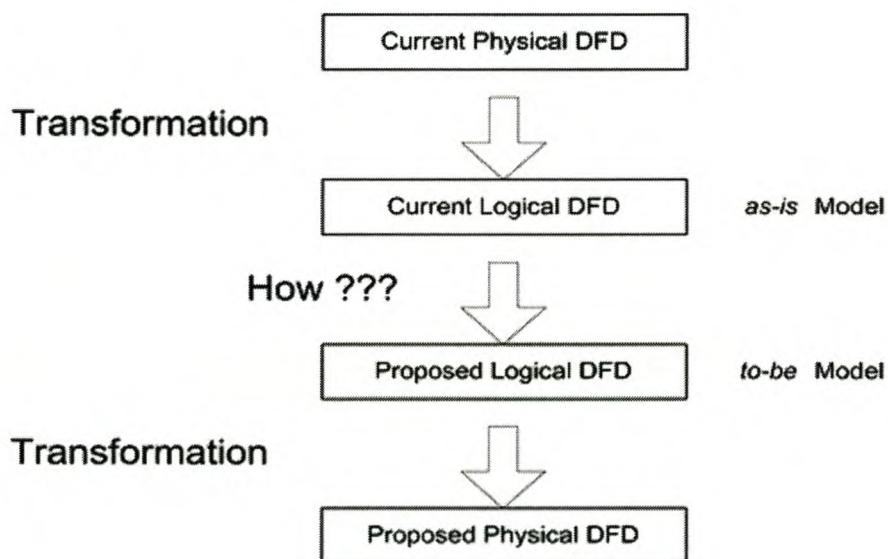


Figure 9: DFA Process

5. Proposed Logical DFD

The most important and difficult step in the formation of DFD is to transform the current logical DFD to the proposed logical DFD. A DFD helps to expose the weaknesses of an existing system and provides valuable opportunities for re-engineering. However, the

final solution must still satisfy certain constraints; suggestions from the customers, the compliance of wants and some standards such as ISO9000.

6. Proposed physical DFD

The proposed physical DFD shows the flow of data among entities such as persons and department within the proposed system.

7. Reporting

This includes the current physical DFD, current logical DFD, proposed logical DFD, and a business report. The business report is concerned with the business plan, which should describe the workflow, software configuration, hardware configuration, advantages and disadvantages of the proposed solutions. The descriptions of software and hardware configuration can be omitted if there are no IT related matters in the existing system, and if IT is unlikely to feature in the proposed system. The report should specify the immediate and future re-engineering solutions.

2.4.1.2 Concluding comments

To quote A.S.M. Tam, L.K. Chu and D Sculli [7]; "as a modelling methodology, DFA has been criticised as having limited capabilities because of its function orientation and lack of precise specification for where and by whom the processes or activities are performed. Difficulties are encountered as the size of enterprise increases. In reality, as a BPM methodology, DFA does not provide a full set of modelling features and methods. Further refinements are required in the following areas:

- *First, a detailed study of the basic features of BPM that are to be performed -* These include the modelling capabilities, especially their abstraction modelling capabilities (e.g. specialisation and aggregation) and their domain of competency (function, information, resource, organisation, human skills and modelling aspects).
- *Second, the mapping from BPM or named enterprise modelling to enterprise integration must be developed as outlined in Figure 10 -* Normally, for a business process that communicates with another business processes, two fundamental components are required. These are the integration platform with its integrating infrastructure (IPIS), and a business process model. The former components

refer to the support, i.e. software and hardware, which allows communication between business processes. In effect, the above requirement refers to two or more business processes communicating with each other in the same language, and focuses on minimising the risk of misunderstandings.

- *Third, DFA alone may be too weak in some situations such as financial analysis - Such a methodology aims to seek a support analysis tool for merging with DFA to enhance the overall capability of the analysis.”*

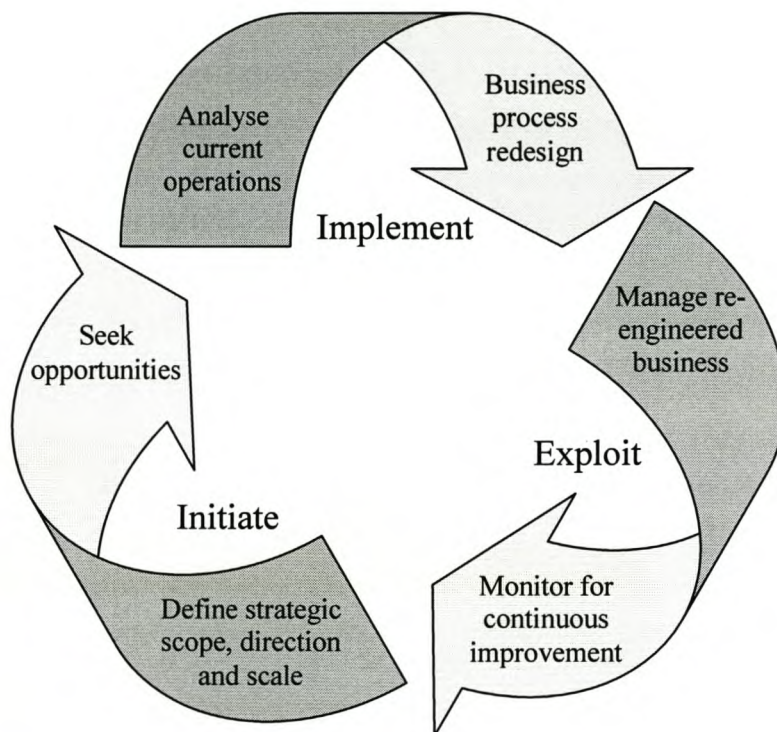


Figure 10: Mapping from BPM to Enterprise Integration – [7]

2.4.2 IDEFØ

From the 1988 IDEFØ manual [8] it was obtained that IDEFØ is a method designed to model the decisions, actions, and activities of an organization or system. IDEFØ was derived from a well-established graphical language, the Structured Analysis and Design Technique (SADT). The United States Air Force commissioned the developers of SADT to develop a function modelling method for analysing and communicating the functional perspective of a system. Effective IDEFØ models help to organize the analysis of a system and to promote good communication between the analyst and the customer. IDEFØ is useful in establishing the scope of an analysis, especially for a functional analysis. As a communication tool, IDEFØ enhances domain expert involvement and consensus decision-making through simplified graphical devices. As an analysis tool, IDEFØ assists the modeller in identifying what functions are performed, what is needed to perform those functions, what the current system does right, and what the current system does wrong. Thus, IDEFØ models are often created as one of the first tasks of a system development effort.

2.4.2.1 IDEFØ Characteristics

As a function modelling language, IDEFØ has the following characteristics:

- It is comprehensive and expressive, capable of graphically representing a wide variety of business, manufacturing and other types of enterprise operations to any level of detail.
- It is a coherent and simple language, providing for rigorous and precise expression, and promoting consistency of usage and interpretation
- It enhances communication between systems analysts, developers and users through ease of learning and its emphasis on hierarchical exposition of detail.

2.4.2.2 IDEFØ Concepts

The IDEFØ method has basic concepts that address each of the needs previously discussed. The basic IDEFØ concepts as outlined in the IDEFØ manual of 1988, include the following:

1. Cell Modelling Graphic Representation

The "box and arrow" graphics of an IDEFØ diagram shows the function as a box and the interfaces to or from the function as arrows entering or leaving the box. To express functions, boxes operate simultaneously with other boxes, with the interface arrows "constraining" when and how operations are triggered and controlled. The basic syntax for an IDEFØ model is shown in figure 11.

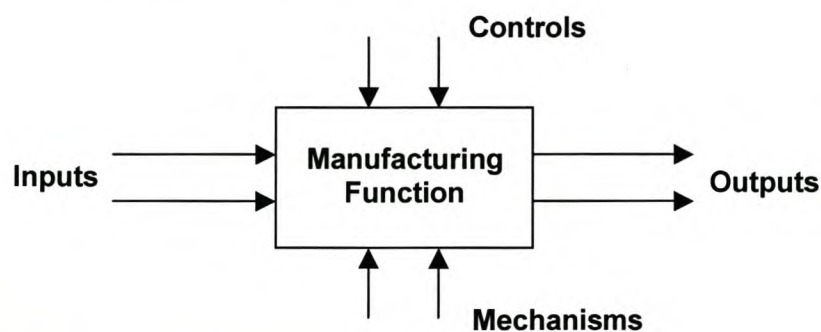


Figure 11: IDEF Function Box and Interface Arrows

2. IDEF0 Function Box

- **Overview**
 - **Function:** An activity, process, or transformation (modelled by an IDEFØ box) identified by a verb or verb phrase that describes what must be accomplished.
 - **Decomposition:** The partitioning of a modelled function into its component functions
 - **A-0 Diagram:** The special case of a one-box IDEFØ context diagram, containing the top-level function being modelled and its inputs, controls, outputs and mechanisms, along with statements of model purpose and viewpoint. Level 1 etc. follows as decomposed child diagrams.

- **Box:** A rectangle, containing a name and number, used to represent a function, from 3 to 6 per diagram, except on A-0.
 - **Arrow:** A directed line, composed of one or more arrow segments, that models an open channel or conduit conveying data or objects from source (no arrowhead) to use (with arrowhead). There are 4 arrow classes: Input Arrow, Output Arrow, Control Arrow, and Mechanism Arrow (includes Call Arrow) as illustrated in figure 12 below.
- **Diagram**

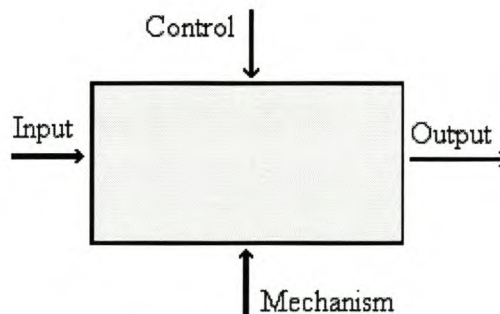


Figure 12: Arrow Classes

- **Box Name:** The verb or verb phrase placed inside an IDEF0 box to describe the modelled function.
- **Box Number:** The number (0 to 6) placed inside the lower right corner of an IDEF0 box to uniquely identify the box on a diagram.
- **Arrow Label:** A noun or noun phrase associated with an IDEF0 arrow or arrow segment, specifying its meaning.
- **Arrow Segment:** A line segment that originates or terminates at a box side, a branch (fork or join), or a boundary (unconnected end).
- **Boundary Arrow:** An arrow with one end (source or use) not connected to any box on a diagram. Contrast with Internal Arrow.
- **Control Arrow:** The class of arrows that express IDEF0 Control, i.e., conditions required to produce correct output. Data or objects modelled as controls may be transformed by the function, creating output. Control arrows are associated with the topside of an IDEF0 box.

- **Input Arrow:** The class of arrows that express IDEFØ Input, i.e., the data or objects that are transformed by the function into output. Input arrows are associated with the left side of an IDEFØ box.
 - **Output Arrow:** The class of arrows that express IDEFØ Output, i.e., the data or objects produced by a function. Output arrows are associated with the right side of an IDEFØ box.
 - **Mechanism Arrow:** The class of arrows that express IDEFØ Mechanism, i.e., the means used to perform a function; includes the special case of Call Arrow. Mechanism arrows are associated with the bottom side of an IDEFØ box.
- **Decomposition**
 - **Decomposition:** The partitioning of a modelled function into its component functions.
 - **Child Diagram:** The diagram that details a parent box.
 - **Child Box:** A box on a child diagram.
 - **Relationship:** The relationship between functions is indicated by relative positions and arrows as illustrated in figure 13.

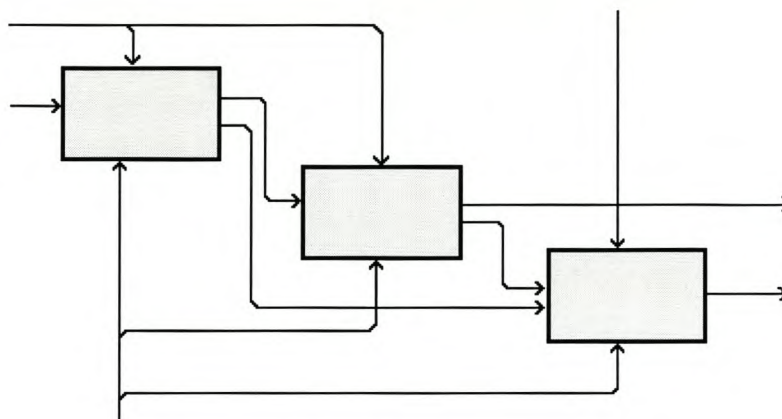


Figure 13: Relationships between functions

3. Communication

- IDEFØ concepts designed to enhance communication include the following:
- Diagrams based on simple box and arrow graphics.
- English text labels to describe boxes and arrows and glossary and text to define the precise meanings of diagram elements.
- The gradual exposition of detail featuring a hierarchical structure, with the major functions at the top and with successive levels of sub-functions revealing well-bounded detail breakout.
- A "node chart" that provides a quick index for locating details within the hierarchic structure of diagrams.
- The limitation of detail to no more than six sub-functions on each successive function.

4. Rigor and Precision

The rules of IDEFØ require sufficient rigor and precision to satisfy needs without overly constraining the analyst. IDEFØ rules include the following:

- Control of the details communicated at each level (three to six function boxes at each level of a decomposition).
- Bounded Context (no omissions or additional out-of-scope detail).
- Diagram Interface Connectivity (Node numbers, Box numbers, C-numbers, and Detail Reference Expression).
- Data Structure Connectivity (ICOM codes and the use of parentheses).
- Unique Labels and Titles (no duplicated names).
- Syntax Rules for Graphics (boxes and arrows).
- Data Arrow Branch Constraint (labels for constraining the data flow on branches).
- Input versus Control Separation (a rule for determining the role of data).
- Data Arrow Label Requirements (minimum labelling rules).
- Minimum Control of Function (all functions require at least one control).

- Purpose and Viewpoint (all models have a purpose and viewpoint statement).

5. Organization versus Function

The separation of organization from the function is included in the purpose of the model and carried out by the selection of functions and interface names during model development.

6. Sequences and Timing Independence

Applying the IDEFØ method results in an organized representation of the activities and the important relations between these activities in a non-temporal fashion. IDEFØ does not support the specification of a recipe or process. Such detailed descriptions of the specific logic or timing associated with the activities require the IDEF3 Process Description Capture Method.

2.4.2.3 Concluding Comments

The primary strength of IDEFØ, according to the IDEFØ manual of 1988 [8], is that the method has proven effective in detailing the system activities for function modelling, the original structured analysis communication goal for IDEFØ. Activities can be described by their inputs, outputs, controls, and mechanisms (ICOMs). Additionally, the description of the activities of a system can be easily refined into greater and greater detail until the model is as descriptive as necessary for the decision-making task at hand. In fact, one of the observed problems with IDEFØ models is that they often are so concise that they are understandable only if the reader is a domain expert or has participated in the model development. The hierarchical nature of IDEFØ facilitates the ability to construct (AS-IS) models that have a top-down representation and interpretation, but which are based on a bottom-up analysis process. Beginning with raw data (generally interview results with domain experts), the modeller starts grouping together activities that are closely related or functionally similar. Through this grouping process, the hierarchy emerges. If an enterprise's functional architecture is being designed (often referred to as TO-BE modelling), top-down construction is usually more appropriate. Beginning with the top-most activity, the TO-BE enterprise can be described via a logical decomposition. The process can be continued recursively to the desired level of detail. When an existing

enterprise is being analysed and modelled (often referred to as AS-IS modelling), observed activities could be described and then combined into a higher-level activity. This process also continues until the highest-level activity has been described.

One problem with IDEFØ, according to the IDEFØ manual, is the tendency of IDEFØ models to be interpreted as representing a sequence of activities. While IDEFØ is not intended to be used for modelling activity sequences, it is easy to do so. The activities may be placed in a left to right sequence within decomposition and connected with the flows. It is natural to order the activities left to right because, if one activity outputs a concept that is used as input by another activity, drawing the activity boxes and concept connections is clearer. Thus, without intent, activity sequencing can be imbedded in the IDEFØ model. In cases where activity sequences are not included in the model, readers of the model may be tempted to add such an interpretation. This anomalous situation could be considered a weakness of IDEFØ. However, to correct it would result in the corruption of the basic principles on which IDEFØ is based and hence would lose the proven benefits of the method. The abstraction away from timing, sequencing, and decision logic allows concision in an IDEFØ model. However, such abstraction also contributes to comprehension difficulties among readers outside the domain. This particular problem has been addressed by the IDEF3 method.

2.4.3 Integrated Enterprise Modelling

2.4.3.1 Introduction

All methods such as Lean Management, Simultaneous Engineering, Total Quality Management and Continuous Improvement Processes aim at strengthening the competitiveness and productivity of the company by improving the product quality, reducing lead times and optimising the marginal pricing.

To improve the competitiveness all efforts are traditionally concentrated on optimising single functions. The traditional way of managing an enterprise is to subdivide it into a number of separate functions that are easier to overview and control. This method results in numerous 'interface' problems regarding the organization and optimisation of single functions at the expense of the manufacturing process and the organization as a whole.

When approaching the mentioned target, companies start to concentrate on [10]:

- their main business processes,
- gearing all functions and resources to their processes and
- improving the communication by widely sharing information within the processes.

The integration of separated functions, the optimisation of the main business processes and the specification of a suitable information flow require a higher degree of transparency within the organization. In consideration of the complex relationships - looking at the manufacturing enterprise as a network of functions - models or modelling methods have to be applied in order to support, to ease and to systematize the planning and integration of functions into business processes and to describe the related organizational structure. Such a concept ensures a common understanding of business processes and an understanding of how the required information and the organizational structure needs to be organized.

In the following, the method of Integrated Enterprise Modelling (IEM) is presented. IEM uses the object-oriented modelling technique for modelling business processes, related

organizational structures and required information systems. It provides a model for planning and optimising the processes and organizational structures within the enterprise.

Models developed according to the IEM method give a transparent representation of planning information and are therefore the basis for discussion between project participants. In order to evaluate the variety of planning information and description requirements it allows different views on one consistent model.

IEM models provide the means to precisely assign the value of planning goals, such as improvements in time, costs, or quality, to each business process and resource and, therefore, to optimise the process organization.

2.4.3.2 The Approach of Object-Oriented Modelling

To quote Bing Yu, David T. Wright [12]; "Object-oriented techniques are extensively used for the development of applications in various fields. The main advantage of this approach is the entirety of data and functions operating on these data. Provided with the powerful inheritance mechanism, it yields models which are more stable and easier to maintain than those based on other modelling approaches. However, a method providing an entire, object-oriented approach to enterprise modelling has not been heard of so far.

In order to utilize its advantages and to provide a comprehensive and extendible enterprise model, the IEM method uses the object-oriented modelling approach, thus allowing the integration of different views on an enterprise in one consistent model as well as the easy adaptation of the model to changes within the enterprise."

2.4.3.3 Generic classes of objects

The generic classes 'Product', 'Resource' and 'Order' are the basis of Integrated Enterprise Modelling for developing models from a user's point of view. They will be specified according to the specifications of an individual enterprise. Each generic class prescribes a specific generic attribute structure, thus defining a frame for describing the

structure and behaviour of objects of its subclasses (see figure 14). Real enterprise objects will be modelled as objects of these subclasses.

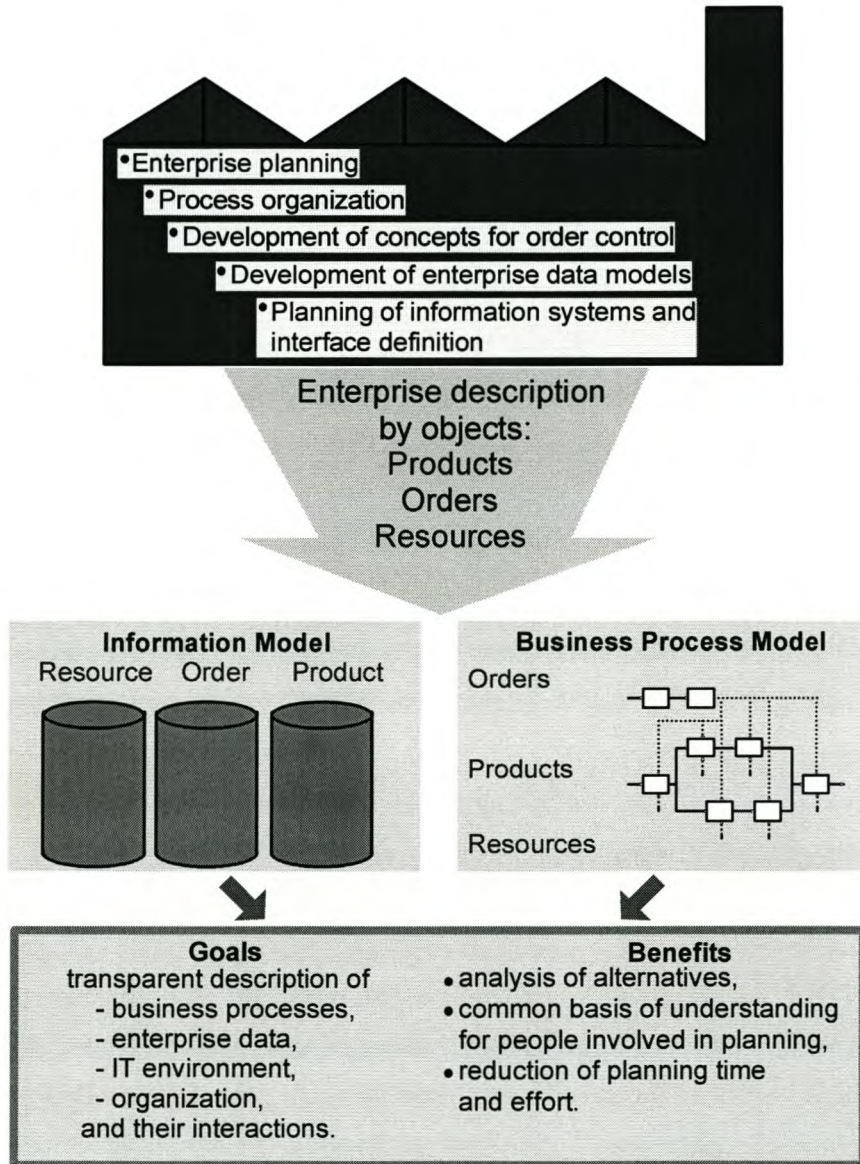


Figure 14: Views of the Enterprise Model – [10]

Required enterprise data and the business processes, i.e. the tasks referring to objects, are structured in accordance with the object classes (see below). Furthermore, the relations between objects are determined. The result is a complete description of tasks, business processes, enterprise data, production equipment and information systems of the enterprise at any level of detail.

The model core comprises two main views. The tasks, which are to be executed on objects, and the business processes are the focal point of the Process Model View, whereas the Information Model View primarily regards the objects describing data, see figure12. Therefore, the core of the enterprise model consists of the data and process representation of classes of objects. The views are interlinked by referring to the same objects and activities, although they represent them in different ways, levels of detail and context. Any view on the model can be derived from this standardized model core. Additional features may be attached to the core if necessary.

2.4.3.4 Business Processes as Interactions of Objects

Everything that happens in a manufacturing enterprise as part of the manufacturing process can be described by activities. In general, activities process and modify objects which were classified above as 'Products', 'Orders' and 'Resources'. The execution of any activity requires direct or indirect planning and scheduling. It is executed by resources which possess the required capacities. The IEM method suggests three levels when describing the essentials of an activity:

- The **Action** is an object-independent description of any task or business, a verbal description of some task, process step or procedure.
- The **Function** describes the processing of objects as a transformation from one determined (beginning) state to another determined (ending) state.
- The **Activity** specifies the order, which controls the execution of the function, and the resource(s), which is (are) in charge of executing the function.

Figure 15 graphically represents the Generic Activity Model. The beginning and ending states are connected with the action rectangle by arrows from left to right. An order state description and a dashed vertical arrow from the top represent the controlling of the activity. The required or actually assigned capability for executing the function is represented by a resource state description and a dashed vertical arrow from the bottom.

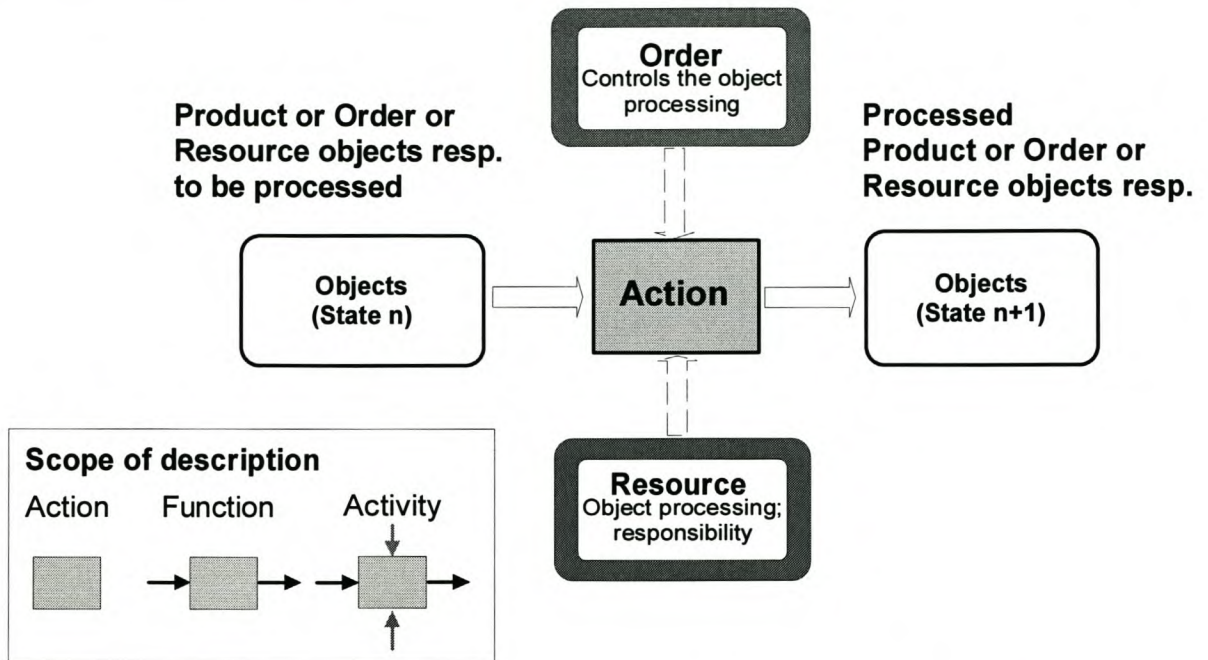
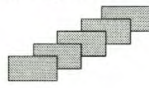

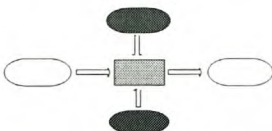
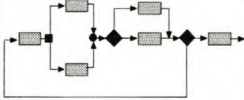
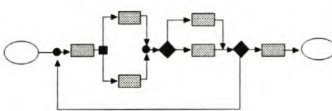
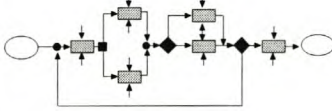
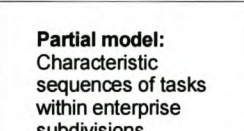
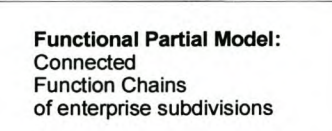
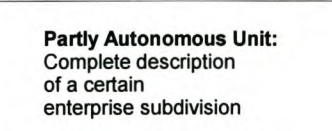


Figure 15: Interactions of Objects Described by the Generic Activity Model
– [10]

The Generic Activity Model represents the processing of objects of the product, order or resource class respectively indicating the interactions of objects while processing. Specific resource classes along with their interrelations describe the related organizational structure. The IEM modelling constructs of the Process Model View are shown in figure 16.

Constructs of Function Model view		Scope of description		
		Object-independent	Objects to be changed	All affected objects
Aggregation levels	Functional elements	Action Catalogues of Actions 	Function 	Activity 
	Functional chains	Method: + Characteristic task sequences + Catalogues of Methods 	Function Chains: + Main functions + Adjacent functions 	Activity Chain: Completely specified Function Chain 
	Partly autonomous units	Partial model: Characteristic sequences of tasks within enterprise subdivisions 	Functional Partial Model: Connected Function Chains of enterprise subdivisions 	Partly Autonomous Unit: Complete description of a certain enterprise subdivision 






Concatenating constructs	● Sequential	● Parallel	● Alternative	● Join	● Loop
					

Figure 16: Constructs of Function Model View – [10]

Product classes represent the principal results of the entire enterprise process - the products. Resource classes represent all means, including organizational units, which are necessary to carry out any activity in the enterprise. Order classes represent planning and control information. Figure 17 describes the attribute schemes of the generic classes.

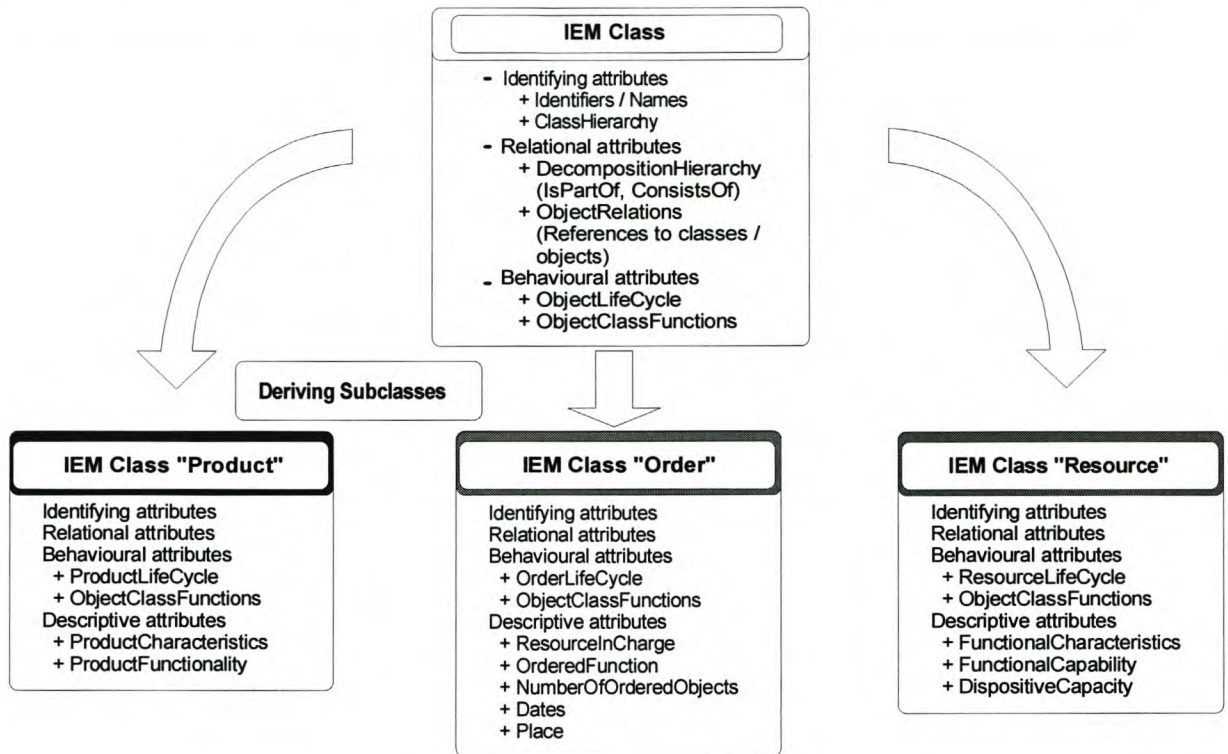


Figure 17: IEM Object Class Attributes – [10]

Further modelling aspects related to special modelling purposes may be integrated as additional views on the model. Examples of such special views include representations of control mechanisms, organizational units and costs. The two main views are the basis for the development of application-oriented views to describe all relevant aspects for meaningful decision-making.

2.4.3.5 The Process of Determining the Potentials of an Enterprise

The application of a modelling method should not only support single steps of factory planning. It has to guide and support the whole project. Therefore, it is necessary to reveal all aspects which are relevant to clarify weak points, to show potentials for optimisation and their contribution to the objectives of the enterprise. The following modelling phases can be distinguished:

- system delimitation,
- model design,
- model evaluation and utilization and

- model modification.

The purpose of the **system delimitation** is a well-aimed selection and limitation of the model which is to be prepared. It is indicated which enterprise-specific object classes and function areas have to be considered. The motto is 'fewer equals more'.

The **model design** is the phase of the composition of models. In operational planning projects enterprise-specific models are usually used to illustrate the actual state with so-called 'actual state models'. The model design is carried out in three basic steps:

1. Identification of the relevant enterprise-specific class structures for products, resources and orders within the delimited system;
2. Development of the two main perspectives: information model (identification of the class-describing attributes as far as necessary) and function model (description of functions and processes performed on the objects);
3. Derivation of partial models to clarify relevant planning aspects.

In the phase of **model evaluation** the weak points of the developed models are identified. The potentials for improvement are estimated and possible suggestions for optimisation are evaluated. Improvement potentials, which can be realized by means of abolishing weak points, should be evaluated according to:

- the degree of an improved accomplishment of enterprise goals and
- the expenditure necessary to abolish weak points.

The phase of **model modification** transfers the actual state into an ideal state. In general, the extended use of actual state models is far more effective and entails less expenditure. Figure 18 shows the modelling sequences.

For the participants, the results of a model-based business process-reengineering project appear to include an effective support of teamwork, a fairly simple opportunity to participate and an easiness to follow and understand the entire project. However, it also has an effect on costs, time demand and quality of the project work and the concepts to be compiled.

<u>project phases</u>	<u>modelling phases</u> system delimitation	model forming	model evaluation	model modification
project specification	determination of required model delimitation and detail			
goal determination		model of goals, i.e. in a goal tree		
analysis of the actual state + inquiry of the actual state		actual state description + main modelling views + special views		
+ identification of weak points			analysis of actual state description	
estimation of improvement potentials			comparison: actual state /goals	
development of concepts			comparison: actual state/ideal concepts	description of ideal state
realization				description of realized state

Figure 18: Relation between the Phases of Projects and Modelling Phases – [10]

2.4.3.6 Supporting Tools

Tools are available to effectively apply the object-oriented modelling to business process modelling and analysing. A manual with modelling rules describes effective proceedings to design an enterprise model with IEM. The rulebook includes descriptions of detailed modelling rules with examples of applications for different fields of application, for example, the identification of the product structure and relevant processes and the identification of weak points and improvement potentials.

Many of the applications and fields of application can only be employed successfully with the support of appropriate software. A suitable software tool, called MO²GO (see figure 19), has been developed.

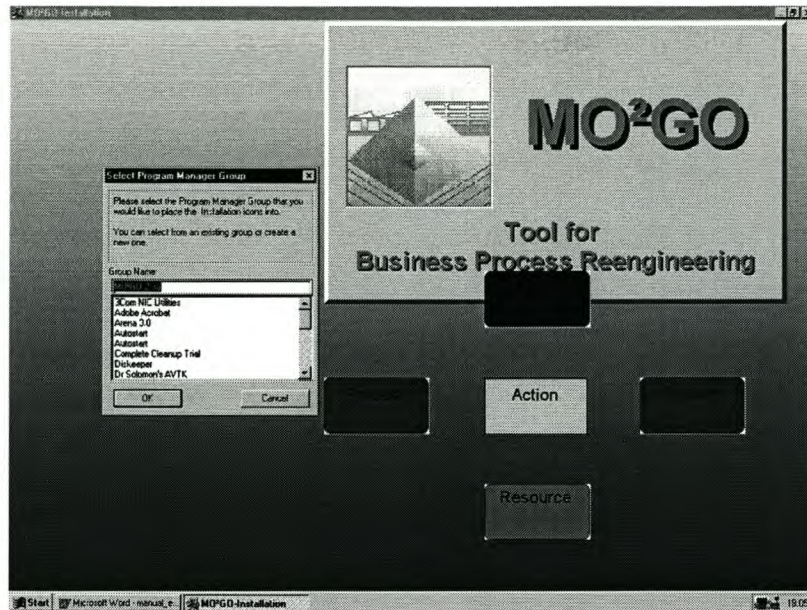


Figure 19: MO²GO

The software tool MO²GO supports the object-oriented modelling of IEM. The universal tool for the description and analysis of operational structures and business processes allows the comfortable description and the purposive analysis of products, orders, resources and the respective business processes. The main advantages of the application of the tool are the possibilities to systematise the re-engineering and optimisation process and to reuse the enterprise model for later projects with different objectives and optimisation tasks.

To quote Mertins, K, Jochem, R, Jakel, F.W [10]; “with MO²GO the design and certification of companies are sped up and facilitated. MO²GO increases the acceptance by employees and thus reduces costs. Refinement functions, deposited modelling rules and structured procedures support a structured approach to modelling tasks. The possibilities of the object oriented approach and extensive functions to define objects and business processes enable the user to describe his specific notion of the company. The illustration of the results of re-engineering and optimisation processes is supported by various evaluation and documentation functions. Results may therefore enter the operational decision-making processes much faster.”

2.5 Summary

Data flow diagrams (DFD) are a roadmap-like representation, which model function and data-processes in sequence [5][11]. The utility of the method underpins the requirement for faster generation of an information model by tracing information step by step. In spite of its popularity, the method is limited by its function orientation, and lack of specifications for where and by whom the processes or activities are performed. Also difficulty is often caused by the size of the model created when people investigate whether the way information processed is efficient or effective.

IDEF0 is the most commonly supported methodology [5][8][11]. With this method, activities or functions (i.e. subsidiaries of a process) are denoted by boxes, with communication or transformation between processes denoted by arrows. The advantage of the method is the progressive decomposition capturing all necessary information, coinciding with the natural understanding gained through the model building. Therefore, the technique has been adopted in almost all tools found. It is believed that IDEF readily creates an "as-is" descriptive model. However, the "as-is" model is transformed with difficulty into the "to-be" model in the redesign stage because of lack of explicit information expression.

In contrast with the DFD method, the object-oriented analysis (OOA) method differs conceptually [5][11]. The essential element in OOA is the object, which encapsulates its data descriptions and the operations that apply to it. As the operations are captured in an object, reorganising objects into different groups will not affect process control. Such reorganisation is vital during model and enterprise redesign. Due to data encapsulation, the data file model is no longer needed. Modellers can group object classes according to re-engineering requirements to create candidate databases for the redesigned system. All of these characteristics of the OOA method enable a modeller to reuse his/her model constructed with OOA more effectively, elegantly, and easily than the DFD and IDEF0 methods in the redesign stage.

3. Identify and Model Business Processes

3.1 Introduction

The goal of the two phases shown in figure 20 was to identify the AS-IS and TO-BE business processes and to develop a methodology for the modelling of these processes. The models of these processes are then used to assist in the development of the Roadmaps for the EDEN™ environment. Detailed explanations of the Roadmaps follow in chapters 5,6 and 7.

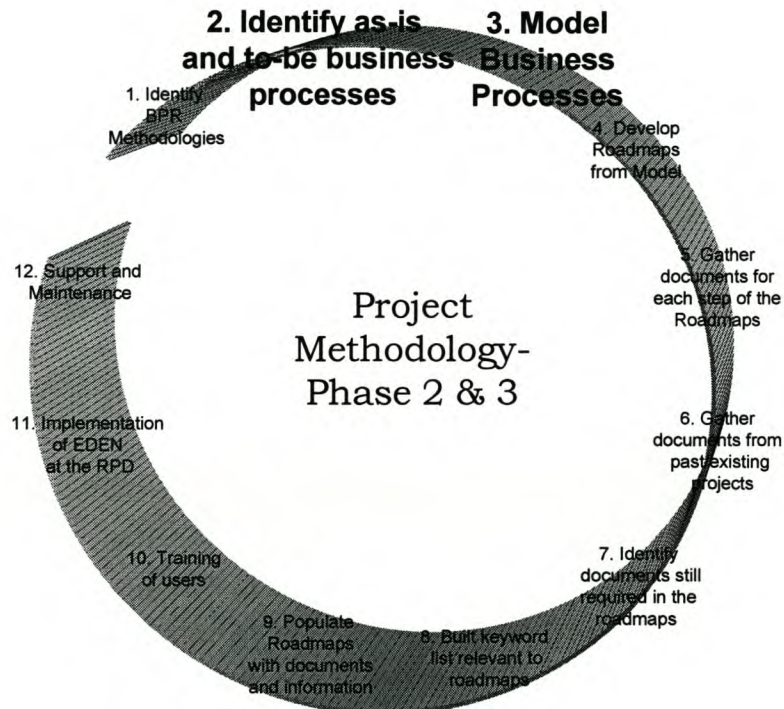


Figure 20: Phase 2&3 of the Project Methodology

Dina Birkenstock, an ex-employee of the GCC, developed an AS-IS and a preliminary TO-BE model during a previous project. The preliminary TO-BE model was found to be inadequate for the development of Roadmaps and was therefore remodelled.

The methodology outlines the methods used to model the developed TO-BE processes of the RPD. From these processes, procedures for each activity were developed. The

TO-BE model illustrates how these procedures could be incorporated into the RPD's business processes.

The MO²GO modelling tool, developed by the Fraunhofer Institute for Production Systems and Design Technology (IPK¹) of Berlin, was used to model the TO-BE processes of the RPD. The institute specializes in applied research and development in the fields of production technology, machine tools and factory management and mechatronics. The MO²GO tool, as described in section 2.4.3.6, is an object-orientated modelling tool that uses objects to represent business actions, orders, products and resources.

This chapter first explains the methodology used to model the developed TO-BE business processes. It then describes the general components of the TO-BE model and illustrates the TO-BE business process models. The chapter ends by verifying and validating the developed models.

3.2 The Modelling Methodology

The methodology that was developed to model the business processes of the RPD and to identify the procedures of the processes is based on a gap analysis approach. The steps and a description of each of the steps in the methodology are outlined below:

Step 1: Define Goals of Modelling Exercise

This step clarifies the ultimate goals of the modelling exercise. Why the model is being built, what the user hopes to achieve with the model and how the model will help achieve these goals.

Step 2: Define the RPD

It is vital to understand the overview of the RPD business, what they do and who they are. Boundaries around the RPD should be developed so that the scope of the modelling exercise is clear.

¹ Website: www.ipk.fgh.de

Step 3: Interview RPD Employees

The necessary information needs to be gathered. There are several ways in which this information gathering can occur. The most difficult but most valuable means of gathering information is to interview the relevant RPD employees.

Step 4: Develop TO-BE Class Structures

The class structures for the TO-BE resources, orders and products was developed and categorized. Once these are correctly formulated the modelling exercise will be efficient.

Step 5: Model TO-BE Processes

The business processes are modelled by first addressing the required tasks for each process and then by attaching the necessary orders, resource and products.

Step 6: Identify the Required Procedures of the Processes

This step requires a detailed look at the requirements of each process or action. The procedures that are required are documented and described. The procedures are included in chapters 5,6 and 7.

3.3 Step 1: Define Goals

The first goal of this modelling exercise is to depict the TO-BE processes graphically and to develop requirements for each process with respect to quality management. These requirements include:

- Procedures
- Checklists
- Responsibilities
- Templates
- Examples

The second goal is to model the processes in such a way that these models can assist in the development of the Roadmaps for the EDEN environment. The final goal is to verify and validate the developed models with the assistance of the RPD personnel.

3.4 Step 2: The Rapid Product Development (RPD) Enterprise

RPD is a commercial venture that provides highly specific and technical services to South African Industries. The RPD execute each interaction or job for a client in the form of a project and this has significant influence on the modelling of the business processes.

The RPD unit provides a wide range of services, which include:

- CAD Modelling
- Reverse Engineering
- Product Quality Control
- 3D Printing
- Silicon Mould Manufacturing
- Tool Machining

3.5 Step 4: Components of the TO-BE Model

The three components of the TO-BE Model are listed below. A class structure for each component was developed. These class structures play a fundamental role in construction of models and are described in the following sections. The three components are:

- Orders
- Products
- Resources

3.5.1 Orders

Orders describe and control the activities in the enterprise e.g. customer orders, design and production orders. Figure 21 illustrates the class structures of the orders for the TO-BE Model.

3.5.1.1 External orders

The external orders would be the control or trigger activities made outside the enterprise, in this case the customer. External orders are all the triggers that are not done by the enterprise.

- **First contact by customer**

This order controls the whole project lifecycle and would trigger the first activity of the process.

- **Customer requests quote**

After the customer made the first contact, certain activities follow. These activities would determine if the customer would request a quotation. The 'First contact by customer' order is thus changed to a 'Customer requests quote' order. This order triggers the activities that determine the quotation.

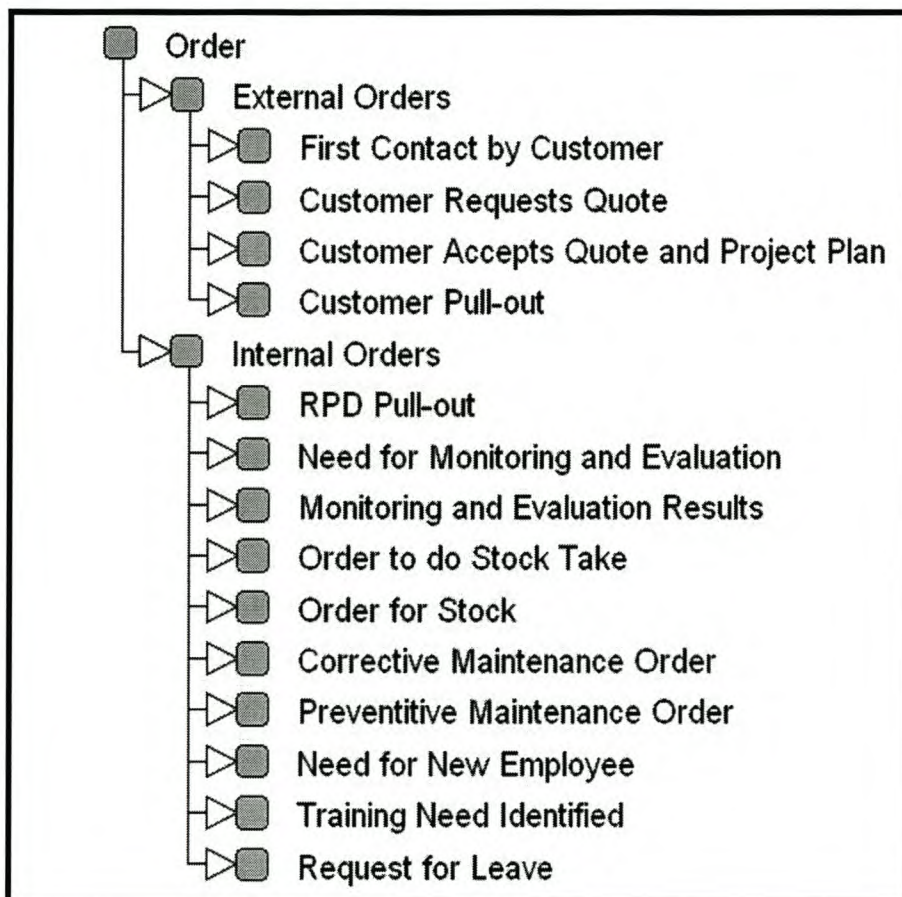


Figure 21: Order Class Structure for TO-BE Model

- **Customer accepts quote and project plan**

After a quotation is given to the customer he must decide whether the RPD enterprise should proceed with the job. A completed quote, including the project duration, are given to the customer from which the decision to proceed with the job is made. The acceptance of a quote is the trigger for executing the job.

- **Customer pullout**

The customer can withdraw at any stage before the execution of a job starts. In this case the 'first contact by customer' order is changed to a 'customer pullout' order.

3.5.1.2 Internal orders

The internal orders are all orders that are made internally. These orders would trigger internal activities.

- **RPD pullout**

The RPD enterprise can also pullout at any stage before the execution of a job. Limited resource capabilities can be a reason for a RPD pullout. The 'first contact by customer' order is change to a 'RPD pullout' order.

- **Need for Monitoring and Evaluation**

There is always the need to monitor and control a project to capture information such as project expenditure and material consumption. The 'need for monitoring and evaluation' order controls the activities that create the relevant information of a project.

- **Monitoring and Evaluation results**

The need for monitoring and evaluation is an ongoing process and will give certain results at certain stages of the project lifecycle. These results are interpreted and certain decisions are made accordingly.

- **Order to do Stock Take**

The RPD enterprise has certain raw materials for production purposes. The Stock Take order is requested at specified instances to prevent shortages in stock.

- **Order for Stock**

The Order for Stock is triggered if the stock levels are below the reorder levels.

- **Corrective Maintenance order**

When a machine experiences a breakdown, corrective maintenance are required. The order, 'corrective maintenance', request this action.

- **Preventive Maintenance Order**

To prevent and minimize machine breakdowns, preventive maintenance is required. The 'preventive maintenance' order requests this action.

- **Need for New Employee**

The need for a new employee triggers the order, 'new employee'.

- **Training Need Identified**

The need to train new and current employees requests the 'training need identified' order. All the activities concerning training are controlled by this order.

- **Request for leave**

The request for leave by an employee triggers the 'request for leave' order.

3.5.2 Products

All Products are objects, which include final products as well as raw materials and by-products. Figure 22 illustrates the product class structure of the products for the TO-BE Model.

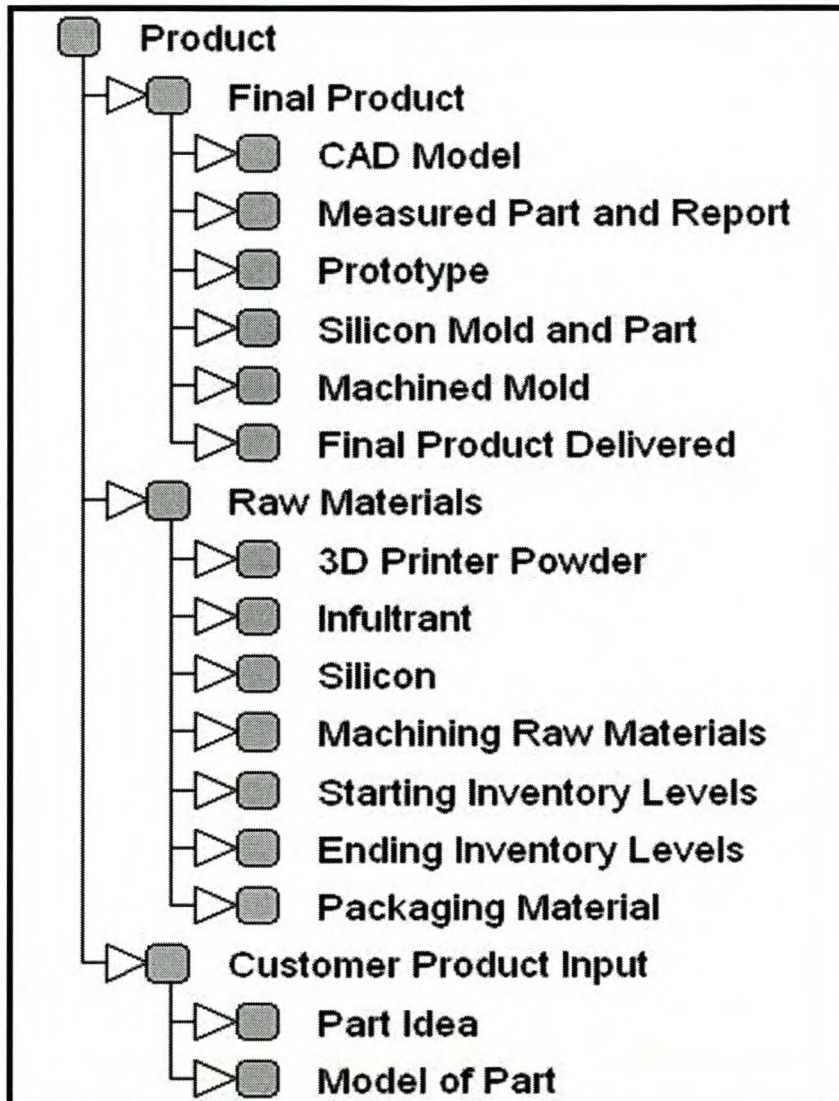


Figure 22: Product Class Structure of the TO-BE Model

3.5.2.1 Final Product

This will be all the products and services that the RPD enterprise provides. There are six different products.

- **CAD Model**

A CAD model is created through either CAD Modelling or Reverse Engineering.

- **Quality Control**

To ensure the quality, critical dimensions of a part is measured. A report with the relevant information can be printed to ensure the customer and the quality management team of the correctness of the part's dimensions.

- **Prototype**

Prototypes of a product are used as visual aids or for assembly or functionality testing.

- **Silicon Mould and Part**

A silicon mould operates as a bridge tool to produce a small pre-production batch of the product for testing and marketing purposes.

- **Machined Parts**

Machining has the purpose of producing parts or tooling. Machining is done either internally or externally, depending on the availability of machines and size of the part.

- **Final Product Delivered**

A product is ready for shipment after completion and testing. 'Final product delivered' is the end result of the project lifecycle.

3.5.2.2 Raw Materials

The raw materials are used for production purposes. Different raw materials are required for the range of products that RPD produces.

- **3D Printer Powder**

Two types of printer powder are used for the printing of 3D parts.

- **Infiltrant**

Infiltrant is a material applied to a 3D part for various reasons.

- **Silicon**

Silicon is used to form moulds that are used to produce a pre-production batch of products, as described in section 3.5.2.1. The silicon mould can only be used for a limited number of products.

- **Machining Raw Materials**

These are the raw materials used for the machining of parts and tools.

- **Starting Inventory Level**

The starting inventory level is the level that is acquired through the 'stock take' procedure. Procurement of materials are required if the starting inventory level is below the reorder level.

- **Ending Inventory Level**

The inventory levels are updated with the quantities of the received goods.

3.5.2.3 Customer Product Input

The input of the customer can either be a product idea or a model. The model is normally a CAD drawing or a physical part.

3.5.3 Resources

Resources are the service carriers of the enterprise that is required to execute the processes. The Resource Structure is illustrated in Figure 23.

3.5.3.1 Responsibilities

The responsibilities of each employee play an important part in the enterprise. The responsibilities are divided into the main figures of the enterprise namely the Head of RPD, General Manager, RPD Operational, Business Partners, New Employee and Ex-employee.

3.5.3.2 Business Partners

Business partners of the RPD include the customers, suppliers and outsourced services.

3.5.3.3 New Employee

New employees are appointed when the need arises. These employees follow a specific training program to align them with the business processes and functions.

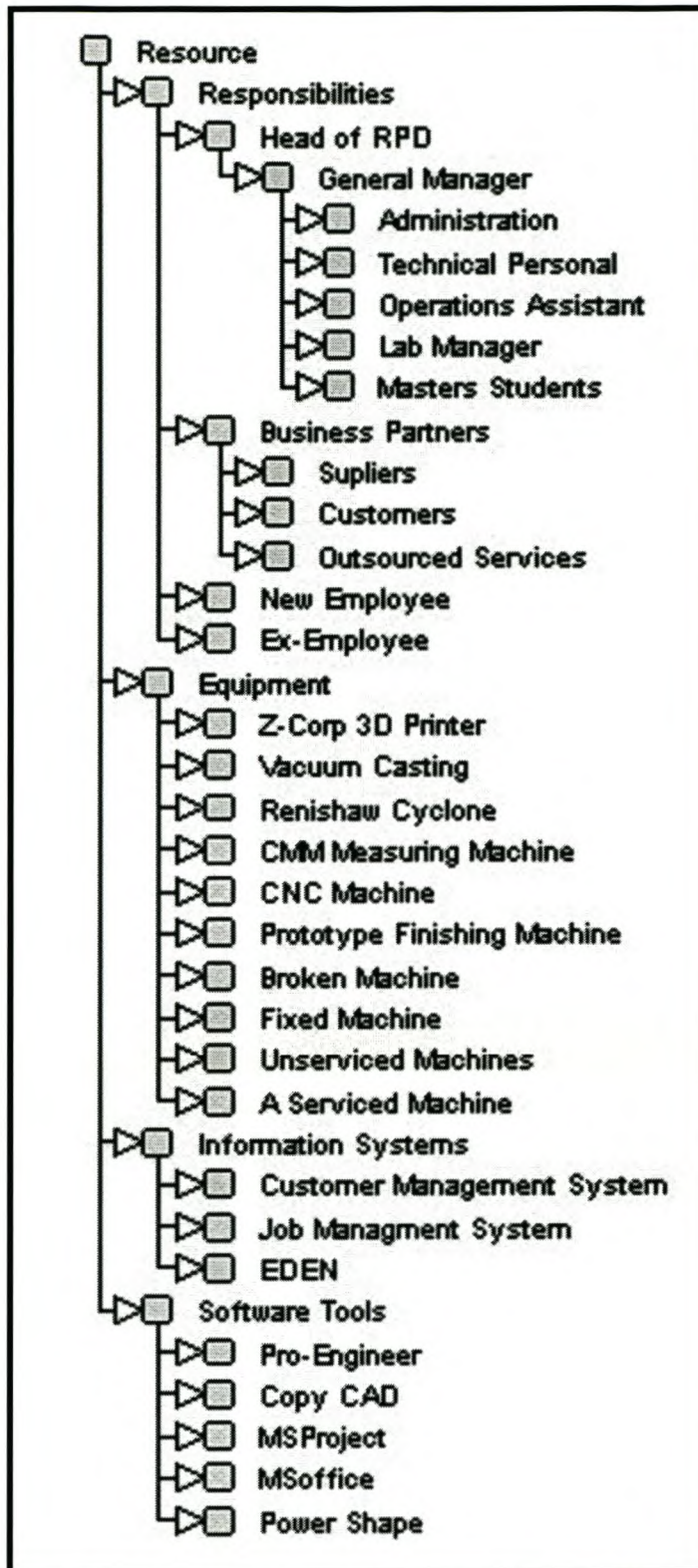


Figure 23: Resource Class Structure of the TO-BE Model

3.5.3.4 Ex-employee

An ex-employee is an employee that has resigned and or does not work for the RPD enterprise anymore.

3.6 TO-BE Processes

The TO-BE models of the business processes were modelled using the MO²GO modelling tool. There are 2 distinct types of processes, namely the Project Management processes and the Business Function processes.

The Project Management Processes are vital as all the RPD's work for clients are managed in the form of projects. The development of the TO-BE Project Management Processes is based on a Theory of Constraints approach. The Product Development Processes form part of the execution step of the Project Management Process.

3.6.1 Project Management Processes

The highest level of the Project Management Processes consist of 5 main phases:

- Initiation
- Quotation and Planning
- Execution
- Closure
- Monitoring and Evaluation

Each of the above steps is described in more detail in the following sections.

The main order input of the Project Management Processes is the *first contact made by a customer*. The main order output is the *acceptance of a quote and project plan*. This order is then the trigger for the start of the execution step, which is followed by the closure step. There are 2 possible product inputs for the execution step. The product input can either be a *part idea* or a *model of a part*. *Final product delivered* is the main product output of the execution and closure steps.

The activities of Monitoring and Evaluation, and Execution are performed concurrently. The order output of Monitoring and Evaluation acts as a trigger of the closure step. The high-level Project Management Processes are included in Appendix A.

3.6.1.1 Initiation Phase

The Initiation Process consists of 3 main tasks:

- Capture Data in CMS
- Feasibility and Profitability Study
- Scope and Cost Proposal

The order input is the first contact the customer makes with the RPD and the order output is the customer requesting a quote. There are also orders during the process where either the customer or the RPD are able to terminate the process.

There are several key resources required during this process. From the RPD employee resources the General Manager, the Lab Manager, Technical Personnel and administrative staff are required. The Customer Management System (CMS) system is also required.

The Initiation step is illustrated in Appendix A.

3.6.1.2 Quotation and Planning Process

The Quotation and Planning Process consists of 3 main tasks:

- Preparing Quotation
- Prepare Activities Schedule and Do Material Planning
- Update CMS and Job Management System (JMS)

The order input for this process is the same as the order output of the previous process, which is the customer requesting a quote. The order output is therefore the customer accepting the quote and the project plan.

The main resources once again include the RPD employees. The CMS, JMS and MS-Project are all the software resources required during this process. The quotations and planning step is illustrated in Appendix A.

3.6.1.3 Execution Process

The Execution Process consists of 8 main tasks. These tasks make up the Product Development Process. They are the following:

- Determine Customer Requirements
- Reverse Engineering
- Quality Control
- CAD Modelling
- Procurement of Special Materials
- 3D Printing
- Post Processing
- Machining

The Product Development Process can comprise of one or more of the tasks, depending on the customer requirements. Therefore each task can have it's own output products. The input products also vary from task to task, as each task requires different raw materials. The main input tasks are either a part idea or a part model. Some of the raw material input products include 3D printer powder, Silicon and machining materials. Some of the output products include CAD models, prototypes, silicon moulds and machined parts.

Several resources are required for this process. The human resources from the RPD include the Technical personnel, Lab manager and Masters students. The equipment resources include the Z-Corp 3D Printer, Vacuum Casting equipment, CMM Measuring machine and a CNC machine. The software required includes the CMS, JMS, Pro-Engineer, Unigraphics, PowerShape and Copy CAD. This step is illustrated Appendix A.

3.6.1.4 Closure Process

The Closure process consists of 5 main tasks:

- Packaging of Products
- Shipping of Products
- Invoicing
- Payment
- Check On Customer

The input product for this process is a final product and the output product is a delivered, invoiced and paid product. Here resources include Technical Personnel, Administration, the CMS, JMS and outsourced services. The closure step is included in Appendix A.

3.6.1.5 Monitoring and Evaluation Process

The Monitoring and Evaluation Process involves 4 main tasks. These include Material Consumption Monitoring, Expenditure Monitoring, Project Planning Monitoring and Reporting. Each of these tasks changes the need for monitoring and evaluation to management reports and triggers the closure step. These monitoring tasks are performed throughout the execution step of a project. This step is illustrated in Appendix A.

3.6.2 Business Function Processes

The Business Functions of the RPD are functions supporting the organisation's operations and the Project Management processes. The Business Functions identified for the RPD are listed below:

- Marketing
- Finance
- Material Management
- Quality Management

- Human Resources
- Business Information
- Management Information
- Project Research
- Maintenance

Most of the above listed business functions do not consist of fixed procedures. It was therefore not necessary to model all the business functions. The only business functions that contain fixed procedures are Material Management, Human Resources and Maintenance. The modelling of these processes was done on a high-level.

3.6.2.1 Maintenance

This Business Function consists of two types of maintenance namely, corrective and preventive maintenance. Corrective maintenance deals with the processes that repairs equipment or machinery once it has failed, while preventive maintenance is concerned with preventing the machinery or equipment from failing. Preventative maintenance is normally done according to a predefined schedule. The maintenance function is included in Appendix A.

3.6.2.2 Material Management

The Material Management function consists of a few sub-functions. Only the inventory control sub-function has a fixed procedure. Inventory control deals with stocktaking, the procurement of materials and the receiving of the goods from suppliers. The high-level process of the inventory control is shown in Appendix A.

3.6.2.3 Human Resources

The Human Resource Process deals with the lifecycle of an employee at the RPD. The lifecycle starts at the induction and training of a new employee. It is followed by career development and leave applications and ends with the departure of an employee. Human resources function is illustrated in Appendix A.

3.7 Verify and validate the TO-BE model

To verify the above models we ask the question “did we build the models right?”. The main action here is debugging, to verify that the computerised models are illustrated correctly. Other actions include the correction of syntax errors and checking the logic of the models. After verifying the TO-BE models of the processes, the models have to be validated.

Verification allows us to confirm that we have built the model right, whereas validation allows us to confirm that we have built the *right* model. Three questions must be considered:

- **Conceptual validity:** Does the model represent the real world system adequately?
- **Operational validity:** Can the model's outputs be associated with the real world system's behavioural outputs?
- **Credibility:** Does the model's end-user have confidence in the model's results

The verification and validation of the models was done during a workshop with the assistance of the RPD personnel.

4. The EDEN™ Environment

4.1 Introduction

The development and modelling of the TO-BE business processes and functions were explained in the previous chapter. After this was finalised, the development of the Roadmaps for the EDEN™ Environment could start. Before the development process can be explained, the EDEN™ Environment has to be described. The descriptions of the main features were taken from EDEN™ User Manual [13].

4.2 Roadmaps

A roadmap is a pre-defined structure consisting of a Life Cycle Section, a Process Definition Section and an Additional Information Section. A roadmap is a guide that leads the user through a series of steps in order to create an understanding of the methods to be used when starting a new project or product design.

The Roadmaps could take the form of a virtual lifecycle, a continuous process or a methodology. There can be many or as little as one Roadmap for a specific EDEN™ solution. The Roadmaps can have one level, which is the step level, or the steps can be further divided into functions and even sub steps. The decision as to the depth of the Roadmap will depend on the amount of detail required for the specific solution.

4.2.1 Life Cycle Section

The Life Cycle is designed with steps that represent the phases to be executed. Each step may consist of various sub-steps that need to be completed in order to complete the step as a whole.

The whole structure of the specific Life Cycle is displayed in the Life Cycle Section. This section is situated on the left hand side of the EDEN™ environment (see figure 24). Selecting the different tabs at the top of this section allows access to different Life Cycles.

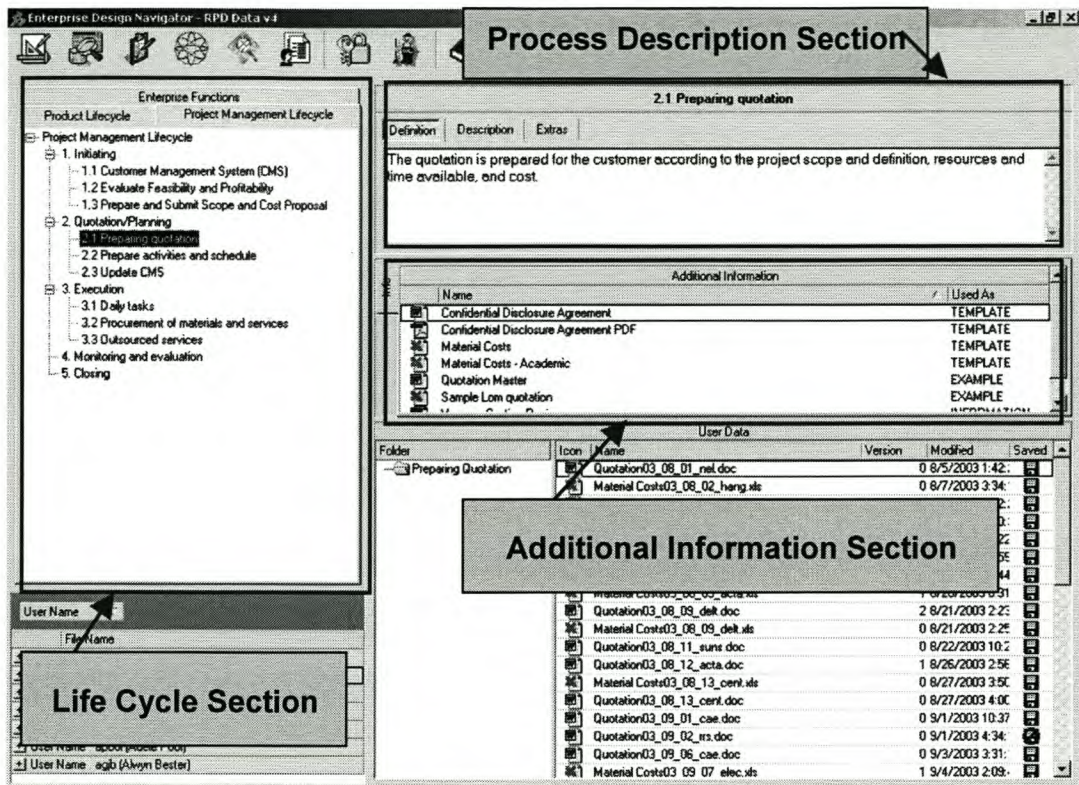


Figure 24: Roadmap of EDEN™ Environment

4.2.2 Process Definition Section

Each step in the selected Life Cycle is defined and described in the top right section of the EDEN™ screen (see figure 24). The user can either view the definition of the step or a more detailed description of what needs to be accomplished in a particular step by clicking on the corresponding tab at the top of this section. The user cannot change this information, as it is pre-defined.

4.2.3 Additional Information Section

In the Additional Information section of EDEN™ information is displayed that assists the user in executing the specific Life Cycle step. This information takes the form of templates of required documentation, examples of completed templates and/or best practises. Information is linked to a specific Life Cycle step or sub-step.

The templates and examples fulfil two important roles. Firstly the Examples provide suggestions for the user about “how” to complete a particular step. Secondly, Templates give the user good starting points.

4.3 The Checklist Function

Checklists are used to ensure the comprehensive completion of a step. Each step has a list of tasks, which need to be completed and ticked off before the step can be considered finished.

The Checklists are time stamped so the progress of the project can be carefully monitored. Checklists are used to check that all the necessary activities have been completed before moving on to the next step in the Life Cycle structure. It also displays the progress of specific tasks. Clicking inside the box next to a specific task, assigns a completion tick to that task.

The Checklist of a step can be viewed by first selecting the specific step, and then by clicking on the Checklist button on the Toolbar. See figure 25.

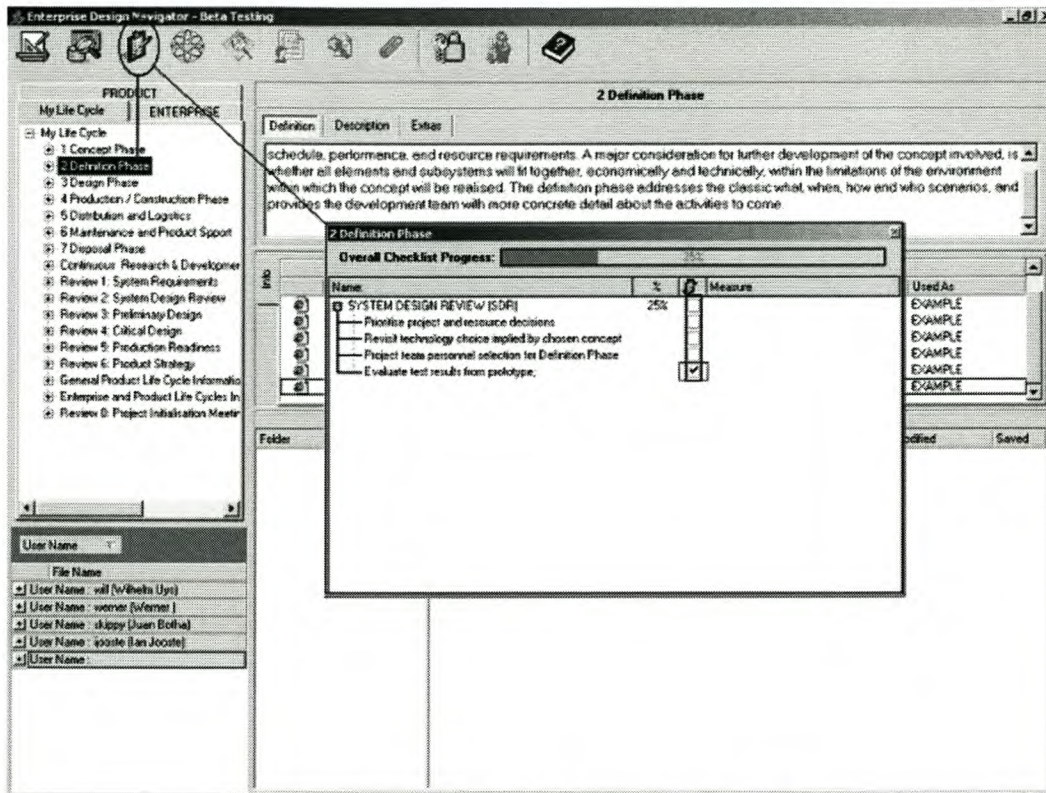


Figure 25: Checklist Function of EDEN™

4.4 User Data Document Management Section

The document management system in EDEN™ assists the users to control the specific documentation of a project. The system includes document version control; a document audit trail and a functionality to capture document Meta Data.

- **Version Control:** Document version control automatically assigns a new version number to a document when it has been edited. All users work from the most up to date document but can return to old versions if needed.
- **Audit Trail:** EDEN™ tracks which user edited which document. Other users can see what information has been added and by whom.

The User Data Document Management Section consists of a Scratch Pad section and a User Data Section. The Scratch Pad is used to temporarily store documents that are still

in the early development stage and do not require a collaborative effort. Once more users are required to either add information or access the document, the document is added to a specific Life Cycle Step.

The User Data Section serves as a pigeonhole for storing and managing user documents. These documents are grouped and linked to a specific Life Cycle step, whereas the documents in the Scratch Pad are not step specific. See figure 26.

4.5 The Search Function

EDEN™ internally has a Keyword Search and a Full Text Search function. Clicking on the Search icon on the EDEN™ toolbar can access these search functions. Both of these search functions uses the dtSearch engine.

These search functions are primarily used to search for documents inside EDEN™ using specific words to search with. See figure 27.

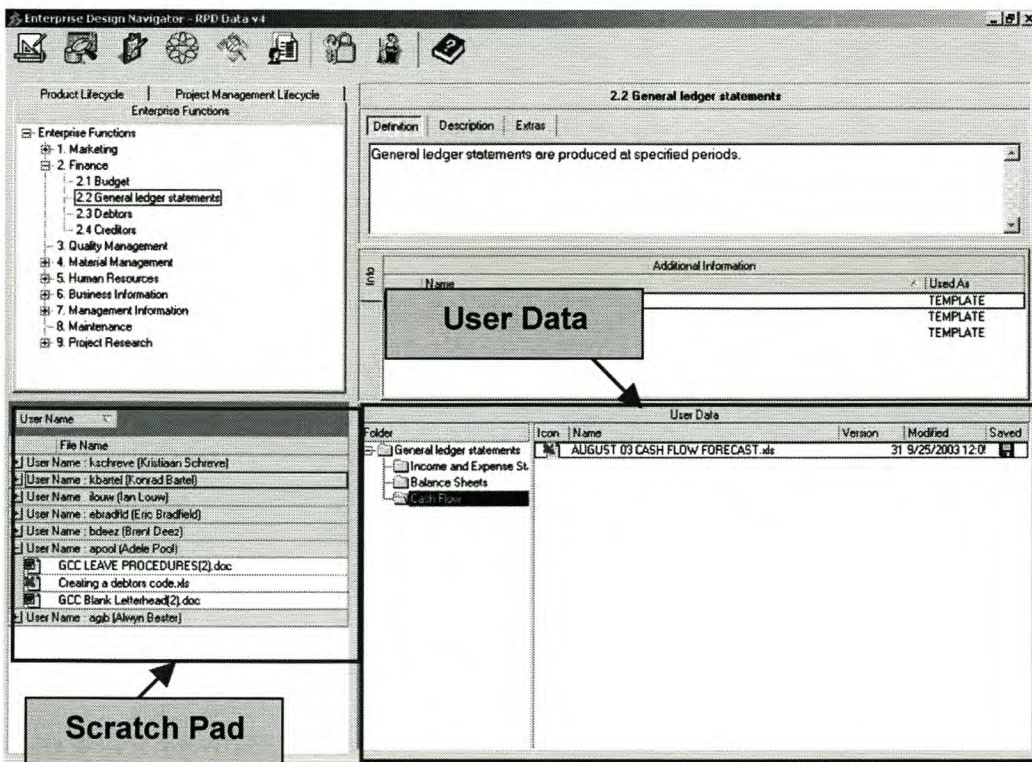


Figure 26: User Data Document Management Section

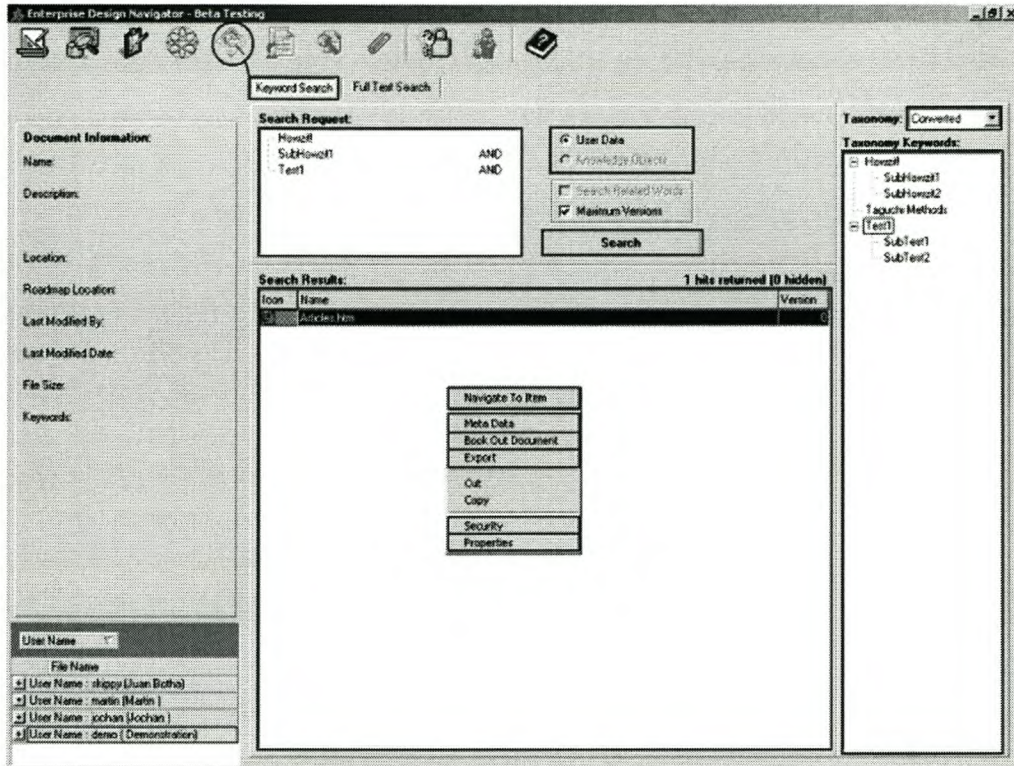


Figure 27: The Search Function

5. Project Management Roadmap

5.1 Introduction

The Project Management processes as described in chapter 3 are very important for the RPD, because all their jobs are managed in the form of projects. The model of the Project Management processes was used to support the development of the Project Management Roadmap. Figure 28 illustrates the phase of the Project Methodology.

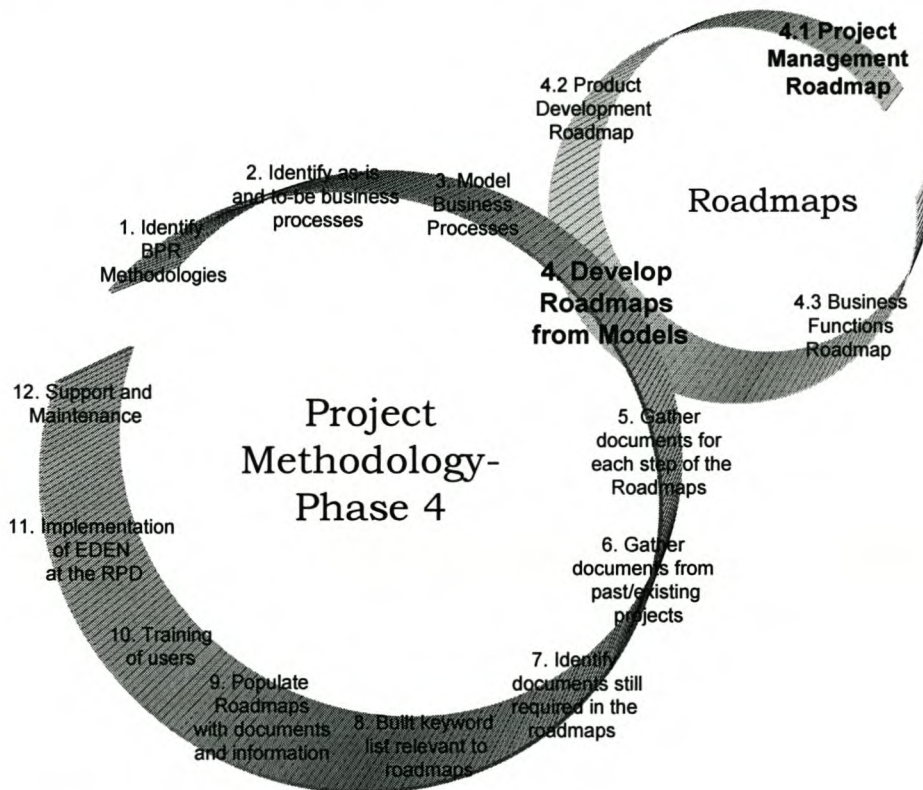


Figure 28: Phase 4.1 - Develop Project Management Roadmap

The Project Management Roadmap is firstly a guide that leads the user through a series of steps in order to create an understanding of the methods to be used when starting a new project. Secondly, the Roadmap is used as a reference point to direct and support users when managing a project.

This chapter firstly illustrates the Project Management Life Cycle in the Life Cycle Section of the EDEN™ environment (see figure 29). It further describes each step and sub-step of the Life Cycle. The same description of the steps and sub-steps given was used for the Process Description Section of EDEN™. Procedures were developed for each step of the Project Management Life Cycle. These procedures are used as checklists in the EDEN environment. The checklists/procedures are included in Appendix B.

5.2 The Project Management Roadmap

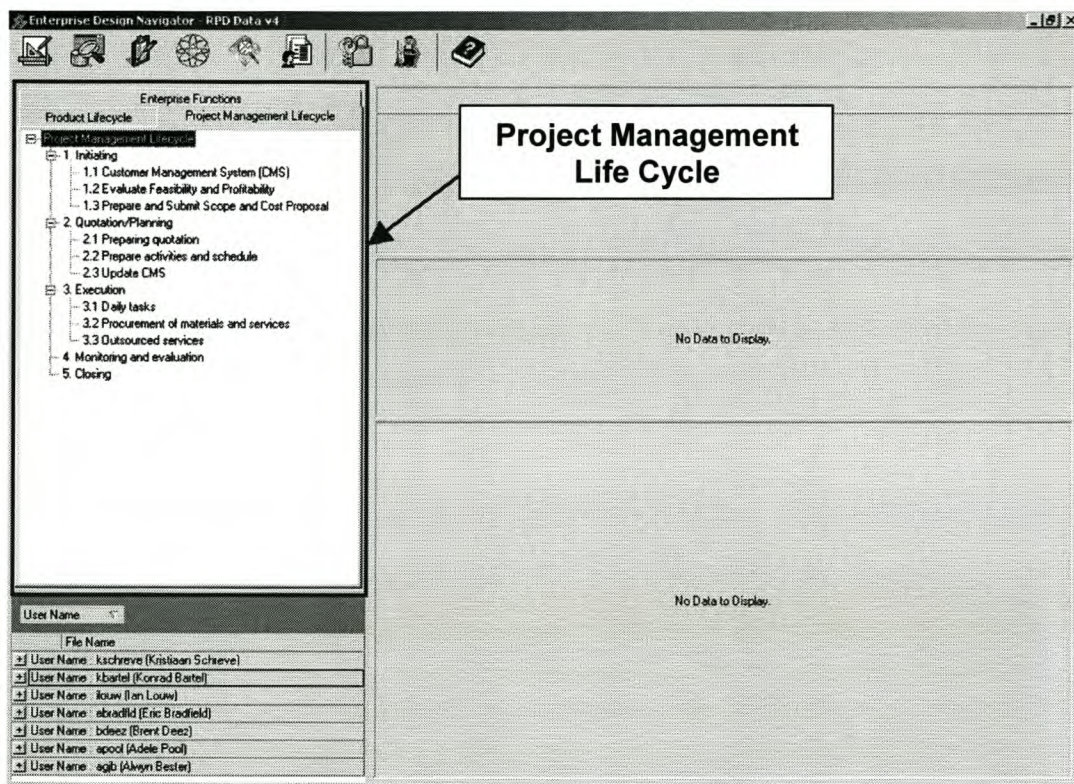


Figure 29: Project Management Life Cycle in the EDEN™ Environment

The steps of the Project Management Roadmap, which follow, are numbered in the same manner as the steps in the EDEN™ environment as illustrated in figure 29.

1. Initiating

The initiating phase is to establish first contact and to follow-up potential clients in order to establish the possibility of future business.

It is important that all client information be captured for reference purposes. The Customer Management System is used for this purpose. All potential projects are evaluated for feasibility and profitability before preparing and submitting a scope and cost proposal. This evaluation is done by following the checklists provided in EDEN™. The scope and cost proposal is not a final proposal, but rather a rough estimation of the money and time required for the project.

1.1 Customer Management System (CMS):

The customer management system is used in various steps of the project management life cycle. In the initiation phase it is important to capture new client information according to predefined fields, or provide information on previous clients.

1.2 Evaluate Feasibility and Profitability:

The evaluation of feasibility and profitability is done in accordance to guidelines. This is done to ensure that projects are not undertaken that falls outside the scope and capabilities of the RPD.

1.3 Prepare and Submit Scope and Cost Proposal

This step is concerned with the submitting of an initial proposal that provides broad outlines on the scope and cost of the job requested by the client. A standard template is provided for preparing the proposal. It also serves to open doors of communication.

2 Quotation/Planning

The scope and cost proposal in the initiation step provides the starting point for quoting the client. A detailed quotation is prepared and submitted to the client. After the quotation is accepted, detailed activities and schedules are prepared for the execution of the project.

The quotation process consists of the following activities:

- Project scope and definition - This is done to formally define the type and size of the project to be undertaken for the client.
- Resource planning -This is done to see what the availability of resources required are in order to provide a realistic time of completion.

- Establish Project Cost Baseline - Pricing for the client is done by using the costing tool provided in EDEN™.

The size of the project will determine if a detailed project plan will be provided to the customer. Usually a detailed project plan is done after quotation to customer. The plan is set up in order to obtain preliminary activities and schedules. The CMS and JMS are then updated according to quotation that was submitted to the client.

2.1 Preparing quotation

The quotation is prepared for the customer according to the True Variable Cost (TVC).

2.2 Prepare activities and schedule

Here a detailed project plan with activities and schedules is determined. The information of the quotation is used to guide this process.

2.3 Update Customer Management System (CMS)

Depending on the acceptance of the quotation, the client orders must be captured and maintained in the customer management system.

2.4 Update Job Management System

All job related information gathered until this point of the project management life cycle should be recorded in the JMS.

3 Execution

Execution is concerned with the daily completion of tasks in order to meet deadlines for the various specific projects. This step is the beginning of a concurrent interaction with the product life cycle.

Using planning on activities and schedules (done in step two), the daily tasks for execution are determined by taking queuing rules and time for procurement of goods and service into consideration. Job cards are completed for each project, but the execution of these is dependent on the planning of daily tasks.

3.1 Daily tasks

Electronic job cards are completed for each project. These job cards are used as communication and for scheduling of daily tasks. Queuing rules are used to do these scheduling of tasks.

3.2 Procurement of materials and services

The step, procurement of materials, is only concerned with materials that are not normally stocked by the RPD. Normal inventory control is part of the inventory management business function.

The process consists of:

- Obtaining a quote
- Completing a requisition form
- Purchase
- Delivery and sign off.

3.3 Outsourced services

The RPD also serves as project coordinator to source services that it cannot provide. Services such as delivery services are of the services that are sourced.

4 Monitoring and evaluation

Monitoring and evaluation is concerned with monitoring improvements and to evaluate the success of each project.

Monitoring and evaluation is done on each project (or groups of projects) in order to evaluate the success of each project and to facilitate continuous improvement by considering improvements that has been achieved. It is also used to provide information to management. The monitoring and evaluation procedures and forms are provided as tools in EDEN™.

5 Closing

Closing is at the completion of the project when delivery of product/service has been done to customer, and all queries have been dealt with.

Closure deals with two aspects:

- Contract Closure – Ensure that the customer is satisfied with product/service and that all queries have been dealt with. Ensure that product /service is paid for.
- Administrative Closure – Ensure that all administrative aspects are updated to reflect the closure of the contract.

6. Product Development Roadmap

6.1 Introduction

The Product Development processes as described in chapter 3 forms the core of the Project Management Roadmap. These processes are all part of the execution phase of the Project Management Life Cycle.

As shown in the model included in Appendix A, the execution phase forms a lifecycle on its own. Because of this a separate Roadmap was developed for the Product Development processes. This Roadmap is illustrated in figure 30.

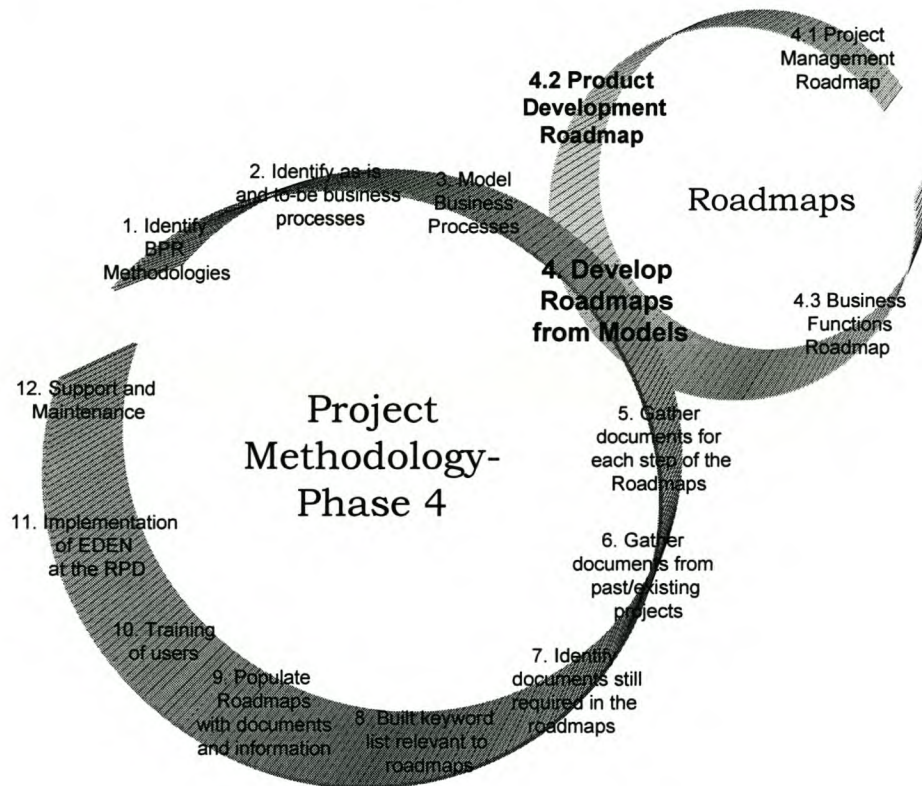


Figure 30: Phase 4.2 – Develop Product Development Roadmap

The Product Development Roadmap acts as a guide that leads the user through a series of steps in order to firstly create a better understanding of the methods to be used and secondly how to use these methods when starting a new product development.

Detailed descriptions of each step and sub-step are given in the next section. For each step procedures were developed and are used as checklists in the EDEN environment. Checklists/procedures are included in Appendix C.

6.2 The Product Development Roadmap

The steps of the Project Management Roadmap, which follow, are numbered in the same manner as the steps in the EDENTM environment as illustrated in figure 31.

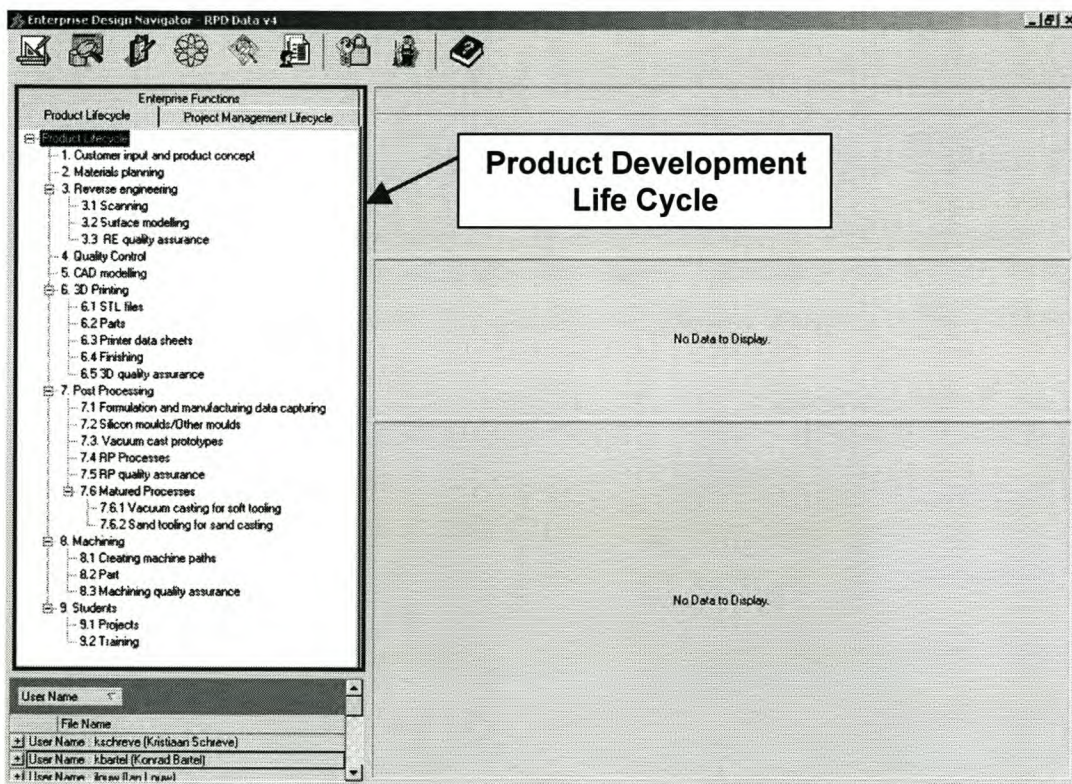


Figure 31: Product Development Life Cycle in the EDENTM Environment

1. Customer input and product concept

Customer input is about the physical product, drawings, models or ideas that the customer provides. This forms the basis of the product concept.

All the possible input from the customer must be captured. Define and document customer's expectations and also the end goal of the data. This information is important because it forms the basis of the product concept. The customer input is transformed into a product concept according to the requirements of the customer and the functional specifications. The product concept represents in principle the basic solution for the customer input containing the functional structure as well as the underlying active principles and combinations of active principles. The main result of product concept is usually a set of drawings and sketches that will be detailed in the process of product design, usually using CAD.

2. Reverse engineering

The objective of this process is to generate a product concept from a given product model. In the process of Reverse Engineering the product model will be scanned, the cloud of measuring points will be transferred to a computer, and surfaces will be generated from the measuring points using special CAD-functionalities. This way a product concept can be generated as a CAD-file. A quality control procedure is then performed by comparing the measurements of the original product with the measurements of the modelled product.

2.1 Scanning

The product is scanned with the Renishaw Cyclone scanner and scan-data is produced.

2.2 Surface modelling

The scan-data is used in various CAD packages to do surface modelling.

2.3 RE Quality Assurance

RE quality assurance is done by measuring a product in three dimensions and comparing this to original specifications. Quality procedures for scanning, surface modelling and Pro/E modelling is listed below.

3. Quality Control

Quality control is concerned with assuring quality through measurement. A report on the quality of the product is produced which is submitted to the client.

4. CAD modelling

The objective of this process is to produce detailed electronic drawings. It usually follows a process by which the main functions and then the secondary functions of the product are detailed. The drawings are normally 2D or 3D, depending on what it is used for.

5. 3D Printing

The objective of this process is to produce prototypes of the product as visual aids, assembly or functionality testing.

In the course of producing prototypes, all the main functions of the product and later all secondary functions should be tested. This may result in shape and material modifications of the product. If an adequate shape of the product is achieved, the detailed documents of the development phase can be generated, e.g. assembly drawing, single part drawings, parts list.

According to the purpose of the prototype, different prototyping technologies can be applied. Methods, which generate the prototype in layers in an additive approach instead of a removing a pproach, are called rapid prototyping (RP) technologies. Typical rapid prototyping technologies are Laminated Object Manufacturing (LOM), 3D printing, Stereo lithography, Selective Laser Sintering and Fused Deposition Modelling (FDM). The process of (rapid) prototyping should therefore start with a comprehensive analysis of technologies including a thoroughly conducted quotation of alternatives to find the most suitable technology for the desired purpose. After an RP-technology has been chosen the CAD-model has to be divided into layers that can be generated physically into 3D-models by an RP-machine. Finally the prototypes will be used according to the defined purpose.

5.1 STL files

STL files are required by the 3D printing machine.

5.2 Parts

Pictures of the part grown can be stored for reference.

5.3 Printer data sheets

Data on each of the parts grown should be captured after completion. This produce important information such as powder usage, duration, etc.

5.4 Finishing

Finishing is where additional work is done on the part to make it stronger or to give it a better appearance.

5.5 3D quality assurance

To ensure the quality of the 3D prototype that was produced

6. Post Processing

The purpose of this process is to generate a bridge tool to produce a small pre-production batch of the product for testing and marketing purposes.

The bridge tool should be specifically manufactured for the desired lot and can be made from softer material than steel, e.g. silicon rubber. The process to produce a bridge tool should therefore start with a comprehensive analysis of technologies including a thoroughly conducted quotation of alternatives to find the most suitable technology for the desired lot and product specifications. After a technology has been chosen the further procedure depends largely on the chosen technology. The process ends with the production of the desired lot and the testing of the batch. Then the product is either reworked, or clearance for production is given.

6.1 Formulation and manufacturing data capturing

The formulation used and machine settings must be captured for each mould produced.

6.2 Silicon moulds/Other moulds

Images of silicon and other moulds can be stored.

6.3 Vacuum cast prototypes

Images of the prototypes can be stored.

6.4 RP Processes

Any new type of process that is used.

6.5 PP quality assurance

To ensure the quality of the mould and part.

6.6 Matured processes

RP processes, which are known to the RPD department, are called matured processes. As soon as a process is matured it can be added to this section. Vacuum casting with soft tooling and sand tooling for sand casting is some of the matured processes and are listed in Appendix C.

7. Machining

Machining has the purpose of producing parts or tooling making use of CNC milling or lathe machines. Machining is done either internally or externally, depending on the availability of machines and size of the part.

7.1 Creating machine paths

Machine paths are created by either writing the machine path code or generating it from CAD drawings or models.

7.2 Part

Images of the part can be stored.

7.3 Machining quality assurance

To ensure the quality of the machined part

8. Students

Students form an important part of the outputs of the RPD. Students need to be trained and exposed to the field of RPD.

8.1 Projects

Projects that are completed by students are stored in this step.

8.2 Training

The various student training programs are stored here.

7. Business Functions Roadmap

7.1 Introduction

The Business Functions of the RPD are functions that support the organization’s operations and the processes of the Project Management and Product Development Roadmaps. All these functions are independent and do not form a lifecycle.

The business functions identified in chapter 3 were combined to develop the Business Functions Roadmap. This Roadmap is illustrated in figure 32.

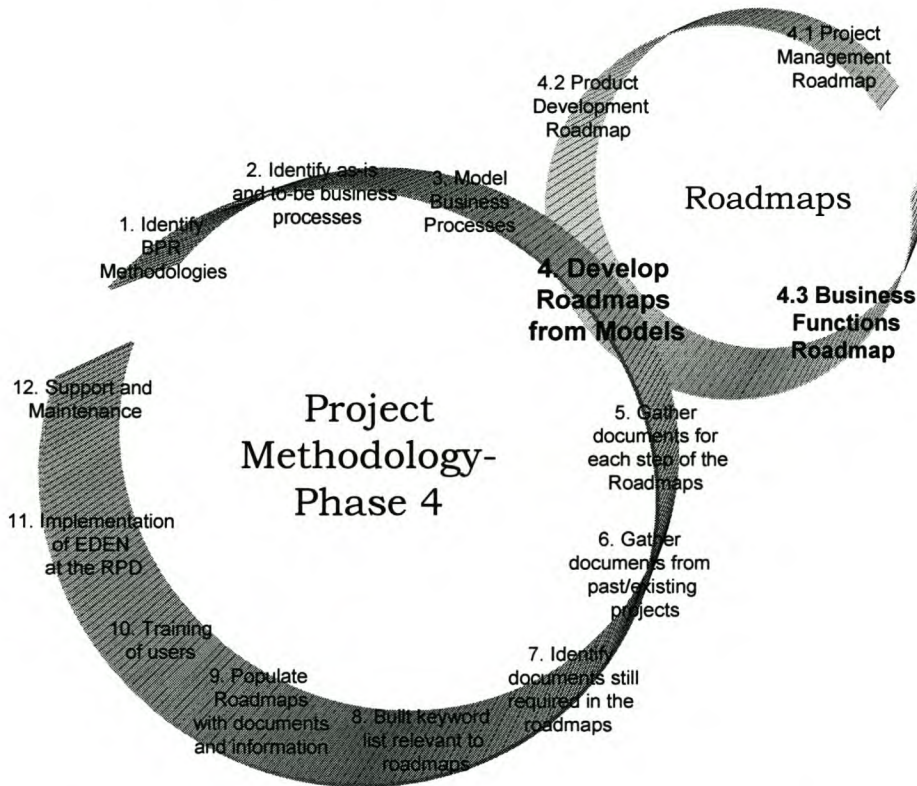


Figure 32: Phase 4c – Develop Business Functions Roadmaps

In the following section each step and sub-step of the Roadmap is described. The applicable procedures are included in Appendix D. The procedures are used as checklists in the EDEN™ environment.

7.2 The Business Functions Roadmap

The steps of the Project Management Roadmap, which follow, are numbered in the same manner as the steps in the EDEN™ environment as illustrated in figure 33.

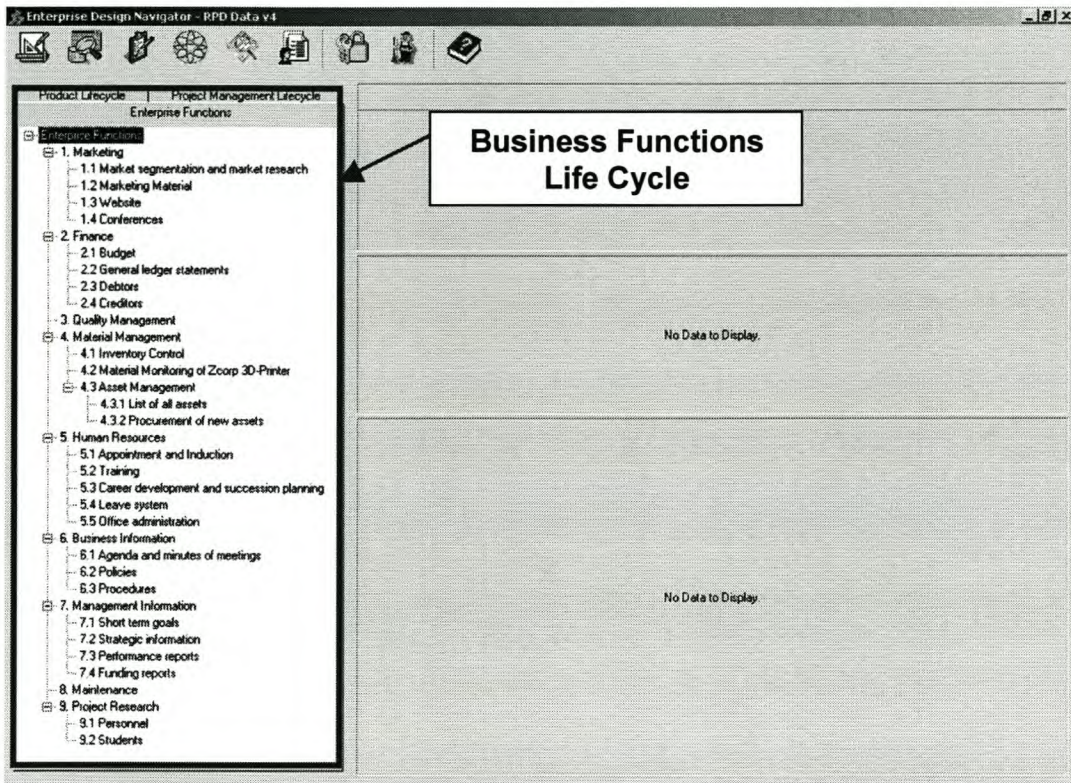


Figure 33: Business Functions Life Cycle in the EDEN™ Environment

1. Marketing

Marketing has to do with all materials and means by which RPD is communicated to the market. Since rapid product development is such a new technology, marketing should be one of RPD's main focuses.

Five key areas to focus on:

- Marketing strategy
- Market research and segmentation
- Marketing material
- Website

- Conferences

1.1 Market strategy

The marketing strategy is outlined in this step. The strategy is based on the Get Clients Now!™ program. All the relevant information, templates and outcomes are stored in this step.

1.2 Market segmentation and market research

Information regarding market segmentation and market research are stored in this step. This is done with a Theory of Constraints (TOC) perspective on marketing.

1.3 Marketing material

Marketing material consists of brochure, pamphlets, advertisements, display window, posters, business cards, standard e-mail formats, etc.

1.4 Website

The website is continually developed and maintained as an electronic medium through which RPD can be marketed. Information regarding the website are stored in this step.

1.5 Conferences

Conferences, both internal and external, can be captured and used as future reference sources.

2. Finance

Proper finance management is essential for the success of RPD. It is important that proper budgets and general ledger statements are prepared.

2.1 Budget/Cash flow plan

Management should ensure that budgets are completed and communicated at the start of and periodically throughout the financial year.

2.2 General ledger statements

General ledger statements are completed at specified periods.

2.3 Debtors

All relevant information about RPD's debtors can be stored.

2.4 Creditors

When a new supplier is targeted for business, all the necessary information has to be captured and a creditor's code has to be generated. The code and all the supplier information are stored in the supplier database.

There are two procedures for paying creditors, the US procedure and the RPD procedure. The two procedures are listed in Appendix D.

3. Material Management

Material management consist of:

- supplier information
- inventory control (procurement of material and stock taking)
- material monitoring of the Zcorp printer for costing purposes
- asset management (procurement of assets)

3.1 Supplier information

New suppliers' information are captured and stored. The checklist below lists the most important features. This information should be regularly updated.

3.2 Inventory Control

Inventory control focuses only on the materials generally used by the RPD. Reorder levels are specified according to supplier lead-times and material usage. New orders are placed when the inventory level reaches the reorder level. At the arrival of the material, the delivery reports should be handed to the administration officer so that the transactions can be closed. The inventory is updated accordingly.

3.3 Material monitoring for costing purposes

RPD uses various raw materials during a product development lifecycle. An excel costing tool was used to calculate the cost of the raw materials. Management identified that this costing tool is inappropriate to calculate the True Variable Cost (TVC) of a product. Because of this a new costing tool was developed by the RPD.

The new costing tool required the monitoring of material usage. The most raw materials are used at the 3D Printing and Post Processing stages. The procedures to monitor the material usage at these stages are listed in Appendix D.

3.3 Asset Management

This involves the procedures for the procurement of new assets and the management of all assets.

4. Quality Management

The quality systems should consider the market requirements with respect to quality standards. Quality management is concerned with establishing quality processes within the RPD. This aspect has not yet been fully developed.

5. Human Resources

Human resources are concerned with the management of employees.

5.1 Appointment and Induction

New employees go through an induction programme at the RPD. The materials to be studied are supplied in EDEN™.

5.2 Training

The training done and the relevant training material (if possible) needs to be captured.

5.3 Career development and succession planning

It is of strategic importance that the RPD do career development and succession planning. This is because of the dynamic environment in which it operates, and the opportunities that are available.

5.4 Leave system

The leave system is about coordinating leave of individuals. Documents and templates concerning the leave system are provided in EDEN.

5.5 Office administration

Office administration is concerned with general internal office matters such as coffee money, birthdays, socials, etc.

6. Business information

The business information function provides information that relates to the business functions of the RPD. The business information consists of:

- Agenda and minutes of meetings.
- Policies.
- Procedures.

6.1 Agenda and minutes of meetings

Agenda and minutes of meetings should be kept.

6.2 Policies

The policies of the RPD are captured here.

6.3 Procedures

The procedures are captured here.

7. Management Information

The management information is high-level information used for strategic planning and decision-making. The management information is not general information that is shared, but information that is provided only to management.

7.1 Short term goals

The short-term goals are short-term strategic information that needs to be communicated to individuals in the RPD.

7.2 Strategic information

Strategic information and decisions made are stored here for reference.

7.3 Performance reports

This step provides management with a quick view on what the current situation of the RPD is with relation to its mission.

7.4 Funding reports

Reports for funding such as THRIP are stored and compiled here.

8. Project Research

Information gathered during research can be stored for reference.

8.1 Personnel

Information gathered by personnel.

8.2 Students

Information gathered by students.

9. Maintenance

Preventive maintenance procedures and policies should be developed for all the equipment of the RPD. Procedures of how and when to carry out maintenance services should be documented and stored at this step.

8. Prepare EDEN™ Environment for the RPD

8.1 Introduction

In the previous three chapters, the development of the Roadmaps was explained. After the finalization of the Roadmaps, the preparation of the EDEN™ environment could start. This chapter addresses five of the project methodology phases as shown in figure 34.



Figure 34: Phase 5-9 – Preparing EDEN™ for RPD

8.2 Gather documents for each step of the Roadmaps

Only documents and information relevant to the steps of the roadmaps were considered significant. These included information of past/existing projects. Most of the documents were found on the RPD network space. The folder structure used to store information

was very unorganised and a lot of duplication was found. Because the documents were not centrally managed, the gathering process was extremely time consuming.

After all the documents and information were gathered they were sorted into relevant categories. Firstly, the gathered documents and information were grouped according to the steps of the roadmaps. Secondly, they were divided into templates, articles, procedures and guidelines.

8.3 Identify documents still required in the roadmaps

The roadmaps were developed from the TO-BE situation. A lot of new procedures and functions were identified and included in the TO-BE business processes. Because of this a few steps of the roadmaps still require documentation. The documentation needed for these steps are mainly procedures, guidelines and templates. The steps identified are listed below:

- Machining – Step 7: Product Development Roadmap
- Students – Step 8: Product Development Roadmap
- Market segmentation and research – Step 1.2: Business Functions Roadmap
- Supplier information – Step 3.1: Business Functions Roadmap
- Quality management – Step 4: Business Functions Roadmap
- Training – Step 5.2: Business Functions Roadmap
- Career development and succession planning – Step 5.3: Business Functions Roadmap
- Policies – Step 6.2: Business Functions Roadmap
- Maintenance – Step 9: Business Functions Roadmap

8.4 Build Keyword List Relevant to Roadmaps

EDEN™ internally has a keyword search function. The search function is primarily used to search for documents inside EDEN™ using specific words to search with. The keyword list used for the search function is called a taxonomy.

The Taxonomy Builder, developed by Indutech, supported the process of building the keyword list. The Taxonomy Builder made use of the gathered documents and information to build a complete word list. From this list a RPD specialist had to extract only the words that are relevant to the RPD, in order to finalise the taxonomy.

After the taxonomy was built, it was imported into EDEN™. Before the first keyword search could be made, the correct taxonomy had to be selected.

8.5 Populate Roadmaps with gathered documents

After the taxonomy was finalised, the steps of the Roadmaps could be populated with the gathered documents and information. The process to populate the roadmaps was very easy since the documents was already sorted and categorised. Each document was imported into a specific step of the Roadmaps by the 'drag and drop' process. Keywords were attached to each document imported into EDEN™.

9. Training of Users

9.1 Introduction

The training of users is one of the most critical phases of the project methodology. The lack of a good training can cause the entire project to fail. The training methodology followed is outlined in figure 35.

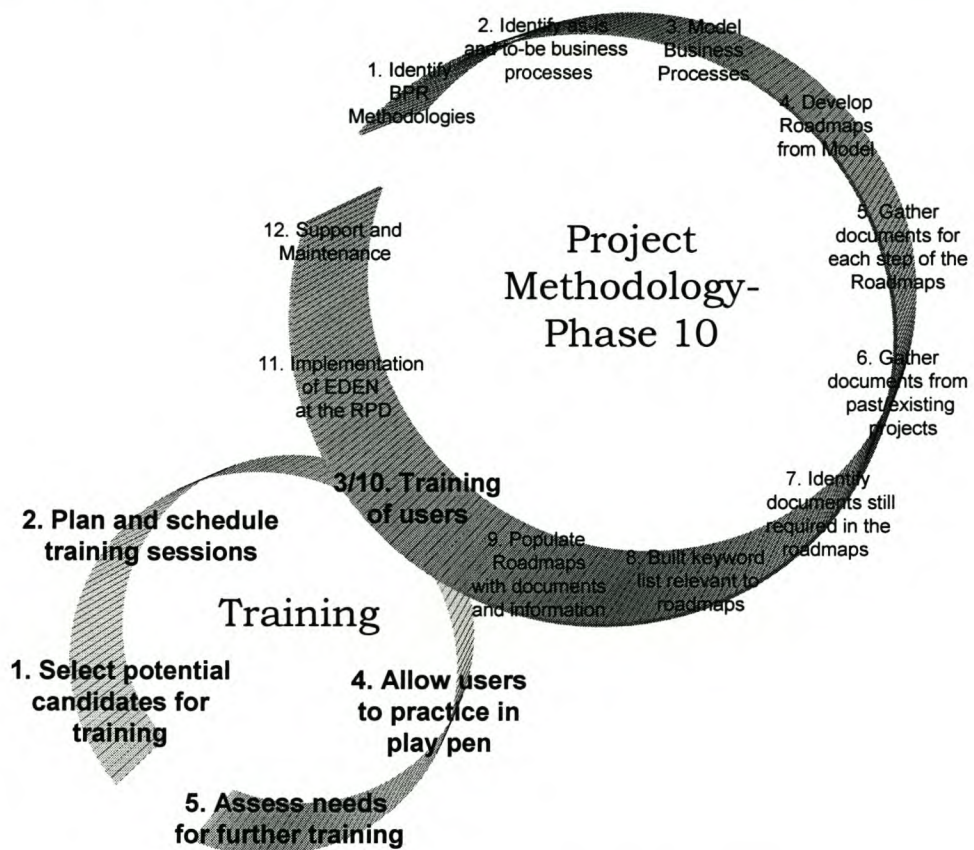


Figure 35: Phase 10 – Training of Users

9.2 Training Methodology

9.2.1 Select Potential Candidates for Training

The first step was to identify and inform the potential candidates for training. Another

training program will be used for the candidates that were not selected.

9.2.2 Plan and Schedule Training Sessions

Three training sessions were planned. The first session was scheduled just after the initiation of this project. The second training session was scheduled after the EDEN™ environment was prepared for RPD. The last training session was scheduled in the period while the users practised in the play pen.

9.2.3 Training of Users

Three training sessions were held as scheduled. The first training session was an introduction course held at Indutech. The course primarily handled the main features and functions of EDEN™. A better understanding and experience was gained through the execution of various practical exercises.

The second training session mainly focused on the EDEN™ environment prepared for the RPD. One of the objectives of the training session was to introduce the RPD personnel to this new environment. The other objective was to run through the main features and functions of EDEN™.

The last session was held while the users practised in the play pen. Individual sessions were held with the aim to address the areas that were not yet clear to the trainees.

9.2.4 Allow Users to Practise in Play Pen

A play pen was setup for the users. The play pen was a safe environment where users could operate the system without causing serious damage to a database. Practising in the play pen allowed the users to gain practical experience and to identify areas where they found difficulties.

9.2.5 Assess Needs for Further Training

The only requirement that needs to be assessed is the training of the personnel that were not selected for the initial training.

10. Implementation of EDEN™ at the RPD

10.1 Introduction

After the environment of EDEN™ for RPD was completely ready, the implementation of the software tool could start. The various stages of the implementation methodology used are outlined in figure 36.

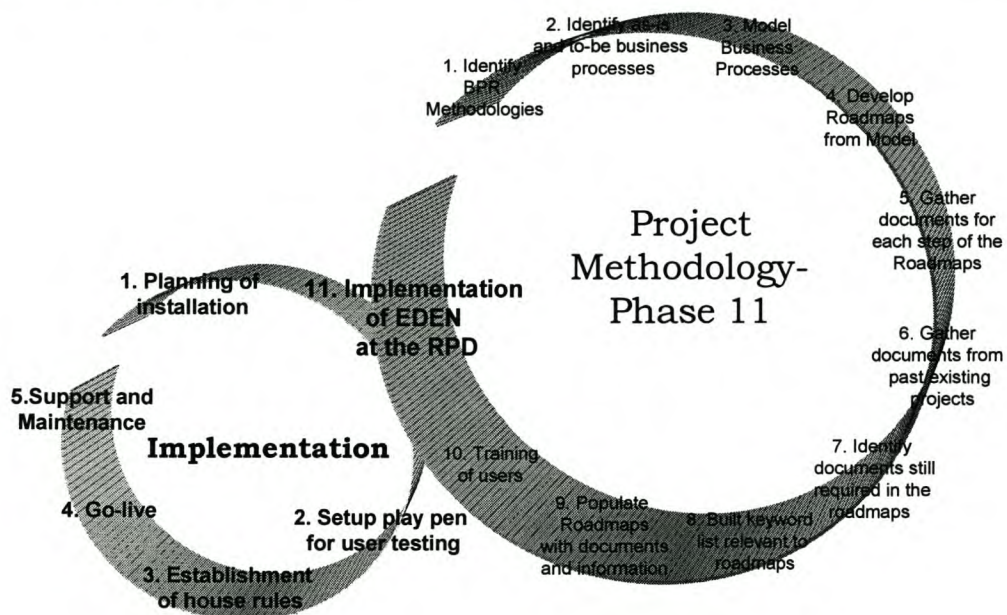


Figure 36: Phase 11 – Implementation of EDEN™

10.2 Implementation Methodology

10.2.1 Planning and Installation

Only eight computers required the installation of the software and this made the planning very simple. The installation itself was in fact not as simple. Numerous problems occurred which made the installation time consuming. The biggest problem was experienced with the network security and security rights of the individual computers.

However, all the problems were solved and the installation of the software could be completed.

10.2.2 Set up play pen for user testing

After the installation was completed, a play pen was setup for two weeks. This allowed user testing and for the RPD personnel to gain more practical experience. Support was given during this time and no major problems occurred.

10.2.3 Establishment of House Rules

By this stage the users were quite familiar with the EDEN™ environment. The only thing left was to determine how the system would be used. This issue was addressed by establishing specific house rules. These house rules were set up during a workshop with the RPD personnel. The established house rules are listed below:

1. **Every customer** phoning in will be captured into the Customer Management System (CMS) located at the initiation step of the Project Management Roadmap.
2. **Only major events** will be captured in the event register of the CMS.
3. **Instances** will be created on an ad hoc base and will only be done for long-term projects e.g. SI Project, Diego mouse, etc.
4. **Naming of files** in the user data section of EDEN™ should be done consistently.
5. **All information** relevant to a project should be stored at the applicable steps of the Roadmaps, except for the CAD drawing files, Scan data, etc.
6. **Meta data** must be completed correctly and thoroughly.
7. **Only relevant keywords** should be attached to documents.
8. When a customer gives a new order number, a **new job number** must be created.

10.2.4 Go-live

At the stage just before going live; the EDEN™ environment was completed, the users were trained, the software was installed and the rules, of how to use the system, were established. The only thing that still had to be done before going live was to import all the documents and information that were currently in use for daily operations. A period of a few hours before the scheduled going-live time was used to import all these documents.

10.2.5 Support and Maintenance

Like any other system, EDEN™ has to be supported and maintained. Because of this a postgraduate student was appointed as the system administrator. The postgraduate student went through extensive training to gain the needed knowledge.

The support and maintenance responsibilities of the system administrator are listed below:

- Have to be the link between Indutech and RPD
- Addressing of all problems and errors relevant to EDEN™
- Updating of the Additional Information Section
- Updating Checklists
- Monitoring of the User Data Section
- Updating of Roadmaps if necessary
- Updating of taxonomy when needed
- Frequently run the file indexing function
- Check if house rules are obeyed
- Updating of Job Management System if necessary
- Updating of Customer Management System if necessary

11. Job Management System

11.1 Introduction

In any business it is essential to keep record of all current and completed jobs. The storing of correct information is vital for management purposes. The initial method used by RPD records all the information in a Microsoft® Excel® spreadsheet. An Excel® spreadsheet is not the most appropriate place to keep this information since it is easily edited or deleted. Additionally queries, which are very important for management, are difficult to perform in excel. Due to all these factors it was decided to use a new method.

The Excel® spreadsheet was replaced by a Microsoft® Access® database and interface called the job management system (JMS). The JMS contains all the fields of the previously used excel spreadsheet. The interface of the JMS is much more user friendly than the excel spreadsheet and the information of each job can be recorded with ease, with protection against accidental editing and deleting. The system has built-in queries to retrieve specific information and more queries can be built into the system.

The main features of the JMS are described below. A detailed explanation of how the JMS works is included in Appendix E and this can also be used as a guidance and training manual.

11.2 Features of Job Management System

The main screen of the JMS can be divided into 4 main sections as shown in figure 37:

- Job Number
- Client Details
- Job Details
- Financial Details

Figure 37: Main screen of JMS

11.2.1 Job Number

The job number field is used to record the job number of a specific job. The job number is the primary key of the database and it is therefore necessary that this field be completed right at the beginning of recording a new job record.

11.2.2 Client Details

The client detail section is used to record the name of the company, the name of a contact person and the US debtor number. Each client has a unique US debtor number. Detailed information of each client is stored in the Client Management System. To avoid duplication of data only the above fields are included in the JMS.

11.2.3 Job Details

The job details section includes information related to the workings of a specific job. The fields included in this section are work description, part description, responsible person,

work tools used, job status and internal/external job. This information is very important for management reports, especially the job status field.

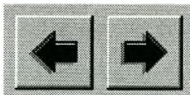
11.2.4 Financial Details

The financial details section consists of a quote, an invoice and a payment form. These forms can be selected by clicking on the label of a specific form. The amount due field displays the difference between the values of quoted price and total payments of a specific job.

11.2.5 Extras

Navigation arrows:

The two arrow buttons are used to navigate through the existing records.



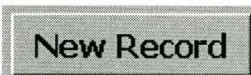
Binocular:

Clicking on the binocular button enables a search function. The search function is used to search for a specific record (job) by entering the job number in the required field.



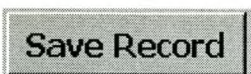
New Record:

Clicking on the New Record button opens a new record



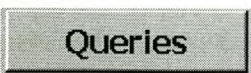
Save Record:

Clicking on the Save Record button saves a record.



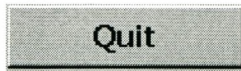
Queries:

The window containing the list of queries is displayed by clicking the queries button.



Quit:

Clicking the Quit button closes the JMS



12. Marketing Plan for the RPD

12.1 Introduction

Marketing has to do with all materials and means by which RPD is communicated to the marketplace. Since rapid product development is such a new technology, marketing should be one of RPD's main focuses.

A marketing plan was identified by the RPD developed by C.J. Hayden [14]. The strategy, called Get Clients Now!™, is perfectly suited for the RPD since it focuses particularly on enterprises in the service business. The strategy is also developed for enterprises struggling to get a marketing strategy in place.

12.2 The Marketing Cycle

The marketing and sales operates on a predictable cycle, with four separate stages:

1. Filling the pipeline
2. Following up
3. Getting presentations
4. Closing sales

The marketing cycle can be seen as a water system. At the top are the collection buckets for the prospects, contacts, leads, and referrals with which the pipeline are filled.

The marketing pipeline empties into the follow-up pool, in order to move potential clients and referral sources further along the system. The goal is to keep the follow-up pool constantly circulating.

The next stage of the cycle is to get presentations at potential clients. Presentations may happen formally or informally, in person, by telephone, or even by mail. The desired result is to move prospects forward in order to close a sale. If a client says yes to a presentation, the sale is closed. If the client rejects a presentation, the client moves back into the follow-up pool.

When a sale is closed with a client, that specific client should also stay in the follow-up with the hope to close more sales.

12.3 The Marketing Program

The marketing program spans over a period of 28 days and consists of 5 basic steps. The steps are listed below:

- Step 1:** Choose the marketing stage
- Step 2:** Choose marketing strategies for program
- Step 3:** Set program goal
- Step 4:** Choose success ingredients
- Step 5:** Decide on daily actions

12.3.1 Step 1: Choose the marketing stage

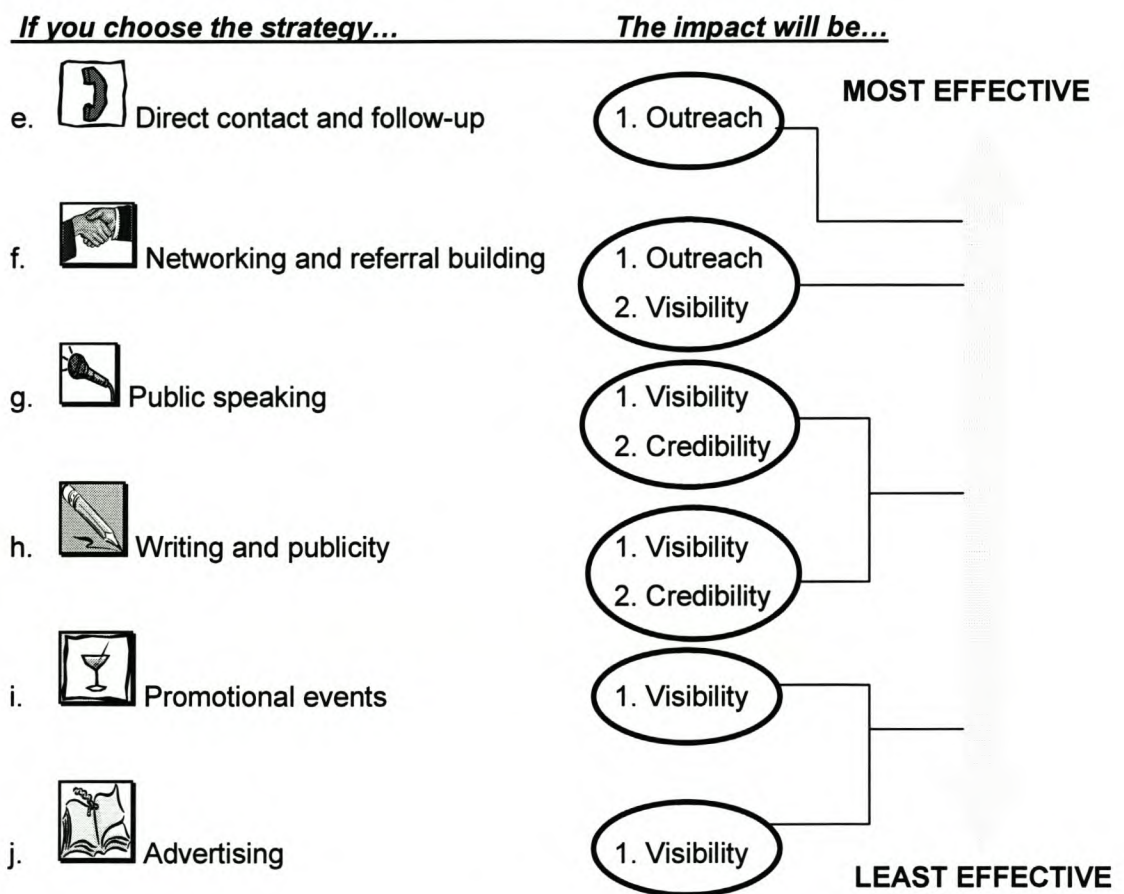
In the above section the 4 stages of the marketing cycle was explained. Not all enterprises always know on which stage of the marketing cycle to focus on in order to get more clients and eventually to close more sales. As mentions above, the services that RPD provides is very new to the market and not a lot of businesses know the capabilities of their services. The stage to focus on is therefore 'filling the pipeline'.

<i><u>If RPD choose ...</u></i>	<i><u>The impact needed is...</u></i>
a. Filling the pipeline	1. Outreach 2. Visibility
b. Follow up	1. Outreach
c. Getting presentations	1. Outreach 2. Visibility 3. Credibility
d. Closing sales	1. Outreach 2. Visibility 3. Credibility

The impact needed when choosing 'filling the pipeline' is Outreach and Visibility. In the next step of the program the market strategies are chosen to provide the necessary impact.

12.3.2 Step 2: Choose marketing strategies for program

In order to achieve the needed impacts, specific marketing strategies have to be chosen. From the diagram below it is seen which strategies are needed for a specific impact. The most effective impact is Outreach and the least effective is Visibility.



Thus, the strategies that RPD requires for 'filling the pipeline' are:

- Direct contact and follow-up
- Networking and referral building
- Public speaking

- Writing and publicity

12.3.3 Step 3: Set program goal

At step 3 the goal of the program is defined, that is, the results RPD plan to achieve over the 28-day period of the program.

The acronym **SMART** describes the five important characteristics of a meaningful goal:

- S**pecific It spells out the target you are aiming for very precisely
- M**easurable It states the target in such a way that you can measure exactly when you have arrived, as well as how far along you are at any specific moment
- A**chievable It is physically possible to accomplish within whatever limits you must consider
- R**ealistic It can be accomplished within the specified time and with the resources available
- T**imed There is a calendar date by which you plan to achieve it

Examples of SMART goals:









































- Two new clients with signed contracts by the end of the program
- Five thousand rand in business booked for the following month by Week 3
- Six new qualified prospects by the end of the program

12.3.4 Step 4: Choose success ingredients






At this step the missing ingredients needed to be successful in the marketing program are chosen. The 'shopping list' below includes success ingredients for all the stages of the marketing cycle. It is therefore important to choose ingredients that only apply to the chosen marketing stage, which is 'filling the pipeline'. To the left of each of the ingredients, in the shopping list, is an icon that identifies which of the six marketing strategies that ingredient is used for. It is important to keep the chosen strategies (in step 2) in mind when selecting the ingredients.

Success ingredient shopping list:





















To fill the pipeline...

						Description of services
						Target market definition
						10-second introduction
						Business cards
			Prospect list			
		Lead sources				
		Networking venues				
		Referral partners				
		Networking skills				
		Speaking venues				
		Speaking topics				
		Speaker's bio				
		Writing venues				
		Writing query				
		Publicity venues				
		Press release or kit				
		Letter to the editor				
		Promotion concept				
		Promotion plan				














To fill the pipeline (continues...)

	Web site
	Web registrations or links
	Advertising venues
	Flyer venues
	Ad copy, layout, or script

























To follow up more effectively...

		Brochure			Personal mailing list
		Marketing kit			Postcard or mailer
		Model marketing letters			Newsletter
		Contact management system			E-mail address
		Computer			30-second commercial




















To turn more contacts into presentations...

	Telephone script					
	Telemarketing skills					
	Qualifying questions					
	Higher-quality leads and referrals					
						Professional visibility
						Competitive research

To turn more contacts into presentations (continues...)

						Target market research
						New market position
						Better service package
						Narrower focus of services

To turn more presentations into sales...

	Better-qualified prospects					
	Presentation script					
	Presentation visuals					
	Presentation skills					
	Selling script					
	Selling skills					
	Portfolio					
						Narrower focus of services
						Narrower focus of services

12.3.5 Step 5: Decide on daily actions

Ten actions are chosen that are executed on a daily or weekly basis over the 28-day period of the program. Only actions that represent the chosen stage of the marketing cycle and the marketing strategies should be selected from the action plan menu.

The action plan menu is divided into three sections:

- *Appetizer* – actions that will help you to create or acquire success ingredients
- *Main course* – actions focused directly on getting business
- *Dessert* – actions to help you be more effective and productive in general

The action plan menu follows bellows:







Appetizers: Choose 1 or 2

To create success ingredients...










- Spend 1 hour each day on the success ingredient project
- Complete 1 item on the success ingredient project list each day
- Practice skills or script once per day
- Spend 1 hour each week doing research
- Read or write 1 hour every day
- Interview one person per week
- Collect 1 new fact per day
- Observe how it's done once per week

Main Course: Choose 7 or 8










To fill the pipeline by attracting more prospects...

-    Send a mailing to 10 new people each week
-   Distribute or post 10 flyers weekly
-   Post 1 on-line bulletin board notice weekly
-    Introduce yourself in front of a group once per week
-  Volunteer in a visible position once per week
-  Do 1 thing to get your name in print each week







To fill the pipeline by making more contacts...

-     Meet 20 new people in your target market each week
-  Go to 1 networking event each week
-  Spend 1 hour each day cold-calling
-   Call 1 new person per day
-  Contact 3 groups or associations each week about speaking













To fill the pipeline by gathering more leads...






-   Read 1 trade paper or journal each week
-   Review 5 pages of an advertising or professional directory daily
-   Spend 1 hour each week at the library or on the Internet
-  Attend 1 leads group every week
-  Visit one professional meeting or trade show per week
-  Have lunch or coffee with a colleague once per week

To fill the pipeline by collecting more referrals...

-  Have 1 lunch per week with a center of influence
-  Contact 2 new potential referral partners each week
-  Send updated information to 5 former clients each week
-  Send an item of interest to 1 colleague per week
-  Ask for a referral once per week
-  Give a referral once per week

To follow up more effectively...






-   Call 2 recent contacts every day
-   Send a note to 1 person I'm out of contact with each day
-   Add 10 names to my contact manager system each day
-   Enter contact activity into my contact manager system daily
-   Send a mailing to 3 people you know each day
-   Show up at a high-visibility event once per week

-   Invite someone to an upcoming event once per week
-  Have lunch or coffee with a prospect once per week
-  Make the follow-up calls first thing every day
-  E-mail everyone who didn't return your calls each week

To get more presentations...

-  Ask for an appointment with 1 prospect per day
-  Practice your phone daily
-  Send 2 marketing letters per day
-  Interview 1 former or prospective client each week
-   Solicit one testimonial each week
-   Research 1 competitor each week
-  Meet with 1 new referral partner each week
-  Follow up with 3 potential referral partners weekly
-  Volunteer for a high-profile organization once per week
-  Make 2 queries about speaking each week

To close more sales...

-  Call all prospects back within 7 days
-  Get 10 no's each week
-  Make 1 challenging phone call every day
-  Recontact 3 people who didn't buy, every week
-  Recontact 1 former client each day

Desserts: *Choose 1*

To be more effective in everything you do...

Plan your day each morning

Do all your "A-list" tasks first each day

Write in your success journal each evening

Exercise 3 times per week

Get 8 hours of sleep every night

Meditate for ½ hour per day

Schedule a day of fun each week

Add up your income and expenses each week

Spend ½ hour each day organizing your office

Visualize success daily



12.4 Action Worksheet

To document all the chosen stages, strategies, success ingredients, etc., an action worksheet is used. The worksheet is shown in figure 38.

Marketing – Action Worksheet

Which strategies will you used?



1. Direct contact and follow-up



2. Networking and referral building



3. Public speaking



4. Writing and publicity



5. Promotional events



6. Advertising

Where are you stuck? Filling the pipeline Following up Getting presentations Closing sales

How much business do you have now? _____

How much business do you really want? _____

What would that get you? _____

What is your program goal? _____

What will be your reward? _____

Success Ingredients	Target Date
1. _____	_____
2. _____	_____
3. _____	_____

- Daily Actions**
1. _____
 2. _____
 3. _____
 4. _____
 5. _____
 6. _____
 7. _____
 8. _____
 9. _____
 10. _____

Special Permission _____

Figure 38:Marketing Action Worksheet

12.5 Final Comments

The program of Get Clients Now! is packed with tremendous client-attracting tools that will help the RPD inject their marketing efforts with energy and enthusiasm, design an effective plan of action, and dramatically increase their client base in just 28-days.

Using the author's reader-friendly cookbook approach, straightforward tips, and specific techniques will enable the RPD to:

- overcome "analysis paralysis" and determine exactly what they need to do first-and every step of the way
- make their voices heard and their services stand out in a crowd (critical in an era when the average consumer is barraged with approximately 2,700 marketing messages a day)
- create customized, affordable, reusable, and realistic marketing plans.

13. Summary

The first phase of the project was to identify Business Process Modelling and Re-engineering methodologies. Numerous modelling methodologies were found, but the most commonly used, for modelling business processes, are Data flow diagrams (DFD), IDEFØ and object-oriented modelling (OOA). Through a study of each of the mentioned methodologies, it was found that object-oriented modelling seems to be the most effective. Thus this methodology was chosen.

In chapter 3 the second and the third phases of the project methodology were addressed. The TO-BE model for the RPD business processes, developed in a previous project, was found to be inadequate for the development of Roadmaps. It was therefore remodelled using an object-oriented modelling tool. The models were verified and validated with the assistance of the RPD management and operational personnel.

Different modern management approaches, such as TOC and CRM, and the TO-BE Business Process Models were combined to build three Roadmaps on the EDEN™ platform to provide an enterprise wide business solution. The three Roadmaps developed are Project Management Roadmap, Product Development Roadmap and Business Functions Roadmap.

The Project Management Roadmap was developed given that all the RPD's work for clients are managed in the form of a project. The roadmap should provide the necessary guidance and support to manage any project.

The most important processes of the RPD are without doubt the product development processes. The Product Development Roadmap was developed with detailed procedures to assist with any product design.

The business functions of the RPD are functions, such as finance and management information, supporting the organisation's operations and the project management

processes. The Business Functions identified for the RPD was combined into the Business Functions Roadmap.

Phases 5 to 9 of the project methodology were described in chapter 8. These five phases address the preparation of the EDEN™ Environment for the RPD. The preparation includes the gathering of relevant documents and information for each step of the Roadmaps, as well as the gathering of documents from past and existing projects. Steps that still require documents were also identified. After this a keyword list (taxonomy) was built with the use of a Taxonomy Builder. The keyword list is used for the search function provided in EDEN™. The final phase of the preparation was to populate the steps of the Roadmaps with the gathered documents and information. Keywords were attached to each document imported into EDEN™.

Chapter 10 explains the training methodology used to train the personnel of the RPD. The identified candidates were successfully trained during three training sessions. The only requirement that needs to be addressed is the training of personnel that was not selected for the initial training.

The implementation of EDEN™ at the RPD was the final phase of the project methodology. The software tool was successfully implemented. A play pen was set up for user testing. After everything was put in place, the RPD went live with EDEN™. A postgraduate student was appointed as system administrator to support and maintain the Environment of EDEN™. Responsibilities of the system administrator were formulated at this stage.

The Job Management System (JMS) for the RPD is explained in chapter 11. The JMS is a Microsoft® Access® database and interface that was developed to record all the information of a job.

14. Conclusions

The project methodology, developed at the initiation of the thesis, was highly appropriate and breaking the project down into smaller projects proved useful.

The main objective of the thesis was to integrate the business processes and all the software applications into one workable system and to share common data in a real-time environment by making use of the EDEN™ Environment. This objective was successfully accomplished.

The use of Business Process Modelling and Re-engineering played a valuable role in the development of the Roadmaps for the EDEN™ environment.

However, the further success of the project depends on the RPD management and personnel. Management have to motivate change and sustain momentum. Necessary support and guidance should also be provided.

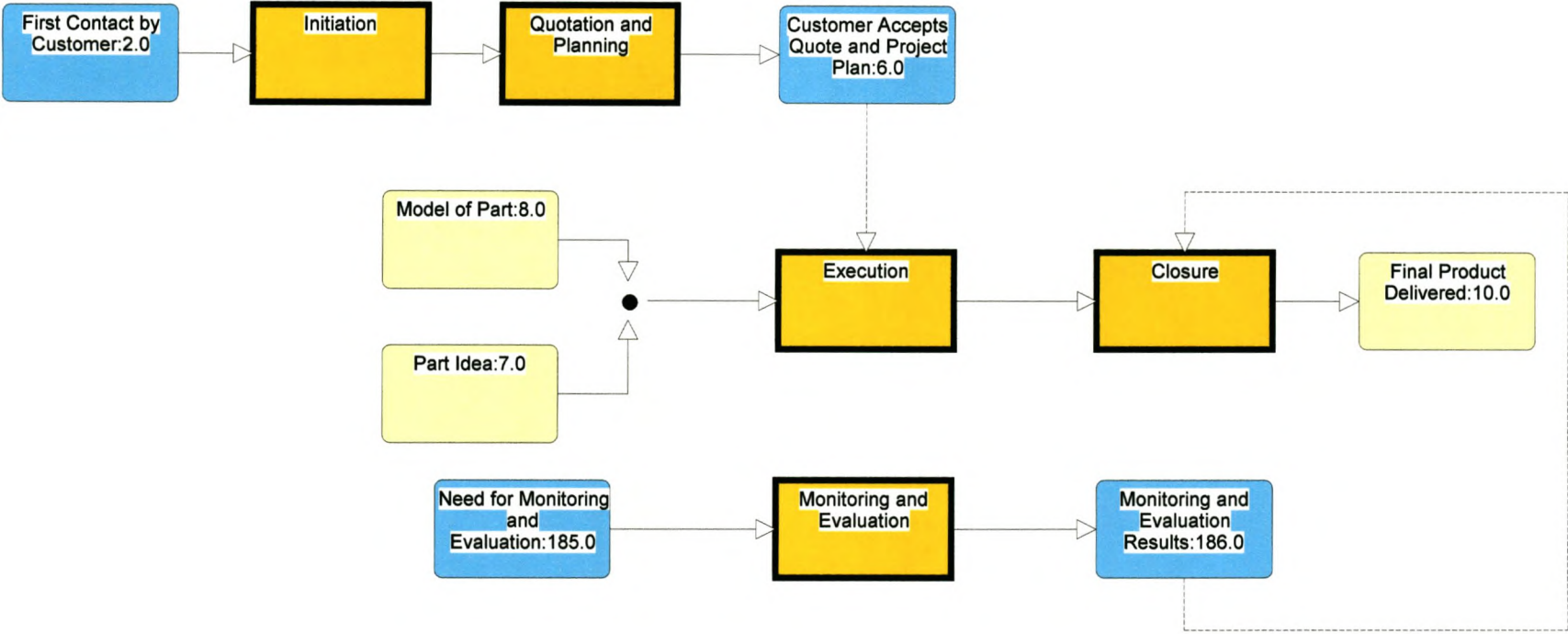
For the efficient use of the EDEN™ system in the RPD, the updating of current network should be seriously considered.

Work that still needs to be done includes the development of procedures for steps, which do not have procedures yet. It also includes the adding of certain documents, such as templates, that is still required by certain steps. Additionally a product development library could be developed with the use of the Product Development Roadmap.

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<p>Appendix A Execution Phase of Project Management Processes</p>



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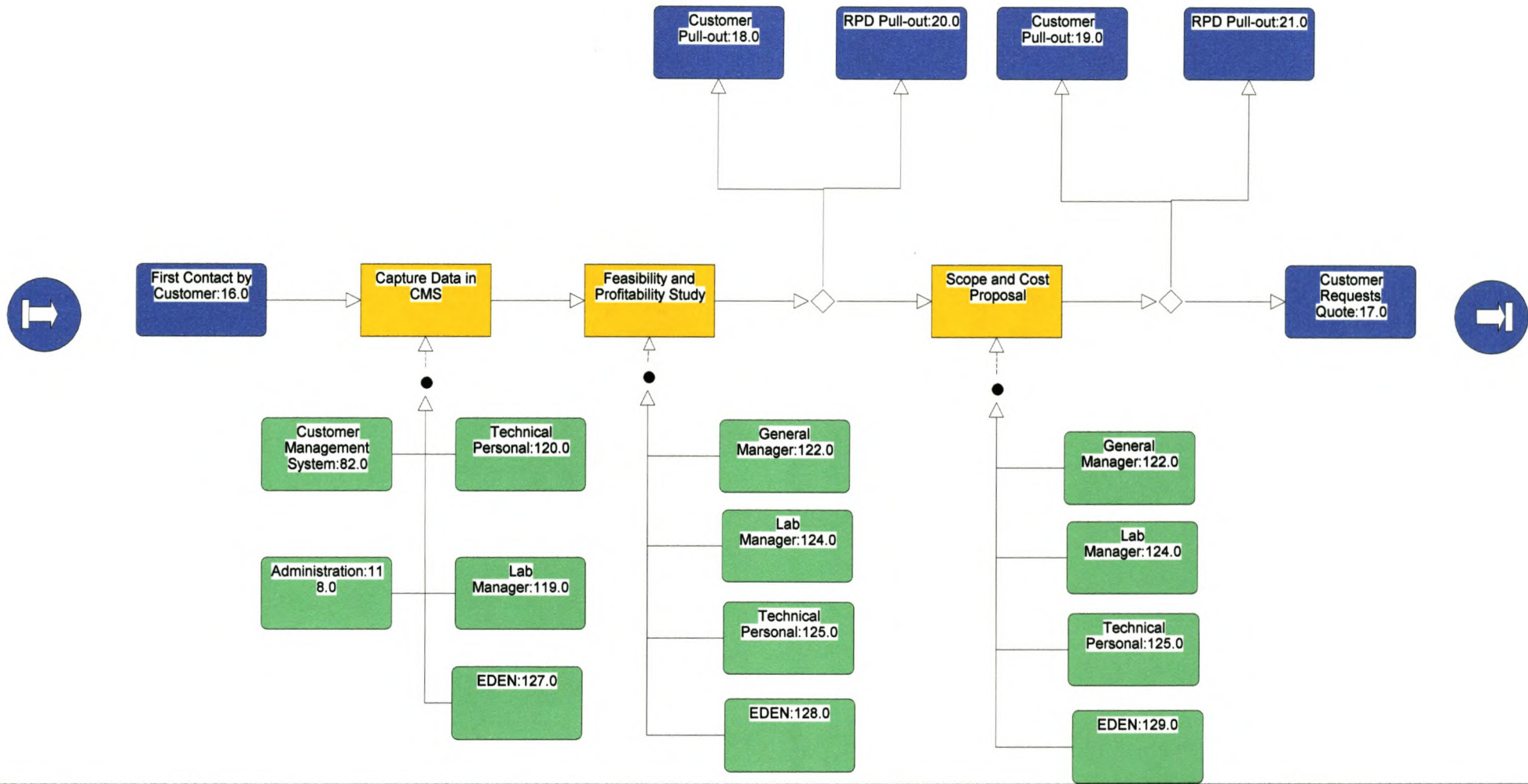
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
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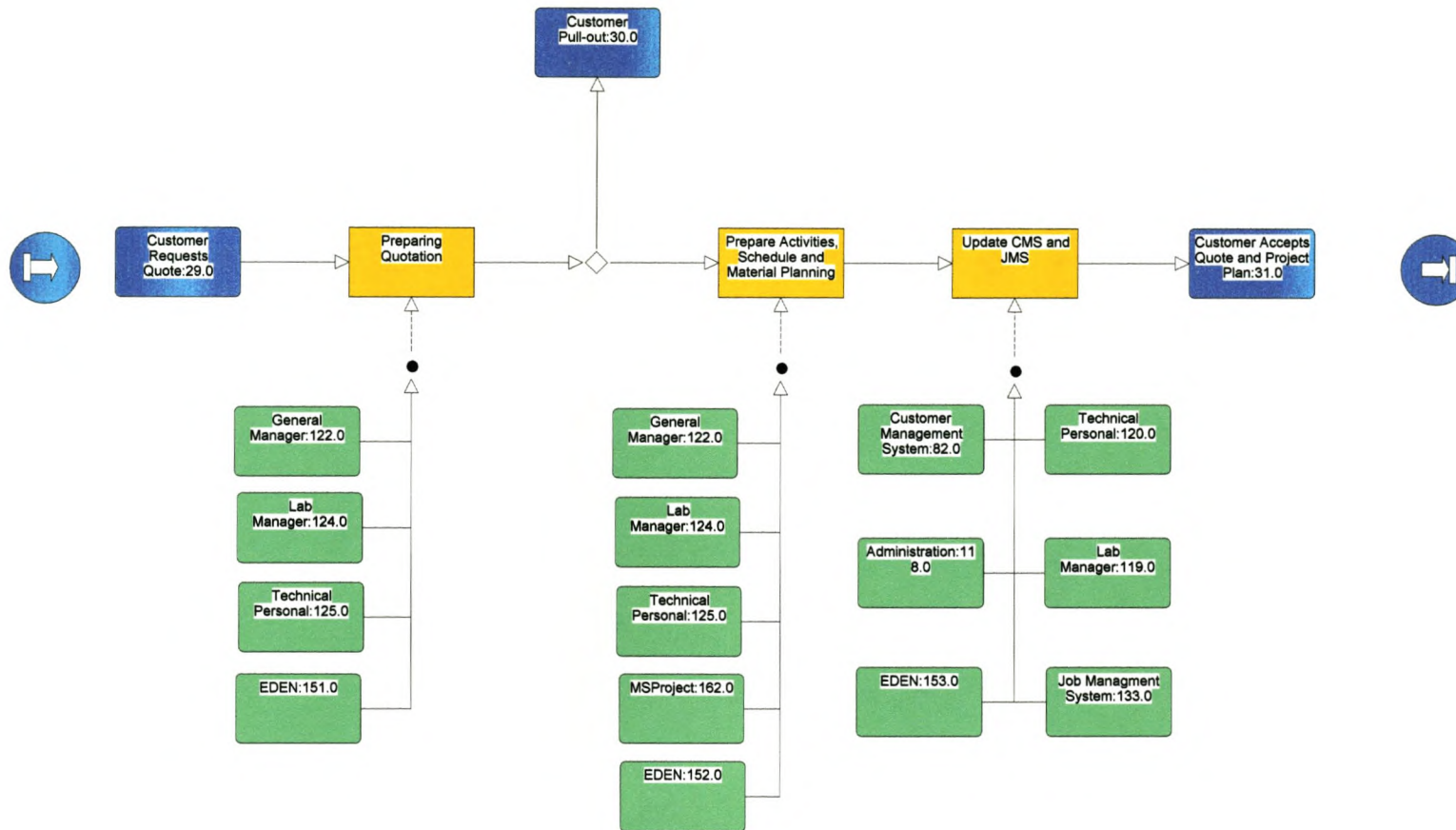
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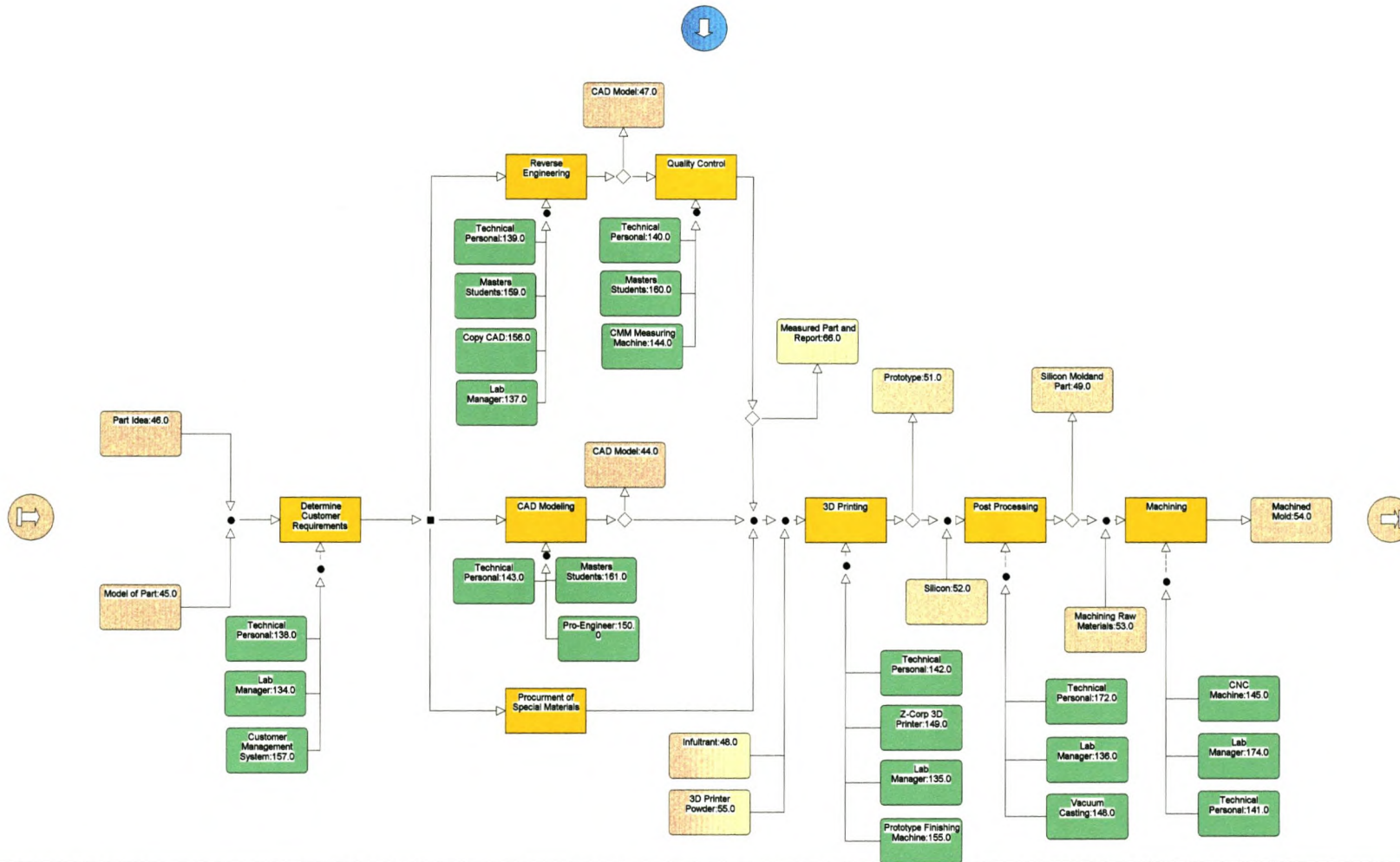
 **MO²GO 2.3c**
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Initiation

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 MO²GO 2.3c <small>Copyright IPK-Berlin 2003</small>





Project: Model-1 -
Execution

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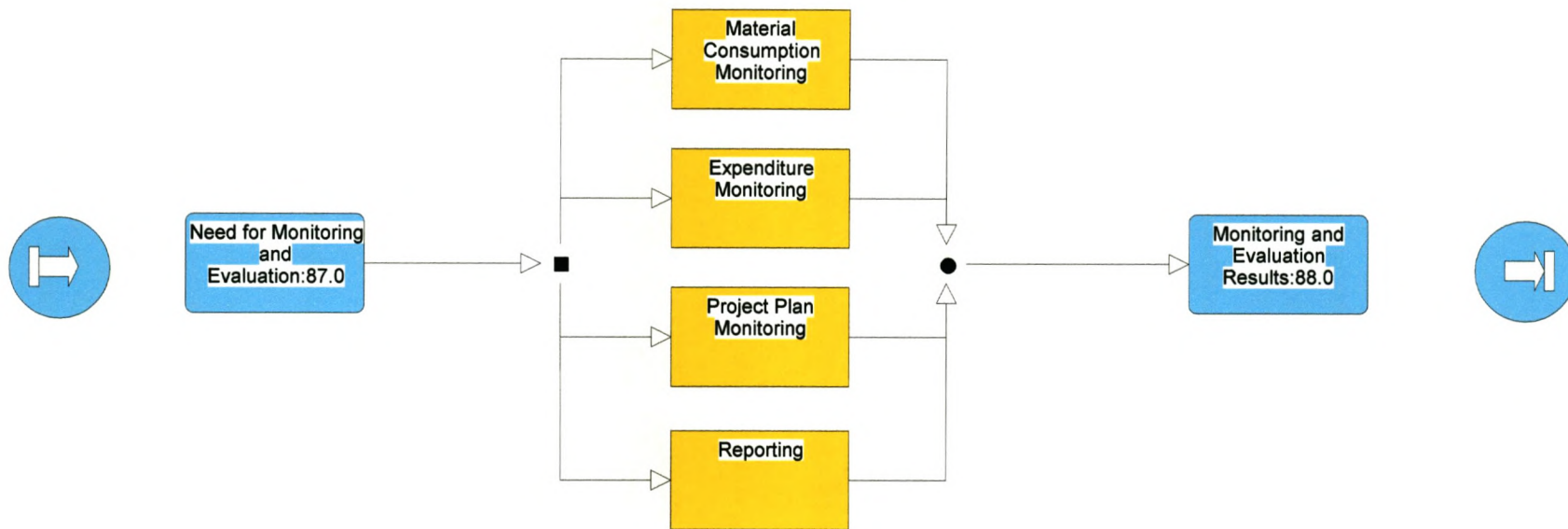
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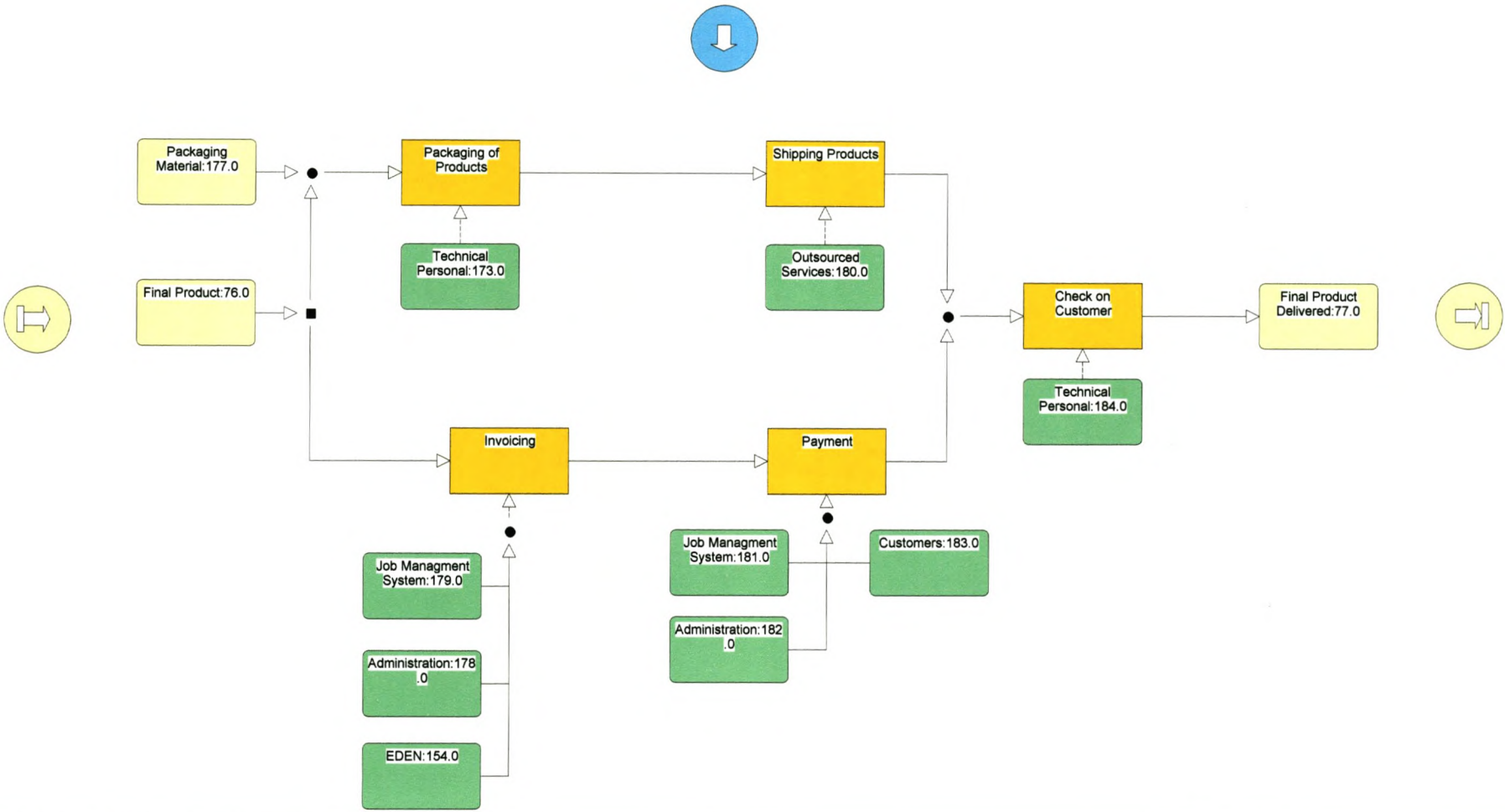
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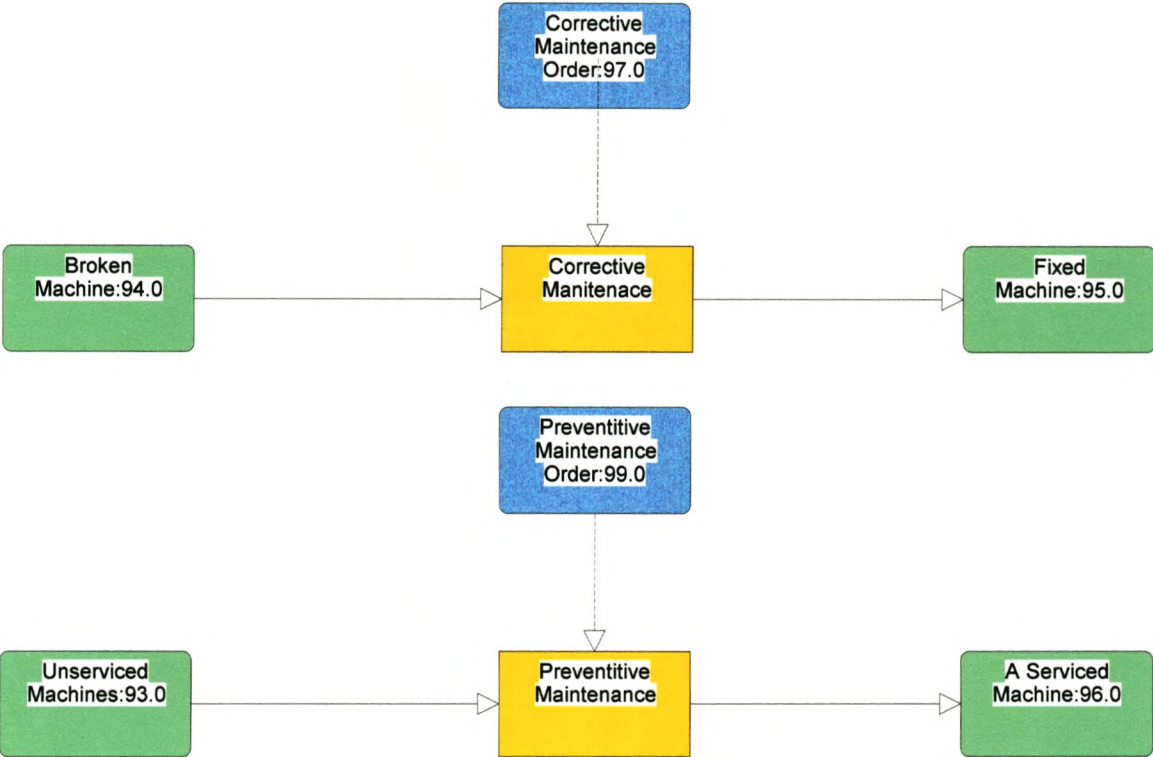
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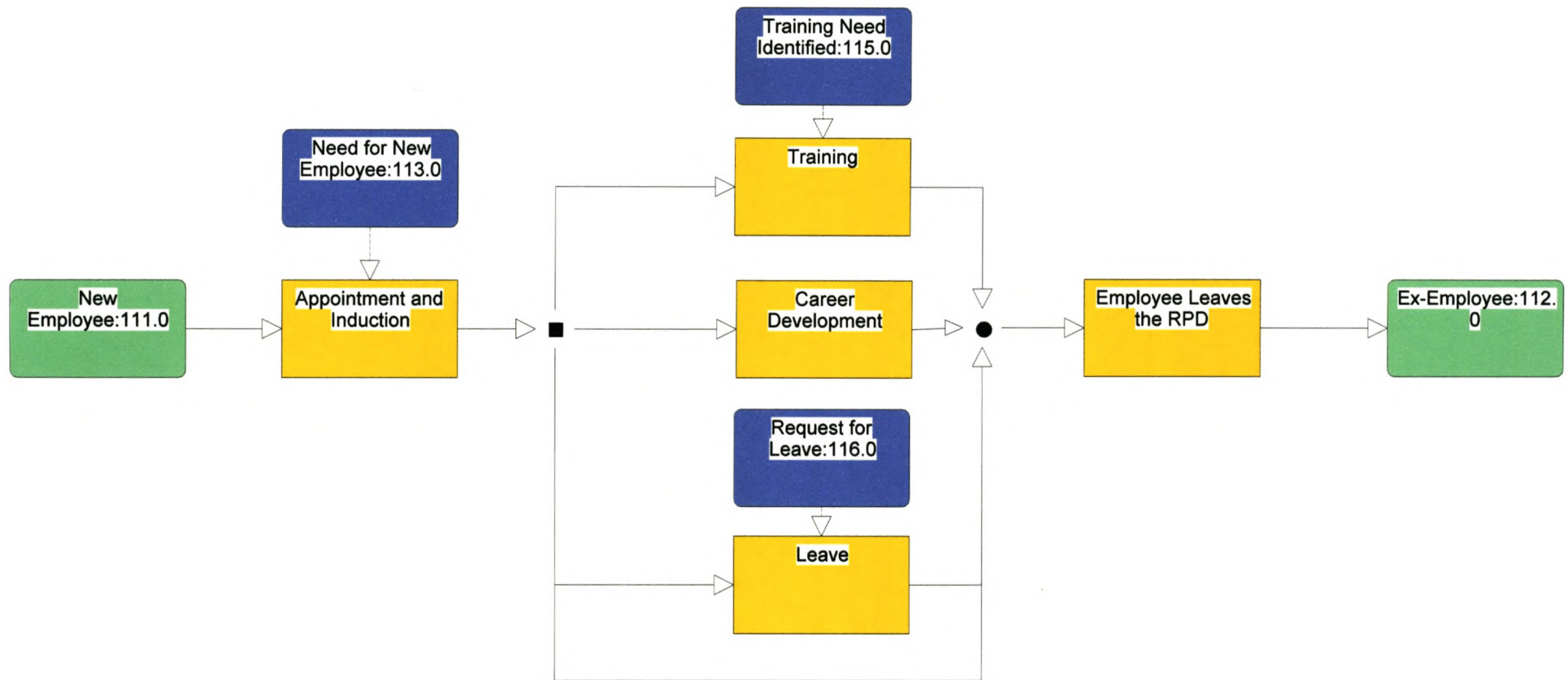
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Closure

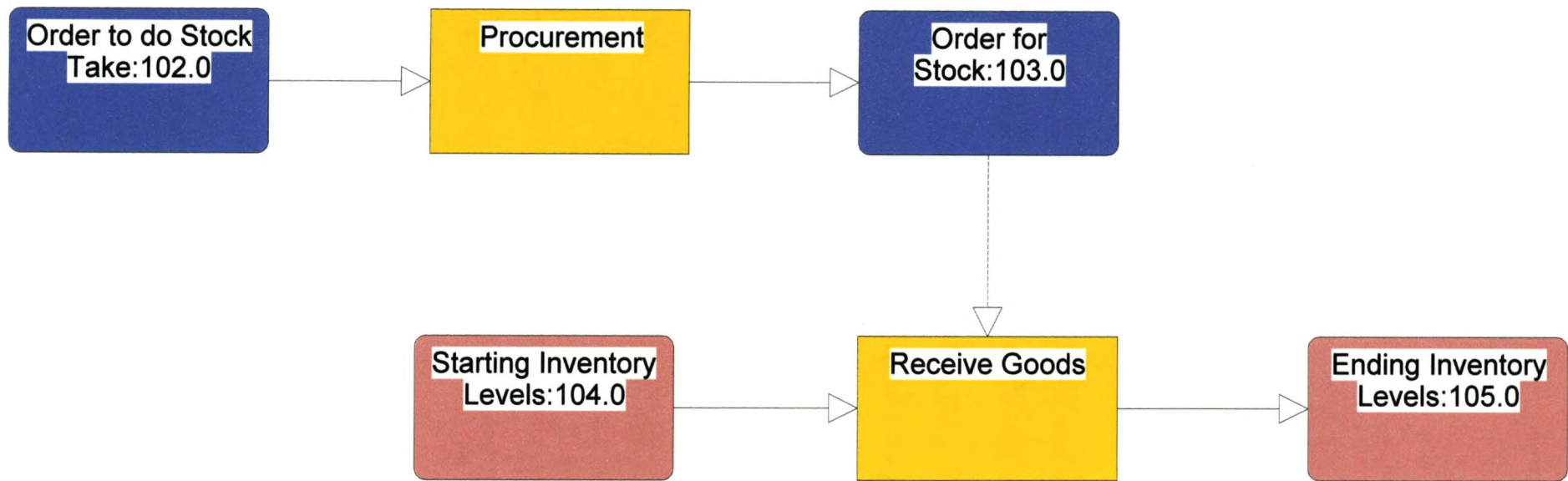
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Project:Model-1 -
Maintenance Process

Company:
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Date: 11/17/2003 - 1:25:05 PM





Project:Model-1 -
Procurement Process

Company:

Name: u

Date: 11/17/2003 - 1:09:26 PM



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Appendix B	Checklists of Project Management Roadmap
-------------------	---

1. Initiation

1.1 Customer Management System

Collect/Confirm Customer information:	
Name of business	
Contact person	
Contact number(s)	
Physical address	
Postal address	
Debtor code ²	
List of project codes	

Creating Debtors Code:	
If client is new, send debtors form to client	
Client (or RPD) complete debtors form and send it back to RPD	
Send debtors form to debtors department at administration	
Debtors department create debtors code for new client	
Acquire debtors code from debtors department	
Enter debtors code in Job Management System	

1.2 Evaluate Feasibility and Profitability:

Feasibility and profitability:	
Evaluate customer proposal	
Evaluate and determine if support documents (CAD, STL) are usable	
Is RPD capable for specific project?	
Check available capacity and resources	
Evaluate constraints	

² A debtors code is created for every new client. The debtors code is used for identifying a client on the US system and for invoice payment purposes.

Discuss assumptions	
Evaluate profitability	

1.3 Prepare and Submit Scope and Cost Proposal

Scope and cost proposal	
Estimate project duration	
Estimate project cost	
Estimate a start and completion date	
Update CMS	
Update Job management system (JMS) ³	

2. Quotation/Planning

2.1 Preparing quotation

Complete quotation:	
Check with internal/external support document (historical data)	
Prepare detailed quotation (this step requires that some steps in 2.2 are completed first)	
Determine cost of project according to the RPD pricing policy	
Complete quotation template	
Send quotation to customer	
Confirm delivery of quotation	

2.2 Prepare activities and schedule

Activities and scheduling:	
Check with internal/external support document (historical data)	

³ A detailed explanation of the JMS is given in chapter 11.

Appendix B

Define activities (low-level work breakdown structure) – project specifications	
Allocate responsible persons to activities	
Allocate materials to tasks (materials planning)	
Acquire quotations of special materials	
Find out supplier lead-time and delivery	
Prepare project cost baseline (TVC)	
Complete project plan	
Revise project plan	
Approve project plan	
Order maintenance (if customer order changed, go back to step 2.1 and change the necessary)	

2.3 Update Customer Management System (CMS)

CMS:	
Update client-product matrix	
Update “current position” field	

2.4 Update Job Management System

JMS:	
Correct Job number	
Correct customer details	
Quotation field completed	
Job status updated	
Work tools selected	
Work description completed	
Part description completed	

3. Execution

3.1 Daily tasks

See Product Development Roadmap.

3.2 Procurement of materials and services

Procurement of materials and service:	
Confirm material requirements	
Check if any such materials are in stock	
Verify materials – open the cans	
Determine the quantity of materials to be purchased according to stock level	
Determine the order date for materials according to the supplier lead times	
New supplier? If yes, capture supplier's information, otherwise ignore step.	
Purchasing of goods with US system? If yes, see step 2.2. EF ⁴ . If no, ignore step	
Purchasing of goods with RPD system? If yes, see step 2.2.EF. If no, ignore step	
Orders received? – Delivery notes and documents to administration officer	
Update inventory	

4. Monitoring and evaluation

Monitoring and evaluation	
Capture material consumption	
Capture project expenditure	
Evaluate project according to project plan and cost baseline	
Performance reporting (Internal & External)	

5. Closing

Closure:	
Invoice customer	
Shipping details correct	
Project delivered	
Delivery notification	

⁴ Enterprise Functions Roadmap

Appendix B

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Complete performance reports	
Update CMS	
Update JMS	
Follow-up customer for future business	

<p>Appendix C Checklists of the Product Development Roadmap</p>

2. Reverse Engineering

2.1 Scanning

Scanning:	
Soft parts must be made rigid.	
Provide reference features if parts must be aligned with existing CAD data.	
Choose part features for robust coordinate system setup.	
Choose probe for capturing all features – watch for internal sharp corners (cannot be scanned). Warn designer if probe cannot reach all features and internal corners.	
Choose probe and part orientation so that probe stem will not touch part and interfere with scanning results.	
Ensure small cordal tolerance is used (0.005) to capture sharp edges.	
Choose step over and pitch that will capture all features with enough points.	
Choose scanning direction to capture all data on vertical walls – multiple scans may be necessary.	
Create true surface for probe offset.	
From Tracecut export as points via IGES, ASCII.	
From Tracecut export as lines via DXF, IBL.	
From Tracecut export as .MOD file.	

2.2 Surface modelling

Surface modelling:	
Import .Mod true surface.	
Triangulate model. (Use small tolerances so that good triangulation is ensured.)	
Align different scans.	
Approximate surfaces – Use large surfaces; Start with large surfaces Watch out for probe-induced fillets.	
Use as few control points as possible – this will minimise the file size and ensure faster operation.	
Set line and surface fitting tolerances low enough – typically 0.01.	

Appendix C

PowerShape is used as an alternative surfaces modelling tool. PowerShape will be used to model surfaces that cannot be modelled in CopyCAD and/or to modify/redefine surfaces that could not be modelled smoothly enough in CopyCAD. PowerShape can also be used to add or remove new features to the reverse engineered part. Import surfaces from CopyCAD. This will most likely be a highly iterative process. Surfaces will be copied backwards and forwards between CopyCAD and PowerShape until the desired shape is obtained.	
Make sure, where surfaces share the same boundary, that the boundary of the neighbouring surface is selected when fitting a new surface. This will improve the chances that a single quilt will be generated in Pro/E.	
Export as IGES files.	
Translate surface data via IGES.	
Create closed surface quilt in Pro/E using the Heal Geometry function.	
Create solid protrusion using surfaces and curves from CopyCAD. Surfaces can be used directly or by using it to create completely new geometry when a parametric model is required. Hybrid imported geometry and parametric models are also possible.	
If client do not want a Pro/E file, translate using a suitable translator.	

2.3 RE Quality Assurance

Scanning:	
Check measurements where possible with Vernier, especially the position of sharp edges.	
Do visual check that flat surfaces are indeed flat – when looking along the surface; the scan lines must lay on top of each other.	
Do visual check so see that straight lines are indeed straight – i.e. corners on consecutive scan lines must lie in a straight line.	
If scans must align with existing CAD data, check this.	

Appendix C

Check that all features were captured completely, e.g. all surfaces were scanned right up to their edges.	
---	--

Surface modelling:	
Check accuracy – CopyCAD colour map; 3DTol; Vernier.	
Check that all required features are captured.	
Check that free form surfaces are smooth – visual; minimum radius shading in PowerShape.	
Check tangencies where required – visual.	
Check that flat surfaces are indeed flat.	

Pro/E:	
Check accuracy of parts – 3DTol, Vernier. If the quilt was fixed in Pro/E and new surfaces created to generate a single quilt, then the new surface will need checking to ensure that it conforms to the specified tolerance.	
Compare with existing CAD data of rest of assembly – Interference, style lines that must be parallel with style lines on rest of assembly	
Check surfaces that must be parallel with the assembly.	
Check smoothness – visually, Gauss Rendering	
Check tangencies between surfaces – visual.	
Style lines must resemble design intent.	
Check that all required features are on the model.	
Check specifications for features that were not reverse engineered, but added additionally.	

3. Quality Control

Quality control:	
Confirm with the client which parts of the product should be measured	
Confirm the format of the results and namely these results would be a standard report, excel spreadsheet or a measurements report	
Documentation of client should be in order (e.g. CAD drawings)	
Sort out the coordinate system with the client if necessary	
Plan measurements	
Execute measurements	
Report measurements	

4. CAD modelling

CAD Modelling	
Acquire product specifications from client	
Acquire data (specifications) of parts which integrates with the model	
Obtain additional information (e.g. ergonomics)	
Determine the file format of the end product (e.g. Pro/E file, IGES, etc.)	
Model	

5. 3D Printing

3D Printing	
Determine the format of the files beforehand (e.g. STL files, Pro/E files, etc.)	
Discuss the background of the part with the client	
Acquire part dimensions	
Acquire critical dimensions	
Acquire the type of finishing	
Acquire material specifications	
Generate build files – Zcorp	
Print part	
Cure part	
Clean	

Dry and size part in oven	
Infiltrate part (e.g. wax, epoxy or elastomere)	
Measure critical dimensions	

6. Post Processing

6.6 Matured processes

Vacuum casting with soft tooling:	
Acquire material specifications from client	
Acquire the type of finishing and the colour of the end product	
Confirm critical dimensions	
Acquire the quantity of parts that needed be casted	
Prepare a box for casting purposes	
Define split plane	
Determine the location of the casting funnel and vents	
Apply release agent on box and part	
Suspend part in box	
Prepare silicon mixture	
Pre-vacuum silicon in oven	
Cast silicon in box	
Vacuum mould in oven	
Cure mould in oven – 12 hours	
Split mould according to the defined split plane	
Cast poly – parts	

Sand tooling for sand casting:	
• Developing the cores	
○ CAD-Modelling	
○ Grow Zcorp parts	
○ Let parts dry in printer	
○ Remove and clean parts	
○ Sizing of parts	

Appendix C

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o Wax infiltrate parts	
o Assembling the infiltrated parts	
o Finishing and Final sizing	
• Developing the Right-hand side	
o CAD-Modelling	
o Grow Zcorp parts	
o Let parts dry in printer	
o Remove and clean parts	
o Sizing of parts	
o Wax infiltrate parts	
o Assembling the infiltrated parts	
o Finishing and Final sizing	
o Build Retaining frame for casing	
o Apply a Gel-coating	
o Backing medium and Lay-up	
o Overnight setting of Backing medium	
o Removing model and cleanup	
o Fitting the cores (check wall thickness)	
• Developing the Left-hand side (same as Right-hand side)	
• Developing the LH + RH Patterns	
o Preparation for release	
o Apply Gel-coats	
o Backing Medium and Lay-up	
o Curing	
o Remove from Negative – Cleaning	
• Developing the core-boxes	
o Split Development and Preparations	
o Build Retaining frame for one half	
o Release, Gel-coating, backing-medium	
o Build Retaining frame for other half	
o Release, Gel-coating, backing-medium	

<p>Appendix D</p>	<p>Checklists of the Business Functions Roadmap</p>
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2. Finance

2.4 Creditors

Order and Payment procedure of creditors on US system:	
Complete requisition form and create requisition number for specific order	
Send requisition number and order to Purchases Department	
If order is approved, Purchases Department creates purchase order number	
Place order	
Acquire invoice (original)	
Write goods receive information on invoice – Purchase number, Costing point, RPD account number, Goods receive number (computer generated)	
Send invoice and requisition form to Budget Control	
Bank transaction	

Order and Payment procedure of creditors on RPD system:	
Place order	
Receive order	
Acquire invoice (original)	
Complete a check requisition form (if international transaction, extra form)	
Send above forms to Purchases Department	
Purchases Department creates purchase order number	
Foreign payments by Budget control	
Bank transaction	

3. Material Management

3.1 Supplier information

Suppliers information:	
Company name	
Contact person	
Phone number	
Fax Number	
Postal address	
Physical address	
Product pricelist	

3.2 Inventory Control

Inventory control:	
Specify reorder levels – high volume materials	
Check inventory on specified intervals	
Check expiry date.	
Is inventory less than reorder level? If yes, do the following steps. If no, quit procedure.	
Determine the quantity of materials for purchasing according to the stock level and expiry dates of materials – funds available, etc.	
Acquire quotations	
Place order	
Order received?	
Update Inventory	

3.3 Material monitoring for costing purposes

Material Usage Monitoring Overview:	
Pre-initiation job decisions	

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Correct powder? If yes, go to next step. If no, do Powder Change Procedure.	
Enough Powder? If yes, go to next step. If no, do Add Powder Procedure.	
Pre - Printing Procedure	
Post Printing Procedure	
New Cartridge? If no, go to next step. If yes, do Cartridge Change Procedure.	
Post Processing required? If no, go to next step. If yes, do Post Processing Procedure.	
Cost Summary	
Management Reports	
Feedback and system correction	

Powder Change Procedure:		
1.	Obtain current and recent powder containers	
2.	Select current container first	
3.	Fill container with powder from - Printer feed box, Printer print box and Printer vacuum bag	
4.	Printer empty of powder? If yes, go to step 7. If no, go to next step.	
5.	Container full? If yes, go to next step. If no, go to step 3.	
6.	Select previously used container in sequence	
7.	Seal and weigh container(s)	
8.	Enter weight data	
9.	Clean printer thoroughly with vacuum cleaner	
10.	Follow Add Powder Procedure	
11.	Follow Pre-Printing Procedure	

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Add Powder Procedure:		
1.	Obtain current and recent containers and/or new containers with correct powder.	
2.	Open container for first time? If yes go to next step. If no, go to step 5.	
3.	Weigh new container (with lid on)	
4.	Enter data – Container number and opening weight	
5.	Fill printer feed box, while intermittently pressing down with powder scoop.	
6.	Printer full enough? If no, go to next step. If yes, go to 9.	
7.	Container empty? If no, go to step 5. If yes, enter data – container number and closing weight. Go to step 3.	
8.	Return to Pre-Printing Procedure	

Pre - Printing Procedure:		
1.	Obtain Job Number	
2.	Obtain CAD model (from client)	
3.	Create .BLD – file(s)	
4.	Correct powder in printer? If yes, go to next step. If no, do Powder Change Procedure.	
5.	Enough powder in printer. If yes, go to next step. If no, do Add Powder Procedure.	
6.	Enough binder fluid? If yes, go to next step. If no, insert new binder container	
7.	Weigh binder fluid	
8.	Enter pre-print data	
9.	Apply water and oil	
10.	Start Print	

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11.	New cartridge required? If no, go to next step. If yes, do Change Cartridge Procedure.	
12.	Follow Post Printing Procedure	

Post Printing Procedure:		
1.	Wait for post-curing time to elapse	
2.	Enter post print data – actual build time, binder usage and date/time	
3.	Remove print job from printer	
4.	Clean printed parts in vacuum cleaner	
5.	Clean printer vacuum bag and vacuum box filter	
6.	Level powder feed box with Perspex plate	
7.	Vacuum all excess powder	
8.	Perform powder spreads	
9.	Final vacuum cleaning of excess powder	
10.	New cartridge required? If no, go to next step. If yes, do Cartridge Change Procedure.	
11.	Post processing of parts required? If no, go to next step. If yes, do Post Processing Procedure.	
12.	Perform summary costing	

Post Processing Procedure: Epoxy resin infiltrant		
1.	Weigh parts	
2.	Place printed part(s) in 70°C oven for approximate 10-20 min	
3.	Weigh correct quantities of components A & B	
4.	Mix A & B together	
5.	Soak part(s) in mixed resin	

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6.	Place in vacuum chamber for approximate 15 min or until no more excess bubbles emerge from part(s)	
7.	Spread excess resin evenly over part surface with paint brush	
8.	Place part(s) in 70°C oven for approximate 10 min	
9.	Part(s) rotated? If yes, go to next step. If no, rotate part(s) and go back to step 7.	
10	Remove part(s) from oven and log data	

Post Processing Procedure: Wax infiltrating		
1.	Weigh part before placing in waxer	
2.	Place part in waxer	
3.	Start waxing cycle	
4.	Remove part from waxer	
5.	Weigh part	
6.	Log amount of wax used by subtracting pre- from post-infiltrated weight	

Post Processing Procedure: Hand finishing		
1.	Use 120 sanding paper	
2.	Remove most roughness from part	
3.	Apply layer of PVA paint	
4.	Place part in 40°C oven	
5.	Remove layer of paint until smooth	
6.	Any medium-sized grooves or dips? If no, go to next step. If yes, go to step 3.	
7.	Apply one layer of grey primer	
8.	Place part in 40°C oven	

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9.	Have max three layers been applied? If yes, go to next step. If no, go to step 7.	
10.	Sand down primer using 200 sanding paper	
11.	Spray part with desired colour	
12.	Any fine-sized grooves or dips? If no, go to next step. If yes, sand down and go to step 11.	
13.	Log materials used	

Post Processing Procedure: Silicon Moulding		
1.	Define split-plane of part	
2.	Apply tape along split line	
3.	Colour edging red/black pen	
4.	Create retaining box	
5.	Seal any holes and corners with plasticize	
6.	Create gates and attach to part	
7.	Spray with release agent (both part and box)	
8.	Suspend part in retaining box	
9.	Place suspended part in 70°C oven	
10.	Calculate silicon required in cm ³ from box volume.	
11.	Multiply with 1.1 and divide by 1000	
12.	Weigh correct quantity of silicon	
13.	Weigh correct quantity of catalyst	
14.	Mix very well together	
15.	Pre-Vac for approximate 15-20 min and until mixture collapses	
16.	Pour into mould holding it at a slight angle	

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17.	Vacuum for approximate 15 min	
18.	Place in 70°C oven for approximate 90 min	
19.	Log material quantities used	

3.4 Asset Management

Procurement of new assets	
Go to FBG100 on US system	
Complete the asset acquisition form – what, how many, motivation, amount, etc.	
If approve, an asset number is created	
Complete requisition form for assets	
Send requisition number and order to Purchases Department	
If order is approved; Purchases Department create purchase order number	
Place order	
Acquire invoice (original)	
Write goods receive information on invoice – Purchase number, Costing point, RPD account number; Goods receive number (computer generated)	
Send invoice and requisition form to Budget control	
Bank transaction	
Update asset list	

5. Human Resources**5.1 Appointment and Induction**

Appointment and Induction	
Complete IRP2 form	
Banking details	
Send above forms to admin	
Acquire personnel card and activate	
Activate personnel card for specific door entrances	

Appendix E	Job Management System - User Manual
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1. Job Management System Main Features

The database is opened by clicking on the link, Job Management System, in the initiating step of the project management lifecycle. The main screen, shown in figure 39, appears displaying the information of the last record.

Figure 39: JMS Main Screen

The main screen can be divided into five sections:

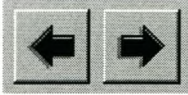
- Extras
- Job Number
- Client Details
- Job Details
- Financial Details

A detailed discussion of each section follows:

1.1 Extras

Navigation arrows:

The two arrow buttons can be used to navigate through the existing records.



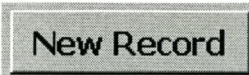
Binocular:

Clicking on the binocular button enables a search function. The search function can be used to search for a specific record (job) by entering the job number in the required field.



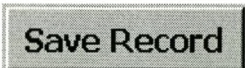
New Record:

Clicking on the New Record button opens a new record



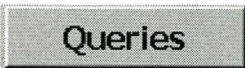
Save Record:

Clicking on the Save Record button saves a record.



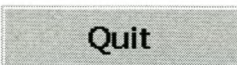
Queries:

The window containing the list of queries is displayed by clicking the queries button.



Quit:

Clicking the Quit button closes the JMS



1.2 Job Number

Each job is unique and therefore each job has a unique job number. The job number is the primary key of the database and it is therefore necessary that the job number field be completed right at the beginning of recording a new job record. If a previously used job number is used for a new job record, the system will display an error message. The job number field is shown in figure 40.

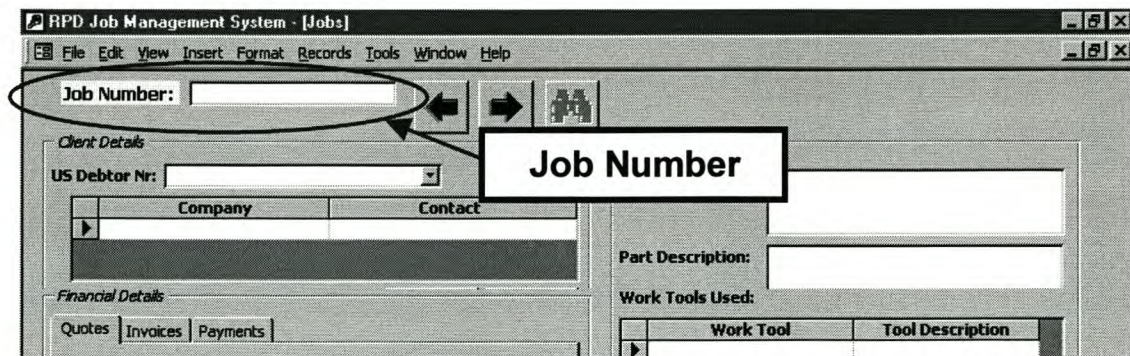


Figure 40: Job Number Field

1.3 Client Details

The client detail section is used to record the name of the company, the name of a contact person and the US debtor number. Each client has a unique US debtor number. Detailed information of each client is stored in the Client Management System. To avoid duplication of data only the above fields are included in the JMS.

1.3.1 Existing Client

If a client already exists on the system the client's information can be selected from the US Debtor Nr. dropdown box as shown in figure 41. After selecting a debtor's code, the company name and the contact person's name will automatically appear in the company and contact fields.

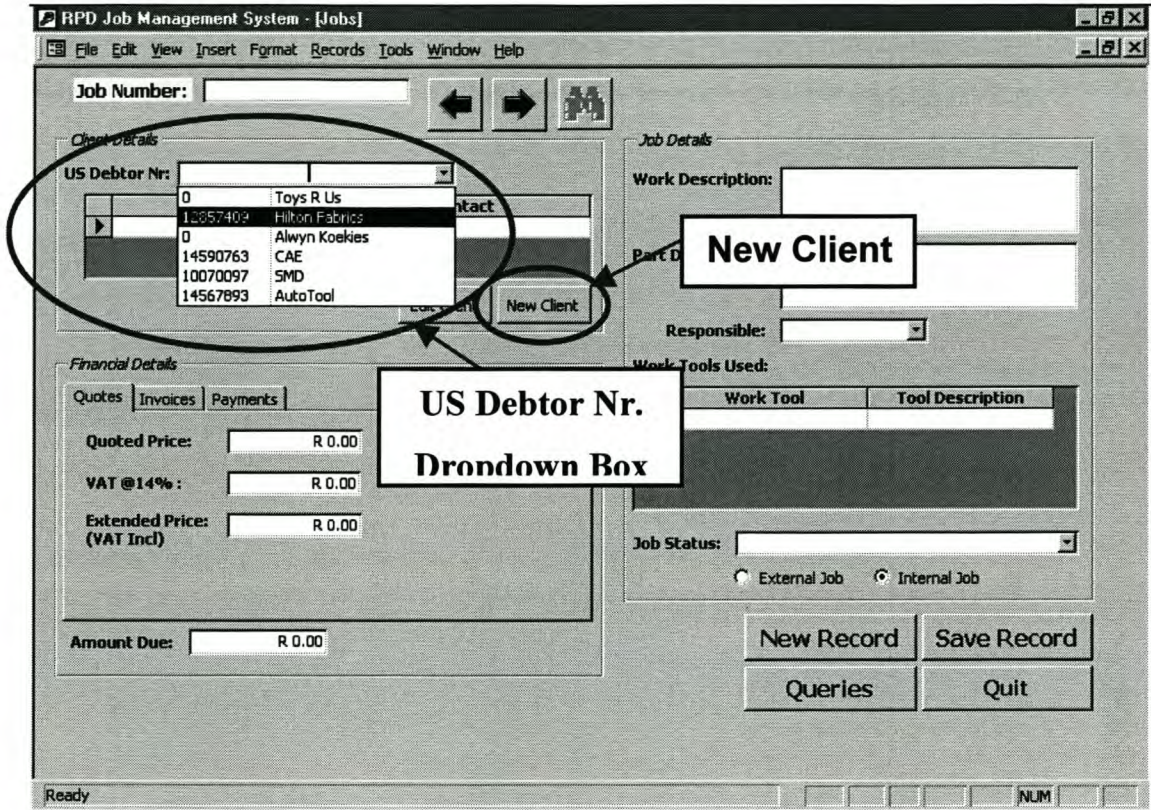


Figure 41: Client Details

1.3.2 New Client

If a client does not exist, the client's information has to be stored. This is done by clicking on the New Clients button, as shown in figure 42. The window that appears is used to enter the new client's details.

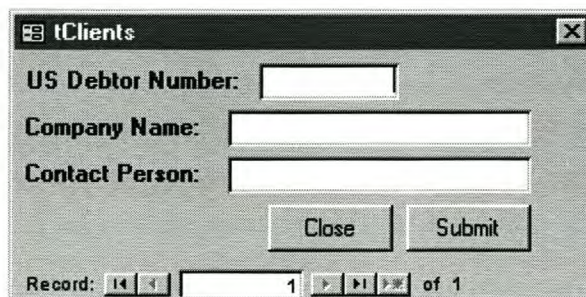


Figure 42: New Client Window

Since the client is new, a US debtor number has to be created. Creating the US debtor is explained in section 1.1 of chapter 4. The US Debtor Nr. field must contain a value to proceed. Since it takes a while to create the US Debtor number, it is safe to use the number zero initially. The following section explains how to change the US debtor number once it is known. When all the fields are completed, the submit button are clicked to save the information. The close button closes the window.

1.3.3 Edit Client

The information of the client can be changed by selecting the client from the US Debtor Nr. dropdown box and by clicking on the Edit Client button as shown in figure 43. A window containing the specific client's information appears. Any of the fields can be edited. If the field US Debtor Nr. contains a zero number, as mentioned in the previous section, the created US debtor number can be entered. The close and submit buttons are the same as those on the New Client window in figure 42.

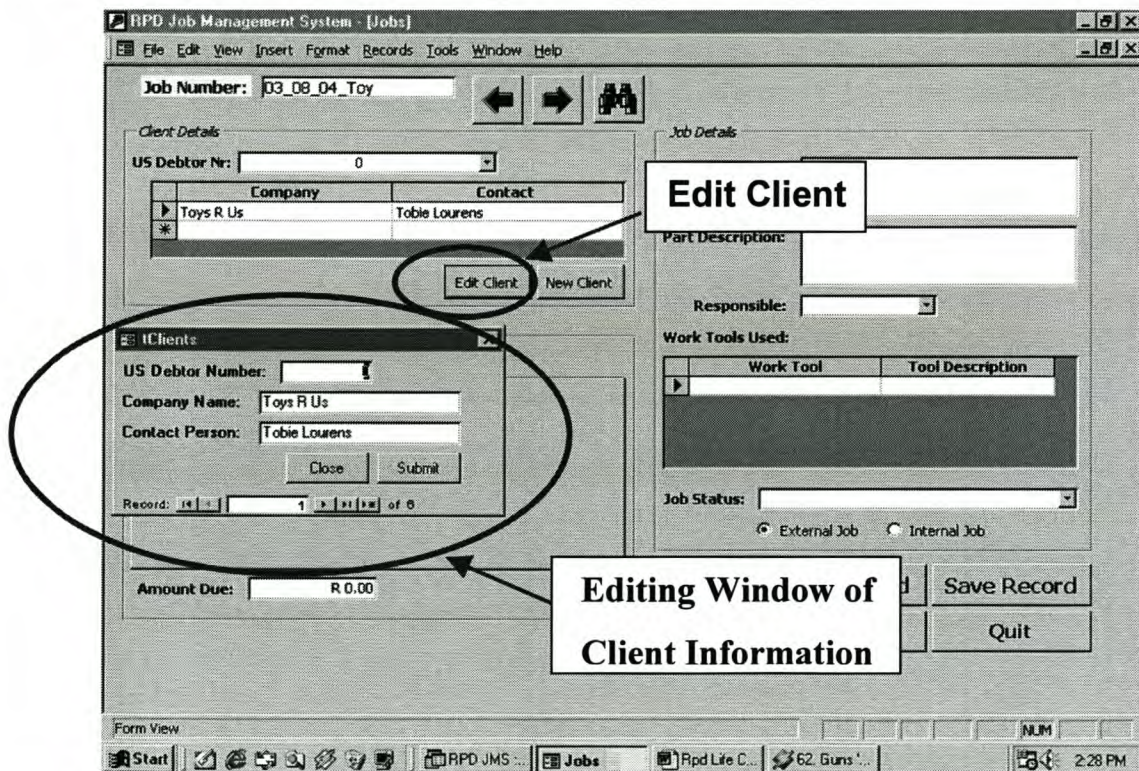


Figure 43: Editing Clients Window

1.4 Job Details

The job details section includes information related to the workings of a specific job. The fields included in this section are work description, part description, responsible person, work tools used, job status and internal/external job. This information is very important for management reports, especially the job status field.

1.4.1 Work and Part Description

The work description field is used to describe the type of work that needs to be done for a specific job. The part description field is used for a detailed description of the part involved in the job. See figure 44.

The screenshot shows the 'RPD Job Management System - [Jobs]' window. The 'Job Details' section is highlighted with a callout box that reads 'Work Description and Part Description'. The 'Job Details' section includes the following fields:

- Work Description: [Text Field]
- Part Description: [Text Field]
- Responsible: [Dropdown Menu]
- Used: [Table]
- Job Status: [Dropdown Menu]
- External Job / Internal Job: [Radio Buttons]

The 'Used' table has the following structure:

Work Tool	Tool Description

The 'Financial Details' section includes the following fields:

- Quoted Price: R 10,000.00
- VAT @14%: R 1,400.00
- Extended Price (VAT Incl): R 11,400.00
- Amount Due: R 0.00

The 'Client Details' section includes the following fields:

- US Debtor Nr: 0
- Company: Toys R Us
- Contact: Tobie Laurens

The 'Form View' status is visible at the bottom left of the window.

Figure 44: Work and Part Description Fields

1.4.2 Responsible Person

At the RPD a specific person is allocated to a specific job. The responsible person is selected from the dropdown box, called responsible. See figure 45.

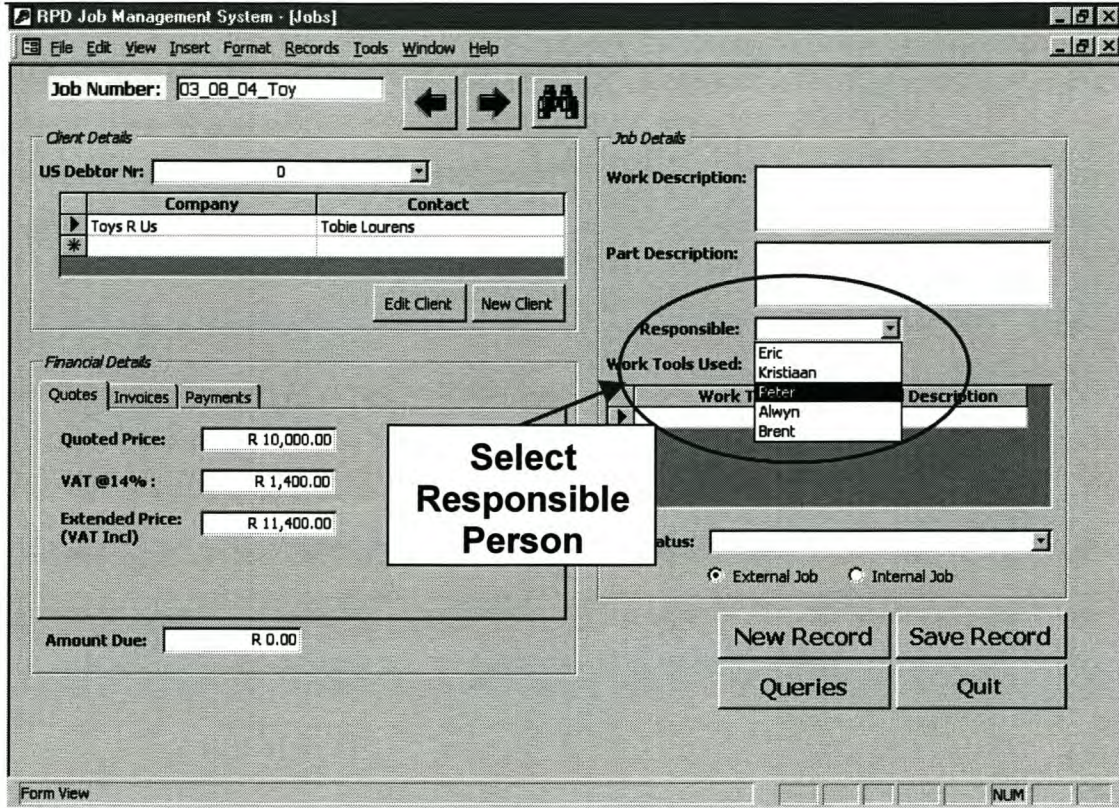


Figure 45: Responsible Person Field

1.4.3 Work tools used

During the execution of a job, specific tools are used. Typical tools are CopyCad, the Zcorp 3-D printer, Renishaw Cyclone, etc. The corresponding description of each of the mentioned tools is surface modelling, 3-D printing and 3-D scanning.

Either the Work Tool dropdown box or the Tool Description dropdown box can be used to select the work tools for a specific job. More than one tool is often used to complete a job and it is therefore possible to select more than one from the list. See figure 46.

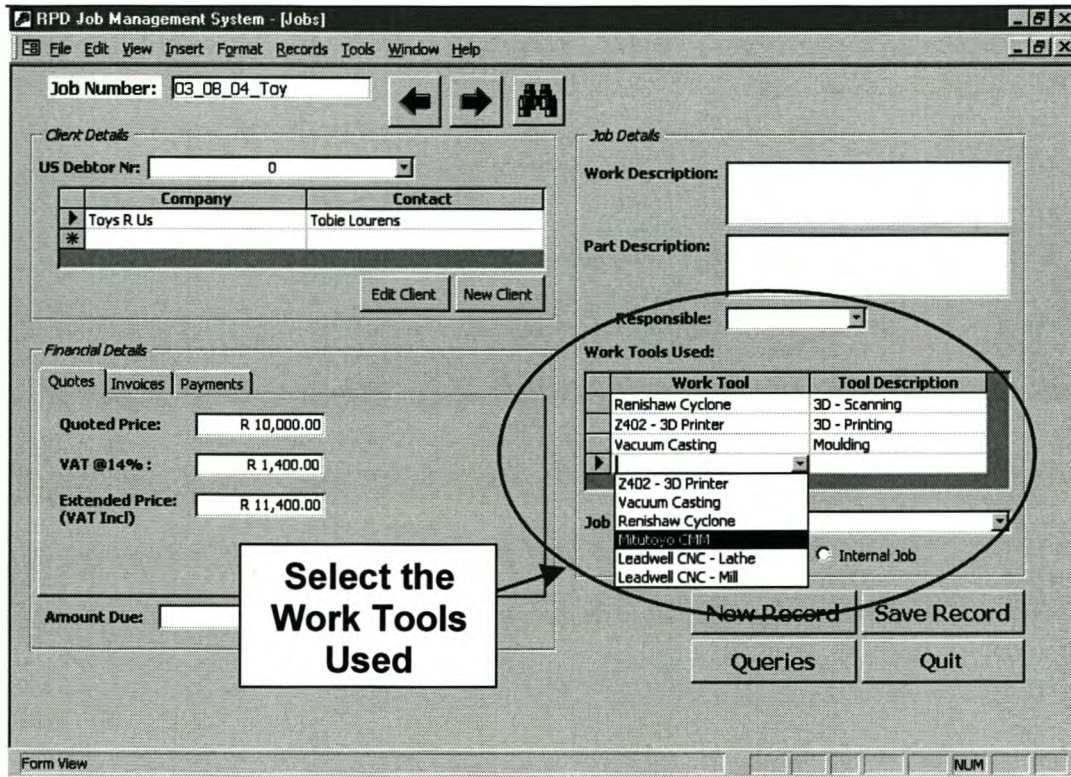


Figure 46: Work Tools Field

1.5 Job status

The job status field consist of a dropdown box with a list of the various job states. It is important that users change the status of the individual jobs as the jobs progress. See figure 47 for the various job states.

The screenshot shows the RPD Job Management System interface. The Job Number is 03_08_04_Toy. The Client Details section shows US Debtor Nr: 12857409 and a table with columns Company and Contact, listing Hilton Fabrics and Verona Swart. The Financial Details section shows Quoted Price: R 10,000.00, VAT @14%: R 1,400.00, and Extended Price: R 11,400.00. The Job Details section shows Work Description, Part Description, Responsible, and Work Tools Used. The Work Tools Used table lists Renishaw Cyclone (3D - Scanning), Z402 - 3D Printer (3D - Printing), and Vacuum Casting (Moulding). The Job Status dropdown is currently set to 'In Progress' and is highlighted with a callout box labeled 'Select the Job Status'.

Company	Contact
Hilton Fabrics	Verona Swart

Work Tool	Tool Description
Renishaw Cyclone	3D - Scanning
Z402 - 3D Printer	3D - Printing
Vacuum Casting	Moulding

Job Status: In Progress

- Closed (Paid)
- In Progress
- Incomplete (50% Deposit Invoiced)
- Job Done (Invoiced)
- Job Done (Not Invoiced)
- Promotional Project (GCC Project)
- Quote Not Accepted
- Written Off (No Payment)

Figure 47: Job Status Field

1.5.1 Internal/External Jobs

The difference between internal and external jobs is that no VAT is included in the price of an internal job. Internal jobs are jobs completed for any department inside the engineering faculty. Checking the *external job* check box enables VAT while checking the *internal job* check box disables it. See figure 48.

The screenshot displays the RPD Job Management System interface for a job titled '03_08_04_Toy'. The interface is divided into several sections:

- Client Details:** Includes 'US Debtor Nr: 12857409' and a table with columns 'Company' and 'Contact'. The table lists 'Hilton Fabrics' with contact 'Verona Swart'. Buttons for 'Edit Client' and 'New Client' are present.
- Financial Details:** Contains tabs for 'Quotes', 'Invoices', and 'Payments'. Fields include 'Quoted Price: R 10,000.00', 'VAT @14%: R 1,400.00', and 'Ext(ended) Price: (VAT Incl) R 11,400.00'. A callout box labeled 'VAT' points to the VAT field.
- Job Details:** Includes 'Work Description', 'Part Description', 'Responsible', and 'Work Tools Used' (a table with 'Work Tool' and 'Tool Description' columns). The 'Job Status' is set to 'In Progress'. Radio buttons for 'External Job' (selected) and 'Internal Job' are circled, with a callout box labeled 'Select Internal or External Job' pointing to them.
- Buttons:** 'New Record', 'Save Record', 'Queries', and 'Quit' are located at the bottom right.

Figure 48: External/Internal Jobs

1.6 Financial Details

The financial details section consists of a quote, an invoice and a payment form. These forms can be selected by clicking on the label of a specific form. See figure 49.

1.6.1 Quotes

The quoted price of a job is entered into the Quoted Price field. The VAT and Extended (Total) Price fields are automatically calculated by the JMS. For more detail about the VAT refer to section 11.2.4.5. See figure 49.

The screenshot displays the RPD Job Management System interface. The main window is titled "RPD Job Management System - [Jobs]" and contains several sections:

- Job Number:** 03_08_04_Toy
- Client Details:** US Debtor Nr: 12857409. A table lists "Hilton Fabrics" with contact "Verona Swart".
- Job Details:** Work Description, Part Description, and Responsible fields.
- Financial Details:** A tabbed interface with "Quotes" selected. It shows:
 - Quoted Price: R 10,000.00
 - VAT @14%: R 1,400.00
 - Extended Price (VAT Incl): R 11,400.00
 - Amount Due: R 0.00
- Work Tools Used:** A table listing tools like "Renishaw Cyclone" (3D - Scanning), "Z402 - 3D Printer" (3D - Printing), and "Vacuum Casting" (Moulding).
- Job Status:** In Progress (radio buttons for External Job and Internal Job).
- Buttons:** New Record, Save Record, Queries, and Quit.

Two callout boxes are present: "Form Labels" pointing to the "Quotes" tab and "Quotes Form" pointing to the "Quoted Price" field.

Figure 49: Financial Details – Quotes

1.6.2 Invoices

Before any payments can be made, RPD has to invoice the client with the agreed price. A client is normally invoiced after a job is completed, or after some part of a job is completed. This means that more than one invoice can be made for a job and therefore there is no limit on the number of invoices that can be entered. An invoice is entered in the *Invoices* form as shown in figure 50. All invoices have a unique invoice number and the duplication of an invoice number will generate an error message.

When the invoice details are known, an invoice can be entered by clicking the *new invoice* button as shown in figure 50. The *new invoice* form appears and the invoice number, invoice date and invoice amount can be entered into the specified fields. By clicking the submit button, the entry is submitted to the corresponding fields on the

invoices form. While the new invoice form is open more than one invoice can be submitted. Clicking the *done* button closes the *new invoice* form. See figure 51.

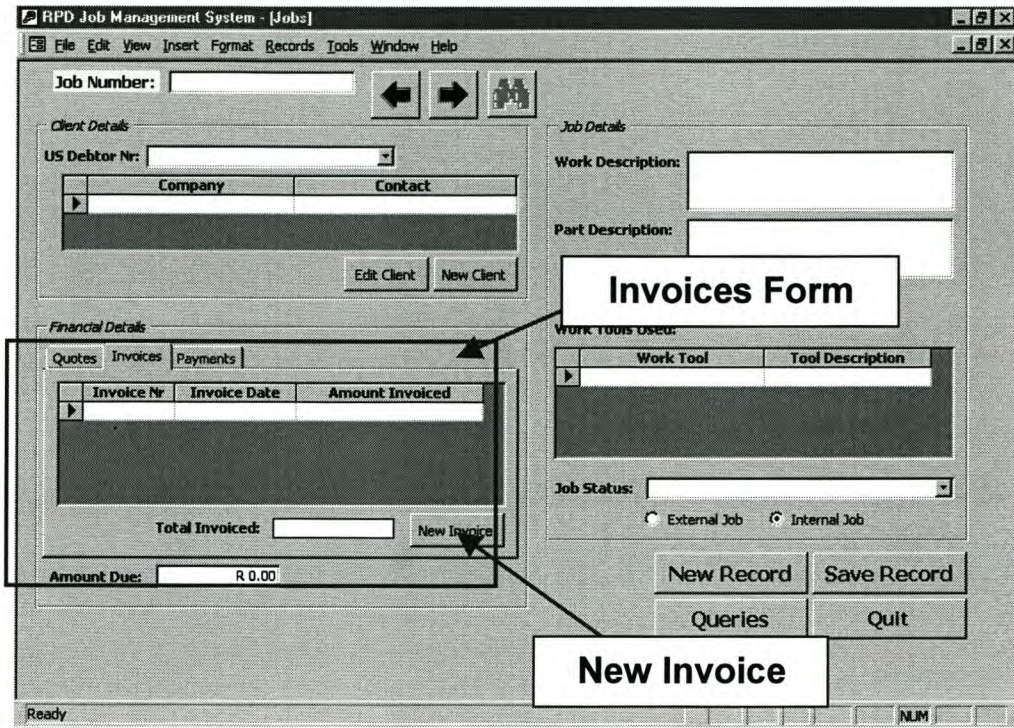


Figure 50: Financial Details – Invoices

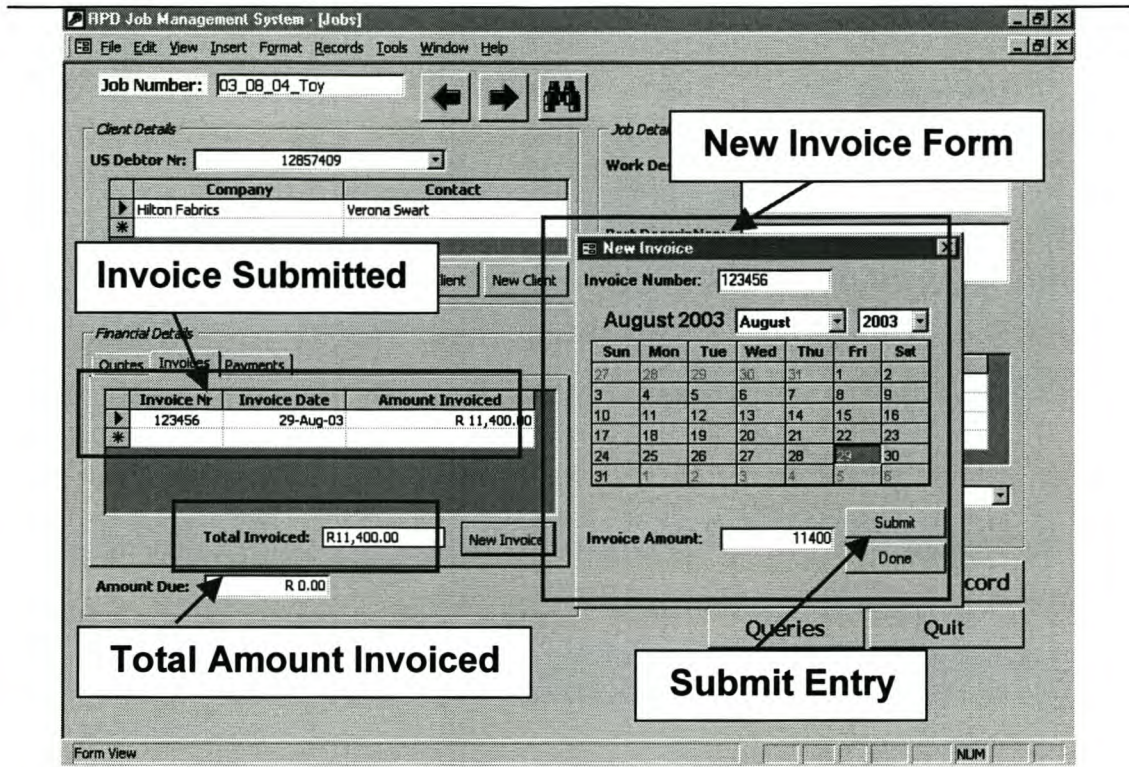


Figure 51: Submitting New Invoices

1.6.3 Payments

The payment form shows all payment information. New payments can be entered by clicking the *new payment* button (See figure 52). This displays the new payment window in which details can be entered.

All payments are attached to a specific invoice number. The required invoice number can be selected from the dropdown box on the new payment form. For convenience, the dropdown box contains only the invoice numbers of a specific job. The payment date and payment amount must also be entered into the new payment form. The entry is submitted to the corresponding fields on the payments form by clicking the submit button. Clicking the done button closes the form.

The total paid field displays the sum of all payments made for a specific job. See figure 53.

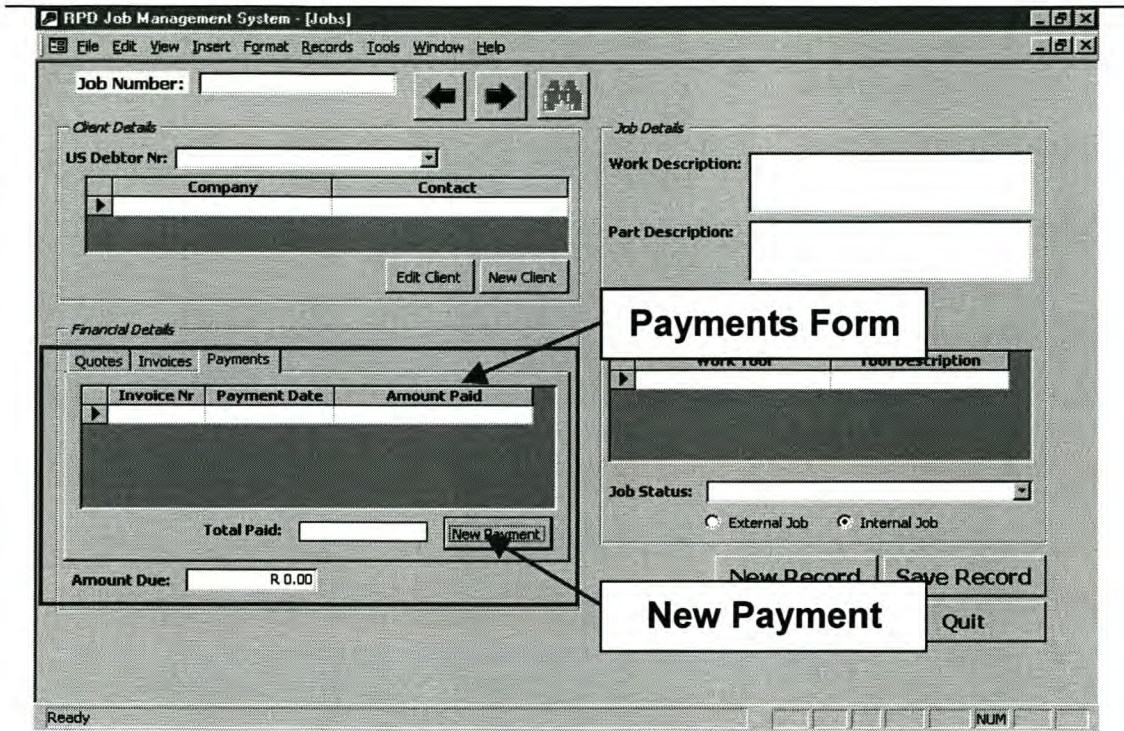


Figure 52: Financial Details: Payments

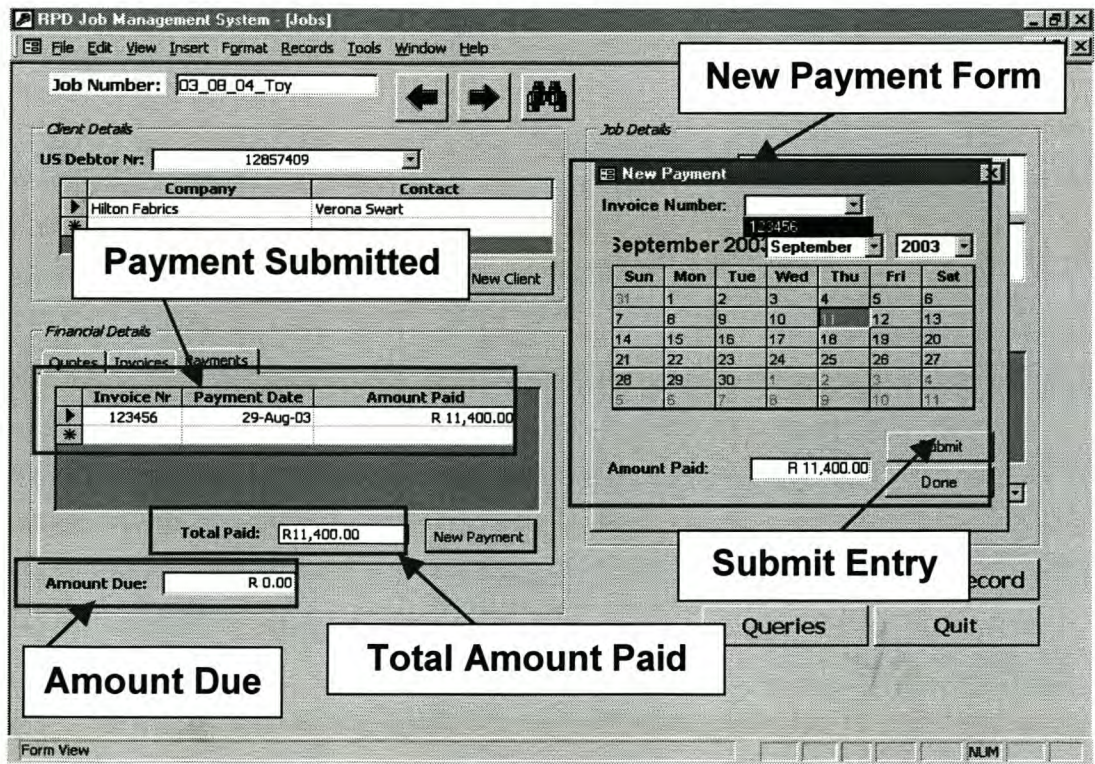


Figure 53: Submitting New Payments

1.7 Amount Due

The amount due field displays the difference between the values of quoted price and total payments of a specific job. See figure 53.