DEVELOPMENT OF A DATABASE OF MINE PLANNING AND PERIPHERAL SOFTWARE USED IN THE SOUTH AFRICAN MINING INDUSTRY

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A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Science in Engineering

Johannesburg, 2012

DECLARATION

I declare that this dissertation is my own unaided work. It is being submitted to the Degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

.....Fataqual..

(Signature of candidate)

Signed on the 19th day of SEPTEMBER year 2012

at BRAAMFONTEIN, JOHANNESBURG

Abstract

The mining industry uses computers for major administrative tasks, common to most industries, along with a range of applications highly specific to mining where the computer speed, accuracy and ability to cope with large volumes of data present the opportunity for optimal solutions to problems. However, the nature and extent of the software utilisation in the South African mining industry has never been evaluated. The aim of this research therefore was to collate and analyse the current utilisation of software in the South African mining industry. This was done through the development of a database of mine planning and peripheral software utilised in the South African mining industry.

The database is expected to help at least 13 educational institutions with decisions on facilities and training vital to the education of geologists, surveyors, mining engineers, metallurgists and other professionals who are directly involved in planning across the mine value chain. Exploration, mining, mineral processing and consulting companies will benefit from information relating to availability of software solutions. There are about 1 200 mining companies exploring for, extracting or processing more than sixty different mineral commodities at more than 1 600 sites in South Africa. At least 50 consulting companies and at least 20 software providers were identified. The database will also enable software providers to have a better understanding of their market share.

Snowball sampling was used to collect the data because the industry is diverse and software utilisation is fragmented across and within sectors of the mining industry. The data was then organised into distinct categories so that the information from a variety of sources could be evaluated on the same basis. The database was designed to reflect this categorisation and relationships between the data entities.

The major result of this research is a web-based database of mine planning software in use in the South African industry. The information can be accessed through a user-friendly frontend platform which is available online at http://db.mining.wits.ac.za. One may browse through the data to see which companies are included in the database and at same time view the associated sites and mineral commodities. Software provided by a company is also listed when one browses to the page that shows information on the company. A utility for searching through the database for software based on certain criteria has been included. Depending on the privileges granted to the user, he may also view where the software solutions are installed. Functionality has also been included to analyse the data relating to adoption of software solutions and their relative market share.

An analysis of the data collated in this research shows that about 73% of the users are mining companies, 21% are consulting companies, 4% are mineral exploration companies and the rest being other providers, educational institutions, mineral processing companies. The software in use in South Africa is largely provided by Gemcom Software, MineRP Solutions and MRM Mining Services. CAE Mining is widely accepted as a major software supplier in South Africa, however, due to certain limitations and constraints, data from them had not been obtained at the time of submission of the dissertation.

To Lidia and Wyatt Yanji

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List of acronyms

ACID	Atomicity, Consistency, Isolation, and Durability
CSS	Cascading Style Sheets
ERP	Enterprise Resource Planning
GB	Gigabytes
GPL	General Public License
GUI	Graphical User Interface
HTML	Hypertext Markup Language
ICT	Information and Communication Technology
PGM	Platinum group metals
PHP	PHP: Hypertext Programming (a recursive acronym, which originally stood for Personal Home Pages)
RSA	Republic of South Africa
SAIMM	Southern African Institute of Mining and Metallurgy
SQL	Structured Query Language
TB	Terabytes

1 INTRODUCTION

1.1 Background

It is a well-known and documented fact that the cost of computer equipment has dropped drastically over the years and continues to drop. Computer prices fell by 90% over the period 1998 to 2008 (Perry, 2009). During the same period computer performance doubled every 1.5 to 2 years (Koomey et al, 2009). In view of the rapid increase of performance per computer cost it is not surprising that there has been a rapid growth of computer usage in most industries.

The use of computers for major administrative tasks such as stores control, payrolls, accounting systems and financial planning is commonplace in most industries including the mining industry. For these tasks general solutions are often used. That said, the ability that computers have of coping with large volumes of data at high speeds and high degrees of accuracy enables mining professionals to obtain comprehensive solutions to problems which could previously only be superficially examined. Areas such as geological modelling and reserves estimation, mine design and planning readily come to mind. Many of the solutions to problems in these areas are common to the entire mining industry or a large sector of it. Such packages are available to the industry professionals from three major sources, which are, off-the-shelf from a software supplier, from a specialist mining software company or from a central in-house software development team. Worldwide, the mining industry uses computers in general and specialised software in particular for virtually all aspects of its business. Software usage is integral to the design, planning and operation of mines. The solutions range from simple spreadsheet programs to sophisticated 3D mine design and planning packages.

1.2 Problem statement and motivation

In spite of the inherent usage of software across the mine value chain, the nature and extent of the software utilisation has never been evaluated for the South African mining industry. This leads the research question which this dissertation seeks to answer, that is, “What is the current nature and extent of mine planning and peripheral software utilisation in the South African mining industry?” The methodology for answering this question included developing a database of software utilised in the South African mining industry. The database also forms a basis for a framework which may be used to analyse trends and predict future challenges.

The intended beneficiaries of the database are educational institutions, consulting companies, mining companies and software providers. Educational institutions may use the database to expedite decision making pertaining to facilities and training vital to the education of mining industry professionals. In South Africa, four universities have curricula designed for training mining engineers namely, the University of Johannesburg, the University of Pretoria, the University of South Africa and the University of the Witwatersrand. These and at least nine other universities offer training to other professionals involved in the planning process such as geologists, surveyors, metallurgists and environmental specialists.

Mining companies and consulting companies may consult the database to check the availability mine planning and related software solutions. Companies that need to set up mineral resource management departments are in a position to find out which solutions are available, how they relate to each other and in which contexts they are currently being used (with respect to mineral commodities and mining methods). Even companies that have well established mineral resource management departments may find the database useful in keeping informed on developments in the industry. There are about 1 200 mining companies exploring for, extracting or processing more than sixty different mineral commodities at more than 1 600 sites in South Africa. Over 50 consulting companies provide services to the mining industry. They offer services in the areas of legal compliance, geophysical data interpretation, geological modelling, resource estimation, feasibility studies, geotechnical studies, water management planning, mine designs and layouts, production schedules, equipment selection and many others.

At least 20 software providers have software solutions being used in the South African mining industry. Using the database, software providers should have a better understanding of their market share. The database is expected to enhance the visibility of their software solutions and help them in identifying opportunities for future growth.

1.3 Significance of the dissertation

Decision makers may obtain information from a variety of sources. Kaye (1995) classified sources of information using format, status and location. *Format* refers to whether the means of conveying is oral versus documentary. The *status* refers to whether the source is personal versus impersonal, formal versus informal and whether it is published or open versus unpublished or confidential. The *location* refers to whether the source of information is internal versus external with respect to a given organisation. A literature survey by de Alwis, Majid and Chaudhry (2005) identified accessibility, ease of use, a high level of perceived credibility of information and a perception that the most relevant information has been received as the factors which are given much weight in influencing the choice of the source preference.

In the past, decision makers have placed heavy reliance on external personal informal sources such as news, ideas and gossip picked up in the course of business dealings or at conferences and trade shows (Kaye 1995). However, there has been a gradual change in the information seeking behaviour of decision makers. This view is supported in the work of de Alwis, Majid and Chaudhry (2005) which acknowledged the impact of the emergence and extensive use of Information and Communication Technology (ICT) in the workplace. The internet permits formal and informal information to be transferred worldwide on a massive scale.

The mine planning and peripheral software database is meant to combine the advantages of traditional sources of information with the advantages presented by the internet. The database is used not only to store and retrieve raw data but also to analyse the information. Data from a variety of sources is structured and this facilitates making comparisons between various companies and software solutions. The data may also be filtered and summarised and this reveals patterns that may allow one to extract unique items of useful information.

1.4 Objectives of the dissertation

In order to achieve the aim of this dissertation, the following objectives had to be reached:

- Compile data from providers and users of mine planning and related software in South Africa;
- Design a database model;
- Implement the database model;
- Capture the data compiled from interviews and other sources;
- Analyse the data using quantitative methods; and
- Present the data and analysis in a web browser.

1.5 Structure of the dissertation

In addition to this chapter, there are five other chapters. Chapter 2 presents a literature survey of background information and concepts relevant to this dissertation. It starts by giving further details about the context of the problem. Then it expands on the significance of the dissertation. Finally it discusses the technologies available to solve the problem.

Chapters 3 to 5 discuss the progression of two parallel tasks that were carried out to achieve the objectives of this dissertation. The tasks are:

1. Gathering and categorising the data required; and
2. Developing appropriate platforms for storing, retrieving and analysing the data.

Chapter 3 is divided into two sections. The first section outlines the requirements of the project as well as the functional and non-functional requirements of the system used to collate the data and present the information. The second section goes on to describe the plan for data gathering as well as the design of the database and the front-end application. Chapter 4 details how the data gathering was carried out and how the designs for the database and the front-end application were implemented. Chapter 5 presents the outcomes of the two tasks in the form of findings and analyses of the results of the research. It gives details on how the information can be accessed.

Chapter 6 concludes this dissertation. It highlights what has been achieved by this research, assesses the limitations that constrain the research problem and suggests future directions for further research.

1.6 Summary

This chapter has endeavoured to introduce the reader to this dissertation by giving some background, the main research question, motivation and structure of the dissertation. The next chapter itemises the findings of a survey of literature on topics relevant to this dissertation.

2 LITERATURE REVIEW

2.1 Chapter overview

Chapter 2 provides a review of the literature and research related to the use of software in the mining industry specifically focussing on mine planning. The chapter is divided into sections that include:

a) the historical development of software adoption in the mining industry;
b) the factors that affect choice of software at different sites;
c) previous related studies; and
d) a comparison of the tools available for documenting software adoption and utilisation.

2.2 Adoption of computers in the mining industry

Computer applications are used to simplify the process of storage, retrieval and analysis of mining data as well as facilitating the design simulation and monitoring of mine plans and mining operations (Badiozamani, 1996). This assists engineers in the day-to-day decision-making process.

According to Kapageridis (2005) the evolution of mine planning software started towards the late 1970's across the world with a clear focus on operational gold mines where it was crucial to avoid any wasteful mining. The use of computers in the South African coal mining industry increased in the 1980's (Oberholzer and Hardman, 1987). The needs of the mining industry had shifted from exploration to optimising productivity at mine sites (Johnson, 1987). Computers played a significant role in the effort to achieve higher rates of mining and better utilisation which were needed in order to counter rising costs and to remain competitive. In the wake of the global economic crisis of mid-2008 this role is highlighted again. The mining industry must find ways to remain sustainable amid the sea of legal, social, economic and environmental issues (Deloitte Touche Tohmatsu Ltd., 2008). These challenges present opportunities for the ICT sector. The provision of enterprise resource planning (ERP) software, which coordinates the entire mining value chain, from exploration data management to final rehabilitation planning is one example of such an opportunity. In addition the mining industry in South Africa faces real challenges with regards to the improvement of health and safety. Webber-Youngman and van Wyk (2009) concluded that virtual mining interactive simulations can have a major impact in this regard.

It is evident that over the past four decades mining companies have relied on advances in information technology in order to tackle some of the challenges they have faced and consequently have remained competitive. As the processing power of computers increases there will be new ideas and products for visualisation and optimisation. This is likely going to continue because mining companies are not the only stakeholders driving this trend. Binning (2009) reported that software providers are also competing to help mining companies extract minerals in the most profitable manner. The level of competition is evident from statements made by some leading software solutions providers.

Gemcom Software International Inc. (2010) stated that:

> "Gemcom Surpac™ is the most widely used software system of its kind in the world, supporting open pit and underground mining operations and exploration projects in more than 90 countries."

In a similar vein, Maptek Pty Ltd (2009) stated that:

> "Maptek Vulcan™ is the leading 3D modelling and mine planning software covering the full mining cycle. More than 4,000 licences are installed at 800 sites worldwide."

In this highly competitive market, mine planning software must continue to evolve in form and functionality to satisfy current requirements and provide new methods for solving existing problems (Kapageridis, 2005). This evolution will continue as long as there is a close relationship between end-users and software developers and this will ensure the future sustainability of mine planning software.

A study by Mugodi and Fleming (2003) noted that mining companies are conservative in their approach when it comes to adopting new technologies. Among the recommendations made in the study, three are pertinent to this dissertation:

1. Mine managers must view the adoption of ICT as the principle that will enable energy and growth in the future;
2. Large mining companies must assist joint venture or empowerment partners to adopt ICT; and
3. The ICT industry must reduce the cost of ICTs to encourage their adoption.

2.3 Functionality and cost of mining software

All too often, cost is the primary consideration for companies when buying software. After some surveys conducted in the 1990's, Gibbs (1999) concluded that educators want free software, small companies and consultants want low-priced software and large companies are willing to pay higher prices to purchase the same software. Software licences represent a substantial part of every ICT budget. The Info-Tech Research Group (2009) advised that it is important for organisations to understand how to better negotiate licence agreements in the first place, and how to renew them for the lowest cost. The cost of maintenance support and training of individual users must also be considered.

Software can be a major cost and a proper cost-benefit analysis is an important step to take when choosing mining software. In view of the fact that some software may provide more functions while less functional software may be less expensive, Wilkinson (2002) suggested that choosing one software solution over another should involve balancing what functionality is required and one's budget. However, cost-effectiveness is of paramount importance. Brickley (2009) noted that cheaper is not necessarily better. Each software package has its own unique features, abilities, advantages, and shortcomings. The best software to use may be a combination of several software tools. Ultimately, the best choice is the collection of software that can be used to clearly communicate the solutions to mine planning problems and return the highest net value to the project.

2.4 The need for standardisation, classification and integration of software

Finding, evaluating and developing a new mine is technologically and economically complex, expensive and long term. Walker and Kemp (1987) observed that mining is a multi-disciplinary function which involves interaction and cooperation between the various disciplines involved in the overall mining operation. The effectiveness of these many disciplines as an orchestrated team relies heavily on a sharing of data. It is important, therefore, for software programs to be able to share data with programs from other providers.

Keyser (2001) illustrated a set of applications used at an open pit mine and the data flow between each application. Figure 2-1 illustrates a disordered and chaotic information flow catering for an individual application's specific needs. The diagram can be used to show that a similar situation can exist at an underground mine. The problem of a disordered and chaotic information flow results when applications are implemented independently from each other while the need for interaction and the benefit of integration are given little or no consideration.

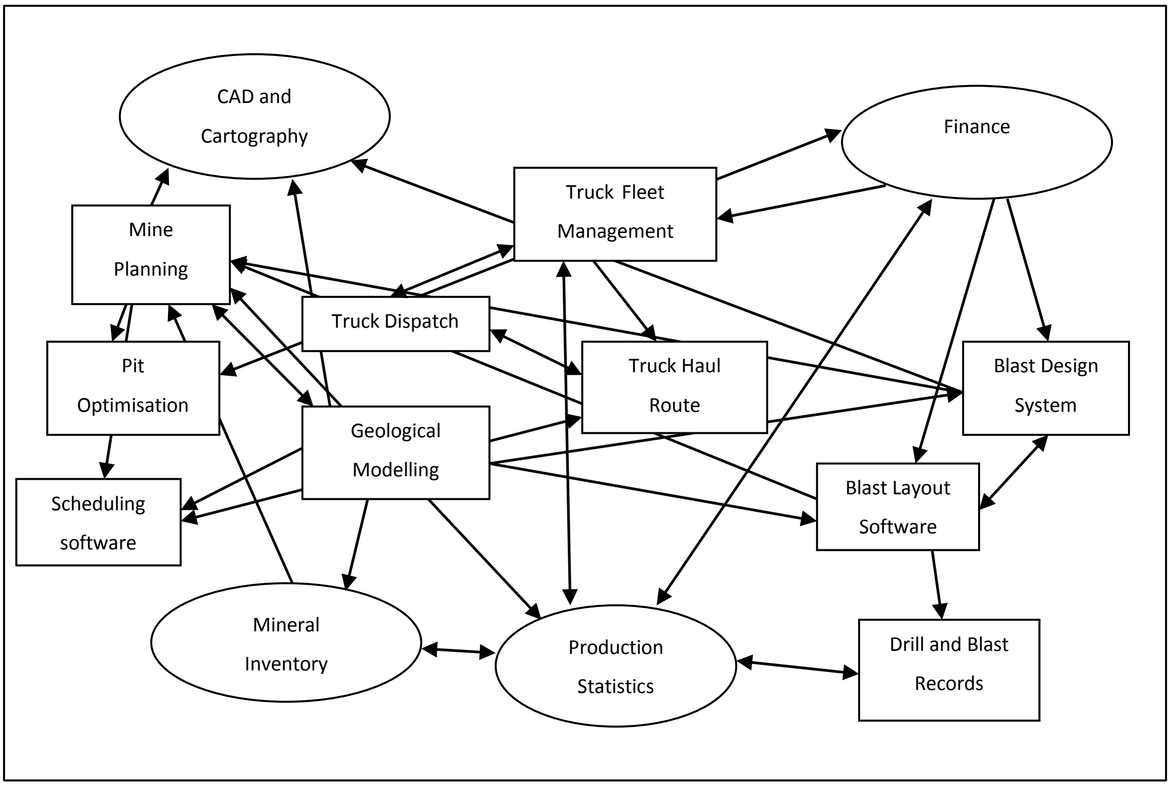

Figure 2-1Typical information flow at an open pit mine (Source: Keyser, 2001, p. 141)

Another researcher (Vorster, 2001) realised that, to handle the complex mining environment, the creation of representative models that use classification and visualisation technologies is necessary. To that end he applied the Zachman framework and value chain concept to model the complex modern mining environment. The Zachman Framework for Enterprise Architecture is a two dimensional classification scheme for descriptive representations of an enterprise (Zachman, 2003). Using Table 2-1, Vorster (2001) attempted to assimilate all activities supporting mine planning in one Zachman framework. He highlighted the importance of modelling the mining environment in sufficient levels of detail in order to reflect the situation in real life. Adopting that approach would ensure that the execution of plans aligns with the goals of an organisation. This idea can be extended to implementing software solutions interactively with input from the various disciplines involved in the overall mining operation.

Table 2-1 The Zachman framework applied to mine planning (Source: Vorster, 2001, p. 65)

	What (Things)	**How** (Processes)	**Where** (Locations)	**Who** (People)	**When** (Temporal)	**Why** (Motivation)
Planner model (contextual)	List of the production deliverables	List of processes the business performs	List of locations where business operates	List of users/ groups/ units of the business	List of business events/ cycles	List of business goals/ strategies
Owner model (conceptual)	Identification of the production requirement and deliverables	Mining and supporting services process model	Mining and supporting logistics network	Organisation chart	Master production schedule	Business plan
Designer model (strategic)	Logical production requirements and deliverable model	Model of the business processes required to manage the ore body	Distributed systems model (ventilation water & electricity reticulation, transport, ore flow etc.)	Strategic structure model (production teams and targets)	Processing schedule	Business rule model (statutory and mining specific rules and regulations)
Builder model (tactical)	Design of supporting infrastructure to establish the production environment	Definition of the business processes required to manage the ore body	Workplace environmental design	Determination of the work team structure (capability and competency requirements)	Set development and mining schedules	Business rule design (statutory and mining specific rules applicable to specific task, environment)
Sub-contractor model (operational)	Machines, material, consumables, equipment, transport mechanisms, products	Extraction processes (geology, rock engineering, survey, sampling, development, stoping, cleaning processes)	Workplace (ventilation, heat, humidity, dust, radiation, industrial water, potable water, electricity, communication etc.)	Work teams (mine planners, geologists, surveyors, engineering, development, stoping, cleaning)	Determine priorities of mining schedule subject to operational constraints	Business rule specification (statutory and mining specific rules applicable to specific task, environment)
Product model (execution)	Products (quantity and quality)	Activity	Equipped workplace	Team member	Execution schedule	Strategy (execution of activity within mining rule framework)

Morgan (2002) observed that viable computer standards evolve in two ways, firstly, driven by vendors with significant market dominance and, secondly, driven by industry in response to an industry need. Work on modelling the mining environment has continued and has resulted in a Business Reference Model developed by the Open Group's Exploration, Mining, Metals and Minerals vertical, a mining industry forum (Woodhall and Viljoen, 2010). Figure 2-2 shows a conceptual view of the model. In the diagram the outer boxes represent the business focus, the horizontal boxes represent the management processes and the vertical boxes represent the enterprise level processes (The Open Group, 2010). Within the vertical boxes, the processes are further broken down into lower level processes each time with increasing level of detail.

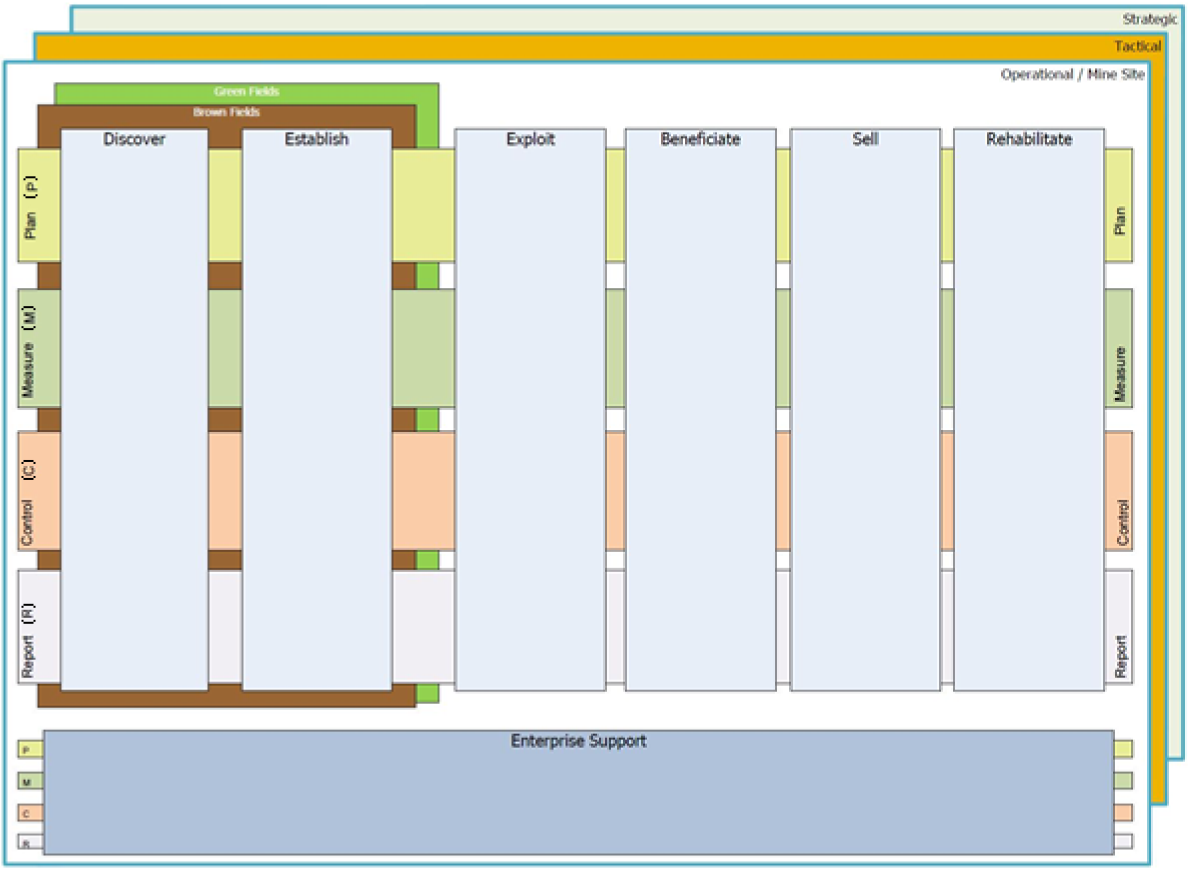

Figure 2-2 A simplified view of the Exploration and Mining Business Reference Model (Source: The Open Group, 2010, p. 6)

To the extent possible, this dissertation uses the Open Group's Business Reference Model to categorise mine value chain stages, mining methods and functionalities of mine planning software. The overall benefit is that information is streamlined. Software solutions may subsequently be mapped to business processes and mining methods. In addition, it is easy to relate how the various software solutions interact with each other.

The need for integration coupled with certain limitations of off-the-shelf applications has given rise to the use of scripting languages. Hack (2003) outlined how a variety of scripting languages are being applied to mining software and the benefits derived. The database of mine planning and peripheral software is designed to store information on which software can be customised and the languages used as well as how each application shares data with other related applications.

2.5 Related work

Surveys were conducted in the 1990's to ascertain hardware and software utilisation in the mining industry (Gibbs, 1999). About 6% of the responses came from South Africa. It is more than a decade now since the surveys were conducted. The results then will not be very useful to show the current state of the usage of software the mining industry in South Africa.

More recently, Mugodi and Fleming (2003) conducted a study of the diffusion of ICT into South Africa's platinum mining sector. The Mugodi and Fleming (2003) study focussed on the technology (not limited to software) adoption in the platinum mining sector of the mining industry. This dissertation will focus on mine planning and related software usage across the whole mining sector.

South Africa boasts a vibrant software industry, comparable to developed economies. The country is the twentieth-largest consumer of Information Technology products and services in the world (Department of Trade and Industry, RSA, 2009). One would want to find out what software solutions are being used in the mining industry, by whom, where and for what purpose. Who are the providers and what opportunities are open in the South African mine planning software industry?

Professional software enhances the understanding of how mining works and students should be educated to use these tools. Kecojevic, Bise and Haight (2005) observed that a recently employed mining engineer with knowledge of modern software packages can produce results comparable to an independent consultant at less than 25% of the cost. Universities are consequently interested in finding out which applications they should include in their curricula. The Southern African Institute of Mining and Metallurgy (SAIMM) has supported the development of qualifications in the areas of mine planning and design through the establishment of a Mine Planning and Design Industry Forum (Macfarlane, 2012). The forum is involved in various initiatives to promote skills development in the field of mine planning. Expertise in this area is perceived to be scarce.

The realisation that there is a skills shortage in the area of mine planning has been made even outside South Africa. Lyle, McKinnon, McIsaac and Dasys (2011) noted that, traditionally, training in mine design and planning has involved acquiring a broad technical background followed by an apprenticeship usually working with experienced engineers. However they questioned the sustainability of this model in view of the shortage of young professionals and the imminent retirement of experienced engineers. In order to address this challenge, they are in the process of building a workbook using a web-based wiki framework. The project is named MineDesignWiki. It is designed to ensure reliability of information content through author attribution and formalised peer review. While MineDesignWiki compiles mine design knowledge over a broad range of topics, the database of mine planning and peripheral software seeks to inform on which software solutions are available and how and where they are being used for mine planning purposes.

2.6 Access to information

The intended beneficiaries of information on mine planning and related software utilisation in South Africa are clearly varied and are located over a large geographical area. It is imperative to compare the technologies available to disseminate this information in order to choose the one which best serves the purpose of the project.

Generally speaking, there are two types of applications, namely, standalone applications and web-based applications. Web-based applications may be deployed as intranet or internet applications. Löfberg and Molin (2005) discussed the advantages and disadvantages of standalone applications and web-based applications.

A standalone application can run on desktop operating systems such as Windows, Macintosh or Linux. The machine does not need to be connected to a server. The major disadvantages of standalone applications are related to deployment. It would take much time and effort to install the application on all machines that will be used to access the data. Similarly when the system is updated all the applications on the different machines will have to be updated.

Standalone applications are usually platform dependent. An application which runs on one operating system (on which a run-time environment is needed) will usually not run on another.

The advantage of standalone applications is that they are considered to be secure because a limited number of people will access the specific computer on which an application is installed. Another advantage is that since an application is run on a local machine the network traffic is reduced and information can be obtained offline (Löfberg and Molin, 2005). Figure 2-3 illustrates a client/server configuration residing on a local machine.

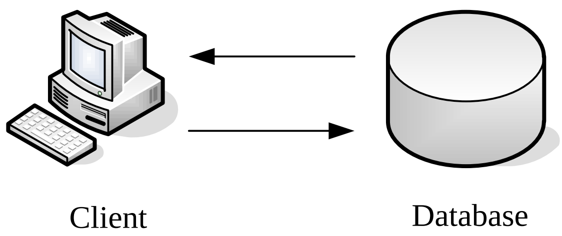

Figure 2-3 Standalone client/server model (Source : Löfberg and Molin, 2005)

On the other hand, a web-based application can be accessed through a web browser. It usually consists of three layers, which are the:

1. interface, which provides user interaction through the web browser;
2. middle layer, which provides interaction between the client and the server; and
3. database, which resides on the server.

In contrast with standalone applications a web-based application can run on any platform and is accessible from virtually anywhere. It is easy to deploy because the users basically need an internet or intranet connection and have a web browser installed. In order to update any changes can be made on one machine and they reflect on all the client machines. The main disadvantages are that the users need to have an internet or intranet connection to be able to get the information they need and that if many users send requests to the server at the same time, the server becomes heavily loaded (Löfberg and Molin, 2005). Figure 2-4 illustrates a client/server model in which content resides on a network location and is accessible through a web-based interface.

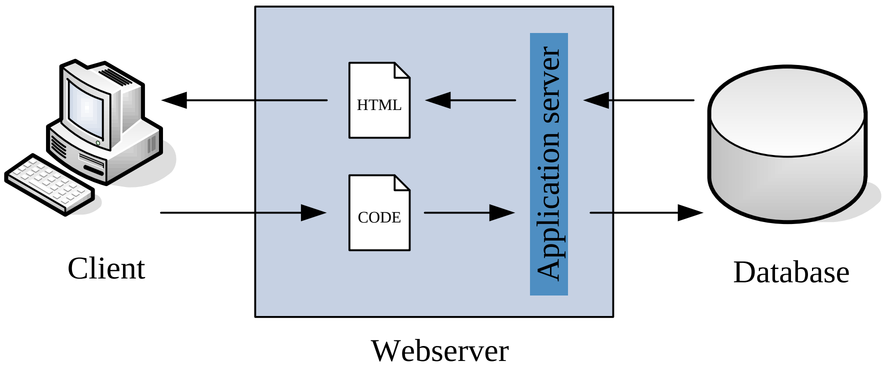

Figure 2-4 Web-based client/server model (Source : Löfberg and Molin, 2005)

Access to information on Internet is usually free, and it is possible with some effort to find practically anything on some computer hooked into the network. However after browsing sites such as World Mining Equipment (http://www.wme.com/) and InfoMine (http://www.infomine.com/) it is clear that information on mine planning and related software utilisation in South Africa is not readily available in a single repository. Hence the decision to develop a web-based database was made because the advantages of web-based applications outweighed those of standalone applications in achieving the objectives of this project.

2.6.1 *Comparison of database management systems*

There are several database management systems (DBMS). A programming language known as Structured Query Language (SQL) is used to manage data in these systems.

Table 2-2 compares some features of Microsoft Access (MS Access), Microsoft SQL Server (MSSQL) and MySQL. These were readily available to the researcher.

MS Access is a rapid application development tool that can be used with any database engine. It ships with its default database engine, Jet/ACE, which is not a server database engine but a file-based engine (Jakšić, 2010). A web-based application works best with a server database engine.

Of the server database engines MySQL has the distinct advantage of being platform independent. It may be installed on a server running any operating system. It may be downloaded on the internet and used for free subject to General Public Licence (GPL) terms and conditions (Oracle Corporation, 2011). Although its interface is SQL, there are a variety of Graphical User Interface (GUI) tools that are freely available on the internet. From Table

2-1 it can also be seen that MySQL has been in development for a long period which is comparable to that of SQL Server.

Table 2-2 Comparison of database management systems

	MS Access	MSSQL	MySQL
Software licence	Proprietary	Proprietary	GPL or Proprietary
First public release date	1992	1989	1995
Latest stable version and year of release	v14 (2010)	v11 (2012)	v5.5.17 (2011)
Operating system support	Windows only	Windows only	Windows and most UNIX
Atomicity, Consistency, Isolation, and Durability (ACID)	Yes	Yes	Yes
Referential integrity	Yes	Yes	Yes
Interface	GUI and SQL	GUI and SQL	SQL
Triggers, functions and procedures	No	Yes	Yes
Maximum database size	2GB	524 258TB	Unlimited

2.6.2 *Choice of front-end web application technology*

Of all websites whose server side programming language is known, most use a scripting language known as PHP – a recursive acronym which stands for PHP: Hypertext Programming. Originally, PHP stood for Personal Home Pages (Olson, 2007). PHP has over three quarters of the market share of websites (Rakesh, 2011). PHP is very popular for a number of reasons. Here is a list of advantages offered by PHP which influenced its selection for this project (Rakesh, 2011):

1. Stable and secure – It is capable of developing powerful web applications that are scalable up to a very large number of users. PHP is stable and secure, robust enough for business-critical applications needing constant up-time and high security;

2. Rapid and easy deployment – It is easy to understand and learn. In addition there are development frameworks such as QCubed which separate business logic from the user interface resulting in cleaner and reusable code;
3. Cost – It is free;
4. Portable – It is available for every operating system;
5. Database integration – It includes the ability to connect directly to a MySQL database which removes the additional overhead when using Open Database Connectivity; and
6. Support – It is supported by a vibrant community, estimated to consist of about 5 million developers that share code, evangelise about PHP, support each other to improve the language and increase its capabilities.

2.6.3 *How PHP works*

It is important to note the difference between Hypertext Markup Language (HTML) and PHP. When using HTML a web developer writes code which is interpreted by a web browser. The web pages are static which means that the user downloads all the code and the contents displayed on the page do not change until the developer changes the code.

On the other hand, PHP is a server side scripting language which allows one to create dynamic web pages. The developer’s code is not downloaded but is first processed by the server and the output is in HTML format. This output is what is displayed in the web browser (Pataki, 2009). Figure 2-5 shows a diagrammatic representation of this process. A dynamic web page is a page whose contents are a result of interaction with the user. The contents can change after the page has been loaded depending on user actions without the developer having to change the code. It is possible to connect the web page to a database which stores the information that is required to be displayed on the web page.

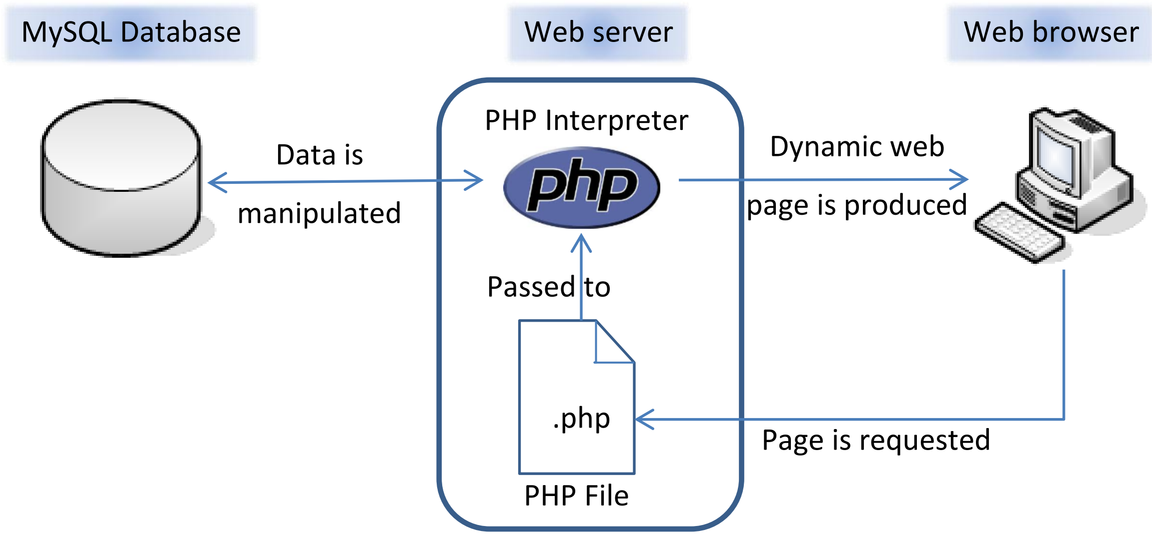

Figure 2-5 Diagrammatic representation of how PHP works (Adapted from Khan, 2012)

2.7 Software development life cycles

In order to solve actual problems using software, it is necessary to include a development strategy that encompasses the process, methods and tools used. This strategy is often referred to as a 'process model' (Pressman, 2001). A process model is chosen based on the nature of the project and application, the methods and tools to be used, and the controls and deliverables that are required.

Web-based systems and applications are different from other categories of computer software in that they are network intensive, content driven and continuously evolving. They generally have a short development time, need strong security measures and have to be aesthetically pleasing. In addition they should cater for a diverse population of users (Pressman, 2001).

The oldest and most widely used process model for software development is the linear sequential model (Pressman, 2001). It is also referred to as the *classic life cycle* or the *waterfall model*. It suggests a systematic, sequential approach to software development that begins at the system level and progresses through analysis, design, coding, testing, and support. Figure 2-6 illustrates the linear sequential model for software engineering.

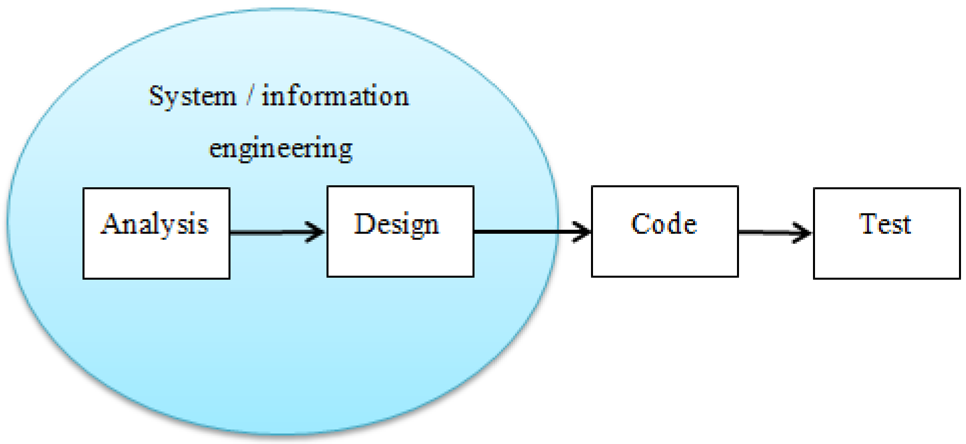

Figure 2-6 The linear sequential model (Source: Pressman, 2001, p. 29)

The Waterfall Model's sequential step-by-step process is its distinctive feature. Its major weakness is that the requirements have to be well-defined and understood before coding starts. In practice, this is rarely the case. In addition, a working version of the program will not be available until late in the project time-span. A major blunder, if undetected until the working program is reviewed, can be disastrous. For the Waterfall Model to succeed the developers should ideally have worked on similar systems in the past.

In response to the weaknesses of the Waterfall Model, many new models were developed that add some form of iteration to the software development process. In the Spiral Model, the development team starts with a small set of requirements and goes through each development phase (except installation and maintenance) for those set of requirements. Based on lessons learned from the initial iteration, the development team adds functionality for additional requirements in ever-increasing "spirals" until the application is ready for the installation and maintenance phase (production). Each of the iterations prior to the production version is a prototype of the application. Pressman (2001) adapted the spiral model and suggested a process model for Web Engineering (WebE). Figure 2-7 illustrates this model.

The WebE process model consists of six main stages outlined below:

- *Formulation* – identifies the goals and objectives of the web-based application and establishes the scope for the first increment;
- *Planning* – estimates overall project cost, evaluates risks associated with the development effort, and defines a finely granulated development schedule for the initial increment;

- *Analysis* – establishes technical requirements for the web-based application and identifies the content items that will be incorporated. Requirements for graphic design (aesthetics) are also defined;
- *Engineering* – incorporates two parallel sets of tasks. One set involves content design and production which is non-technical work. This involves gathering text, graphics, and other content to be integrated into the web-based application. At the same time, a set of technical design tasks (Architectural design, Navigation design, and Interface Design) are conducted;
- *Page generation* – makes heavy use of automated tools for web-based application creation. *Testing* exercises web-based application navigation, attempts to uncover errors in applets, scripts, and forms, and helps ensure that the web-based application will operate correctly in different environments; and
- *Evaluation* – reviews each increment of the WebE process.

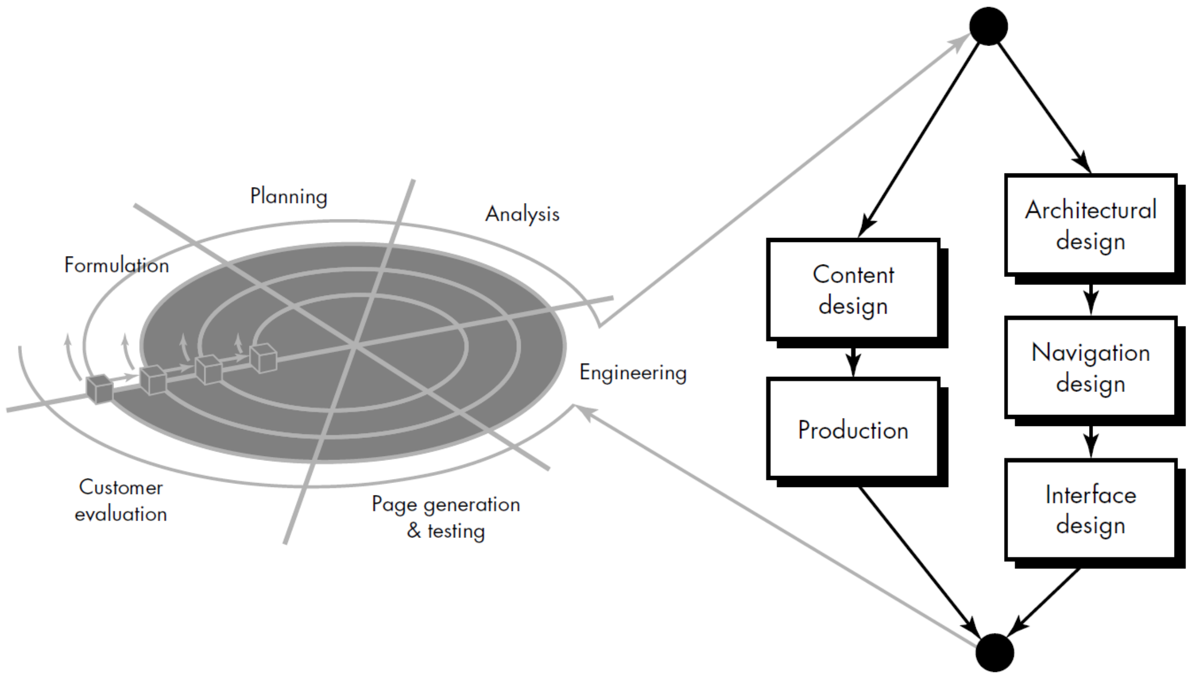

Figure 2-7 The WebE process model (Source: Pressman, 2001, p. 775)

2.8 Summary

This chapter presented the findings of a survey of literature on topics relevant to this dissertation. It started with the topic of adoption of software solutions in the mining industry and the factors that determine why solutions are adopted. This was done to establish a context for the subject area of this dissertation. The current focus on standardising classifications used in the industry and the benefits that can be derived from the process were discussed. Studies and projects carried out in the past and current initiatives were outlined in order to show which gaps this research intends to fill. The chapter concluded by discussing the technologies that can be used to address the research problem.

The next chapter has two sections. The first section analyses the objectives of this project and the requirements of the database system used to answer the research question. The last section describes the strategies followed to achieve the aim of this project.

3 REQUIREMENTS AND DESIGN

3.1 Chapter overview

This chapter is divided into two sections. The first section is a list of the objectives of the dissertation and the requirements of the database and the web-based user interface. The second section discusses the design processes which are the:

1. plan for data collection and analysis,;
2. database design process; and
3. web application design process.

3.2 Project requirements

As stated previously, the aim of this research is to develop a database that can be used to find mine planning and peripheral software solutions and analyse the current state of their adoption and utilisation within the South African mining industry.

Therefore, the requirements are:

- to compile as much detail as possible from the industry about mine planning and related software;
- to develop a database that can hold records of different types of software, companies and user sites;
- to allow privileged users to maintain the database by adding, updating or deleting records, and by backing-up or resetting the database;
- to develop a client interface that allows users to view the data or search through the records based on given criteria;
- to develop functionality to show summary information of software, companies and sites based on given criteria;
- to allow access to the information from any internet networked terminal through a web browser; and
- to develop and provide user and administration guides.

3.3 System requirements

Glinz (2007) discussed the two classes into which system requirements fall which are:

1. Functional or operational requirements – These capture the intended input/output behaviour of the system. This behaviour is expressed as services, tasks or functions that the system is required to perform without considering the physical constraints; and
2. Non-functional requirements – These capture the performance requirements or constraints on a system. Some of the main non-functional requirements are reliability, usability, security, availability, portability and maintainability.

3.3.1 *Functional requirements*

The functional requirements for the mine planning and peripheral software database are described below:

- Data storage – The system must be able to store information about companies, related sites and software installed at those sites. The software must be categorised with respect to its functionality and related mineral commodities and mining methods. Companies must be related as to whether they are developers, suppliers or clients of software;
- Data access – It is required that the system provide a main page where anyone surfing the web will be able to access. This page allows any user to browse through or search for basic information on companies and software;
- Summary information – The system must have a menu providing options such as Market Share, Popularity rankings or Solutions available for a certain mine value chain stages;
- Access levels – The system must allow users to have different levels of privileges. The main page should provide a 'login' facility to allow privileged users access to more advanced functionalities of the system. While all users can access all the summary information, only the privileged users must be able to view confidential data and to enter or update the data. A 'logout' facility should be available when necessary; and

- Administration – The system must allow for an administrator to have more privileges to delete data back-up or restore the database.

3.3.2 *Non-functional requirements*

The non-functional requirements for the mine planning and peripheral software database are described below:

- Usability – The system must be based on a graphical user interface which is easy to understand or that most users are already familiar with so that users require no formal training to use the system. It must provide a clear online help documentation at any stage of user interaction. A fast response time will prove to be advantageous;
- Security – Provision must be made to avert potential attacks from hackers; and
- Portability – The system must be compatible with any popular web-browser (e.g. Internet Explorer, Google Chrome, Mozilla Firefox, Opera Safari etc.) running on any operating system.

3.4 Design

After analysing the essential requirements the first step was to design the overarching plan for collection, measurement and analysis of data (Gray, 2009). In the next section the plan for data collection is discussed. Thereafter the design stages for the development of the database are described. Finally information on the design of the web-based system is included.

3.5 Plan for data collection and analysis

One of the most common research methodologies is to conduct a survey because it allows for the collection of significant amounts of data (Gray, 2009). The collection must be done in a systematic way highlighting the importance of standardisation. Collecting the data is carried out by means of interviews, questionnaires and observation methods.

Surveys fall into two broad categories namely descriptive and analytical (Gray, 2009). The descriptive survey method was chosen as it is designed to measure the characteristics of a particular population at a fixed point in time, or comparatively over time. The objective of this work is to take a snapshot of what the current state of mine planning and peripheral software availability and usage in South Africa is, rather than why the situation is as it is (which is addressed by analytical surveys). It is also useful to compare the numbers of software installations around the country in order to ascertain the most widely used for a particular sector in the mining industry. This work establishes a baseline for evaluating software utilisation and can be extended by further work to investigate optimal utilisation of mine planning software.

The main research question that this research seeks to answer falls under the descriptive type of research questions. In view of the fact that the mining industry is diverse and software utilisation is fragmented across and within sectors of the mining industry, it is not sufficient to generalise using information from a random sample. Rather every effort is expended to evaluate the intended population. A population is defined as all the possible units that can be included in the study. The non-random sampling method selected is snowball sampling. Gray (2009) explained that with snowball sampling, the researcher identifies a small number of subjects, who, in turn, identify others in the population. By following this approach it may be possible to eventually reach every subject in the intended population. Using web directories and other resources it was decided to identify key players in the industry (probably the most influential people and organisations), as well as those readily available, in order to start collecting information from these.

3.6 Database design stages

The steps in developing a database can be represented in a linear sequence. The Waterfall Model referred to in Section 2.7 can be applied to database design theory as effectively as it is applied to other software engineering theory. McCaldin (2010) summarised the steps in developing a database as follows:

Requirements specification → Analysis → Conceptual design → Implementation design → Physical schema design and optimisation.

3.6.1 *Data requirements analysis*

Having analysed the functional requirements of the system the next step was to draw up a data requirements document. The data requirements were summarised in a data dictionary. A data dictionary is a collection of descriptions of data objects and their relationships to each other. Entities are objects about which data can be stored. These are the main objects the users are interested in. An entity type is a group of objects with same properties. An entity occurrence is a uniquely identifiable object of an entity type. Table 3-1 is a summary of the entity types for the database of mine planning software.

Each entity type has one or more properties or characteristics. These are called attributes. An extract from the data dictionary tabulates the attributes in Table 3-2.

The associations among entity types are modelled in Table 3-3 as relationships. In the table, the symbol “1” denotes that exactly one entity type instance exists at the association end. While the symbol “*” is used to denote that zero, one, or more entity type instances exist at the association end.

Table 3-1 Extract from the data dictionary for entities

Entity type	**Description**	**Occurrence**
Mine value chain stage	An activity or set of activities that will accomplish a specific organisational goal.	Used to describe the sequence of activities in the mining business and to categorise software.
Mineral commodity	A naturally occurring inorganic element or compound having an orderly internal structure and characteristic chemical composition, crystal form, and physical properties. Manufactured products are also included.	A commodity is mined or processed at a particular site by a given company. Some software is associated with specific commodities.
Company	Any entity engaging in business, such as a proprietorship, partnership, corporation or cooperative.	A company is established to engage in mining, consulting, training, software development or distribution.
Contact details	Information on means of communication.	Contact details available for companies at different sites.
Functionality	What a product can do for a user.	Software is developed to perform specific functions.
Mining method	The technique of extracting ore or minerals from the ground.	Different mining methods are applied at different sites. Some software is associated with specific mining methods.
Site	The spatial location of a structure or set of structures.	Company offices or activities associated with specific sites. Some licences allow software to be used at a specific site.
Software	A program used to operate computers and related devices.	Software is provided by distributors and developers. It is used by client companies.
Speciality	A field of professional work.	Used to describe an area of expertise. Software packages are usually associated with specific fields.

Table 3-2 Extract from the data dictionary for attributes

Entity type	Attributes	Description	Data type	Nulls	Multi-valued
Mine value chain stage	Name	Unique identifier	Text	No	No
	Description	Explanation of process	Text	Yes	No
Mineral commodity	Name	Unique identifier	Text	No	No
	Type	Categorisation of commodities	Text	No	No
Company	Id	Unique identifier	Number	No	No
	Name	Recognisable or registered name	Text	No	No
	Profile type	Categorisation of companies	Text	No	No
	Notes	Additional information	Text	Yes	No
Contact details	Contact person	Person contactable at a company or site	Text	Yes	Yes
	Address	Physical or postal address	Text	Yes	Yes
	Email	An email address	Text	Yes	Yes
	Phone number	Mobile, telephone or fax numbers	Text	Yes	Yes
	Website	Group of web pages made available online by a company.	Text	Yes	Yes
Functionality	Name	Unique identifier	Text	No	No
	Description	Explanation of functionality	Text	Yes	No
Mining method	Name	Identifier	Text	No	No
	Mine type	Whether underground or surface	Text	No	No
	Rock type	Whether hard or soft	Text	No	No
	Mining type	A broad categorisation of mining methods	Text	No	No
Site	Id	Unique identifier	Number	No	No
	Name	Recognisable name	Text	No	No
	Site type	Categorisation of sites	Text	No	No
Software	Id	Unique identifier	Number	No	No
	Name	Recognisable name	Text	No	No
Speciality	Name	Unique identifier	Text	No	No

Table 3-3 Extract from the data dictionary for references

Entity type	Multiplicity	Relationship	Entity type	Multiplicity
Company	1	Has	Contact details	*
Company	*	Has	Site	*
Company	*	Is a client of	Company	*
Site	1	Has	Contact details	*
Company	*	Is a provider / developer of	Software	*
Software	*	Is used at	Site	*
Software	*	Is a module of	Software	*
Software	*	Can interface with	Software	*
Company	*	Is associated with	Mineral commodity	*
Mineral commodity	*	Is mined / processed at	Site	*
Mining method	*	Is used at	Site	*
Software	*	Is designed for	Mineral commodity	*
Software	*	Is designed for	Mine value chain stage	*
Software	*	Is designed for	Functionality	*
Software	*	Is designed for	Mining method	*
Software	*	Is designed for	Speciality	*

3.6.2 *Conceptual design*

After analysing the data requirements it was possible to build a conceptual data model of the database. The most common form of conceptual representation is the Entity-Relationship (E-R) Model. Figure 3-1 depicts a simplified conceptual model of the mine planning and peripheral software database. In the diagram, the symbol "♦" denotes that exactly one entity type instance exists at the association end. While the symbol "•" is used to denote that zero, one, or more entity type instances exist at the association end.

Association tables were used to handle the many-to-many relationships between entity types. For example, in the real world **one** company can supply **many** different software solutions and **one** software solution can be distributed by **many** vendors (companies). To handle the many-to-many relationships between the software and suppliers, use is made of an association table (provider_software_assn). Again considering that **one** company can be a client of **many** other companies and **many** companies can be clients of **one** company, the company entity has to reference itself through an association table (client_company_assn).

This design conforms to the Third Normal Form of database normalisation which has the advantage of removing redundancies, preventing update anomalies and speeding up response time. The design is also flexible enough to allow expansion of the database to include more entity types without introducing redundancies.

3.6.3 *Implementation design*

In the implementation design phase, the conceptual data model is translated into a 'logical' representation of the database system. This model describes how data is stored and conveys the logical functioning and structure of the database in a manner not specific to any DBMS (McCaldin, 2010). The following translations occur:

1. Entity types become tables;
2. Attributes fields or columns; and
3. Relationships between entity types are modelled as foreign keys.

Table 3-4 is a data dictionary extracted from the logical model of the database of mine planning and peripheral software. The integer data types are 'int', which can store whole numbers from 0 to 4294967295 if it is in its unsigned form, and 'tinyint', which can store whole numbers from 0 to 255 if it is in its unsigned form (Oracle Corporation, 2011). The string data type can store strings whose length varies from zero to the number of characters specified in brackets.

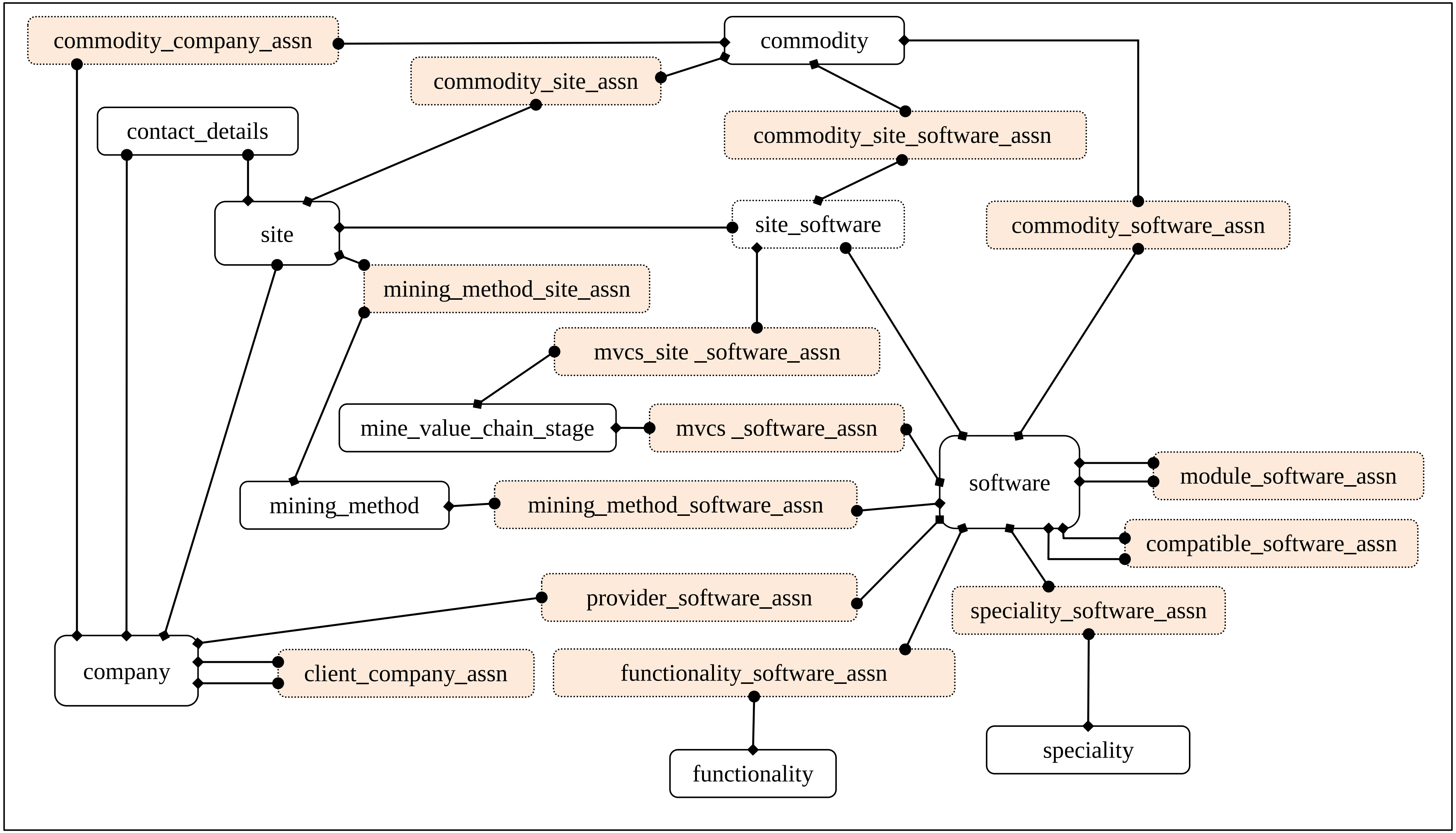

Figure 3-1 Conceptual data model of the database

Table 3-4 Extract from the logical model of the database

Table name	Field name	Type	Required	PK/FK[1]	Table referenced[2]
company	id	int	Yes	PK	
	name	varchar(256)	Yes		
	date_established	date	No		
	notes	text	No		
	company_profile_type_id	tinyint	Yes	FK	company_profile_type
site	id	int	Yes	PK	
	name	varchar(65)	Yes		
	site_type_id	tinyint	Yes	FK	site_type
software	id	int	Yes	PK	
	name	varchar(100)	Yes		
site_software	site_id	int	Yes	PK,FK	site
	software_id	int	Yes	PK,FK	software
	number_licences_installed	int	No		
client_company_assn	client_id	int	Yes	PK,FK	company
	company_id	int	Yes	PK,FK	company
provider_software_assn	company_id	int	Yes	PK,FK	company
	software_id	int	Yes	PK,FK	software
functionality	id	tinyint	Yes	PK	
	name	varchar(45)	Yes		
	description	varchar(256)	No		
functionality_software_assn	functionality_id	tinyint	Yes	PK,FK	functionality
	software_id	int	Yes	PK,FK	software

[1] PK stands for Primary Key, FK stands for Foreign Key, and Blank entries show that the field is neither a primary key nor a foreign key.

[2] Blank entries show that the field does not reference any table.

3.6.4 *Physical schema design*

The logical model is a lower level conceptual model which can be translated into a physical schema design (McCaldin, 2010). Physical modelling deals with internal DBMS specific operations and processes such as how the data is stored secured and kept consistent. In other words, a physical schema is the SQL code used to build the database.

The DBMS chosen for the mine planning and peripheral software database is MySQL™ Version 5.5 (MySQL5.5). MySQL5.5 supports several storage engines that act as handlers for different table types. MySQL5.5 storage engines include both those that handle transaction-safe tables and those that handle nontransaction-safe tables. The InnoDB is transaction-safe (ACID compliant) storage engine for MySQL that has commit, rollback, and crash-recovery capabilities to protect user data (Oracle Corporation, 2011).

Appendix A is an extract from the physical schema of the mine planning and peripheral software database. Writing this code was the first step in physically implementing the database. Implementing the database is discussed fully in Chapter 4 of this dissertation.

3.7 Designing the web application

The WebE process model for software development (discussed in Section 2.7) was chosen for this dissertation. Its advantage is that it is an iterative approach allowing development to begin even before all system requirements are known or fully understood. As each prototype is tested it is possible to keep the project on track by analysing additional requirements as necessary. Section 3.3 presented an analysis of the system functional and non-functional requirements. In the following sections the engineering stage of the WebE process model for the interface of the mine planning and peripheral software database is discussed.

3.7.1 *Architectural design*

The architectural design of a web-based system defines the overall structure of the application. A parallel activity called content design derives the overall structure and detailed layout of the information content that will be presented as part of the application. Four structures are available to choose from (Pressman, 2001). These are linear, grid, hierarchical and networked structures (Figure 3-2).

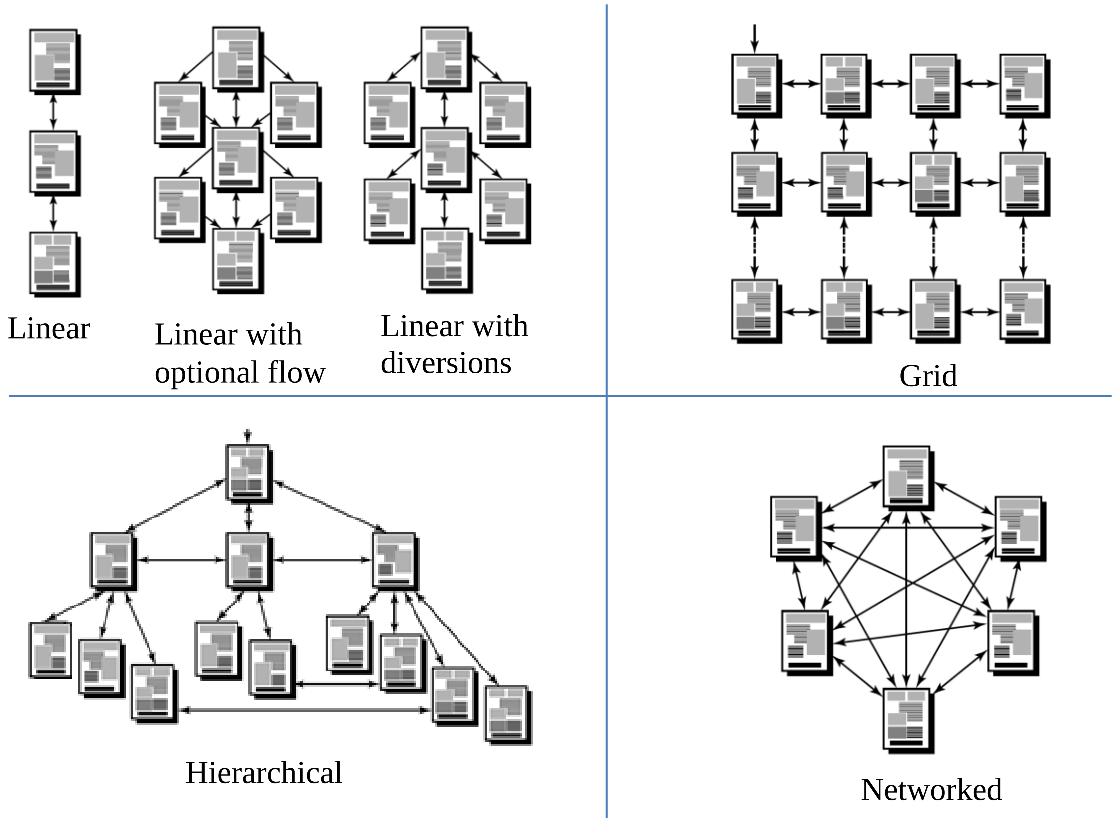

Figure 3-2 Web application structures (Adapted from Pressman, 2001, pp. 780-782)

In practice, the structures of most web sites are a combination of these structures. The nature of the web application for the mine planning and peripheral software database calls for the adoption of the hierarchical and networked structures. This design allows the user to follow along a vertical branch of the hierarchy. At the same time the user may navigate horizontally across branches. This may lead to confusion on the part of the user as to where they are, but this was handled by the navigation design.

Since data processing functionality is necessary for this web application, design patterns are applicable. Among those proposed, the "sieve" and the "neighbourhood" patterns were chosen. Pressman (2001) described the sieve pattern as one that guides a user through a series of options (decisions) in order to direct the user to specific content indicated by the sequence of options chosen or decisions made. The neighbourhood is a pattern that overlays a uniform navigational frame across all Web pages in order to allow a user to have consistent navigation guidance regardless of location within the web application (Pressman, 2001). Following these patterns the system is designed to help the user to find information specific to a certain category, company or software and then drill down to lower levels of detail without losing the 'look and feel' of the website. Figure 3-3 illustrates the website structure for the interface of the mine planning and peripheral software database.

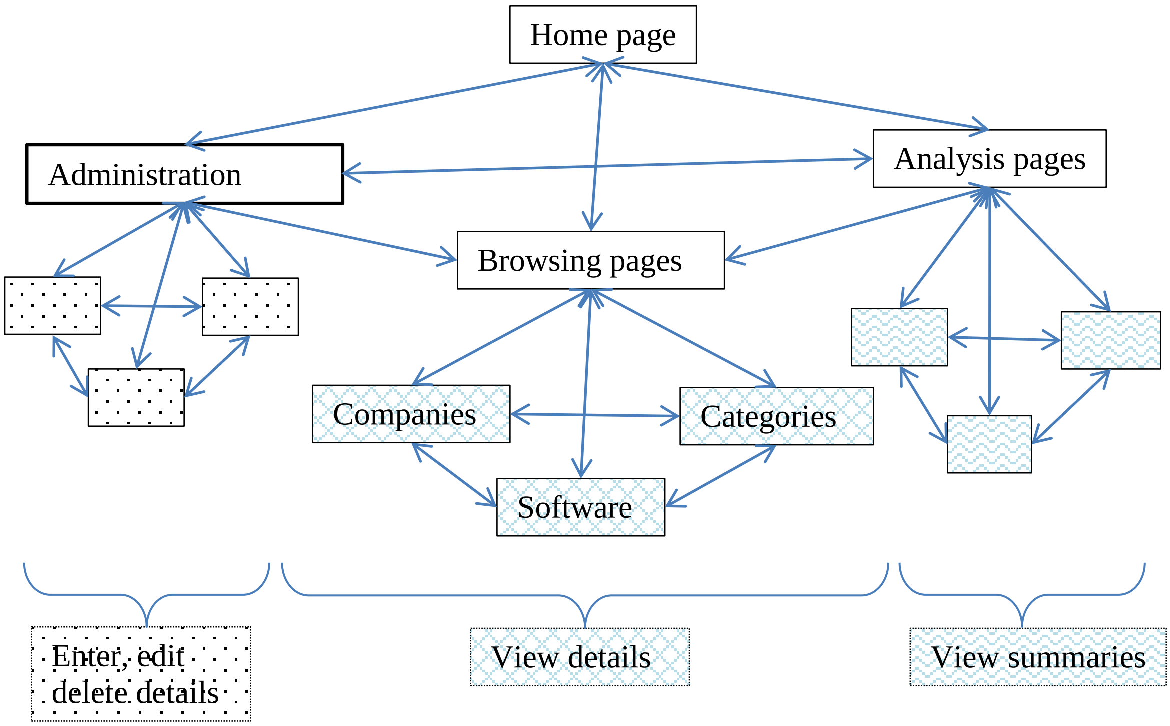

Figure 3-3 Website structure for the web-based interface of the database

3.7.2 *Navigation design*

The navigation design of a web-based system defines the pathways that enable the user to access content and services. Navigational structures are created to cater for the different levels of access granted to the user (Pressman, 2001). The web-based system for the database has three user access levels defined:

- *Administrators* – who may enter, update or delete data and access to all pages;
- *Registered users* – who may view the pages with summaries, details which are not confidential and those that contain confidential information for companies that they are granted access to; and
- *Visitors* – may view pages with summaries and those with details which are not confidential.

Navigational aids were designed to let the users know where they are, where else they may go and how they can get there. Text based links and buttons were chosen as these are familiar to most users. The use of graphics was limited because it would take longer for a page to respond if it has to load images.

3.7.3 *Interface design*

All the web pages had to conform to the layout depicted in Figure 3-4. The consistency in the design helps maintain the look and feel of the website and avoids unnecessary complexity thus enhancing the functionality of the system.

The information in the database may be in the form of long lists that are not wholly visible within the typical dimensions of a browser window. Generally users prefer not to scroll. The pages were designed so that some of the information is contained in collapsible panels to allow all the panels to be visible when the user initially accesses the page. The user may then expand and collapse the panels as desired. In addition efficient guidance is provided through online help and feedback in the form of system messages. Figure 3-5 shows the navigation and interface design of the system.

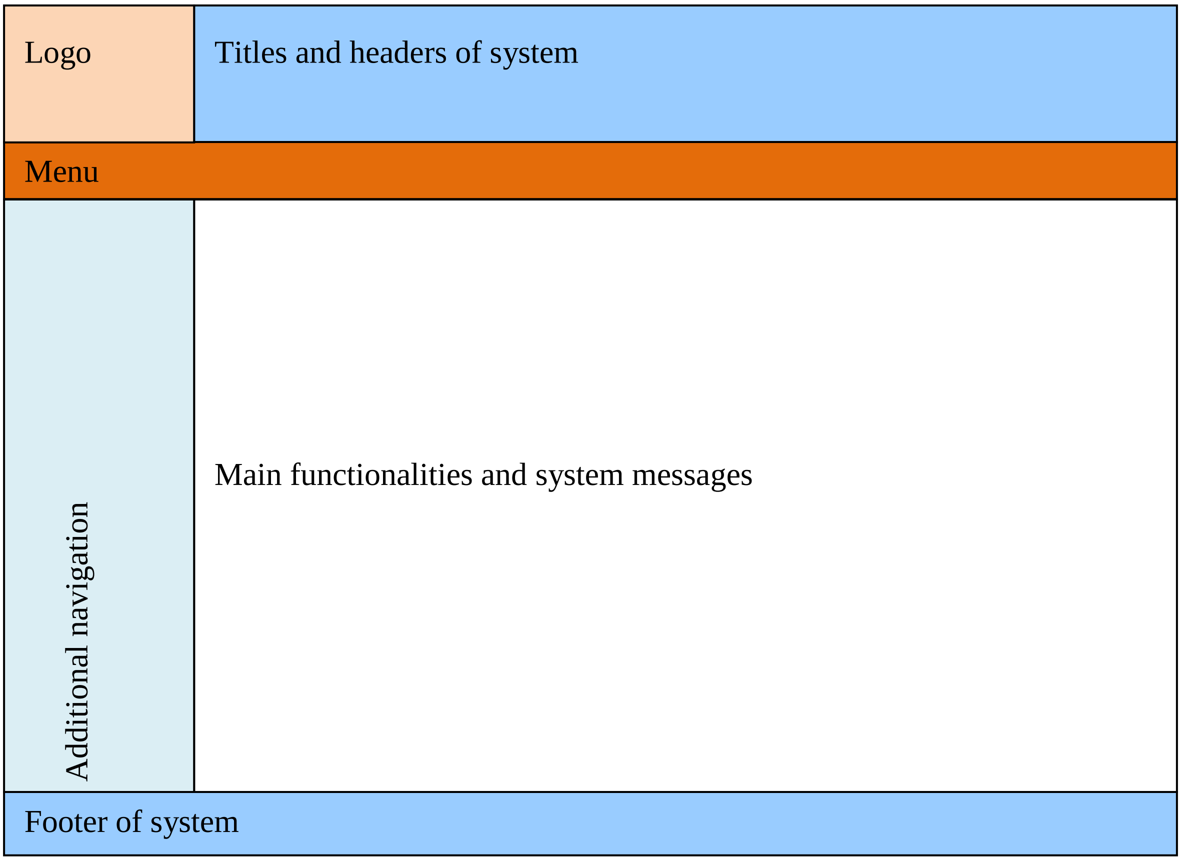

Figure 3-4 General web page layout design

Figure 3-5 Navigation and interface design for the web-based interface of the database

3.8 Summary

This chapter discussed the requirements of the system that are needed to achieve the objectives of this dissertation. This was followed by a justification of the data collection method chosen and then a description of the design process for the mine planning and peripheral software database and its front-end application. The following chapter will describe how the designs were implemented and tested.

4 IMPLEMENTATION

4.1 Chapter overview

Having accomplished the design framework the next phase was implementation and testing. This chapter documents how data was gathered, how the database was created, how the web pages were generated and how their functionality was extended.

4.2 Data gathering

In line with the observation made in Section 3.5 that the mining industry is diverse and software utilisation is fragmented across the whole sector, an effort was made to gather as much data as possible from existing databases, conferences and other sources. Consulting and exploration companies were identified on the Global InfoMine website (http://www.infomine.com). Information about mine companies was obtained from the Department of Mineral Resources (DMR) website (http://www.dmr.gov.za). It includes a full list of operating mines, quarries and processing plants as at the end of the year 2010. Software providers and software users were subsequently approached in order to hold expert interviews and administer questionnaires where possible.

4.2.1 *Categorisation of data*

In order to compile structured questionnaires, the anticipated data was categorised. The categorisation had to be refined interactively by incorporating input drawn from the expert interviews. To the extent possible, the categorisation reflects the categorisation in the business reference model referred to in Section 2.4. The categories are tabulated in

Table 4-1. Table 4-2 breaks down the categorisation of mining sites further down to mining method categories.

Table 4-1 Categorisation of data

Data	Categorisation	Data	Categorisation
Company profiles	• Specialist software provider • Mining company • Mineral processing company • Educational institution • Consulting company • Mineral Exploration Company • Mining Equipment Provider	Site types	• Mine • Quarry • Plant • Office • Agency • Campus
Software functionalities	• Mapping • Geological data management • Geological modelling and resource estimation • Design and layout • Scheduling • Financial Evaluation • Optimisation • Other (Monitoring, ERP, etc.)	Mine value chain stages	• Discover • Establish • Exploit • Beneficiate • Sell • Rehabilitate
Mineral commodity types	• Precious metals and minerals • Energy commodities • Nonferrous metals • Ferrous metals • Industrial minerals • Aggregate and sand • Processed minerals	Specialities	• Mining engineering • Geology • Survey • Rock engineering • Ventilation • Mineral processing • Finance • Human Resources • Environment

Table 4-2 Categorisation of mining methods

Data	Categorisation			
Mining method categories	*Method type*	*Mine type*	*Rock type*	*Mining type*
	Self-supported	Underground	Hard	Tabular
	Supported	Underground	Hard	Tabular
	Self-supported	Underground	Hard	Massive
	Supported	Underground	Hard	Massive
	Caving	Underground	Hard	Massive
	Self-supported	Underground	Soft	Coal
	Supported	Underground	Soft	Coal
	Self-supported	Underground	Soft	Non-coal
	Supported	Underground	Soft	Non-coal
	Frasch	Underground	Soft	Solution
	Hot water	Underground	Soft	Solution
	Single bench	Surface	Hard	Open pit
	Multi bench	Surface	Hard	Open pit
	Quarry	Surface	Hard	Open pit
	Glory hole	Surface	Hard	Glory hole
	Panning and sluicing	Surface	Soft	Placer
	Hydraulicking	Surface	Soft	Placer
	Dredging	Surface	Soft	Placer
	Single bench	Surface	Soft	Open pit
	Multi bench	Surface	Soft	Open pit
	Strip mining	Surface	Soft	Open pit

4.2.2 *Nature of questionnaires*

Two questionnaires were compiled. One was intended for software providers and the other was intended for the users.

The questionnaire for providers examined the following areas:

- Company details – Name and contact details;
- Software solutions provided – Names, licensing and support options, hardware and other software requirements, version history, availability of demo and trial versions, functionality provided, mine value chain stage and speciality catered for, backwards/forwards compatibility and compatibility with other software solutions; and
- Clients – Sites at which software solutions are installed.

The questionnaire for software users examines the following areas:

- Company details – Name, contact details and profile;
- Software solutions used – Names, functionality exploited, mine value chain stages and specialties covered, availability of support and how software is acquired; and
- Sites – Associated commodities and mining methods.

4.2.3 *Questionnaire administration*

Significant role-players from among the providers were identified. The intention was to get as much information as possible from the providers since the number of providers is relatively much smaller than that of users. As providers identified their clients a list of the users was compiled. The software users subsequently identified other providers and data collection continued within the time constraints.

Contact details for most of the major providers were obtained from the Global InfoMine website. Emails were sent through the company email submission forms provided on that website, and alternatively on the respective company's website, in order to obtain their consent that their organisation would participate in the survey and to assist in getting the questionnaire to someone who could help from their organisation. Of those who responded most were willing to assist and wanted the questionnaire sent by email. Some information was obtained from the completed questionnaires but it become apparent that when it came to clients the level of detail requested had to be toned down because of the confidential nature of the information. In addition, a number of questionnaires remained outstanding even after repeated follow-ups. In order to protect information that could be used for competitive advantage by other suppliers, some suppliers requested the researcher to sign confidentiality agreements. This entails that raw data is not divulged in this dissertation but only inferences drawn therefrom is presented.

4.3 Implementing the database and generating web pages

The stage following the design phase for databases is to physically implement the database. For web-based applications it is page generation and testing. In order to carry out these activities it was necessary to install some software on the development machine. The following software was needed:

- A web server (Apache) – a computer program that receives page requests and delivers content back to the user;
- MySQL server – a database management system; and
- PHP engine – for interpreting the PHP scripts.

These could have been installed individually on the Windows operating system but there is a freely available program called WampServer which speeds up installation and configuration of Apache, PHP and MySQL. WampServer was installed on the development machine and all the configuration need for the development environment was made.

4.4 Creating the database

It is possible to connect to a MySQL server through a command line interface and execute SQL scripts to manipulate database objects. The major disadvantage is that it is time consuming to type out the SQL and it would require an intimate knowledge of the language specific for MySQL. A special package called MySQL Workbench is provided by the Oracle Corporation which provides a graphical user interface for SQL development and data modeling. The welcome screen is shown in Figure 4-1. Part of the figure has been obscured for security purposes. Using this graphical user interface it was possible to create the database and the objects it contains without having to type out the SQL commands. The package generated the required commands. The commands were checked and modified when it was necessary to do so and then executed against the connected MySQL server.

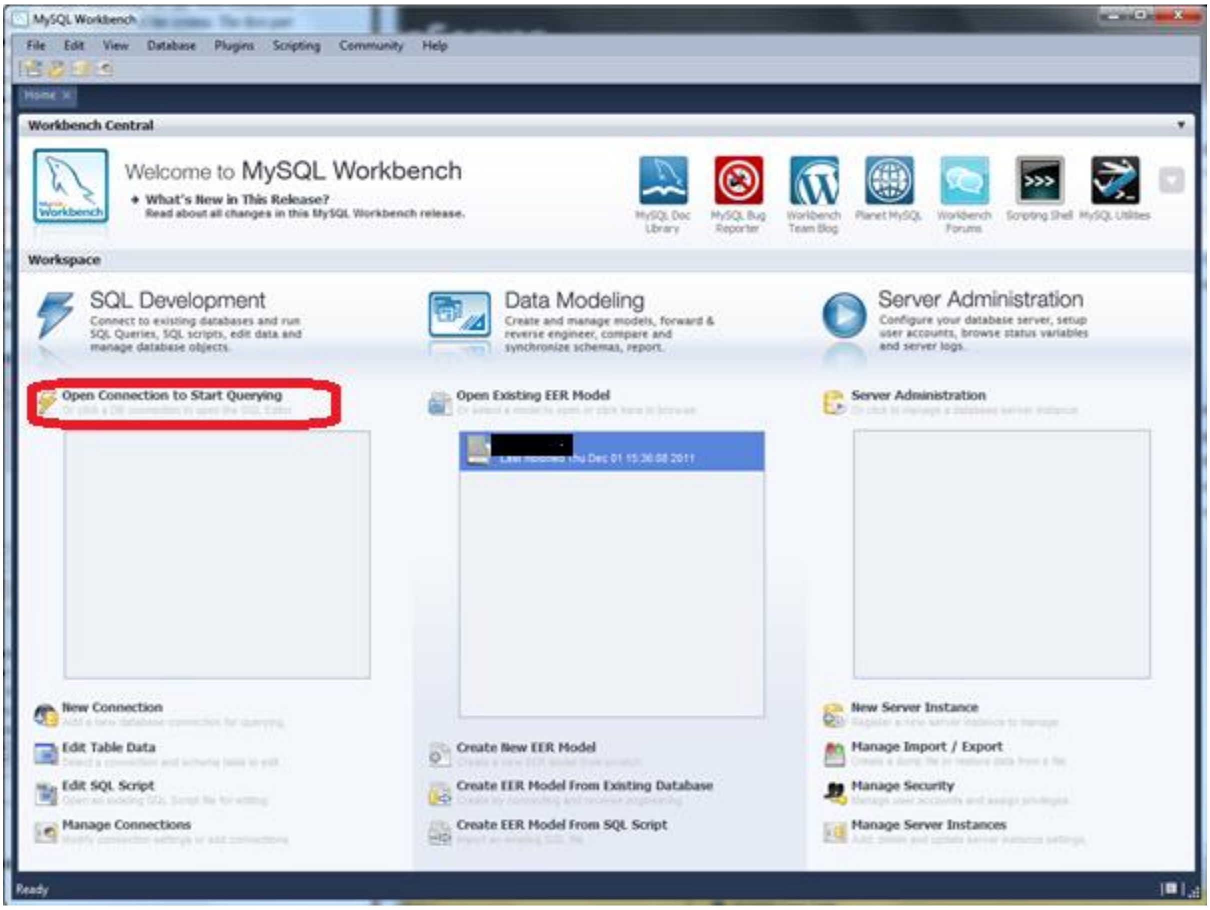

Figure 4-1 Screen shot of the MySQL Workbench welcome screen

The following steps were followed in creating the database:

Step 1: Connecting to the MySQL server by clicking on ‘Open Connection to Start Querying’ in the ‘Workspace’ area of the welcome screen and supplying the user name and password. Figure 4-2 is the interface that appears.

Step 2: Creating a new database by clicking on the ‘Create new schema’ icon and supplying the database name and applying the changes.

Step 3: Connecting to the database by selecting it on the list of schemas.

Step 4: Creating the tables, one after another, by clicking on the ‘Create new table’ icon and naming the tables and their columns in the dialog box that appears (Shown in Figure 4-3, parts of which have been obscured for security purposes.). The data integrity rules were defined in the same dialog box. It was possible to edit the table definitions by right-clicking on a table icon and selecting ‘Alter table’. The same dialog box appears.

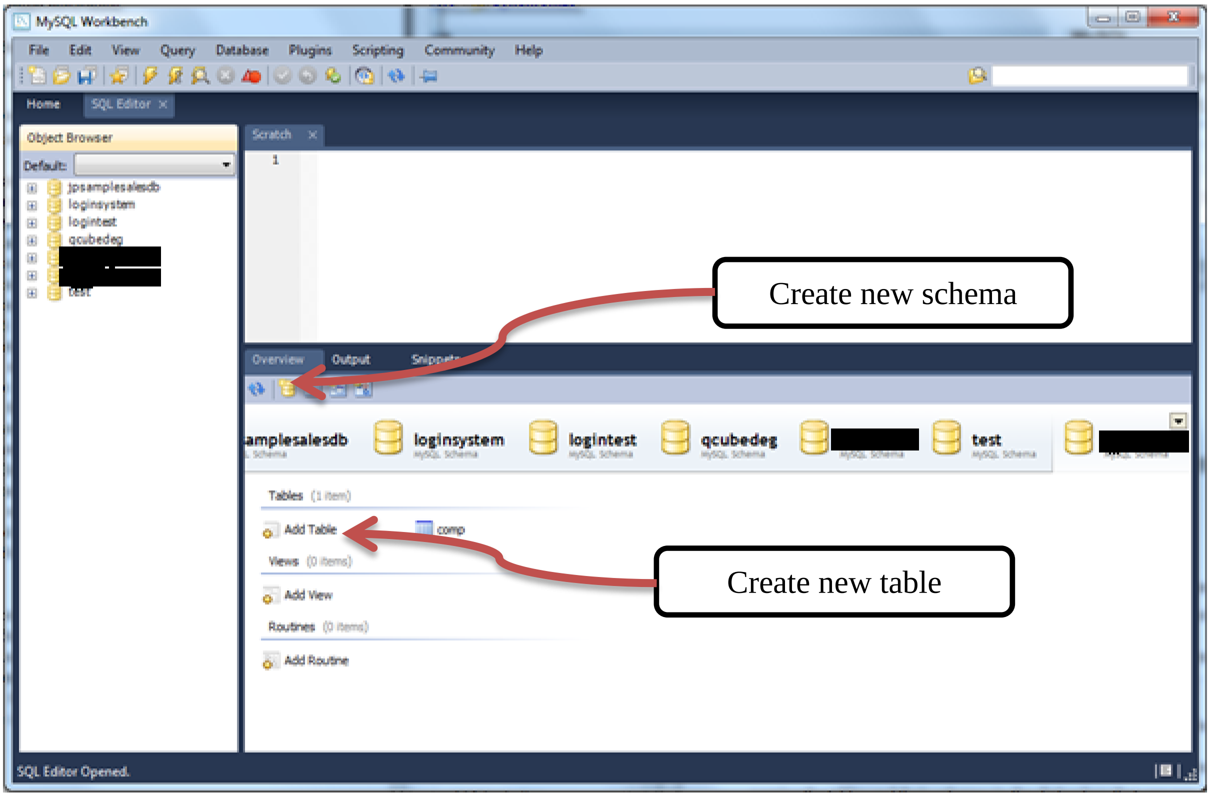

Figure 4-2 Screen shot of the MySQL Workbench interface for SQL development

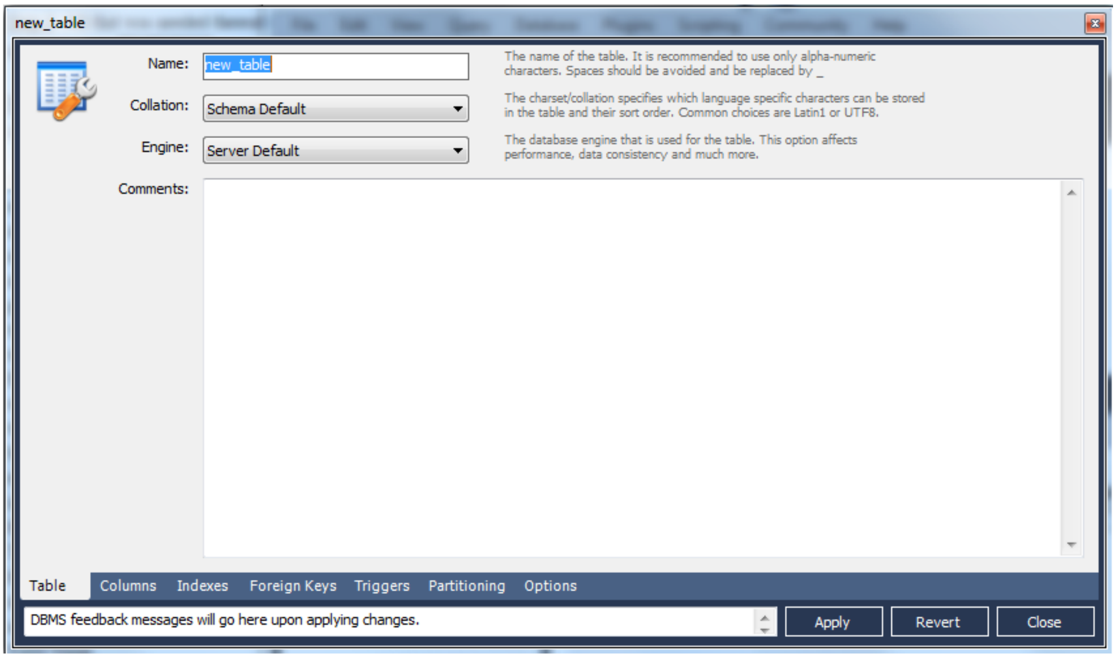

Figure 4-3 Screen shot of the 'New table' dialog box

Step 6: Capturing the data by right clicking on a table icon and selecting 'Edit table data' and entering the data one row at a time. Alternatively the data was captured by executing SQL scripts with '`INSERT`' statements for multiple rows. The final part of Appendix A shows the '`INSERT`' statement for the 'mine_value_chain_stage' table.

4.5 Developing the user interface

Developing the user interface to allow querying the database and analysing the information was the next logical step. Developing the user interface was carried out in two major stages:

1. Generating the server-side code needed to connect to the database and make the web pages dynamic; and
2. Producing the HTML to define the structure of each page and the Cascading Style Sheets (CSS) to apply formatting to the pages.

4.5.1 *Generating PHP scripts*

Server-side scripting languages (such as PHP, ColdFusion, ASP and ASP.NET) are used to connect with a database and manipulate data. PHP was chosen for this dissertation. A simple text editor is all that is needed to create PHP scripts. However it would be time consuming to type out the SQL for each web page to connect to the database and query data. Some tasks such as connecting to the database, inserting, reading, updating and deleting data are repetitive. When there are changes to the database the SQL queries have to be updated in each script to reflect the changes. Problems arise if one forgets to change one or two areas. The solution is to create a class for each table and treat it as an object. That way, methods can be written to insert, select, update and delete data. The task of creating the classes can be a daunting one for a single person with time constraints. PHP frameworks have been developed to solve this problem and reduce the amount of code one has to write for common tasks. The following steps for generating the PHP code were followed:

Step 1: Installing the framework. The framework chosen to develop the web application for the mine planning software database is called QCubed. It is freely available at http://www.qcu.be/. The compressed file that is downloaded contains the instructions that have to be followed in order to install the framework.

Step 2: Configuring the installation. The main configuration file for QCubed is located in the ‘includes’ directory of QCubed and is named configuration.inc.php. QCubed was installed in a subdirectory on the webserver. In this report it is just named as 'db' for security purposes. To inform QCubed of this, the configuration file was edited at the section containing the following lines:

```
define('__DOCROOT__', 'C:/xampp/xampp/htdocs');
define('__VIRTUAL_DIRECTORY__', '');
define('__SUBDIRECTORY__', '/qcubed2');
```

These 3 parameters were modified to match the configuration:

```
define('__DOCROOT__', 'C:/wamp/www');
define('__VIRTUAL_DIRECTORY__', '');
define('__SUBDIRECTORY__', '/db');
```

The database connection properties were also set in the same configuration.inc.php file. The settings below are just for illustration purposes. The real settings are not stated for security purposes.

```
define('DB_CONNECTION_1', serialize(array(
   'adapter' => 'MySqli5',
   'server' => 'localhost',
   'port' => null,
   'database' => 'dbMin',
   'username' => 'userMin',
   'password' => 'xxxxxxx',
   'profiling' => false)));
```

The next step was to verify the configuration. Figure 4-4 shows the start page which confirms a successful installation. Certain parts of the figure have been obscured for security purposes.

Step 3: Code generation. Clicking the first link in the start page ran the code generator. The QCubed code generator generated the:

1. code to translate each table in the database to an object that contains all the basic methods to create, read, update and delete data to or from the database. In addition to this functionality QCubed also generated complex methods to retrieve by index and to ‘associate’ and ‘unassociate’ related objects; and
2. HTML form drafts for each table in the database. Samples of how to implement the PHP frond-end code to view, create, edit and delete table data are provided.

If any changes were made to the database the code generator was run again to overwrite the generated scripts with new ones that reflected the changes.

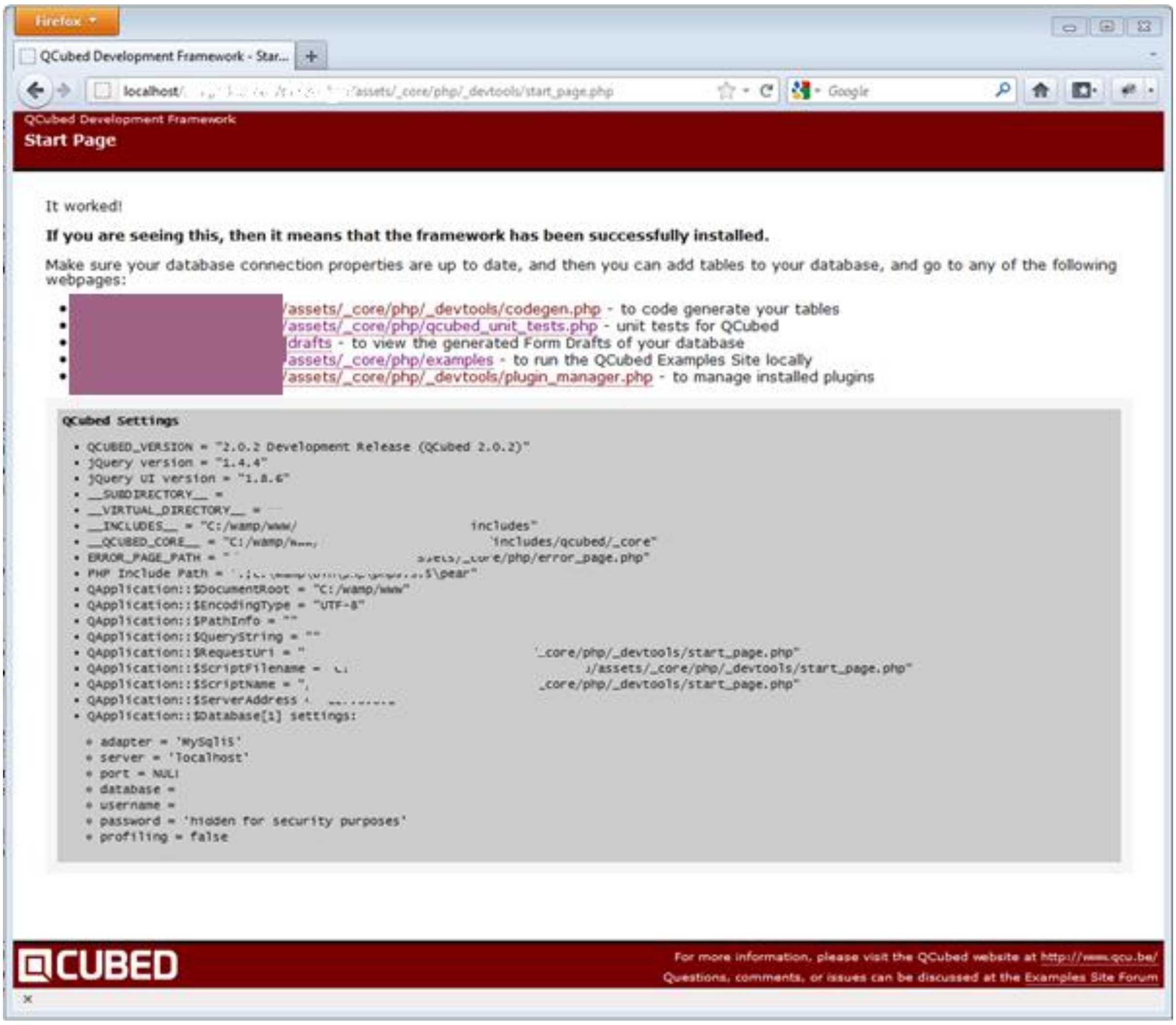

Figure 4-4 Screen shot of the QCubed Development Framework start page

Step 3: Extending functionality. After code generation, the created objects were modified to match the business logic and presentation required for the web application of the mine planning software database. This included designing the system for granting access to users with different roles and the capability to produce charts. Highcharts, available free of charge from http://www.highcharts.com/ for non-profit making projects, is a charting library based on a client side scripting language called javascript. Appendix B shows how the PHP data classes were used to extract arrays that were used in conjuction with the highcharts library to produce the graphs for displaying market share.

4.5.2 *Producing HTML and CSS*

HTML is used to define the structure of a web page and CSS applies formatting to the pages. There are two main ways of producing the HTML and CSS code. One way is to use visual design tools such as Adobe Dreamweaver or Microsoft Expression Web. These have the advantage of allowing a designer to create pages with no significant knowledge of HTML or CSS. However they must be purchased. HTML and CSS are not complicated programming languages so it was decided to use the code-based tools to type the code. The tools ship with operating systems or can be downloaded for free from the internet. Eclipse is an open-source development toolset to which HTML-editing capabilities can be added. It was chosen because it also has PHP-editing capabilities. Eclipse is available for download at http://www.eclipse.org/.

4.6 Summary

The purpose of this chapter was to inform the reader on how the plans were implemented. This encompasses the data gathering, implementing the database and creating the user interface. The results of the implementation are discussed in the next chapter.

5 BASELINE RESULTS

5.1 Chapter overview

A database of mine planning and peripheral software was developed and implemented. Information relating to the availability and usage of mine planning and related software was collected from a variety of sources and then captured into the database. The information can be accessed through a user-friendly frontend platform which is available online at http://db.mining.wits.ac.za.

The research question which this dissertation sought to answer is "What is the current nature and extent of mine planning and peripheral software utilisation in the South African mining industry?" This chapter presents the results obtained from the research. The results will be tabulated or presented graphically where possible in order to make it easier to analyse them. The key areas that will be covered by the analysis are:

- Who are the suppliers of mine planning and related software and what solutions do they provide?
- Who are the current users of mine planning and related software in South Africa?
- How well have software solutions been adopted in the South African mining industry? and
- What is the market share of the software solutions providers?

5.2 Availability of mine planning and related software

There are more than twenty companies providing mining technical solutions in South Africa. In this section the companies are listed in alphabetical order. A brief profile of each company is provided. This is followed by a table of the solutions provided and a summary of the functionality provided by each solution. The grouping of functionalities is based on categorisations made in Table 4-1.

5.2.1 *acQuire Technology Solutions*

In 1995, acQuire Technology Solutions initiated the acQuire project to handle the task of capturing and managing geoscientific observations and measurements (acQuire Technology

Solutions Pty Ltd, 2012). The functionality of their flagship product, acQuire, is summarised in Table 5-1.

Table 5-1 Software provided by acQuire Technology Solutions

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
acQuire		✓						

5.2.2 ***ARANZ Geo***

ARANZ (which is an acronym for Applied Research Associates NZ Limited) is a research organisation which was formed in 1995 to develop and commercialise innovative technologies (ARANZ Geo Limited, 2012). ARANZ developed the 3D scanning and modelling technology for a variety of applications. After collaborating with mining geologists ARANZ Geo was formed in 2003 to develop and market geological modelling software. The three products provided by ARANZ Geo for geological modelling are Leapfrog Mining, Leapfrog Hydro and Leapfrog Geothermal. Their capabilities are summarised in Table 5-2.

Table 5-2 Software provided by ARANZ Geo

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Leapfrog Mining, Leapfrog Hydro, Leapfrog Geothermal			✓					

5.2.3 *Bentley Systems*

Bentley was founded in 1984 (Bentley Systems, Incorporated, 2012). It provides architects, engineers, geospatial professionals, and constructors with software solutions for sustaining infrastructure. They provide Microstation which has been used by some mining technical solution providers as a basis for the computer aided designing (CAD) functionality required for the mine design offerings. Table 5-3 summarises its functionality.

Table 5-3 Software provided by Bentley Systems

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Microstation				✓				

5.2.4 *Bluhm Burton Engineering*

Bluhm Burton Engineering is a ventilation and refrigeration consulting engineering company. According to Bluhm, Marx, von Glehn and Biffi (2001), the Mining Technology Division (Miningtek) of the Council for Scientific and Industrial Research (CSIR) partnered with Bluhm Burton Engineering to develop a software package for simulating ventilation of underground mine atmospheres (from which the acronym VUMA is derived) in the 1990's. VUMA-Network is designed to handle the ventilation and cooling designs for deep mines which a characteristic of the metal mines. VUMA-Coal handles the ventilation of the shallower coal mines. The functionality of the products is tabulated in Table 5-4.

Table 5-4 Software provided by Bluhm Burton Engineering

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
VUMA3D-Network, VUMA3D-Coal, VUMA-Live, VUMA Transient, VUMA-Coolflow, VUMA-Fire				✓				

5.2.5 *CAE Mining*

CAE Mining was formed in May 2010 as the result of CAE's acquisition of the Datamine Group. At the time of acquisition the Datamine Group had been providing software and consulting services to the mining industry for 29 years (CAE, 2010). Century Systems was also acquired by CAE Mining. Mine2-4D, one of their solutions, was developed in partnership with MineRP but the arrangement has been discontinued (CAE Mining, 2011). The company has a number of solutions which cover a broad range of functionalities. CAE Mining's capabilities are tabulated in Table 5-5. CAE Mining is widely accepted to be a major supplier of mine technical solutions. However information about their client base was not available for analysis by the time of submitting the dissertation. On-going efforts are being made to obtain the outstanding information.

5.2.6 *Cyest Analytics*

Cyest Analytics is part of Cyest Corporation which has been offering modelling solutions to address operational performance, production scheduling, optimisation and other business modelling needs for the mining industry in South Africa since about 2002 (Lane, Hudson and Bondi, 2007). The Carbon suite of solutions that they provide has capabilities which are illustrated in Table 5-6.

5.2.7 *Gemcom Software International*

Gemcom Software International was established in 1985 as a spin-off from SRK consulting (SRK Consulting, 2012). The company provides technical mining applications, consulting services, training and support. Of the software they provide, Surpac is the most widely used. Table 5-7 illustrates Gemcom Software International's capabilities in terms of software provided.

Table 5-5 Software provided by CAE Mining

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
DHLogger		✓						
Downhole Explorer		✓						
Fusion		✓						
MineMapper3D	✓							
Sample Station		✓						
Conditional Simulation			✓					
Century LIMS		✓						
InTouch			✓	✓				
Datamine Studio		✓	✓	✓				
Unfold			✓					
Enhanced Production Scheduler					✓			
Interactive Short Term Scheduler					✓			
Mine 2-4 D				✓	✓			
Mineable Reserves Optimizer				✓			✓	
Mineable Shapes Optimizer				✓			✓	
Mine Layout Optimizer				✓			✓	
Multimine Scheduler					✓	✓	✓	
NPV Scheduler					✓	✓	✓	
RM Scheduler				✓	✓	✓	✓	
Ventsim Visual				✓				
Ore Controller				✓			✓	
Rings				✓				
Raw Materials Manager			✓	✓				
MineTrust								✓

Table 5-6 Software provided by Cyest Analytics

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Carbon 14 Mine Scheduler					✓	✓	✓	
Carbon Economics					✓	✓	✓	
Carbon Performance Manager						✓	✓	
Carbon Processing					✓	✓	✓	
Carbon Risk							✓	
Carbon Micro Scheduler					✓	✓	✓	

Table 5-7 Software provided by Gemcom Software International

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
GEMS		✓	✓	✓	✓			
Surpac	✓	✓	✓	✓				
Minex			✓	✓	✓	✓		
MineSched					✓			
PCBC					✓			
Whittle					✓	✓	✓	
InSite								✓
Hub								✓

5.2.8 *Maptek*

Maptek was founded in 1981 as K. Robert Johnson and Associates and operated as KRJA Systems for 10 years before changing to its current name in 1992. The South African office was opened in 1994 (Ehlers, 2011). The company provides technical mining applications, consulting services, training and support. Their main product has a number of modules whose functionalities are summarised in Table 5-8.

Table 5-8 Software provided by Maptek

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Vulcan	✓	✓	✓	✓		✓	✓	
Vulcan Chronos					✓			

5.2.9 *Micromine*

Founded in 1986, Micromine caters for the software and consultancy needs of exploration and mining operations (Micromine Pty Ltd, 2009). The two main products are Geobank, formerly known as Geological Borehole Information System (GBIS), and Micromine. The functionality offered by their solutions is shown in Table 5-9.

5.2.10 *Minemax*

Minemax was founded in 1996 (Minemax, 2012). It specialises in mine planning and scheduling solutions. The capabilities of their solutions are tabulated in Table 5-10.

Table 5-9 Software provided by Micromine

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Geobank		✓						
Field Marshal		✓						
Micromine	✓		✓	✓	✓		✓	
Pitram					✓			✓

Table 5-10 Software provided by Minemax

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Minemax					✓	✓	✓	
iGantt					✓			
Tempo					✓		✓	

5.2.11 *MineRP*

MineRP was founded in 1997 as Graphic Mining Solutions International (GMSI) and was subsequently acquired by Gijima Holdings, a South African ICT company (MineRP, 2012). It was rebranded as MineRP in 2011. The company provides technical mining applications, consulting services, training and support. Mine2-4D, one of their solutions, was developed in partnership with CAE Mining but the arrangement has been discontinued (Gijima Mining, 2012). Their product offerings are summarised in Table 5-11.

5.2.12 *MinLog*

MinLog is a distribution partner for Maptek. Starting from January 2012, however, MinLog assumed all responsibility for the distribution, delivery, development and support of the MineSuite product for Maptek customers (Maptek Pty Ltd, 2012). MineSuite's functionality is shown in Table 5-12.

5.2.13 *Mintec*

Mintec was established as a consulting company in 1970 (Mintec, Inc., 2012). The company provides technical mining applications, consulting services, training and support. Their main product is MineSight. MineSight has a number of modules and their functionalities are summarised in Table 5-13.

Table 5-11 Software provided by MineRP

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
mineSTRUCTURE	✓							
CADSMine			✓	✓				
Mine 2-4D				✓	✓			
Enhanced Production Scheduler					✓			
EPS Schedule Optimization Tool					✓		✓	
mineCAD				✓				
mineSERV				✓				
SpatialDB								✓
MineRP Resource and Reserve Inventory Portal (GRRIP)								✓
G-Risk							✓	✓
Mineral Resource Management		✓	✓					✓

Table 5-12 Software provided by MinLog

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
MineSuite								✓

Table 5-13 Software provided by Mintec

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
MineSight Torque		✓						
MineSight Data Analyst			✓					
MineSight3D	✓		✓	✓				
MineSight Interactive Planner			✓	✓				
MineSight Haulage				✓				✓
MineSight Axis				✓				
MineSight Economic Planner					✓	✓	✓	
MineSight Strategic Planner					✓	✓	✓	
MineSight Schedule Optimiser						✓	✓	

5.2.14 *Modular Mining Systems*

Founded in 1979, Modular Mining Systems develops and markets software for assigning and guiding trucks to loading and dumping points (Modular Mining Systems, Inc., 2012). Their software solutions also produce operating reports during shifts and are used for asset management. DISPATCH, MineCare and Shiftboss are among the solutions they provide. A summary of their functionality is provided in Table 5-14.

Table 5-14 Software provided by Modular Mining Systems

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
DISPATCH				✓			✓	✓
ShiftBoss								✓
MineCare								✓

5.2.15 ***MRM Mining Services***

MRM Mining Services specialises in integrated mine scheduling, equipment simulation and mine financial analysis. It is part of Runge, a consulting, training, and software provider for the mining and related services industries since 1977 (Runge Limited, 2012). For scheduling they offer Xpac and Xact. For equipment simulation there is Talpac, Dragsim and Facets. Xeras is used for financial analysis and Fracsis is used for visualising geological datasets. The capabilities of their software are illustrated in Table 5-15.

5.2.16 ***Orica Mining Services***

Orica Mining Services is a supplier of commercial explosives (Orica Limited, 2012). Hence the company provides consulting services, training and a software package called SHOTPlus-i for use with Orica products. SHOTPlus-i is used for the evaluation and optimisation of blast designs. Table 5-16 summarises the functionality.

5.2.17 ***Palisade***

Founded in 1984, Palisade has been producing software to help users to quantify risk by running Monte Carlo simulations (Palisade Corporation, 2012). Presently they provide @RISK as an add-in to Microsoft Excel and Microsoft Project which is used for risk analysis. This functionality is illustrated in Table 5-17.

Table 5-15 Software provided by MRM Mining Services

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Mining Knowledge Platform		✓	✓					
FracSIS	✓	✓	✓					
Xpac					✓			
Xact					✓			
Xeras						✓	✓	
Talpac					✓		✓	✓
DragSim					✓		✓	
FACETS					✓		✓	
Mining Dynamics								✓

Table 5-16 Software provided by Orica Mining Services

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
SHOTPlus-i				✓				

Table 5-17 Software provided by Palisade

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
@RISK							✓	

5.2.18 ***Rocscience***

Rocscience has been creating geotechnical software since 1996 (Rocscience Inc., 2012). They specialise in 2D and 3D analysis and design programs for civil engineering and mining applications. Table 5-18 summarises the capabilities of Rocscience's software offerings.

Table 5-18 Software provided by Rocscience

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Phase^2, Slide, Examine^{3D}, Unwedge, Swedge				✓				

5.2.19 ***SABLE Data Works***

Starting in 1983, a software system which became known as SABLE, an acronym for Standardised Approach to Borehole Logging for Exploration, was developed in order to capture, process and display the geological and sampling data that would be generated during the life of a hard rock drilling campaign (Sable Data Works Pty Ltd, 2012). Due to the success of the software, the geological department of the Anglovaal Limited, in a joint venture with Marcia van Aswegen, made it commercially available to other mining houses. Table 5-19 summarises the functionality of SABLE Data Warehouse which is provided by SABLE Data Works.

Table 5-19 Software provided by SABLE Data Works

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
SABLE Data Warehouse		✓						

5.2.20 ***SAP***

Founded in 1972, SAP (which stands for "Systems, Applications and Products in Data Processing") provides enterprise application software (SAP AG, 2012). In addition to solutions that cater for most industries, it has solutions which are specific to the mining industry. SAP’s capabilities are illustrated in Table 5-20.

Table 5-20 Software provided by SAP

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
SAP					✓	✓		✓

5.2.21 *Spatial Dimension*

Founded in 1999 as part of the MS Group, Spatial Dimension provides a solution called Flexicadastre for facilitating business processes required for the administration of mineral rights (Spatial Dimension, 2010). The functionality of Flexicadastre is illustrated in Table 5-21.

Table 5-21 Software provided by Spatial Dimension

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Flexicadastre	✓							✓

5.2.22 *TLC Engineering Solutions*

TLC Engineering Solutions was founded in 1987 to provide a range of IT solutions for a broad range of industries including railway, mining, telecommunications, transportation and manufacturing (TLC Engineering Solutions, 2011). Masterblaster is used as an inventory and bulk loading system for explosives. Its functionality is summarised in Table 5-22.

Table 5-22 Software provided by TLC Engineering Solutions

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
Masterblaster				✓				✓

5.2.23 *Wonderware*

Founded in 1987, Wonderware develops and applies technologies that enable the world's manufacturing and energy-generating facilities, mainline and mass transit rail networks, and appliances to operate safely and in an energy-efficient manner (Invensys Inc., 2012). ArchestrA Workflow is used for production and performance management for processing plants. The functionality of ArchestrA Workflow is illustrated in Table 5-23.

Table 5-23 Software provided by Wonderware

	Mapping	Geological data management	Geological modelling and/or resource estimation	Design and layout	Planning and scheduling	Financial Evaluation	Risk analysis and optimisation	Other (i.e. ERP, Monitoring, Reporting, etc.)
ArchestrA Workflow								✓

5.3 Summary information on the user base

In this section the size of the market being analysed is defined. The user base may be broadly categorised as:

- Exploration and mining companies;
- Consulting companies, government departments and research institutions; and
- Educational institutions.

5.3.1 *Exploration and mining companies*

Information was obtained from the Department of Mineral Resources website and captured in the database of mine planning and peripheral software. Based on that information, there are about 1 200 mining companies exploring for, extracting or processing more than sixty different mineral commodities at more than 1 600 sites in South Africa.

The graphs in Appendix C show the distribution of sites producing the different mineral commodities. The total number of sites for the whole category differs from the sum of the number of sites for each individual mineral commodity because a site may be producing more than one commodity.

5.3.2 *Consulting companies, government departments and research institutions*

More than fifty consulting companies were identified in the course of conducting this research. They offer services in the areas of legal compliance, geophysical data interpretation, geological modelling, resource estimation, feasibility studies, geotechnical studies, water management planning, mine designs and layouts, production schedules, equipment selection and many others. The providers of mine planning and related software may also function as consulting companies. In order to carry out their advisory and consulting functions they may acquire software solutions provided by other companies. In addition, there are companies which provide engineering services or mining equipment.

The Department of Mineral Resources is also included in the client base of mine planning and peripheral software. It needs to keep an accurate record of the geographical location, ownership and time validity of exploration and mining rights in South Africa so as to ensure security of tenure. The Department of Water Affairs and the Department of Environmental Affairs may also benefit from mapping and hydrogeological modelling packages. The state also funds research through enterprises, such as the Council for Scientific and Industrial Research, whose aim is to improve safety and cost effectiveness of mining operations.

5.3.3 *Educational institutions*

At least 13 educational institutions in South Africa are providing the training required by the mining sector in fields that have a direct bearing on mine planning. Table 5-24 summarises the areas of specialisation covered by the different institutions.

Table 5-24 Educational institutions offering programmes that relate to planning across the mine value chain

Institution	Areas covered by courses offered				
	Geology	Surveying	Mining Engineering	Metallurgy	Environmental Studies
Cape Peninsula University of Technology					✓
Nelson Mandela Metropolitan University	✓				✓
Rhodes University	✓				
Stellenbosch University	✓	✓			✓
Tshwane University of Technology	✓	✓		✓	✓
University of Cape Town	✓	✓			✓
University of the Free state	✓				✓
University of Johannesburg	✓	✓	✓	✓	✓
University of Pretoria	✓	✓	✓	✓	✓
University of South Africa		✓	✓		
University of Venda	✓				✓
University of Western Cape	✓				
University of the Witwatersrand	✓	✓	✓	✓	✓

5.4 The adoption of mine planning and related software

In this section an analysis of the extent of software adoption in the local mining industry is given. First of all, the distribution of the software clients, grouped by company profile, is presented. Following that the percentage of mine and processing plant sites that have software installations is presented as a measure of adoption of software by mining companies. The limitation of this method is that it does not take into account the sites that make use of consulting companies for planning and related activities. Also not included in the analysis are sites which may be catered for by software installations at the head office of the mining company operating at the site.

5.4.1 *Analysis of client base based on company profiles*

It can be seen from Figure 5-1 that the majority, about 75%, of the users of mine planning and related software are the mineral exploration and the mining companies. However, it is significant that consulting companies constitute 20% of the client base because one consulting company may be providing mine planning related services to a large number of mining companies ranging from the small scale enterprises to the large mining houses.

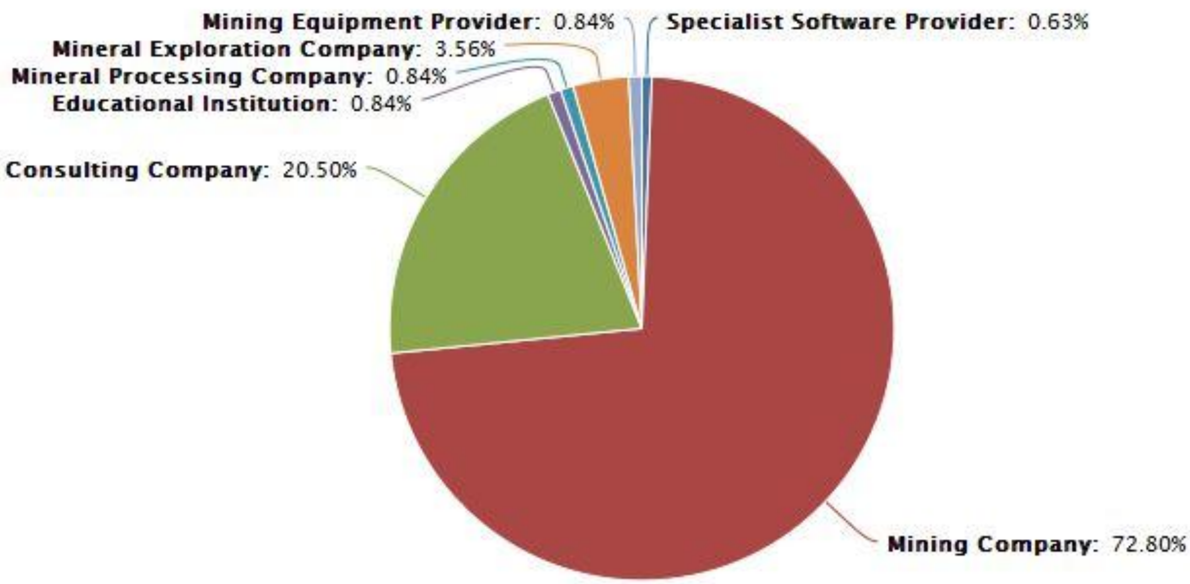

Figure 5-1 Distribution of software installations grouped by company profiles (based on information received between June 2011 and June 2012)

5.4.2 *Extent of software adoption at mining sites*

This research was limited to finding out where software is installed and no investigation was made into how and where the software is being used. Assuming that all the software is being fully utilised and that the software is only used at the site on which it is installed, the analysis of the extent of software adoption focuses on the sites that are producing minerals.

According the Department of Mineral Resources (2010) three mineral commodities comprise 71% of the income generated by mining in South Africa namely coal (27%), platinum group metals (PGM) (24%) and gold (20%). The remaining contribution to total sales revenue comes from ferrous metals (15%), industrial minerals (5%), nonferrous metals (4%) and the rest (5%). In view of the significant contribution of coal, gold and PGM to the South African economy, achieving efficient and cost effective extraction of these minerals is very important. To this end, companies adopt mine planning software and exploit computers' processing power and speed. Since coal, PGM and gold are the major sources of income, in analysing the extent of software adoption this report considers these three individually while other minerals are grouped by their commodity types.

Figure 5-2 shows that 29% of the coal mining sites have software installations, while for gold the figure is 31% and 43.5% for PGM. The contribution of each site to revenue generated by mining has not been taken into account. This information is valuable in order to determine whether there is a correlation between software utilisation and revenue generated. The provider companies can also use the information to make decisions on whether they should market their solutions to the companies which have not yet adopted planning software. It should be borne in mind that some companies rely on consulting companies for planning related activities and it can be assumed that they have indirectly adopted software.

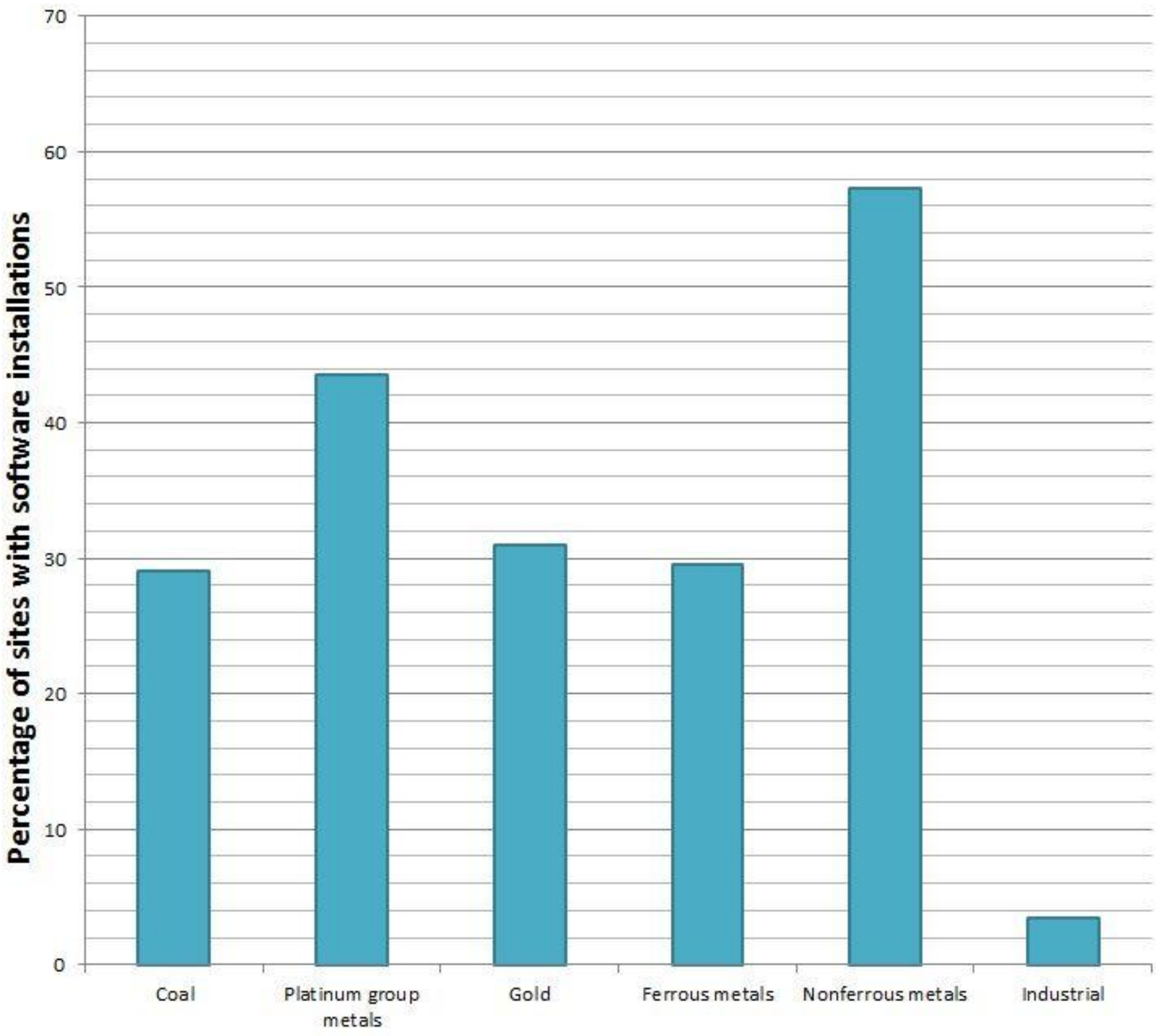

Figure 5-2 Adoption of software solutions at mining sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

5.5 Relative market share

This section seeks to answer the question: 'Which mining and peripheral software is being used in the South African mining industry and in what proportions?' Calculating the relative market share for mine planning and peripheral software is complicated. In South Africa alone there are at least twenty suppliers and the solutions they provide vary from one to over ten products each. To compound the situation, each product can:

- have more than one module;
- have a wide range of functionalities;
- cater for a wide range of specialities; and
- have variety of licencing options.

Nevertheless, it is possible to get useful information from the data collected. Vendor revenue could not be used as a basis to measure relative market share because no data was collected about the cost of the software products installed. The number of units sold could have been used if all the vendors who responded had included the number of licences installed at the different sites. The number of users of a software solution was based mostly on human judgement and could not be relied on for accurate analysis. A decision was made to measure relative market share based on the number of sites where software is installed.

5.5.1 ***Relative market share for solutions with information in the database***

Based on number of sites, Figure 5-3 shows the breakdown of the relative market share for the different solutions. The number of sites used in the analysis is based on the information obtained from the mining technical solutions providers. The formula used to calculate the market share is: $Market\ share\ for\ a\ solution = \frac{Number\ of sites\ where\ the\ solution\ is\ installed}{Total\ number\ of\ software\ installations}$. For example, suppose there are only two software solutions on the market, Solution A and Solution B. Solution A is installed at three sites and Solution B is installed at four sites. Regardless of the number of sites at which the solutions could have been installed or whether some sites have both Solution A and Solution B installed, the market share for Solution A is $\frac{3}{3+4}$, i.e $\frac{3}{7}$, and the market share for Solution B is $\frac{4}{7}$.

This analysis shows that three companies – Gemcom Software International, MRM Mining Services and MineRP have about 80% of the relative market share in total. The solutions that are immediately noticeable are Surpac, Xpac, Mine2-4D, EPS and SABLE Data Warehouse. The packages, however, have different and sometimes overlapping functionalities. Therefore it would be useful to drill down and see how the market breaks down when the data is filtered based on functionalities of the software and the mineral commodities produced by the client companies. The following sections focus on which software is installed at coal, PGM and gold producing sites for planning purposes from a strategic perspective.

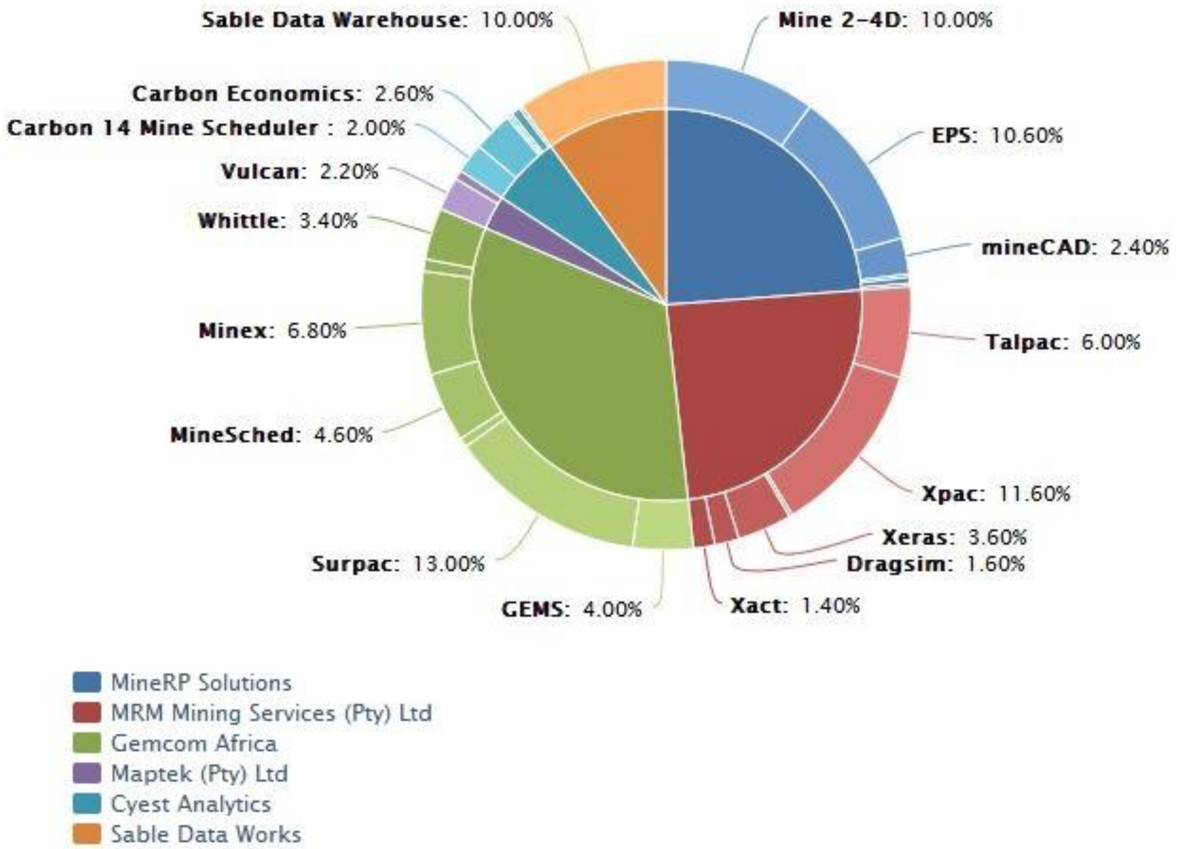

Figure 5-3 Mine planning and peripheral software relative market share by supplier (based on information received between June 2011 and June 2012)

5.5.2 *Analysis of the market share based on sites producing coal*

Table 5-25 shows the software that is installed at coal mining sites and their functionalities. The graphs from Figure 5-4 up to Figure 5-8 give a measure of their prevalent the solutions are, relative to their competition, for a given functionality.

Table 5-25 Functionalities of software installed at sites producing coal

Software	Geological data management	Geological modelling and resource estimation	Design and Layout	Scheduling	Financial valuation
SABLE Data Warehouse	⟷				
Minex	⟷	⟷	⟷		
Surpac	⟷	⟷	⟷		
VUMA-Coal			⟷		
Talpac			⟷		
Xpac				⟷	
Xact				⟷	
MineSched				⟷	
Xeras					⟷
Carbon Economics					⟷

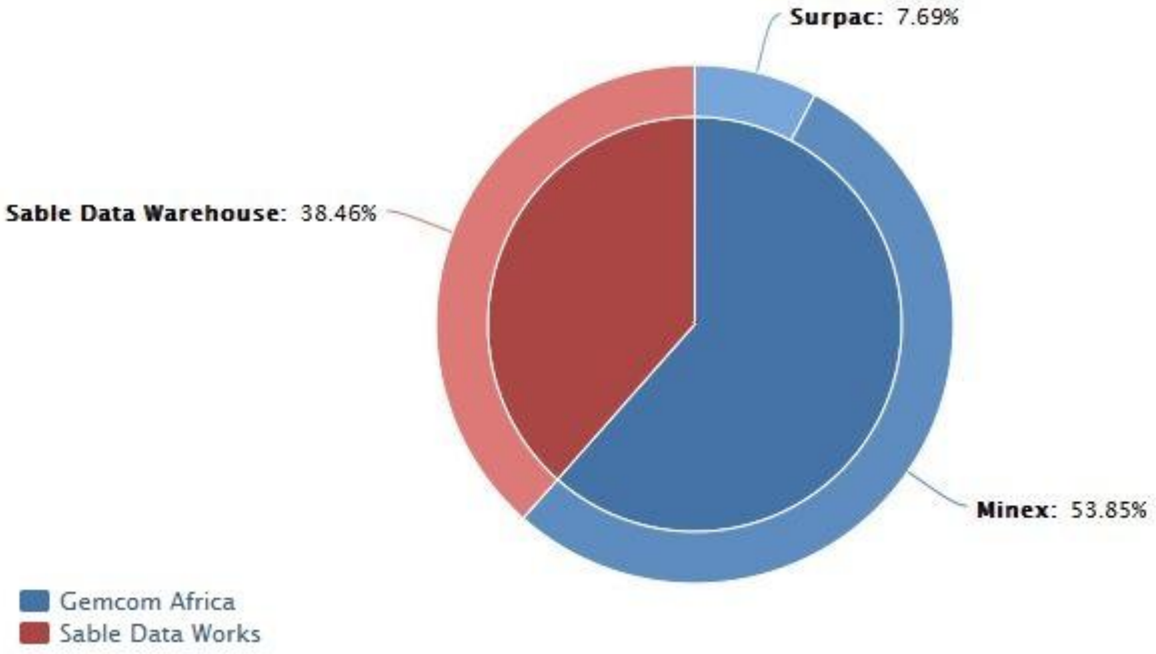

Figure 5-4 Geological data management software relative market share for coal sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

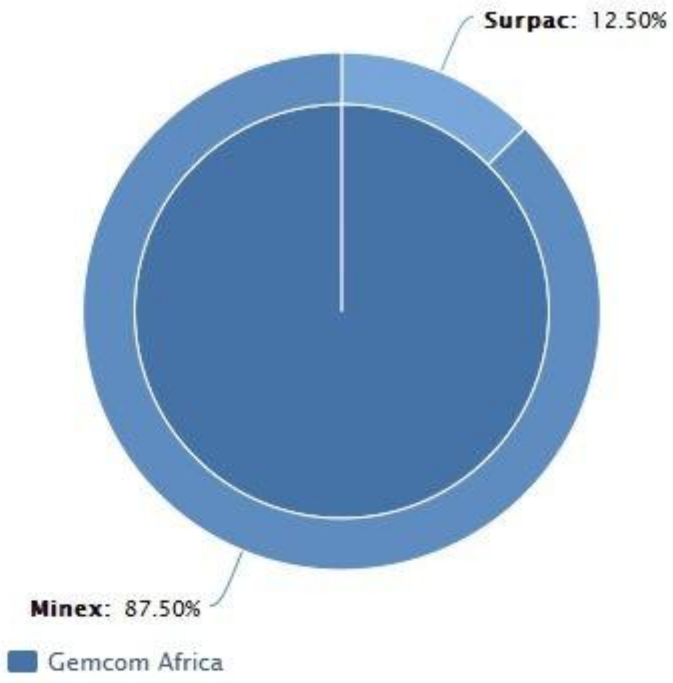

Figure 5-5 Geological modelling and resource estimation software relative market share for coal sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

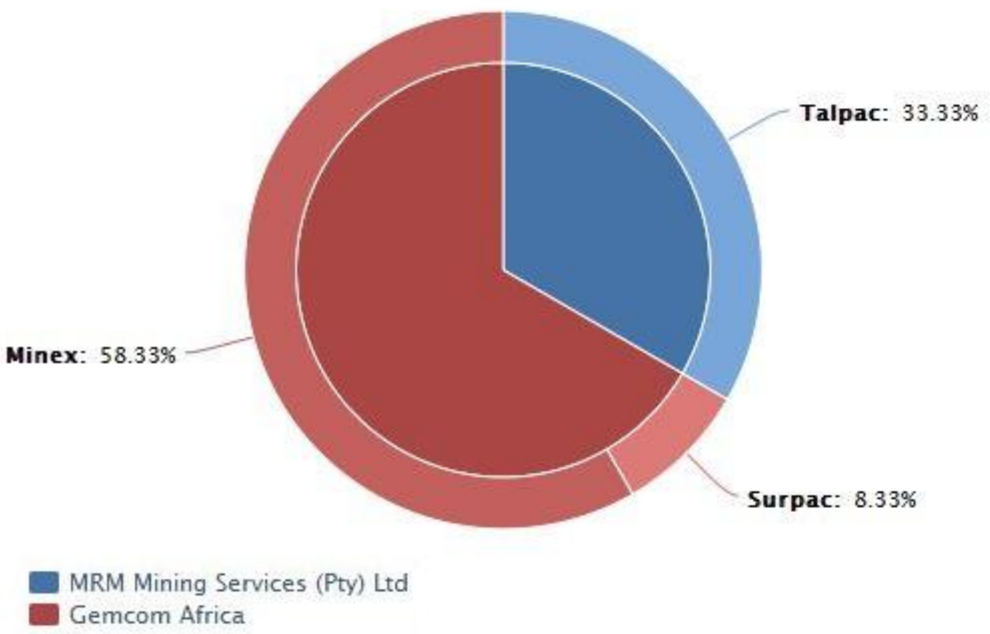

Figure 5-6 Design and layout software relative market share for coal sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

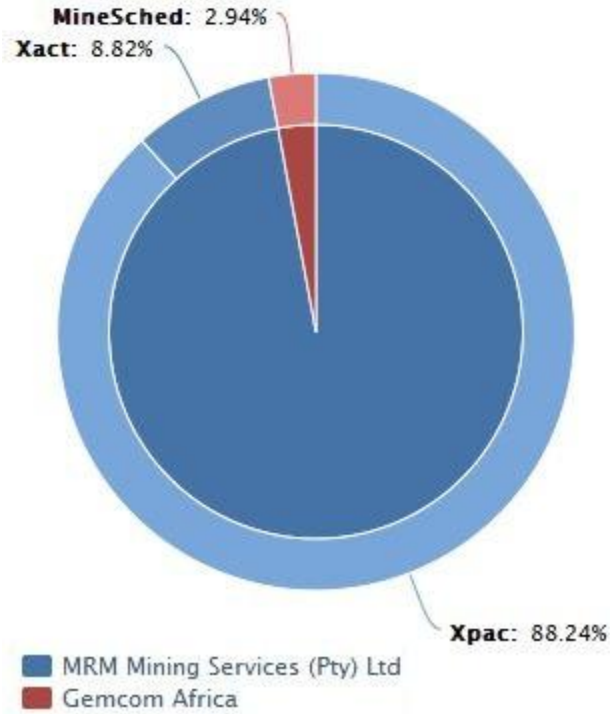

Figure 5-7 Scheduling software relative market share for coal sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

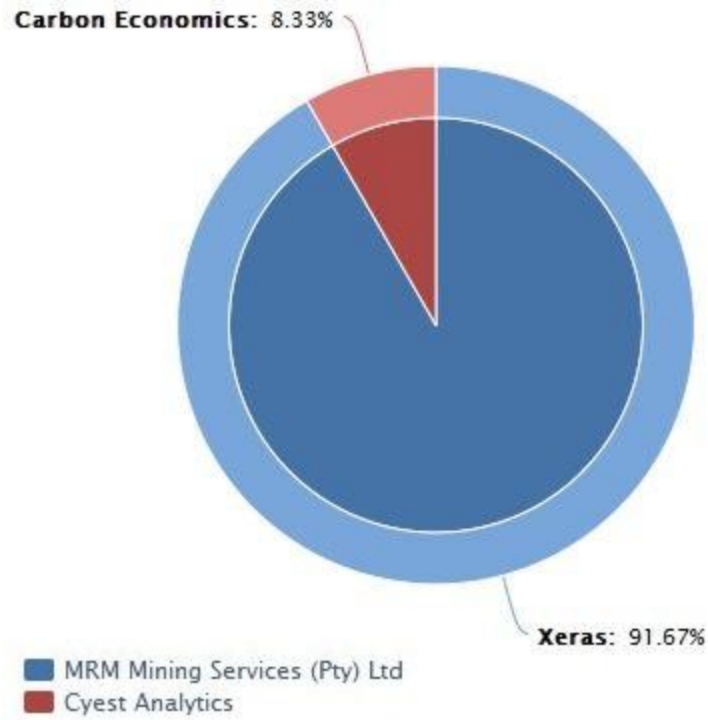

Figure 5-8 Financial valuation software market share for coal sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

5.5.3 *Analysis of the market share based on sites producing PGM*

Table 5-26 shows the software that is installed at PGM mining sites and their functionalities. The graphs from Figure 5-9 up to Figure 5-13 give a measure of how prevalent the solutions are, relative to their competition, for a given functionality.

Table 5-26 Functionalities of software installed at sites producing PGM

Software	Geological data management	Geological modelling and resource estimation	Design and Layout	Scheduling	Financial valuation
SABLE Data Warehouse	⟷				
mineMARKUP	⟷				
Surpac	⟷	⟷	⟷		
Minex	⟷	⟷	⟷		
GEMS	⟷	⟷	⟷		
Vulcan	⟷	⟷	⟷		
mineCAD			⟷		
VUMA-Network			⟷		
Talpac			⟷		
Mine 2-4D			⟷	⟷	
EPS				⟷	
Chronos				⟷	
Carbon 14 Mine Scheduler				⟷	
Carbon Micro Scheduler				⟷	
MineSched				⟷	
PCBC				⟷	
EPS Viz (Visualizer)				⟷	
EPS-PCBC Interface				⟷	
Xpac				⟷	
Xact				⟷	
Carbon Processing				⟷	⟷
Carbon Performance Manager					⟷
Carbon Economics					⟷
Xeras					⟷

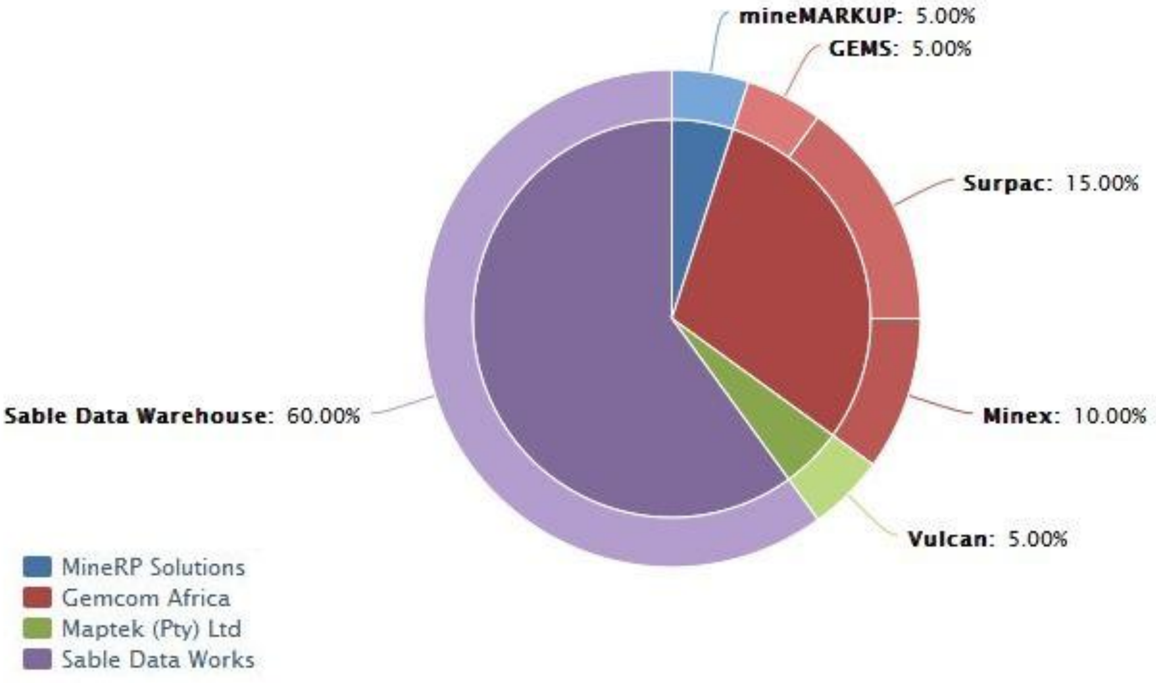

Figure 5-9 Geological data management software relative market share for PGM sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

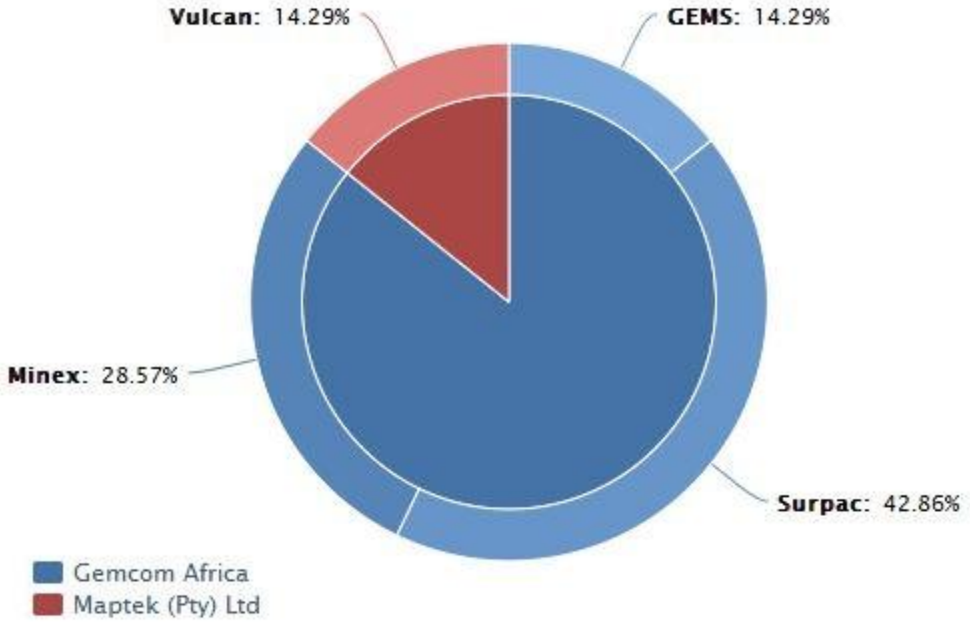

Figure 5-10 Geological modelling and resource estimation software relative market share for PGM sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

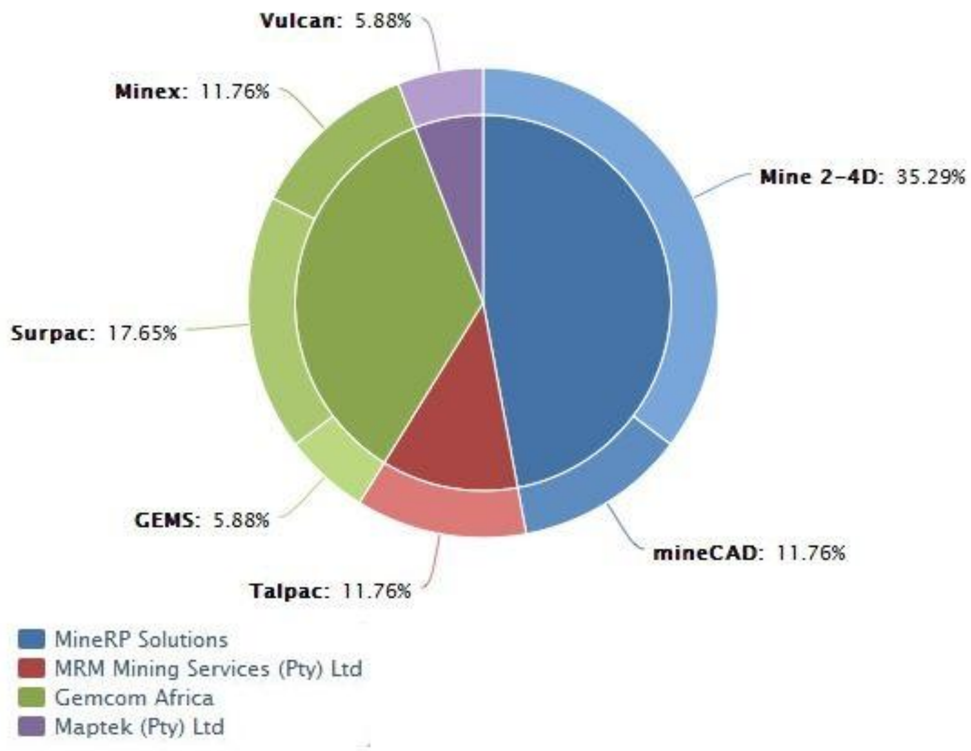

Figure 5-11 Design and layout software relative market share for PGM sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

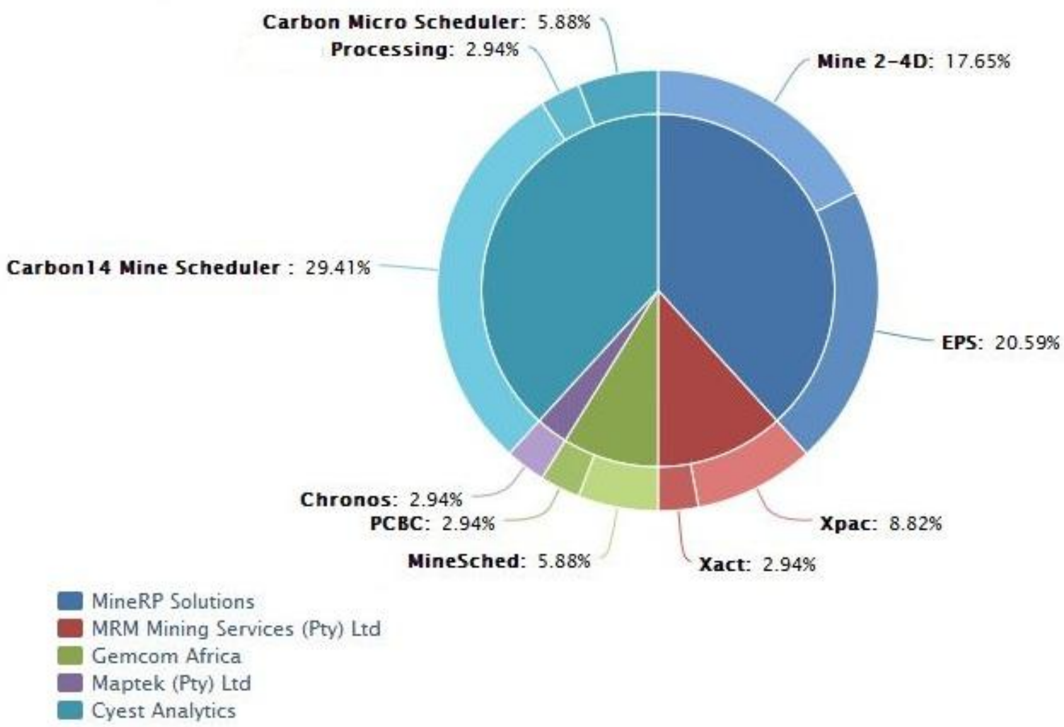

Figure 5-12 Scheduling software relative market share based on PGM sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

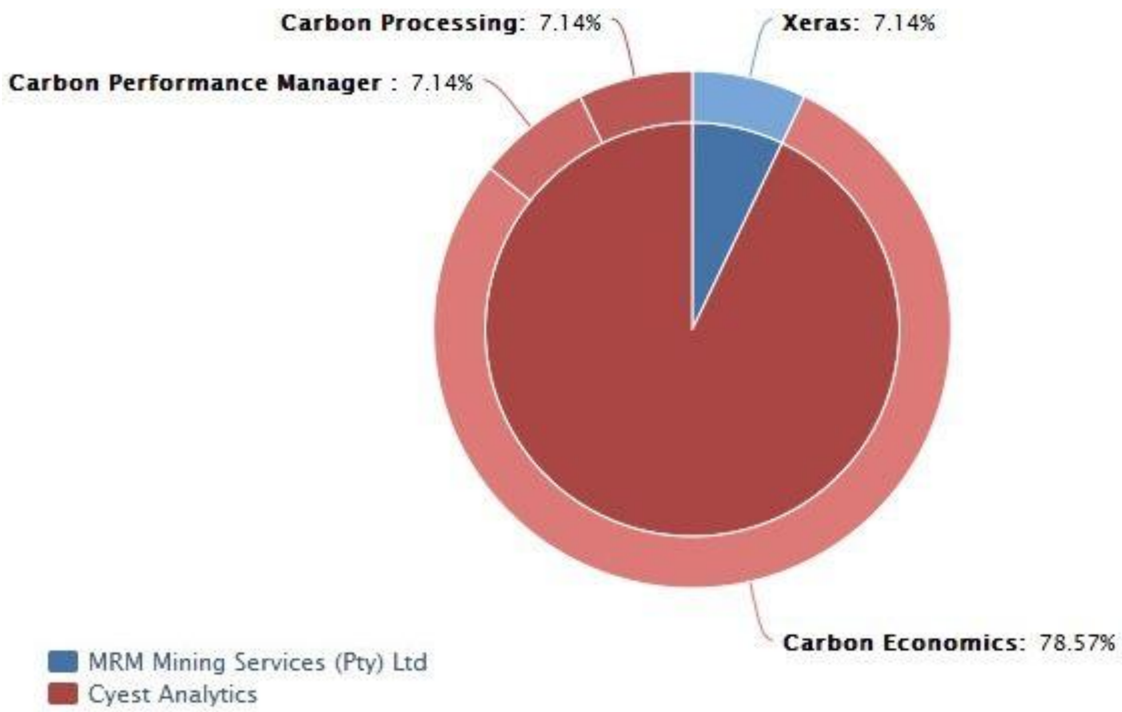

Figure 5-13 Financial valuation software relative market share for PGM sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

5.5.4 *Analysis of the market share based on sites producing gold*

Table 5-27 shows the software that is installed at gold mining sites and their functionalities. The graphs from Figure 5-14 up to Figure 5-18 give a measure of how prevalent the solutions are, relative to their competition, for a given functionality.

Table 5-27 Functionalities of software installed at sites producing gold

Software	Geological data management	Geological modelling and resource estimation	Design and Layout	Scheduling	Financial valuation
SABLE Data Warehouse					
mineMARKUP					
Surpac					
GEMS					
Minex					
Vulcan					
VUMA-Network					
Talpac					
mineCAD					
Mine 2-4D					
EPS					
Chronos					
Carbon 14 Mine Scheduler					
Carbon Micro Scheduler					
MineSched					
PCBC					
EPS Viz (Visualizer)					
EPS-PCBC Interface					
Xpac					
Carbon Processing					
Carbon Economics					
Carbon Performance Manager					
Whittle					

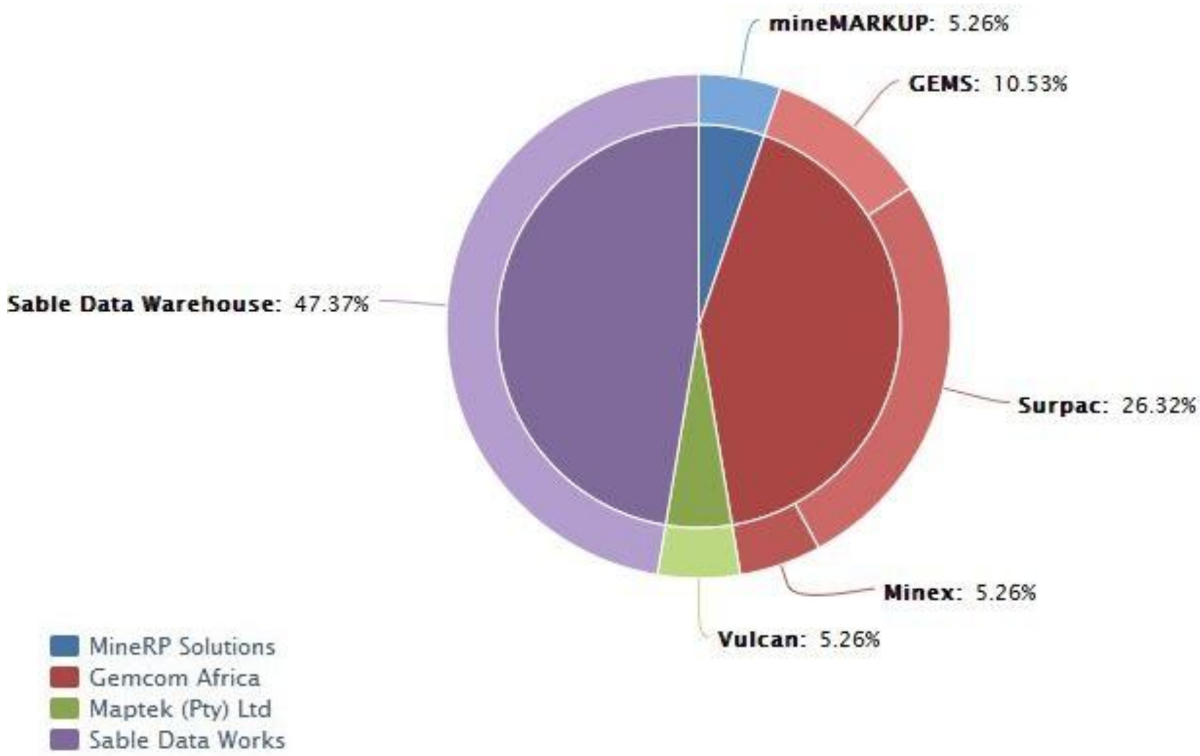

Figure 5-14 Geological data management software relative market share for gold sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

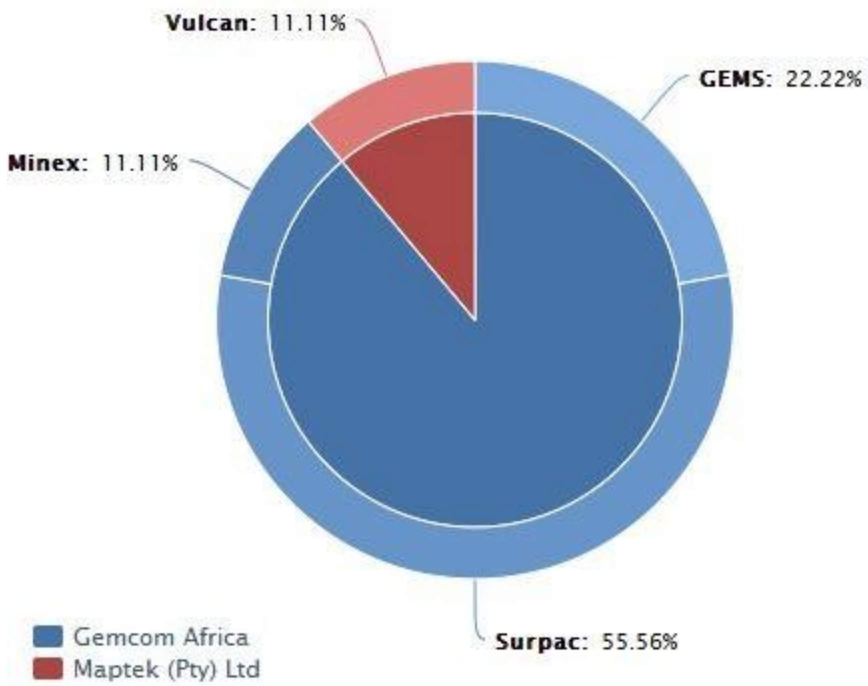

Figure 5-15 Geological modelling and resource estimation software relative market share based on gold sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

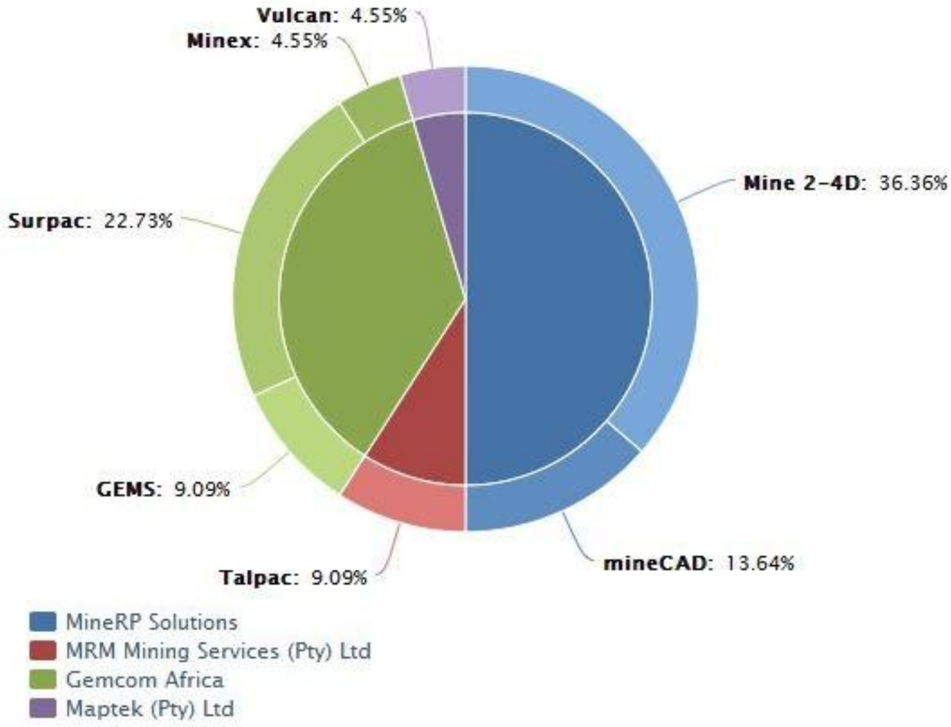

Figure 5-16 Design and layout software relative market share for gold sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

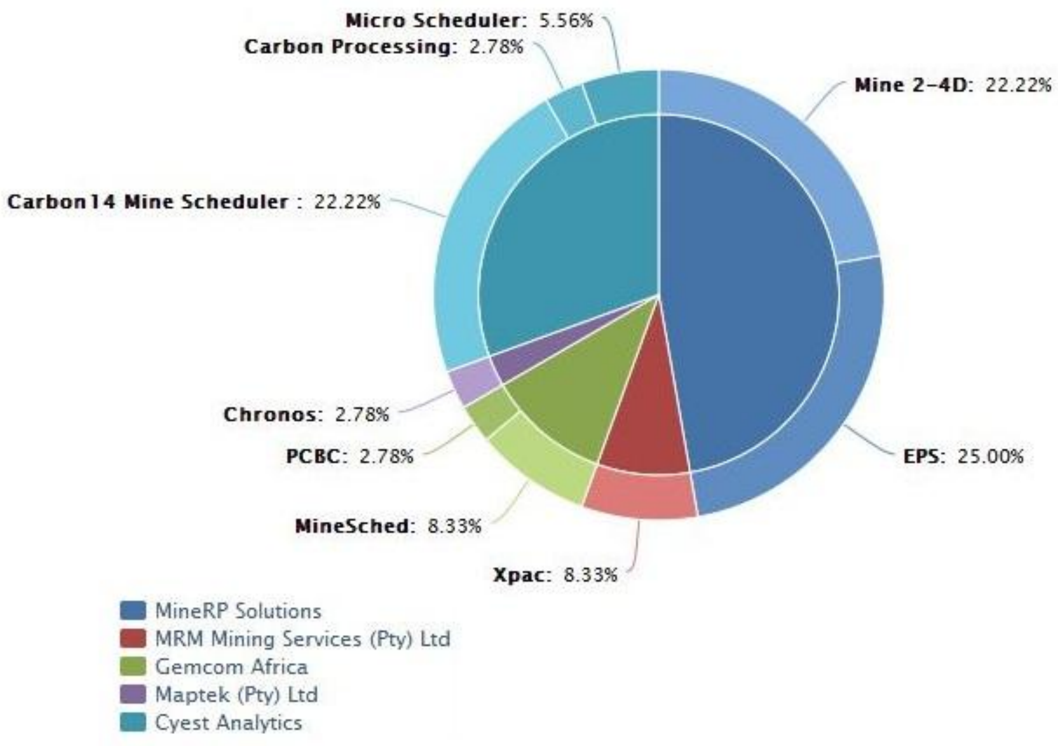

Figure 5-17 Scheduling software relative market share for gold sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

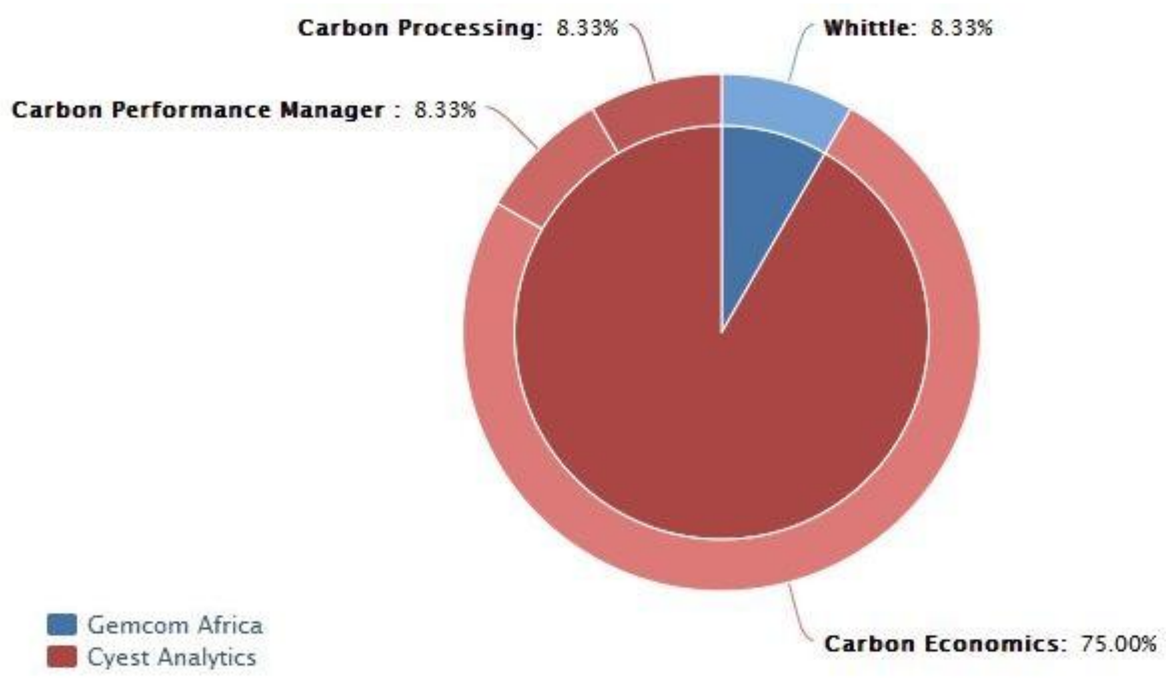

Figure 5-18 Financial valuation software relative market share for gold sites (based on software information received between June 2011 and June 2012 and mining sites as at December 2009)

5.6 Summary

This chapter served to inform the reader about how to access the database of mine planning and peripheral software used in the South African mining industry. It presented a summary of the results obtained during the course of carrying out this dissertation. The results are not static. The reader may access the database to find out if the data has changed and how the analyses change as the database is updated. The final chapter, which concludes this dissertation, follows next.

6 CONCLUSION

6.1 Chapter overview

As was noted in Section 1.2, the nature and extent of software utilisation has never been evaluated. This observation was corroborated by the scarcity of literature in this area of study in Section 2.5. The aim of this dissertation is to establish a starting point for addressing the inadequacies indicated. This chapter concludes this dissertation by highlighting what has been achieved by this dissertation, assessing the limitations that constrain the dissertation and suggesting future directions for further research.

6.2 Contribution

The methodology for evaluating the nature and extent of mine planning and related software utilisation in the South African mining industry included developing a database of this software and deploying the database online. This in itself reflects a new way of seeking to answer similar research problems. In the past, a researcher would take a statistically significant sample and try to draw inferences therefrom. However, this dissertation takes into account that the mining industry is diverse and software utilisation is fragmented across and within sectors of the mining industry (Section 3.5). In addition, the nature and extent of software utilisation varies with time. Having a database that is capable of capturing information from the entire population coupled with the potential to be updated over time presents a powerful tool to deal with these issues.

Since the database is deployed online, the dissertation ceases to be purely of academic interest. Its results are accessible to a wider audience. The intended beneficiaries of the database are educational institutions, consulting companies, mining companies and software providers. Professionals in these companies may access the database and extract relevant information which is useful in decision making for their respective specialities. Having an online database complements the idea of having a workbook using a web-based wiki framework (Lyle, McKinnon, McIsaac and Dasys, 2011), referred to in Section 2.5, which seeks to counter the challenge of skills shortage in the field of mine design and planning.

6.3 Limitations and constraints

Although this dissertation has achieved its aim, there are some limitations and constraints which need to be considered. These are:

- access to information;
- reliability of data;
- legal and ethical constraints; and
- personal skills of the researcher.

6.3.1 *Access to information*

A major problem is that less senior contacts will have to obtain permission in order to supply information which is deemed private, while those who are more senior are generally not available. Some companies have their main offices outside South Africa. As a result, information from one of the companies which is widely accepted to be a major supplier of mine technical solutions, CAE Mining, was not available at the time of submission of the dissertation. Not having direct communication with the contacts with the final say on which information to provide may have impeded the access to it. On-going efforts are being made to obtain outstanding information. The limitation is expected to be surmounted as the significance of the database gains acceptance in the industry.

6.3.2 *Reliability of data*

The list of operating mines, quarries and processing plants obtained from the DMR website has data as at the end of the year 2010. From then up to now this information has changed as some projects have now become fully operational mines and some mines may have ceased operations. There was no straightforward way to get the current list of operational mine sites. Data from suppliers that indicated the existence of a mine not included in the list was verified by contacting the mining companies or checking their websites to ascertain the existence of such mines. This shows that there is an error in the analysis of adoption of software at mining sites. The number of instances of this discrepancy was very small (less than ten) compared to the number in the full list. Therefore the error may be considered to be minimal.

Information supplied by users about the software used at a site was found to be inaccurate at times. In one instance a software package was attributed to the wrong supplier. That is why the decision was made to obtain information about clients from suppliers. However, this presents a challenge of suppliers misrepresenting information to prop up their figures so as to appear to have a larger market share than they have. This can be done in a number of ways including, but not limited to, presenting a module of a package as a standalone package or including software installed at sites outside South Africa. To the extent possible, the researcher verified the information provided.

6.3.3 *Legal and ethical constraints*

Understandably information collected from suppliers of mine planning and related software is considered confidential. It must be kept secure and be used to present summary information. The raw data may not be accessible to anyone who wishes as this may give competitors an unfair advantage. This may also breach the confidentiality agreements that have been reached with some companies. For these reasons, access to raw data is limited to the respective companies that provided it and to the supervisors of this dissertation to verify the validity of the data.

6.3.4 *Personal skills of the researcher*

Building a web based database of mine planning software may be perceived to be simple and straightforward. However, the reality is that, as with any software development project, there are several skills that are needed for the project to succeed. The work is usually done by a team with each member contributing his strengths at the various stages. These may be good communication skills when it comes to gathering data from personal sources of information, sound analytical skills when analysing the requirements of a project and strong design skills at the design stage. At the implementation stage, the technologies available to implement the backend database and the frontend application for accessing the data are varied. Various skills come into play for producing an application that is functional, easy to use while being aesthetically pleasing. Enhancing the requisite personal skills and learning new technologies required considerable effort for an individual within the time constraints of carrying out a dissertation.

6.4 Future work

This dissertation has established a reference point for exploring other research questions. Using this dissertation as a starting point work on a thesis investigating optimal utilisation of mine planning software has commenced in the School of Mining at the University of the Witwatersrand, Johannesburg. Information in the database may be expanded to include the contribution of the individual mining sites to the economy so that an analysis can be made about whether there is a correlation between adoption of software and the contribution made. This will assist providers in evaluating whether to direct their marketing campaigns to companies that have not adopted software.

The database is designed in such a way that it can be extended. It may be extended to include data from other countries. Another addition which may be useful is a forum for dialogue between mine technical solutions suppliers and users on which suppliers can make news releases and users can give feedback. Work is being done to include time trend analysis. The data used in the analysis will be related to the time period in which it was current so that an investigation can be done on how the adoption and relative market share of software solutions change over time.

6.5 Conclusion

A database of mine planning and peripheral software was developed and implemented. The database is available online and analyses can be made from the information contained therein to answer pertinent questions. It is hoped that the acceptance of the significance of this dissertation is sustained from now on and the database benefits the current and future generations of mining industry professionals.

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APPENDIX A. Extract from the physical schema of the database

The physical schema is the SQL code used to build the database. The following is an extract of the code used to create some of the tables, add constrains to them and insert data into one of the tables.

```
-- Table structures
-----------------------------------------------------------------
CREATE TABLE `client_company_assn` (
  `client_id` int(11) NOT NULL,
  `company_id` int(11) NOT NULL,
  PRIMARY KEY (`client_id`,`company_id`),
  KEY `fk_client_company_assn_company1` (`client_id`),
  KEY `fk_client_company_assn_company2` (`company_id`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1;

CREATE TABLE `commodity` (
  `id` tinyint(3) NOT NULL AUTO_INCREMENT,
  `name` varchar(45) NOT NULL,
  `commodity_type_id` tinyint(3) NOT NULL,
  PRIMARY KEY (`id`,`commodity_type_id`),
  KEY `fk_commodity_commodity_type1` (`commodity_type_id`)
) ENGINE=InnoDB  DEFAULT CHARSET=latin1;

CREATE TABLE `commodity_company_assn` (
  `commodity_id` tinyint(3) NOT NULL,
  `company_id` int(11) NOT NULL,
  PRIMARY KEY (`commodity_id`,`company_id`),
  KEY `fk_commodity_company_assn_company1` (`company_id`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1;

CREATE TABLE `commodity_type` (
  `id` tinyint(3) NOT NULL AUTO_INCREMENT,
  `name` varchar(45) NOT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB  DEFAULT CHARSET=latin1;

CREATE TABLE `company` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `name` varchar(256) NOT NULL,
  `address_1` varchar(45) DEFAULT NULL,
  `address_2` varchar(45) DEFAULT NULL,
  `address_3` varchar(45) DEFAULT NULL,
  `postal_code` varchar(8) DEFAULT NULL,
  `city` varchar(45) DEFAULT NULL,
  `country` varchar(45) DEFAULT NULL,
  `date_established` date DEFAULT NULL,
  `notes` text,
  `company_profile_type_id` tinyint(3) NOT NULL,
  PRIMARY KEY (`id`),
  KEY `name_idx` (`name`(255)),
  KEY `fk_company_company_profile_type_id1` (`company_profile_type_id`)
) ENGINE=InnoDB  DEFAULT CHARSET=latin1;

CREATE TABLE `company_profile_type` (
  `id` tinyint(3) NOT NULL AUTO_INCREMENT,
  `name` varchar(45) DEFAULT NULL,
  PRIMARY KEY (`id`),
  UNIQUE KEY `name` (`name`)
```

```
) ENGINE=InnoDB  DEFAULT CHARSET=latin1;

CREATE TABLE `provider_software_assn` (
  `company_id` int(11) NOT NULL,
  `software_id` int(11) NOT NULL,
  PRIMARY KEY (`company_id`,`software_id`),
  KEY `fk_provider_software_assn_company` (`company_id`),
  KEY `fk_provider_software_assn_software` (`software_id`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1;

CREATE TABLE `software` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `name` varchar(100) NOT NULL,
  PRIMARY KEY (`id`),
  KEY `name_idx` (`name`)
) ENGINE=InnoDB  DEFAULT CHARSET=utf8;

-- Constraints for tables
-------------------------------------------------------------------------
ALTER TABLE `client_company_assn`
  ADD CONSTRAINT `fk_client_company_assn_company1` FOREIGN KEY
(`client_id`) REFERENCES `company` (`id`) ON DELETE CASCADE ON UPDATE
CASCADE,
  ADD CONSTRAINT `fk_client_company_assn_company2` FOREIGN KEY
(`company_id`) REFERENCES `company` (`id`) ON DELETE CASCADE ON UPDATE
CASCADE;

ALTER TABLE `commodity`
  ADD CONSTRAINT `fk_commodity_commodity_type1` FOREIGN KEY
(`commodity_type_id`) REFERENCES `commodity_type` (`id`) ON UPDATE CASCADE;

ALTER TABLE `commodity_company_assn`
  ADD CONSTRAINT `fk_commodity_company_assn_commodity1` FOREIGN KEY
(`commodity_id`) REFERENCES `commodity` (`id`) ON UPDATE CASCADE,
  ADD CONSTRAINT `fk_commodity_company_assn_company1` FOREIGN KEY
(`company_id`) REFERENCES `company` (`id`) ON UPDATE CASCADE;

ALTER TABLE `company`
  ADD CONSTRAINT `fk_company_company_profile_type_id1` FOREIGN KEY
(`company_profile_type_id`) REFERENCES `company_profile_type` (`id`) ON
UPDATE CASCADE;

ALTER TABLE `provider_software_assn`
  ADD CONSTRAINT `fk_provider_software_assn_company` FOREIGN KEY
(`company_id`) REFERENCES `company` (`id`) ON DELETE CASCADE ON UPDATE
CASCADE,
  ADD CONSTRAINT `fk_provider_software_assn_software` FOREIGN KEY
(`software_id`) REFERENCES `software` (`id`) ON DELETE CASCADE ON UPDATE
CASCADE;

-- Insert statement for 'mine_value_chain_stage' table
-------------------------------------------------------------------------
INSERT INTO `mine_value_chain_stage` (`id`, `name`, `description`) VALUES
   (1, 'Discover', NULL),
   (2, 'Establish', NULL),
   (3, 'Exploit', NULL),
   (4, 'Beneficiate', NULL),
   (5, 'Sell', NULL),
   (6, 'Rehabilitate', NULL);
```

APPENDIX B. Code snippet showing how data arrays to be used in a chart were obtained

The following is an extract of the PHP code used to create arrays in conjunction with the Highcharts javascript library for charting. The arrays hold data that is used to calculate the market share for companies and the software they provide. The comments for describing key statements are in green after the forward slashes.

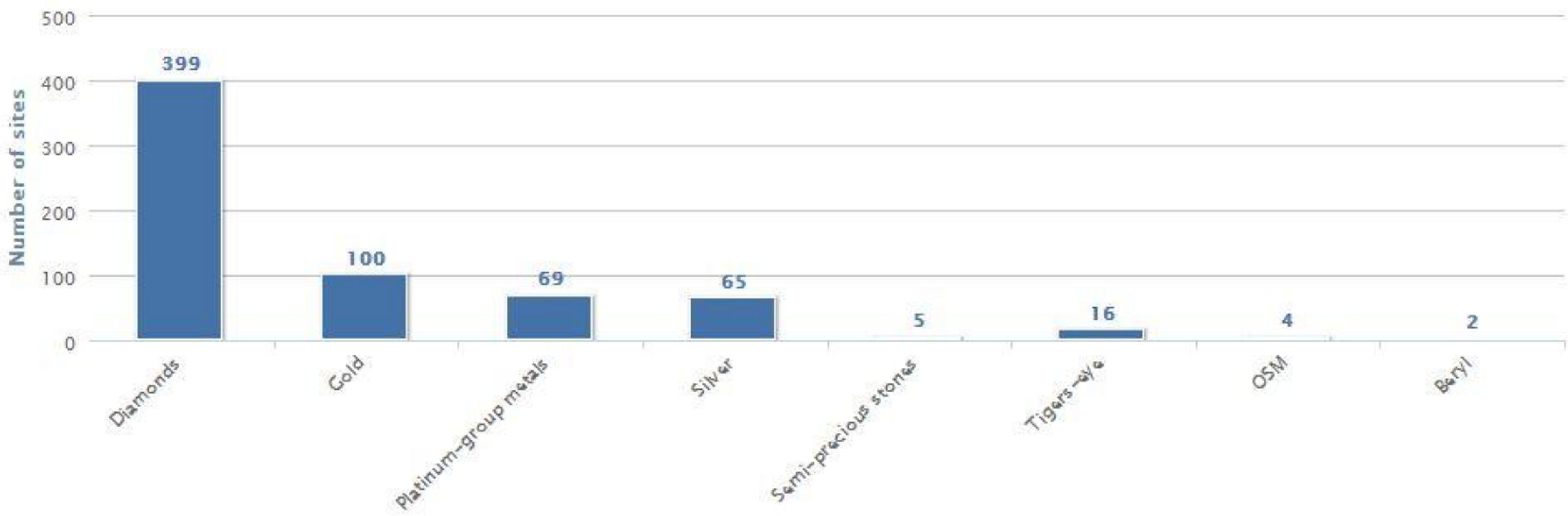
```
// load the array $arrCompanies with Companies that provide software
$arrCompanies = Company::QueryArray(QQ::In(QQN::Company()->Id,
      QQ::SubSql("SELECT DISTINCT `site_software`.`provider_id` FROM
      `site_software`")));

//iterate through the provider companies
foreach ($arrCompanies as $company) {
// load the array $arrClientSites with sites that use software (standalone
not modules) provided by the company on the current iteration
$arrClientSites = SiteSoftware::QueryArray(QQ::AndCondition(QQ::Equal
      (QQN::SiteSoftware()->ProviderId, $company->Id),QQ::Not(QQ::In(
      QQN::SiteSoftware()->SoftwareId, QQ::SubSql("SELECT DISTINCT
      `software_module_assn`.`module_id` FROM `software_module_assn`")))));
if (sizeof($arrClientSites) != 0) {
// fill arrays that hold the company names and number of client sites for
use in highcharts
$arrCompanyName[] = "'" . $company->Name . "'";
$arrCompanyData[] = sizeof($arrClientSites);
// fill the array that holds the software provided by the company on the
current iteration
$arrSolutionsProvided = Software::LoadArrayByCompanyAsProvider($company-
>Id);
if (sizeof($arrSolutionsProvided) != 0) {
unset($arrSoftwareName, $arrSoftwareData);
//iterate through the software
foreach ($arrSolutionsProvided as $software){
// load the array $arrSiteSoftware with sites that use software on the
current iteration
$arrSiteSoftware = SiteSoftware::QueryArray(QQ::AndCondition(
      QQ::Equal(QQN::SiteSoftware()->ProviderId, $company->Id),
      QQ::Equal(QQN::SiteSoftware()->SoftwareId, $software->Id),
      QQ::Not(QQ::In(QQN::SiteSoftware()->SoftwareId, QQ::SubSql("SELECT
      DISTINCT `software_module_assn`.`module_id` FROM
      `software_module_assn`")))));
if (sizeof($arrSiteSoftware) != 0){
// fill arrays that hold the company names and number of client sites
$arrSoftwareName[] = "'" . $software->Name . "'";
$arrSoftwareData[] = sizeof($arrSiteSoftware);
}// close if
}// close foreach
// update arrays that hold the names names and number of user sites for use
in highcharts
$arrCompanySoftwareNames[] = $arrSoftwareName;
$arrCompanySoftwareData[] = $arrSoftwareData;
}// close if
}// close if
}// close foreach
```

APPENDIX C. Graphs showing the distribution of sites that produce mineral commodities

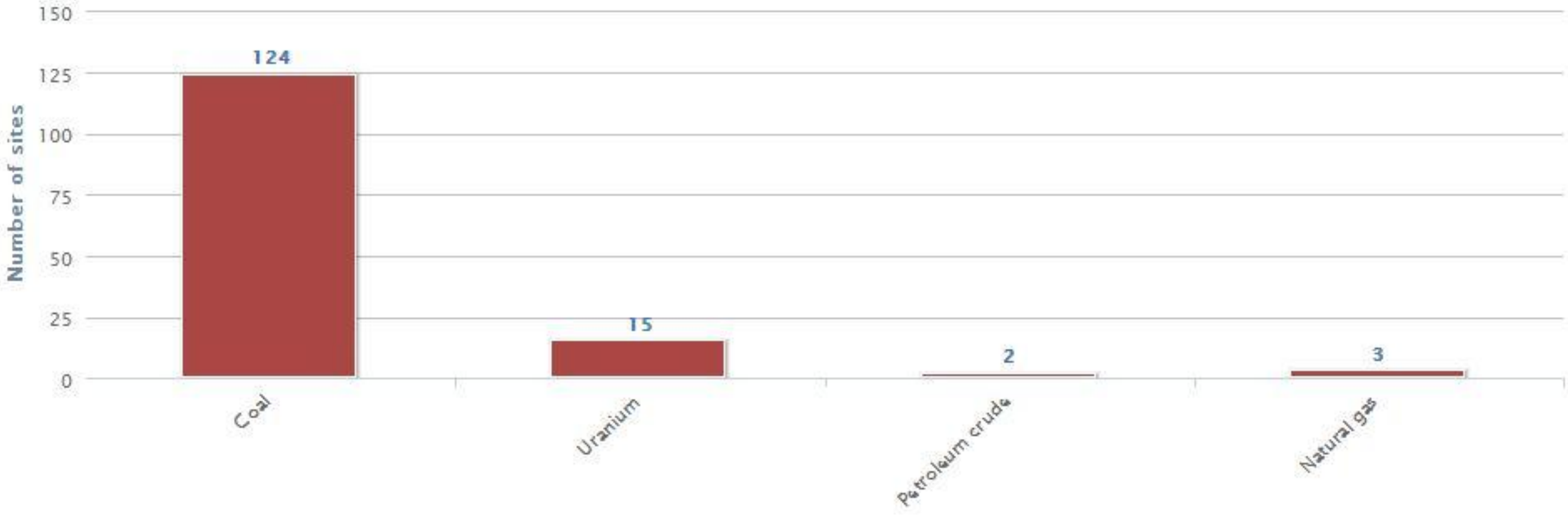
The total number of sites may differ from the sum of the number of sites for each individual mineral commodity because a site may be producing more than one commodity or mineral commodities from different categories.

Figure C-1 Distribution of sites producing precious metals and minerals



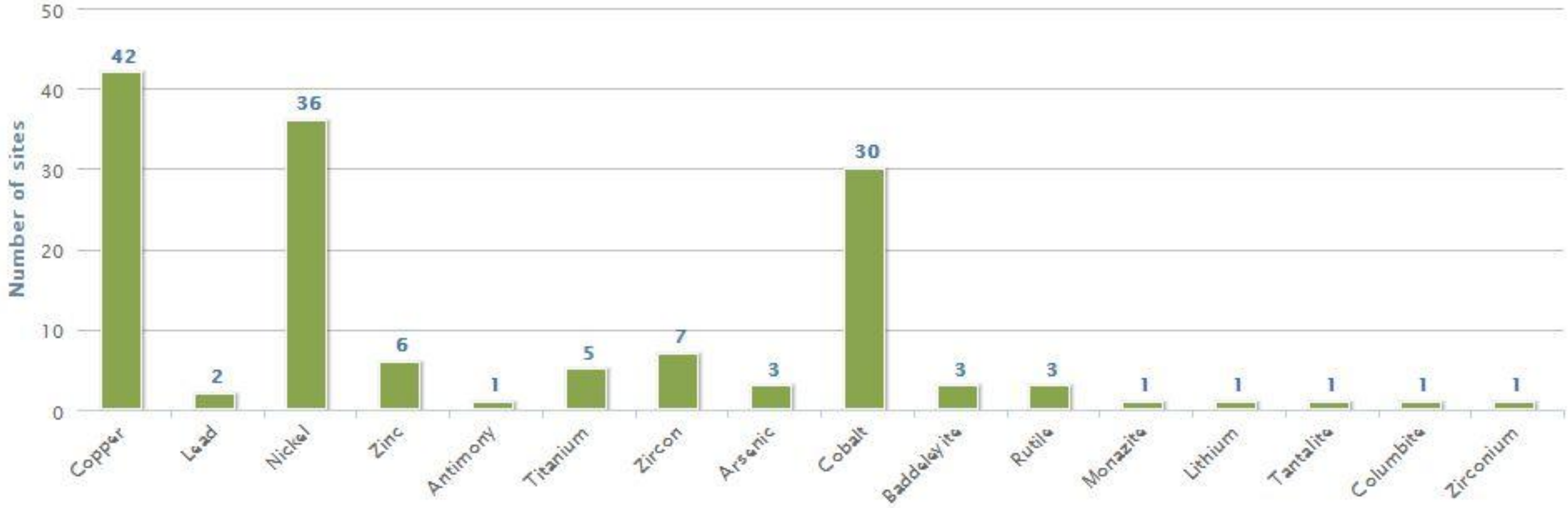
Number of sites represented: 530 (based on DMR figures as at December 2009)

Figure C-2 Distribution of sites producing energy commodities



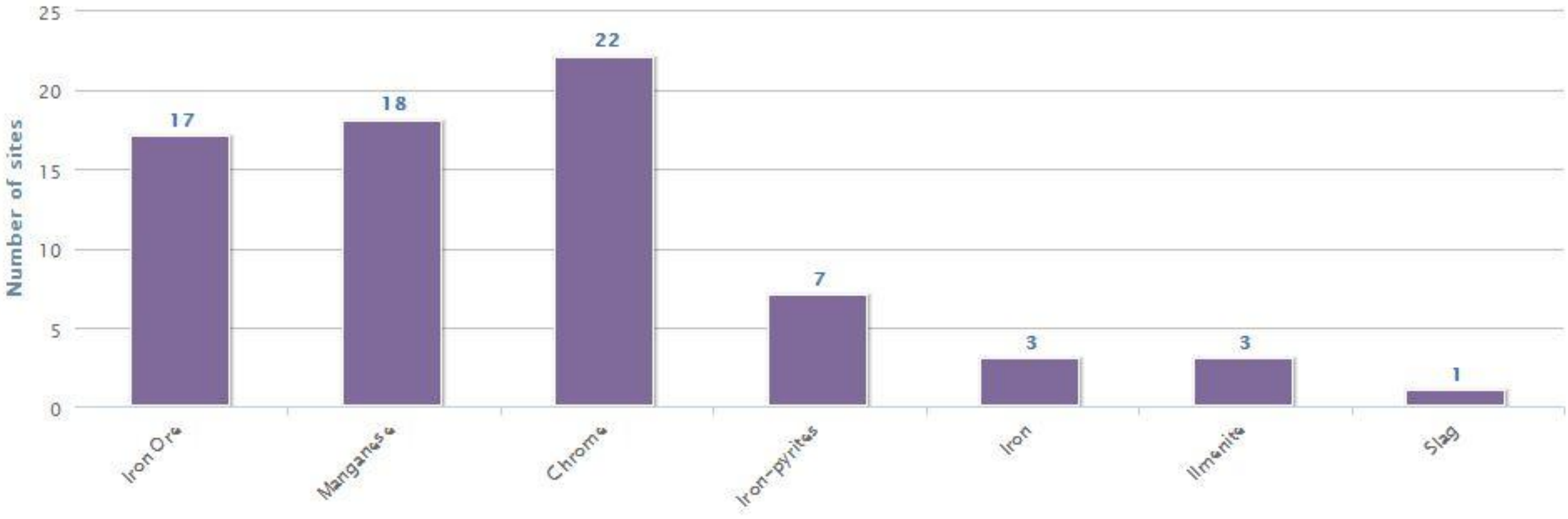
Number of sites represented: 144 (based on DMR figures as at December 2009)

Figure C-3 Distribution of sites producing nonferrous metals



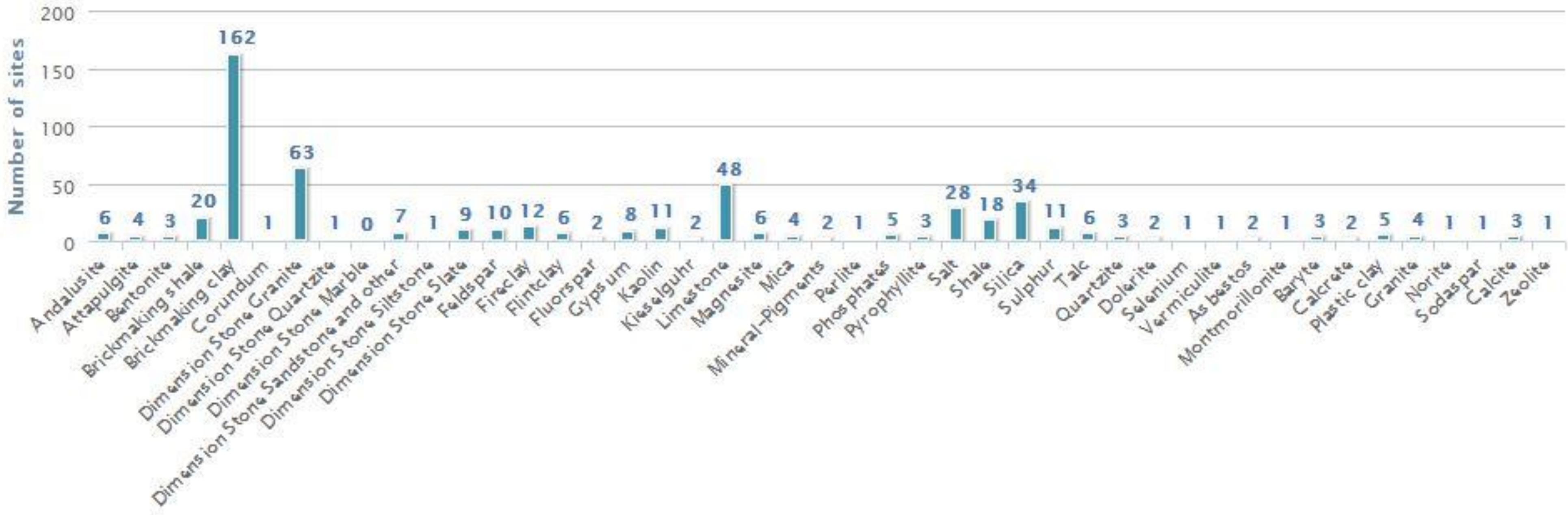
Number of sites represented: 50 (based on DMR figures as at December 2009)

Figure C-4 Distribution of sites producing ferrous metals



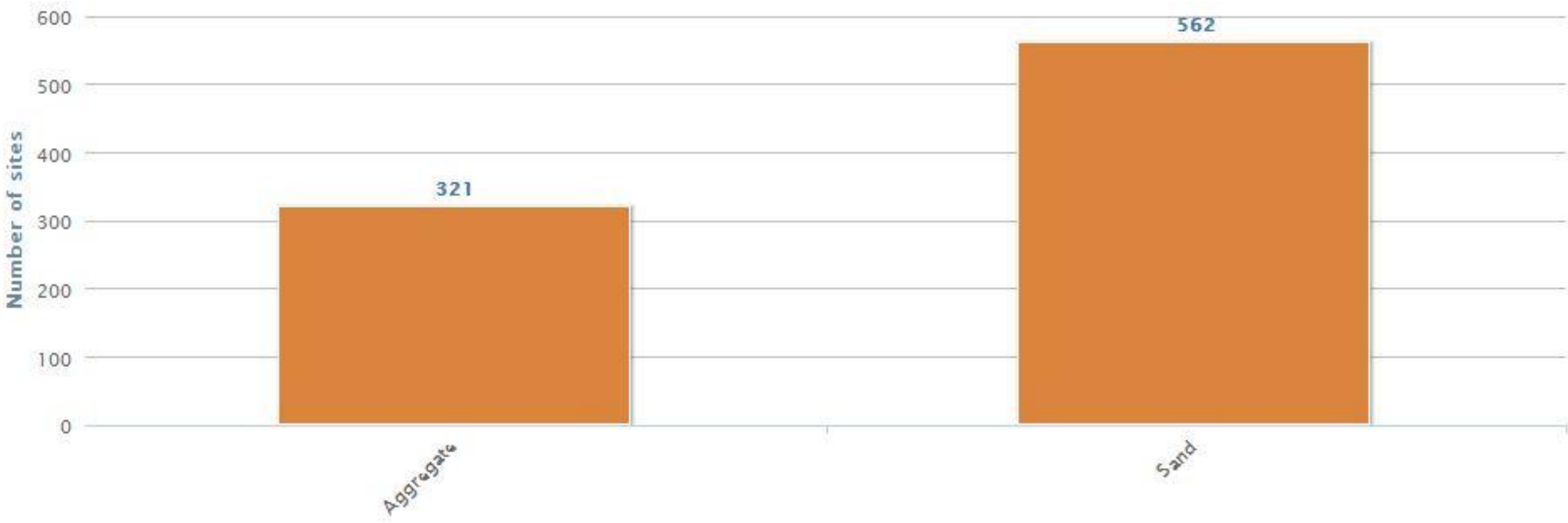
Number of sites represented: 60 (based on DMR figures as at December 2009)

Figure C-5 Distribution of sites producing industrial minerals



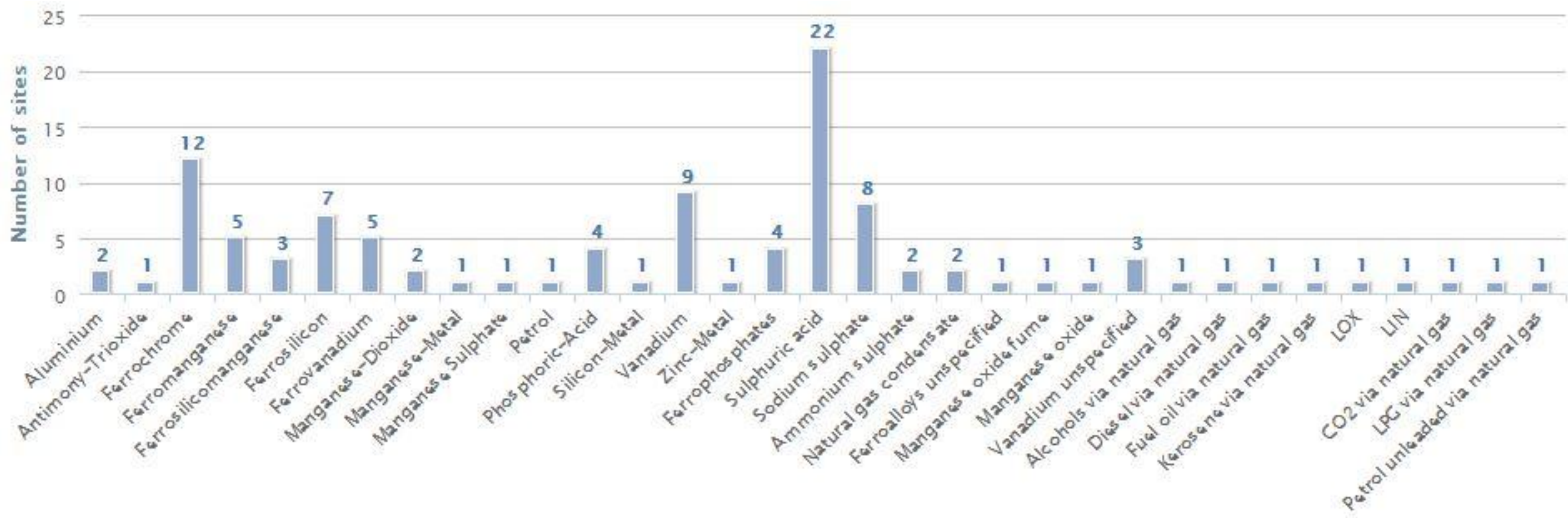
Number of sites represented: 390 (based on DMR figures as at December 2009)

Figure C-6 Distribution of sites producing aggregate and sand



Number of sites represented: 570 (based on DMR figures as at December 2009)

Figure C-7 Distribution of sites producing processed minerals



Number of sites represented: 60 (based on DMR figures as at December 2009)