# Analyzing an orthophoto mapping system using system analysis, SWOT and client satisfaction survey: a case study of the Chief Directorate of Surveys and Mapping, Republic of South Africa

**by**

Mnqweno Mnyengeza

A mini-dissertation submitted to the University of KwaZulu-Natal in partial fulfillment of the requirements for a Masters Degree in Land Information Management in the Centre for Environment, Agriculture and Development (Pietermaritzburg)

Study Supervisor: Dorman Chimhamhiwa

**February 2010**

# DEDICATION

*'I will say of the Lord, He is my Refuge and my Fortress, my God; on Him I lean and rely, and in Him I confidently trust!' (Psalm 91:2)*

*To my loving and caring father Manduleli Mnyengeza, who passed away while I was busy working on this research for his love and support that made me who I am today. Sangweni, you were and will always be my inspiration and may your soul rest in peace.*

# ACKNOWLEDGEMENTS

Different individuals and groups have played a tremendous role in making this research a success and I would like to honour such roles and contributions:

- Firstly, I would like to extend my sincere gratitude to the Management of the office of the Surveyor-General in Cape Town for their support, encouragement and trust that led me to enrol in this program.
- Secondly, to Mr Dorman Chimhamhiwa, my study supervisor, for his patience, guidance and understanding of the challenges and responsibilities of a full-time worker who is a full-time student at the same time.
- The Director of Cartographic Services at CDSM, Mr Victor Mdwara, for his guidance in terms of technical and grammatical correctness of the thesis, and he has been my secondary supervisor.
- The Assistant Director of CDSM Client Relations Management, Dr Francis Twumasi for all the guidance and advice which he rendered within a short period of joining CDSM
- Mr Chris Boonzaier for proof reading and adding grammatical and academic taste to the thesis in order to ensure that it is indeed fit to be referred to as an official academic report.
- My friend, Jerry Mofoka, for proof reading and giving advice and motivation from the beginning to the end of this research.
- My colleagues from the Orthophoto Mapping Division, Mrs Judith Velemani and Mr Yalezo Rasonti, for their willingness to contribute on technical debates that paved the direction of this research
- Ms Linda Fedder, a Principal Librarian at CDSM, for her willingness in assisting me to dig for the relevant literature sources and Mrs Mariana French, the Deputy Director in Cartographic Services, for all the admin work that she did on my behalf.
- All my colleagues from CDSM for their different contributions to this thesis.
- All the friends I made at UKZN through Rev. Armando Sontange. Gents, you have made KZN feel like home and I appreciated my stay with you.
- My lovely wife (Asandiswa Sphelele Mnyengeza) and my kids for their understanding and willingness to award me more time away from them in pursuing this research

# DISCLAIMER

I, MNQWENO MNYENGEZA hereby declare that the work contained in this mini-dissertation is my own original research and that it has not previously in it's entirely or in parts been submitted to any university or other tertiary institution for degree accreditation. Where other author's work has been used, it is duly acknowledged in the text.

2010-02-26

MNQWENO MNYENGEZA

DATE

DORMAN CHIMHAMHIWA

2010-02-26

SUPERVISOR

DATE

:

# ABSTRACT

An orthophoto map is made from a combination of different geospatial datasets such as relief, imagery, powerlines and annotation. These data sets are usually generated by different divisions within national mapping agencies. Often, when an orthophoto mapping project is to be undertaken, other functions within and outside the system, are actuated. Examples of such functions include; photogrammetric scanning, digital elevation capturing, aerial triangulation, ancillary data and imagery acquisition and map compilation.

This research is underpinned by the hypothesis that different components that supply data required for generating orthophoto maps do not work as a coherent whole. This behaviour impacts negatively on the production of orthophoto maps as well as the quality of the end product and can have spill over effects on service delivery. In this research, systems analysis, client satisfaction survey and SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis are used as a collective set of tools to analyze an orthophoto mapping system (OMS) in order to mitigate this unwanted behaviour. The case of orthophoto map production at the Chief Directorate of Surveys and Mapping (CDSM) in South Africa is used. First, systems analysis, which uses the Data Flow Diagram (DFD) technique, is employed to depict the system‘s data stores, processes and data flows. This approach helps to show how the current system works thereby assisting to pin point areas that require improvement. After presenting the system ‘s processes, data stores and data flows, a client satisfaction survey, built on the criteria of; accuracy, completeness, correctness and accessibility of geospatial datasets, is conducted on one of the data stores – the Topographical Information System (TIS) database. Finally, a SWOT analysis is then done on the whole OMS to evaluate the internal and external environment under which the current system operates in. Gaps are identified and recommendations suggested. Although in this case, the recommendations are built based on the CDSM case study, it is believed they can benefit other OMS’s in similar operating conditions elsewhere.

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| | |
|---|---|
| **ADIA** | Ancillary Data and Imagery Acquisition |
| **AOI** | Area of Interest |
| **ATEC** | Aerial Triangulation and Elevation Capture |
| **BPR** | Business Process Reengineering |
| **CDSM** | Chief Directorate of Surveys and Mapping |
| **CSIR** | Council for Scientific and Industrial Research |
| **CARTO** | Directorate of Cartographic Services |
| **DBMS** | Database Management System |
| **DEM** | Digital Elevation Model |
| **DFD** | Data Flow Diagram |
| **DLA** | Department of Land Affairs |
| **DOH** | Department of Housing |
| **DTM** | Digital Terrain Model |
| **DWAF** | Department of Water Affairs |
| **EPS** | Encapsulated Postscript File |
| **FME** | Feature Manipulation Engine |
| **GIS** | Geographical Information System |
| **ISD** | Information Systems Development |
| **ISO** | International Organisation for Standardization |
| **JPEG** | Joint Photographic Expert Group |
| **LPI** | Land Planning and Information |
| **MOD** | Map on Demand |
| **LTVM** | Long Transactions and Version Management |
| **NIMAC** | National Imagery and Mapping Advisory Committee |
| **NJDOT** | State of New Jersey Department of Transport |
| **NMA** | National Mapping Agency |
| **OMS** | Orthophoto Mapping System |
| **QA** | Quality Assurance |
| **REPRO** | Reprographics |
| **SAGNC** | South African Geographical Names Council |

| | |
|---|---|
| **SANDF** | South African National Defence Force |
| **SDW™** | System Development Workbench |
| **SIS** | Spatial Information Systems |
| **SMAC** | Statewide Mapping Advisory Committee |
| **SPSS™** | Statistical Package for the Social Sciences |
| **SQL** | Structured Query Language |
| **STATSSA** | Statistics South Africa |
| **SWOT** | Strengths, Weaknesses, Opportunities and Threats |
| **TIFF** | Tagged Information File Format |
| **TIS** | Topographical Information System |
| **™** | Trademark |
| **UTM** | Universal Transverse Mercator |
| **UNEP** | United Nations Environment Program |
| **WGS84** | World Geodetic System – 1984 |

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# CHAPTER 1: INTRODUCTION

## 1.1 Background

Often, production systems that consist of multiple detached sub systems (complex systems) face many challenges when they attempt to work as a unified whole. Such challenges include fragmentation of production activities and prevalence of silo based approaches within the entities. Maenetja (2009) argues that silos emanate from lack of cross-functional communication, cross-functional planning and failure to share information by the divisions within the same organisation. National Mapping Agencies (NMA) are amongst such complex systems which experience similar problems. NMAs are mandated by their respective communities to develop and produce multiple geospatial products that meet acceptable quality, correctness and reliability. Amongst such products are orthophoto maps. This research utilise multiple concepts to analyze the impact of lack of the integration in the production of orthophoto maps. Based on the analysis of a case study, gaps are identified and improvement options suggested.

An orthophoto map is a combination of a line map and an aerial photographic image whose distortions have been eliminated (CDSM, 2008). After the elimination of distortions in the photographic image, the image is then technically referred to as an ortho-rectified image. The ortho-rectified image serves as a backdrop whereupon some relief data such as contours, spot heights, and trigonometrical beacons are added to make a complete orthophoto map. Modern orthophoto mapping is digital and computer systems based in nature. Remotely sensed imagery from satellites and aerial photography are the main sources of image acquisition for producing orthophoto maps. This research focuses exclusively on the 1:10 000 orthophoto map series whose imagery has been acquired through film based aerial photography. The image background of an orthophoto map portrays a true reflection of the landscape and makes this map series easier to read and understand compared to line maps. Orthophoto maps are referred to as large scale maps, meaning that they portray a small area in greater detail. There are various fields in which orthophoto maps are used as a reliable source of information for decision making. These fields include spatial development planning, census, land reform, civil engineering and environmental management among others.

Like other complex systems, the production of orthophoto maps is usually spread across multiple autonomous role-players. In digital orthophoto production systems, components such as; aerial photography acquisition, ground control, photogrammetric scanning, digital elevation model, aerial triangulation, ortho-rectification and annotation, can be controlled by different autonomous organizations. Such circumstances are common in most NMAs particularly where non core functions are outsourced to private contractors.

### 1.2 Problem statement

The fragmentation of orthophoto map production systems can result in silo based approaches being adopted within the different production units. Silo based approaches are usually caused by a number of factors. These include lack of common goal sharing, lack of cooperation and lack of understanding of common and individual user needs. Silo operations between partners can lead to inefficiencies and dissatisfaction among users and data custodians. This research uses the Chief Directorate of Surveys and Mapping (CDSM), which is South Africa's National Mapping Agency (NMA), as a study area. The orthophoto mapping division (D: ORTHO) of CDSM faces a number of similar challenges, due to fragmentation of its production systems. The entities that supply the various data and information elements required for orthophoto map production; (1) appear not to be logically connected within and between each other, and (2) do not operate in unison. The lack of holism can be attributed partly to the lack of integration which in some cases has resulted in key production data sets being either unavailable when required or simply unfit for use. At CDSM, the key datasets required for orthophoto map production include; contours, spot heights, rectified images, trigonometric beacons, power lines, national boundaries, provincial boundaries and annotation data. This mixture of raster and vector data sets is produced by different autonomous entities within and outside CDSM. Most of these data sets are stored in an oracle database called the TIS and are accessible in different file formats. Different software packages and manipulating engines are used to extract, interpret and manipulate these datasets. The Map Data Processing (MDP) division, within CDSM, is responsible for ensuring accuracy, completeness, correctness and accessibility of all datasets before they get populated into the TIS. However, problems related to quality of supplied data have often been encountered when data for orthophoto production is retrieved from TIS. This has led to production delays and unnecessary frustrations, which sometimes have impacted on production targets and the quality of the end product.

### 1.3 Research objectives

The aim of this research is to utilise a combination of improvement tools, namely: systems analysis, client satisfaction survey and SWOT in order to improve the orthophoto mapping system of CDSM. The three approaches are applied simultaneously and complementary. The core objectives of this study are to:

1.3.1 Analyze the orthophoto mapping system in terms of its data flows, data stores and processes.

1.3.2 Investigate the level of satisfaction from the internal users of topographical data.

1.3.3 Conduct a SWOT analysis of CDSM with relevance to the orthophoto mapping system.

1.3.4 Suggest recommendations for improving the orthophoto mapping system.

### 1.4 Research questions

The set of questions stipulated below serve to give direction on the scope of this research:

1.4.1 How is CDSM’s current orthophoto mapping system structured and where are the gaps?

1.4.2 Are the internal users of topographical data satisfied with data quality with emphasis on accuracy, completeness, correctness and accessibility?

1.4.3 What are the internal and external factors that determine the production of orthophoto maps and what influence do they have on the system?

1.4.4 How can the current scenario be improved to ensure efficiency and effectiveness?

### 1.5 Research structure

The research is structured as follows. In chapter 1, the background, problem statement, research objectives and questions are presented. A review of relevant literature on systems analysis, SWOT analysis and the client satisfaction survey is provided in Chapter 2. Chapter 3 presents the orthophoto mapping case study area at the CDSM while Chapter 4 discusses the research materials and methodology used. The results and discussion are presented in Chapter 5.  Chapter 6 summarises the research findings, concludes and suggests recommendations for improving the current situation.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Introduction

The analysis of complex systems like orthophoto mapping is not new. However, many studies have shown that complex systems analysis lacks holism. This chapter investigates the suitability of three approaches, namely: systems analysis, client satisfaction and SWOT analysis, for analyzing OMS. This is achieved through a review of relevant works and cases where these have been successfully applied. Furthermore, a generic explanation of core elements of OMS's is also given. The chapter concludes with a conceptual discussion that links systems analysis, SWOT and user satisfaction survey in a single framework. The study focuses mainly on information systems that contribute to the production of orthophoto maps. First, a discussion on information systems is presented. A review of client satisfaction and SWOT is then conducted in subsequent sections.

Numerous approaches such as business process modelling, total quality management, systems analysis, SWOT analysis, user satisfaction surveys, amongst many others, have been used to analyze and improve organizational systems and their processes. However, most NMAs have preferred to use systems analysis to ensure the improvement of their business processes. In this study, systems analysis is complimented by SWOT analysis and client satisfaction surveys. In theory, there are various types of systems such as mechanical, electronic, ecological, biological and information systems. They all share the common characteristics:

i) they have a structure that is defined by their parts and processes. The various parts have functional as well as structural relationships between each other.

ii) they are generalizations of reality.

iii) they often function by taking input(s), that are then processed to generate output (s).

## 2.2 Information system analysis

Harris (1995) defines an information system as a well coordinated collection of resources that gather and transform data into information products and services to help the enterprise perform its designed functions. Hirschheim *et al*. (1995) argue that an information system consists of a collection of people, processes, data, models, technology and partly formalized language that form a cohesive structure which serves some organizational purpose or function.

Furthermore, some definitions of an information system refer to it as a two-dimensional concept, with one dimension relating to its structure and another to its function. From a functional perspective, an information system is defined by Langefors (1973) as a technologically implemented medium for the purpose of recording, storing and disseminating linguistic expressions as well as for supporting inference making. He further defines the systems analysis as an approach to problem solving that views problems as parts of an overall system, rather than reacting to present outcomes or events.

Zevenbergen (2004) argues that a systems approach is structured in such a way that the system is studied with emphasis on the relationships between its elements and the common goal that the whole seeks to achieve. Hawryszkiewycz (1988) describes the analysis phase as a stage used to gain an understanding of an existing system, whether it meets its expectations, whereas the design phase proposes the new system that meets these requirements. An analysis of how the current system works is one of the fundamental requirements in successfully conducting a systems analysis. It helps identify problem areas within the system that require improvement. Table 2.1 presents some key characteristics and benefits of systems analysis.

**Table 2.1: The characteristics and benefits of systems analysis**

| Characteristics | Benefits |
|---|---|
| • Understanding the environment within which the system operates | • Ensures that holistic strategies and policies are developed, as opposed to those which act in isolation to the whole |
| • Identifying the core elements of the system, as well as the system boundary | • Establishes a framework for assessing the impact and effectiveness of strategies and policies prior to implementation |
| • Understanding the role or function of each element in the system | • Provides a sound analytical basis for developing strategies and policies that are to be implemented in highly complex systems, such as companies, industries or national economies |
| • Understanding the dynamic interaction between elements of the system | |

Source: Adapted from: Technology Strategies International (2009) http://www.tsicanada.com/systems_approach.htm

Numerous studies have used system analysis to analyse different situations. For example, Karamouz *et al*. (2003) applied systems analysis in civil engineering to improve water resource planning and management systems. In the study, the data flow diagramming (DFD) technique was applied to decompose the existing system. Gaps and loopholes were then identified and a framework with suggestions for improvement was developed. (Zevenbergen, 2004) used a systems based approach to identify loopholes and shortcomings in land registration and the cadastre, in 4 countries. The objective of the study was to devise a holistic framework that could help integrate technical, legal and organizational aspects of land registration and their interrelations effectively. In the health sector, (Wing & Maloney, 1994) applied systems analysis as an underlying analytical concept to support a framework for managing complex asthma management processes in Australia. The as-is situational analysis consisted of identifying all technical issues, problems, gaps and opportunities associated with current asthma management in order to develop a new integrated system.

Orthophoto mapping as a complex system can be subjected to systems analysis in order to improve and keep the system abreast with changing times and demands. The aim of conducting systems analysis in this research is to analyze the relationship between data stores, data flows and processes which are critical for orthophoto map production. The

DFD, a technique which can graphically illustrate the relationship between data and processes (Chilufya, 1996), is used.

## 2.3 Client satisfaction survey

According to the World Health Organization (WHO, 2000), a client satisfaction survey can be defined as a tool used to formally integrate the business and its clientele in the evaluation of its products. It further assists organizations in addressing uncertainties related to: (i) assurance of reliability of the end product (s), (ii) measures of willingness of providers to meet client needs, and (iii) courtesy of providers. This tool also provides a platform for clients to express their concerns about the services rendered and their opinions regarding present and future needs. It is most efficient when it is designed to meet a specific objective and when it uses appropriate methods and measures (WHO, 2000). Client satisfaction and user need surveys are in most cases conducted simultaneously. Usually, instruments such as self administered questionnaires are often used to assess both the level of satisfaction and the needs of users.

The measurement of client satisfaction has over the past decade or so emerged as one of the most essential elements necessary to strengthen customer relations in most organisations. Keung and Wettstein (1999) argue that Total Quality Management (TQM) and Client Relationship Management (CRM) are two key concepts tied to client satisfaction. They further argue that in most TQM programmes, such as the European Foundation for Quality Management (EFQM), client satisfaction is seen as the driving force towards quality improvement initiatives. CRM on the other hand deals with the importance of a long term relationship between suppliers and the customers as well as creating conducive platforms to gain better a understanding of its clientele and their requirements and expectations (Anton, 1996).

There are several approaches that can be used to measure client satisfaction and they all share the common characteristic in that (Grigoroudis and Siskos, 2003).

- The data collected is based on the client’s judgement and that it should be received directly from him/her.

- They define client satisfaction survey as a multivariate evaluation - given that clients overall satisfaction depends on the number of variables representing service characteristic dimensions.

- They understand the most important measurements of satisfaction to be inclusive of quantitative and qualitative methods, data analysis techniques, quality approach models and client behavioural analysis.

Pedic and Gallagher (2008) investigated the level of satisfaction with Home Care Service (HCS) in New South Wales (NSW) against a 2006 benchmark. Their research used a self administered questionnaire to receive clientele responses which were then analyzed using the Statistical Package for Social Sciences Research (SPSS™) software. The 2008 findings showed an overall clientele satisfaction of 96%, which was 2% more than the 2006 benchmark. In another case study, the Forest Science Program of the Ministry of Forests and Range of British Columbia conducted annual client satisfaction surveys which focused on key services of the Forest Science Program, namely; library services, scientific advice and consultation, research products and training and extension services (Ministry of Forests and Range, Province of British Columbia, 2006). In this particular survey, the level of client satisfaction was measured using a rating scale of 1–10, with 10 representing the highest level of satisfaction. The results (figure 2.1) were used to pinpoint strengths and weakness areas of the Forest Science Program.

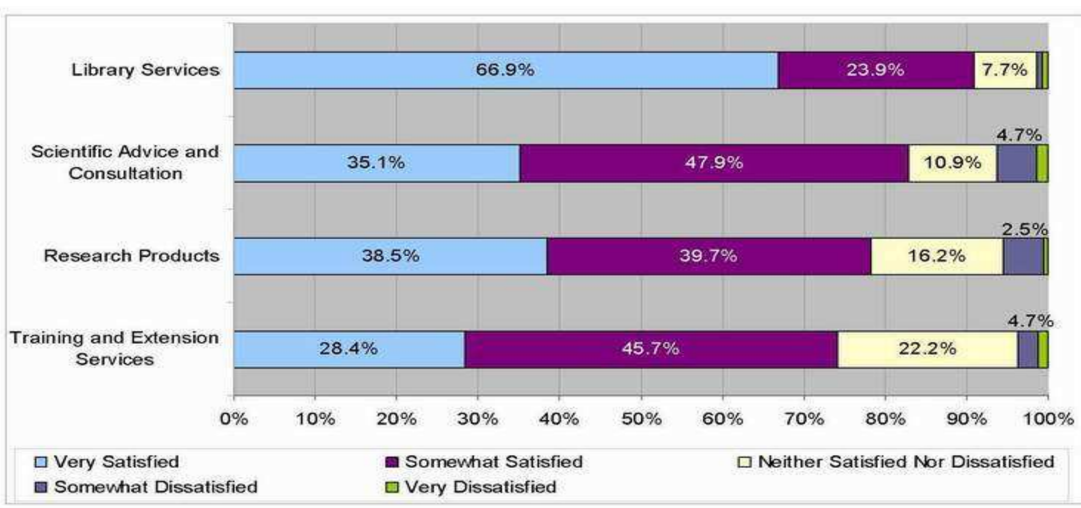


**Figure 2.1: Level of client satisfaction in Forest Science Program of British Columbia.**
(Source: Adapted from Ministry of Forestry and Range, Province of British Columbia, 2006)

Furthermore, in 1999 Spencer-White in association with George Klein and Associates were tasked by CDSM to conduct a national user needs survey, to assess the use and attitudes towards spatial information and mapping products and services. The survey which covered 504 respondents, spanned various sectors that included:- (i) public sector, (ii) parastatals, (iii) aviation, (iv) security, (v) publishing, (vi) mining, (vii) construction, (viii) GIS consultancy, (ix) military, (x) non-governmental organisation, (xi) tourism, (xii) recreation, (xiii) and other users of geospatial information. The survey produced recommendations in the following critical areas:

- Awareness of sources of spatial information.
- Extent of usage of spatial information.
- Kinds and frequency of spatial information being used, currently available and most useful.
- Problems related to accessibility and the usage of spatial information.
- Required improvements to meet client demands and including previously disadvantaged groups and individuals.
- Required training in the use of spatial information.
- Necessary consultation in the compilation of spatial information and or its use.

A client satisfaction survey is however, not an end in itself. Often it is not sufficient to determine the effectiveness of the service rendered to the clientele. The client satisfaction in this research is carried out with the aim of investigating the level of satisfaction of users of topographical data stored in the TIS database. This survey is based on the criteria of accuracy, completeness, correctness and accessibility of this data.

## 2.4 SWOT analysis

SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. It provides a framework to analyse the strengths and weaknesses, and the opportunities and threats faced by an organisation (Tuladhar *et al*. 2002). It further involves identifying the business's internal and external factors that are either favourable or unfavourable towards achieving the business objective. (Tuladhar *et al*. 2002) argue that SWOT analysis is a management tool designed for use during the preliminary stages of decision making. Its results are usually summarised in a SWOT matrix. In the same article, the authors further argue that a SWOT analysis provides a basis for formulating strategies that ensure a fit between the external environment (threats and opportunities) and the internal qualities (strengths and weaknesses) of the organisation. Performing a SWOT analysis involves recording the organization's strengths, weaknesses, opportunities and threats in relation to its core business or objective. Strengths can be defined as market advantages or those areas that the organization does well on and weaknesses being those areas that are problematic and require improvement. Opportunities can be referred to as being future technological developments or growths whereas threats are activities happening outside the system and having immense control over the system but the system has no control over them e.g. budget cuts and or difficult clientele. Strengths and weaknesses of the organization are determined through internal scanning whereas opportunities and threats are determined through external scanning (Chimhamhiwa & Paresi, 2004).

In this research SWOT analysis is used as a tool that analyses the as-is situation of the OMS. It is referred to as part of situational analysis. Hanger and Wheelen (1996) define situational analysis as a process of identifying the relationship between external opportunities and internal strengths while working around external threats and internal weaknesses. The relationship between the two concepts is that the SWOT analysis is commonly used to achieve the objective of conducting the situational analysis.

Akpoyoware (2003) used a SWOT analysis to evaluate the level of efficiency of the cadastral system in Nigeria. From the exercise, decentralization of the system into six zones was recommended. In 2001, the International Institute for Sustainable Development (IISD) was tasked to carry out an evaluation of its collaborating centres in an attempt to make recommendations for improving reporting cycles, communication, products and other aspects of Global Environmental Outlook (UNEP, 2004). In order to fulfil this goal, a combination of SWOT and a user/client needs/satisfaction was used. The SWOT was enhanced by questionnaires which were in the context of five different, but related aspects of Global Environmental Outlook. The Ordinance Survey of Great Britain, Dutch Kadaster, Swedish Land Data Bank System, National Imagery and Mapping Agency of United States of America and the National Land Survey of Sweden provide good examples of NMAs that have regularly conducted SWOT analysis as part of their business improvement initiatives. This, in part, has contributed to them being viewed as world class mapping agencies (Chimhamhiwa & Paresi, 2004).

The next section discusses the generic components common in most OMS's.

## 2.5 Generic components of orthophoto map production systems

In mapping endeavours, the production of orthophoto maps consists of multiple stages and for most of these projects, the following generic components are common:-

### 2.5.1 Aerial photography acquisition

Aerial photography (film based or digital) and satellites are the common technologies used to acquire imagery for mapping purposes. Scale and accuracy to be used in all the technologies is determined by the purpose of a mapping project at hand. A true to scale and a geo-referenced aerial photograph is a fundamental data layer for mapping because it provides an embedment for the production of a 1:10 000 orthophoto map series (Zakiewicz, 2008).

### *2.5.2 Photogrammetric scanning*

In a film based mapping environment, scanning of analogue film is a major process that has to be performed in order to convert analogue film into a digital. Aerial films are usually supplied in rolls of approximately 200 exposures of 9×9 inches each, commonly referred to as canisters (NJDOT, 2007). The advantage of the digital photogrammetric scanning is its ability to transfer accuracy of photogrammetric film into digital format (Gruber & Leberl, 2000).

### *2.5.3 Aerial triangulation*

Aerial triangulation is defined as a mathematical attempt to produce further control points on a photogrammetric model using ground control points in order to enforce accurate orientation of such models used in stereo compilation for orthophoto and other map series generation (Ministry of Sustainable Resource Management, Province of British Columbia, 1998). The data generated out of this process include Cartesian coordinates of all the perspective centres with exterior orientation data and geocentric Cartesian coordinates of the perspective centres of all adjusted photos. This data is used in other photogrammetric phases, which include ortho-rectification, digital terrain model (DTM) generation, topographic compilation and contour generation (CDSM, 2008). There are various types of aerial triangulation parameters and aerial triangulation software packages that can be used to perform this function.

### *2.5.4 Digital elevation model (DEM)*

Bernhardsen (1999) defines DEM as a digital representation of a terrain surface. It is also widely known as digital terrain model (DTM). It is an array of spot elevations whose horizontal and vertical coordinate values are known. These points are collected in a regular grid with breaklines, thus making it possible to depict the characteristics of the topography and to draw contours from there (NJDOT, 2007). Aerial triangulation makes it possible for the DEM to be viewed in three dimensions. Any inaccuracies in the DEM will affect the ortho-rectification process, which will in turn influence the image quality of the orthophoto map.

### *2.5.5 Ortho-rectification*

An aerial photograph is not a map; it is not to scale and cannot be used as the basis for making any accurate measurements because it has some geometric distortions in it that need to be corrected. These distortions are due to various factors like perspective of the sensor optics, motion of the platform, rotation of the earth and terrain relief (University of Fort Hare, 2002). Ortho-rectification is therefore a photogrammetric process of eliminating such distortions and simultaneously giving an image a scale and the projection properties of a map.

## 2.6 Analyzing orthophoto mapping through systems analysis, client satisfaction survey and SWOT – a model

From most of the cases cited in the literature review above, systems analysis, client satisfaction surveys and SWOT are often applied separately to meet certain goals. In this study, the three concepts are used to complement one another, as shown in the conceptual model sketch in Figure 2.2.

The systems analysis examines the OMS from a holistic perspective, with emphasis on; data stores, data flows and processes. This is done with the aim of identifying loopholes and problem areas that require improvement. From this perspective, the OMS is decomposed and data stores, including the TIS, are exposed. Second, the user satisfaction survey seeks to reveal the level of satisfaction of users of the topographical data housed in the TIS database with emphasis on core spatial data quality elements of accuracy, completeness, correctness and accessibility. Third, the SWOT analysis of the orthophoto mapping environment is done to reveal the **s**trengths, weaknesses, opportunities and threats that influence the current situation.

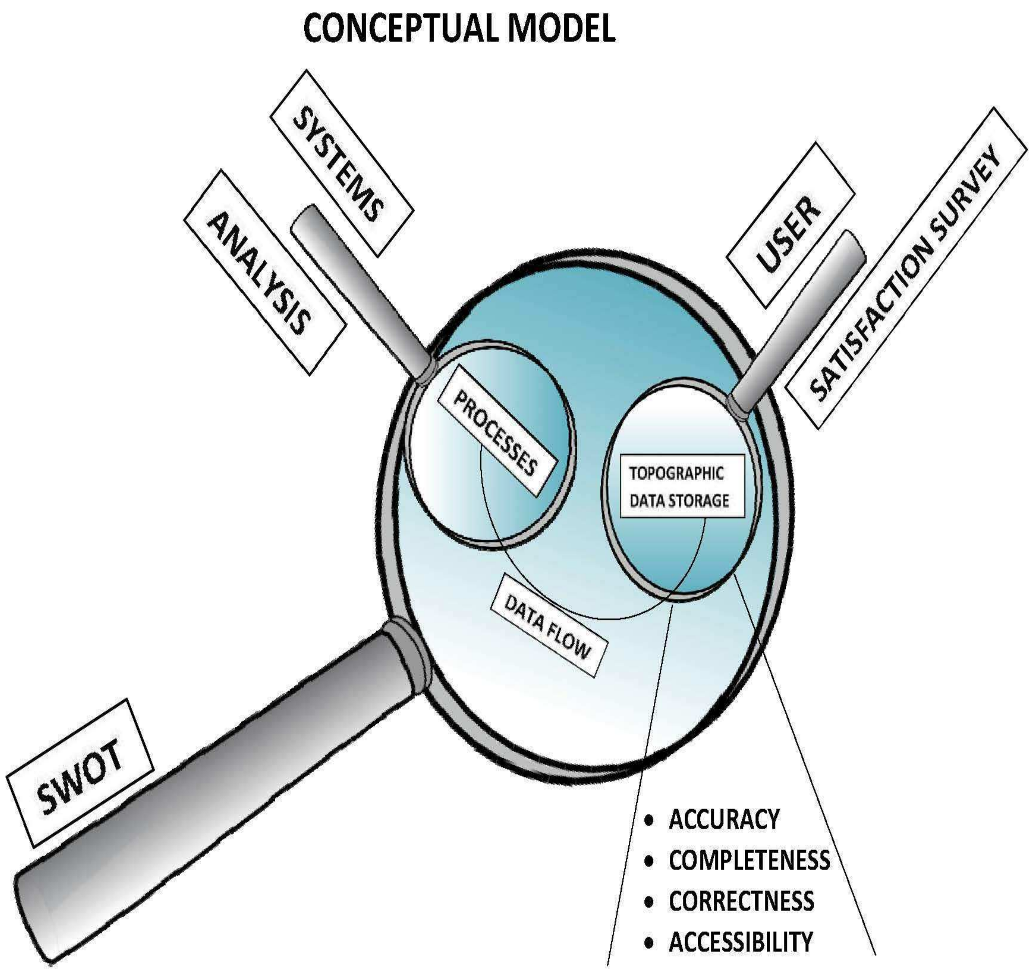


Figure 2.2: A conceptual model illustrating how systems analysis, client satisfaction survey and SWOT are combined in a single framework.

# CHAPTER 3: RESEARCH METHODOLOGY

## 3.1 Introduction

This research is an empirical case, which presents the OMS as performed at CDSM, South Africa's NMA. Robson (1993) defines a case study research as an approach that involves a pragmatic investigation of a particular phenomenon within its real life context using multiple sources of evidence. This chapter outlines the methodology used to address the research questions raised in Chapter 1. The data collection techniques used utilise both primary and secondary data sources.

## 3.2 Data collection instruments

Several data collection instruments were used to capture the responses to the different sub objectives outlined in Chapter 1. These are discussed below.

### *3.2.1 System analysis*

Paresi (1999) suggests process and data modelling as two techniques that can effectively support systems analysis and design. Process modelling aims at structuring an information system in such a way that its functional specifications are developed. The functional specifications form the basis for the technical design of the system and concentrate on the definition of the processes and their interrelations. Data modelling, on the other hand, aims at determining the logical data structure of the system and therefore identifies the important information in the system. Different techniques, such as entity relationship diagrams (ERD), IDEF and DFDs can be used for process and data modelling. The DFD technique, which is capable of both data and process modelling and system development workbench (SDW™) computer-aided system engineering (CASE) tool, were chosen for this research. To identify key data stores, data flows and processes, the OMS was analyzed using semi-structured interviews, focus group discussions and review of documents. From these investigations, terminators (those organizations that feed information into and receive information from the system) where identified. Subsequently, the context, top level and subsequent DFD diagrams, which capture the processes, data and data flows, were then constructed.

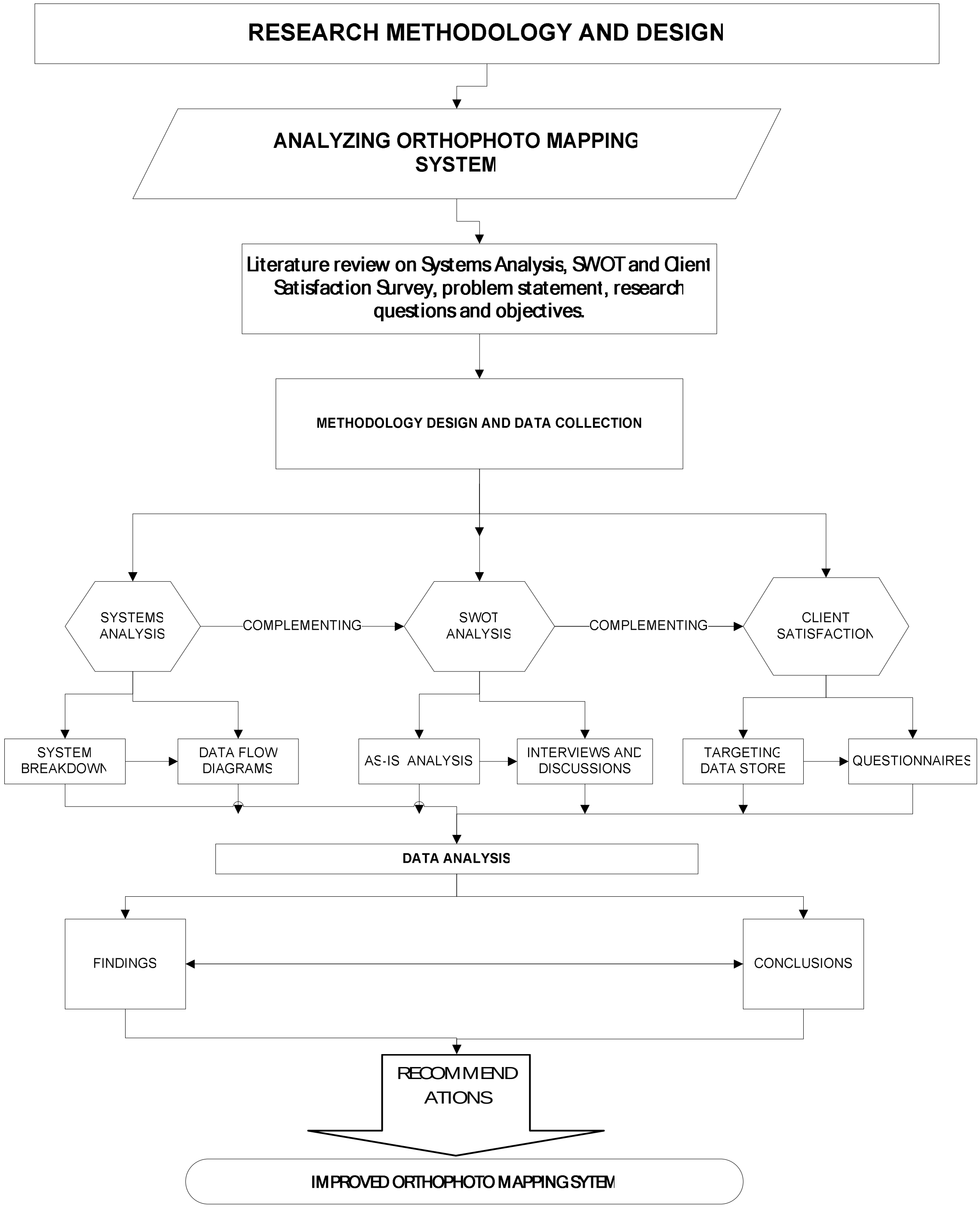


Figure 3.1: Flowchart of the research methodology and data collection methods.

### *3.2.2 Client satisfaction survey*

There are various methods of conducting client satisfaction surveys. However, each method is dependent on what the survey seeks to achieve. The most common method used is the self administered questionnaires. Questionnaires afford the clientele an opportunity to table their opinions and to advise or give inputs and feedback on areas they may think require improvement. In this research, a questionnaire was drafted and distributed to all relevant informants. The goal of the client satisfaction was to investigate the level of users' satisfaction with the topographical data stored in the TIS database. For the purpose of this research, 'the client' is used to refer to the internal frequent users of topographical data stored in the TIS database. These ranged from division managers to specialists and ordinary operators. The spatial data quality attributes of; accuracy, completeness, correctness and accessibility where used as the criteria to assess satisfaction. These variables are discussed below:-

- *Accuracy:* is usually broken up into two perspectives with one focussing on its position and the other on its attributes. From a positional perspective, spatial data accuracy can be defined as the closeness of observed geo-referenced measurements to its relative position on the ground (CCNLIS, 1990). This is referred to as accuracy of geometrical data. Bernhardsen (2002) argues that in a mapping environment this accuracy is inversely proportional to a map scale where a large scale map is accurate than a small scale map. Van Oort (2005) defines attribute accuracy as the accuracy of all attributes other than the positional accuracy of a spatial data set and can be measured according to four scales. They are ratio, interval, ordinal and nominal scales.
- *Completeness:* Bernhardsen (1999) defines spatial data completeness as the degree or measure of how fully the data on an object type has been captured in relation to the ground. This can be verified through a percentage comparison of a total number of objects captured against that of real objects in the Area of Interest (AOI). Errors of commission and omission are the two error types that are associated with spatial data completeness (Van Oort, 2005). He further defines these errors as errors that come as a result of over completeness and incompleteness of data in datasets. *Correctness:* Correctness of spatial data depicts that features are precisely portrayed so as to ensure better quality and reliability of spatial datasets CCNLIS (1990).

- *Correctness:* correctness of spatial data depicts that features are precisely portrayed so as to ensure better quality and reliability of spatial datasets CCNLIS (1990). Bernhardsen (2002) further attests that feature classification correctness can be measured through comparison of the classes assigned to features or their attributes to the AOI.

- *Accessibility:* Bernhardsen (2002) argues that from the user's perspective accessibility information is as important as the other spatial data quality variables. This information gives the user an in-depth knowledge of where a particular dataset is, its custodian, data format, cost and other metadata sets necessary and associated to spatial information.

To capture the different levels of responses, a 7 point scale, which ranged from 7 (for very satisfied) up to 1 (for very dissatisfied), was developed into the questionnaire (see appendix 5). The responses were analyzed using an Excel spreadsheet.

### *3.2.3 Swot analysis*

The aim of conducting a SWOT in this research is to come up with effective strategies that will help give strategic direction from the current scenario towards the ideal one. It is carried out in such a way that it provides the ideas to formulate good strategies of ensuring a fit between the internal (strengths and weaknesses) and external (opportunities and threats) environments of the organization as discussed below.

## 3.3 Defining the sample

Sources of data that was collected as part of this research came from different key informants within their specific functions. Secondary sources of information were documentary evidence on the current technical processes employed by delegated staff members of CDSM who are actively involved in the production of orthophoto maps and its relevant supporting functions. The supporting functions have been evaluated with respect to their content, structure and outcomes through a systematic collection of information and their role in the OMS. The reason for selecting CDSM as a case study was that this office is the only national mapping organization regulated by the countries Land Survey Act (No.

8 of 1997) to collect, revise and supply spatial information, maintain the national control survey network and to update national mapping series for the rest of the Republic. The reason for choosing the internal users of data from the TIS being that they are the only ones who have access to this database and the external users do not, hence the sample size is very minimal. The flowchart diagram in Figure 3.1 above better illustrates the methodology design, data collection methods and how things were drawn into perspective.

The sample is made up of regular users and custodians of the topographical data housed in the TIS database. These users and custodians range from division managers to specialists and ordinary operators yet with technical background. For data security reasons, these users have either read and or write access or both depending on their technical skills, experience and operations. The sample size is composed of 25 out of 30 frequent users who responded to the client satisfaction questionnaire (see questionnaire in Appendix 5) that was sent to them by electronic mail. This case study uses hierarchical cluster analysis that enables us to group respondents with similar behaviours, preferences, or characteristics into clusters, or segments.

# CHAPTER 4: CASE STUDY

## 4.1 Brief history and overview

The Trigonometrical Survey of the Union of South Africa (Trig-Survey) came into being in 1920 under the directorship of Dr W.C. van der Sterr (CDSM, 2008). Before the 1994 transitional period, this organisation had its mapping component based in Pretoria and the surveying component in Mowbray, Cape Town. It is only after the transitional period that the two components were merged under the Department of Land Affairs (DLA): Land Planning and Information (LPI) branch. The name Trig-Survey was then changed to the Chief Directorate of Surveys and Mapping and is still based in Mowbray, Cape Town.

Due to budgetary limitations, most NMAs in developing countries acquire imagery necessary for mapping in consultation with other interested public and private sector organizations. South Africa established the National Imagery and Mapping Advisory Committee (NIMAC), a body that advises on national mapping activities. NIMAC forms part of government's initiative to engage actively with stakeholders to better co-ordinate imagery acquisition amongst public sector users. The aim is to minimize duplication and to pool financial resources to achieve the best solution that meets the annual requirement of government for imagery. Sectors that are invited to participate in this advisory forum include, Department of Water Affairs and Forestry (DWAF), Statistics South Africa (STATSSA), Department of Housing (DOH), South African National Defence Force (SANDF), Metropolitan municipalities, Eskom, Telkom and the Council for Scientific and Industrial Research (CSIR). These stakeholders meet annually to collectively agree on areas whose imagery must be acquired over a given financial period. This engagement is also in accordance with Section 41 of the South African Constitution which mandates all organs of the state to co-operate with one another in mutual trust and in good faith by informing and consulting one another on matters of common interest. NIMAC decisions directly affect all the mapping programs at CDSM. However, in this research the emphasis is on orthophoto mapping.

## 4.2 Technical aspects of the 1:10 000 CDSM orthophoto maps

CDSM uses the Gauss Conformal Projection to produce 1:10 000 orthophoto maps. The Gauss Conformal Projection covers South Africa's extent into degree squares of latitudes and longitudes as indicated in Figure 4.1. Each degree square is approximately 100 $km^2$ in extent. The reference to each degree square is given by its latitude and longitude values and is further divided into four quadrants represented by letters A, B, C and D. An example is 33°South and 21°West, highlighted in Figure 4.1. With the exception of areas along the coast and international boundaries, one degree square is made up of sixteen (16) 15×15 minutes (15′×15′) 1:50 000 topographical map sheets. The reference to each 1:50 000 map sheet is given by its position within the four lettered quadrant of a specific degree square as indicated in Figure 4.2(b). Furthermore, each 1:50 000 map sheet is broken down into twenty- five (25) 3×3 minutes (3′×3′) map sheets to create 1:10 000 orthophoto maps as illustrated in Figure 4.2(a). Its reference is dependent on its position and orthophoto number within a given 1:50 000.

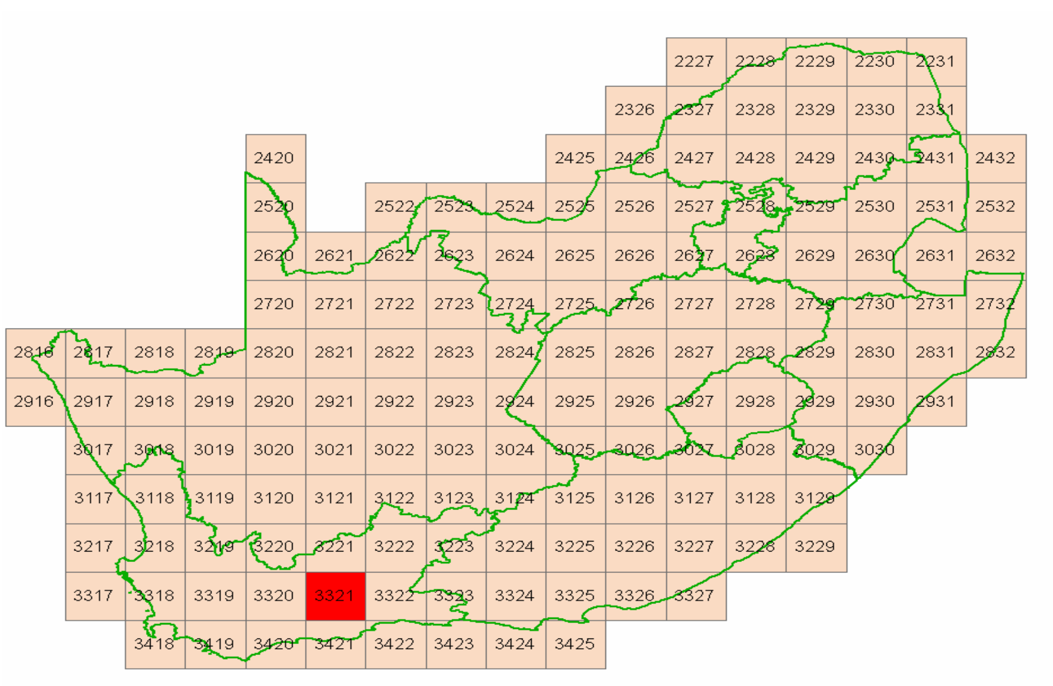


Figure 4.1: Map showing series of degree squares covering South Africa. Map not to scale. (Source: Author)

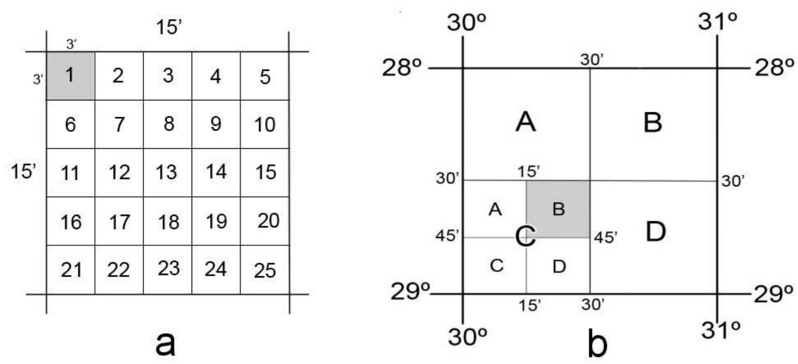


Figure 4.2: (a) Map sheet reference of 1:10 000, (b) map sheet reference of 1:50 000 (2830 CB). (Source: Adapted from CDSM, Draft Map Sheet Reference Standard, 2008)

## 4.3 CDSM Quality Standards for 1:10 000 map series

The CDSM proposed or draft orthophoto map standards of 2008 give guidelines with regard to the quality and standard of every orthophoto map produced. The orthophoto map as produced by CDSM shall:-

- Have an extent of 3′×3′ latitude and longitude with the exception of coastal lines and international boundaries where coverage can be extended;
- Have a unique identification or reference in accordance with its position as indicated in Figure 3.2(a);
- Be projected using the Gauss Conformal Projection and the Hartbeeshoek 94 shall be used as a reference ellipsoid;
- Be such that 95% of all features appearing on such a map are accurate to 0,5m of their true position on the ground;
- Be such that the features reflected on this map series fall within the four feature classes of; communication, culture, hypsography and height-representation, and hydrography) as indicated in Table 3.1 below (CDSM,2008)

**Table 4.1: Different features, feature classification, expression, font size, style and format as annotated on 1:10 000 maps.**

| Classification | Feature name | Expression | Font style | Font size (mm) | Font format |
|---|---|---|---|---|---|
| Building | Shopping Centre | ‘Shopping Centre’ | Arial | 7.5 | *Italic & Uppercase* |
| Building | University | ‘Name of feature’ | Arial | 7.5 | *Italic & Uppercase* |
| Parks and reserves | Botanical Garden | ‘Name of feature’ | Arial | 9–19 | Uppercase |
| Mining | Mine | ‘Name of feature’ | Arial | 9 | Uppercase |
| Monuments | National monuments | ‘Name of feature’ | Times New Roman | 9 | *Italic* |
| Settlement | City | ‘Name of feature’ | Arial | 21 | Uppercase |
| Prominent man-made features | Cemetery | ‘Cemetery’ | Arial | 7.5 | *Italic* |

Source: Adapted from CDSM, Map Sheet Reference Standard, 2008. (Pg 27)

## 4.4 Spatial data management by CDSM

CDSM has been using Oracle Spatial Cartridge (8i) relational database to properly maintain and manage its spatial data since 1999 (Duesimi, 2004). This is a central data store to organize, store and retrieve spatial data. However, the division responsible for orthophoto mapping uses ARCGIS™, an ESRI software package, to produce orthophoto maps. Because ARCGIS™ cannot connect to the Oracle database directly, the Feature Manipulation Engine (FME™) is used as an intermediate link to connect to the Oracle database platform. The FME™, which uses Structured Query Language (SQL) to analyze and export datasets, is capable of translating one data format to another in a fully automated manner.

### *4.4.1 The topographical information system (TIS)*

The topographical datasets stored in the TIS database are meant for use by all CDSM divisions whose operations are vector data dependent. These divisions include Medium Scale, Small Scale, Orthophoto Production and Map Sales divisions. These datasets are available in different file formats like shapefiles, DWG, DXF, and DGN. Different divisions within CDSM populate or extract different datasets into or from this database. The topographic data in TIS is managed by the Oracle Database Management System through a Long Transactions and Version Management (LTVM) application. LTVM is an Intergraph system designed for Oracle Spatial Cartridge (8i) Relational Database with the purpose of letting users lock and or unlock data as and when required to facilitate long transactions and support record locking and versioning of datasets (Duesimi, 2004). This research, however, focuses on datasets used in orthophoto map production exclusively. Orthophoto mapping is responsible for the production, maintenance, revision and digital archiving of orthophoto maps in accordance with the standards and specifications drafted by CDSM’s guidelines for quality. In order for this division to function smoothly and efficiently, supplementary datasets supported by other sections within the Chief Directorate have to be accurate, complete, current and free from any error sources. Furthermore, it can be argued that at operational level, the quality of the end-product is determined by the quality of the supplementary datasets.

In concluding, all the different yet cross functional aspects discussed in this chapter share a common characteristic in that, they portray orthophoto mapping and other mapping systems within CDSM as complex systems.

# CHAPTER 5: RESULTS

This chapter presents the results obtained in pursuit of the objectives outlined in Chapter 1. First, results for each sub objective are presented. Next, a discussion of the results is then conducted.

## 5.1 Results

*Sub objective 1: Analyze the OMS in terms of its data flows, data stores and processes*

To break down the CDSM‘s OMS into its data stores, processes and data flows, three DFDs; the context, top level and low level diagrams (figures 5.1, 5.2 and 5.3 respectively) were created. These are discussed below.

### *5.1.1 The Context diagram*

The decomposition of the system began by establishing the system’s boundary. Terminators that supply information into the system and receive information from it were then identified. Data flows for each terminator were then identified and shown on the context diagram. 8 terminators were established, namely; the ancillary data and image acquisition (ADIA), ortho rectification, map sales, quality assurance, aerial triangulation and elevation capture, software vendor, reprographics and network adjustments. Each terminator and its data flows are discussed in the next sections.

#### ***5.1.1.1 Ancillary Data and Image Acquisition (ADIA)***

As alluded to earlier, boundary, power line and annotation data are critical datasets necessary for orthophoto map production. The ancillary data and image acquisition (ADIA) division of CDSM is responsible for ensuring the correctness and reliability of these datasets before they can be used by other divisions. Orthophoto mapping therefore depends on ADIA to supply updated power lines, geographical place names and boundary demarcation data. The datasets come in both digital (populated into TIS) and hardcopy (stored in filing cabinets) formats. It is only the ADIA division that has read and write access to these datasets.

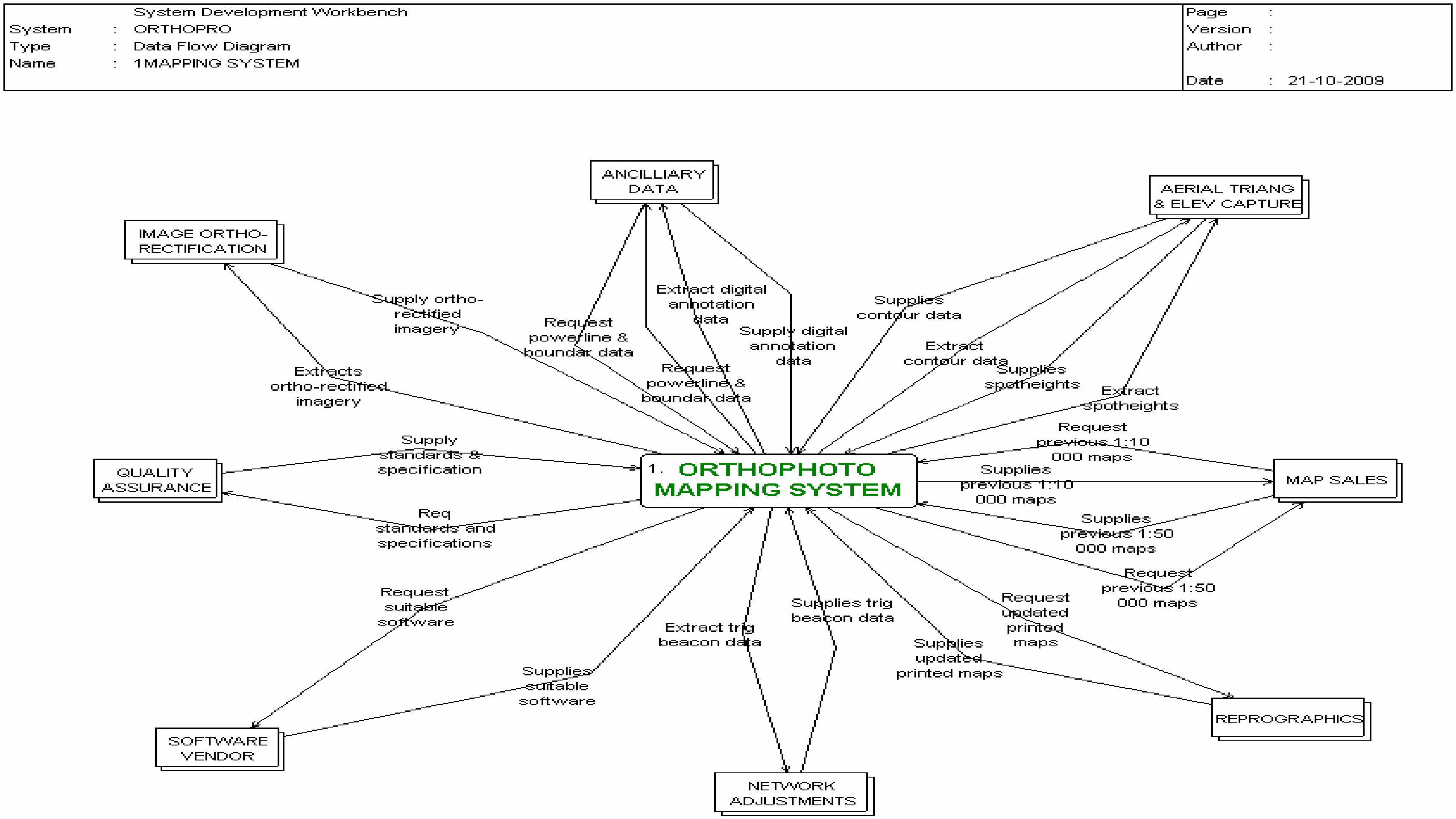


**Figure 5.1: Context diagram of the OMS of CDSM.**

#### *5.1.1.2 Ortho-Rectification*

After the images have been ortho-rectified, they are stored in tagged image file format (TIFF). Orthophoto mapping extracts these images for use as a background in the production of orthophoto maps. There is a small division called Ortho-Rectification which is responsible for this dataset and it is the only division that has read and write access to this information.

#### *5.1.1.3 Map sales*

Current digital and hardcopy 1:50 000 topographical maps and previous 1:10 000 orthophoto map series are used as supplementary data when generating new orthophoto maps. The Map Sales division of CDSM supplies hardcopies on request while the digital versions are available from the digital archives in TIFF format.

#### *5.1.1.4 Quality Assurance*

In order to ensure that materials, products, methods and services are fit for purpose and are performed in the manner intended, the Quality Assurance division of CDSM together with other divisions constantly develop and maintain guidelines, process standards and specifications. This information is shared among relevant users and is available in softcopy format in shared drives.

#### *5.1.1.5 Aerial Triangulation and Elevation Capture (ATEC)*

Contours and spot heights are vector datasets commonly lumped together and referred to as relief datasets. They are core datasets necessary for orthophoto map production. The aerial triangulation and elevation capture (ATEC) division generates these datasets. Any new version of this dataset gets populated into the TIS database for access by other users including Orthophoto mapping division.

#### *5.1.1.6 Software vendor*

Modern digital methods of generating orthophoto maps require customized Geographical Information Systems (GIS) software packages. Technical support services and routine maintenance becomes the responsibility of the successful software vendor. This is done in a form of a contractual agreement between the orthophoto mapping division and the software vendor (s).

#### *5.1.1.7 Reprographics*

The Reprographics division is responsible for the printing of final digital and hardcopy map series produced by CDSM. It is this division that prints film, contact prints and completed paper orthophoto maps. The final products are shared in Encapsulated PostScript (EPS), Tagged Image File Format (TIFF) or Joint Photographic Expert Group (JPEG) formats for the Reprographics division to develop and print out end products on request.

#### *5.1.1.8 Network Adjustments*

Trigonometrical beacons provide control points necessary in all map production activities. Trigonometrical points are amongst the relief datasets necessary for orthophoto mapping. The Network adjustments division, which is responsible for maintenance of this data set ensures that every change that occurs in any of these points is updated on the TIS database. This information is extracted in shape file format using FME.

### *5.1.2 The Top level diagram*

After establishing the context diagram of the OMS (figure 5.1), the next level of decomposition was carried out. 2 top level processes; (1) unprocessed data extraction and (2) cartographic enhancement (figure 5.2) were created from the context diagram. The data flows appearing on the context diagram were then directed accordingly to these respective processes. At the top level, the first data store, the *shared drive*, is introduced. The activities occurring under each process are discussed below.

***Process 1: Unprocessed data extraction***

This phase of production is often referred to as the preparation of data for orthophoto map production. It is performed at a higher level and involves the following sub phases:

- Creating relevant folders and files for the job at hand.
- Connecting to the TIS database and extracting the relevant data set files in different formats e.g. shapefiles or geotiffs.
- Storing such files in a created workspace on a shared drive for access by mapmakers.

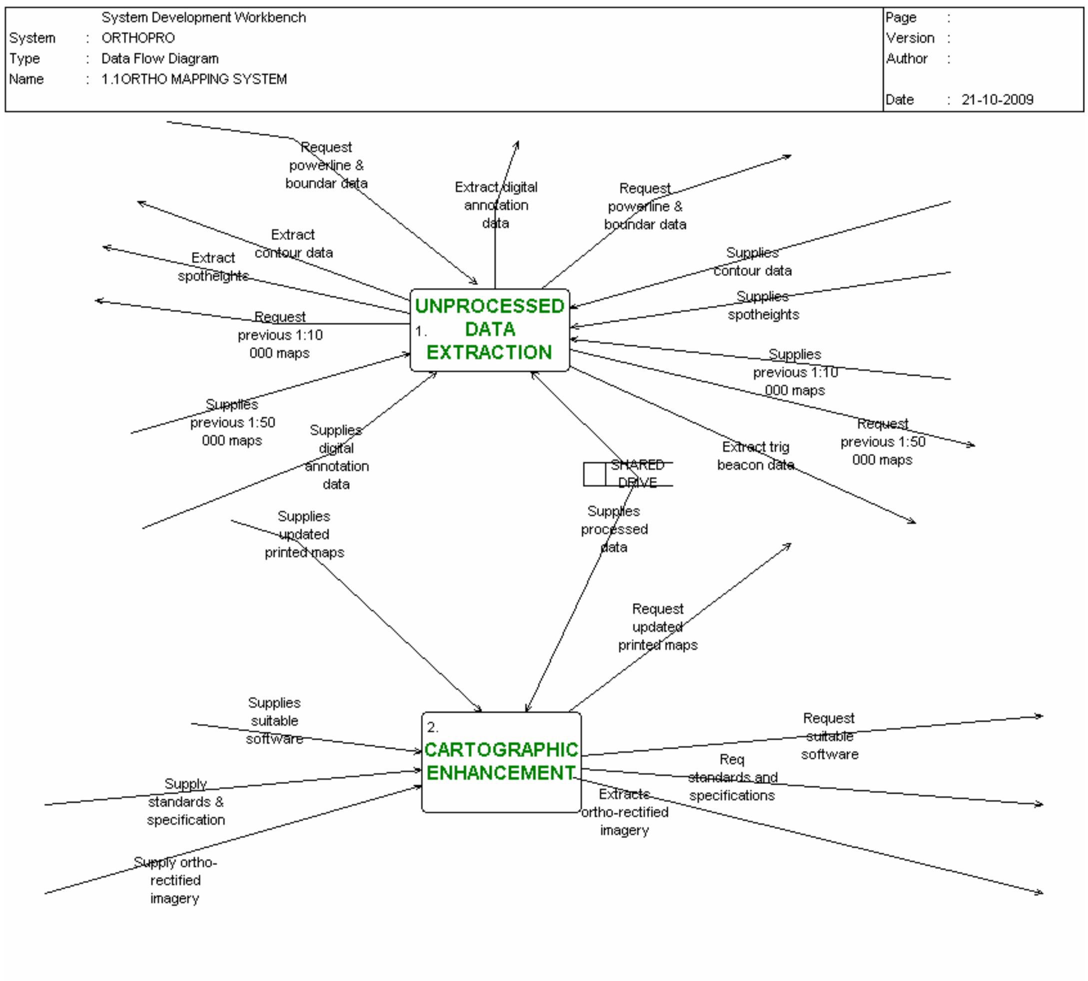


**Figure 5.2: Top-level diagram of the CDSM orthophoto mapping system.**

***Process 2: Cartographic enhancement***

Cartographic enhancement, symbol and text placement refer to the technical processes involved in adding more value to the map such that it becomes more user-friendly, more appealing to the human eye and more understandable. It requires a combination of diverse technical skills which among others include computer skills with windows applications, cartography and some geography skills and relevant GIS software for map production.

To get an even better understanding of lower level activities, the unprocessed data extraction process, created on the top level, was further decomposed into its lower level sub processes of; map production and quality control, as shown in figure 5.3.

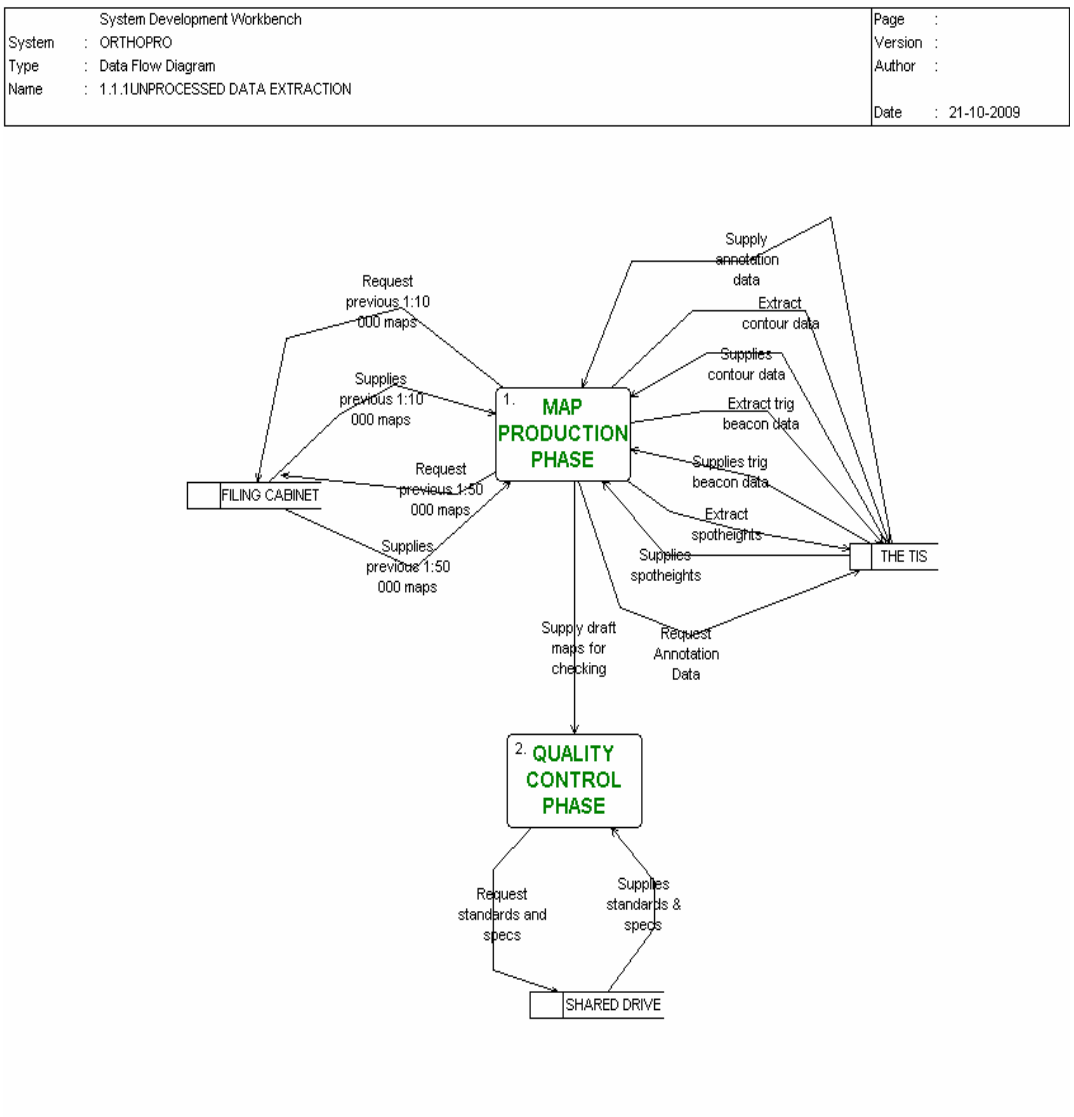


**Figure 5.3: Lower level diagram of an OMS of CDSM.**

### *5.1.3 The lower level diagram*

#### 5.1.3.1 Map production phase

The map production phase involves the editing and labelling of contours, spot heights, power lines, annotation and other themes and or layers. These activities are carried out using the standards and specifications laid out in the production process as a reference. The TIS database and filing cabinets (as depicted in Figure 5.3) are a fundamental data source for these activities.

#### 5.1.3.2 Quality control phase

It is the responsibility of every role-player to ensure that quality of the end product is within the set standards. In this regard, several quality control measures have been put in place to ensure that standards are adhered to. Below is a list of some of these measures:-

- On-screen checking: the operator verifies the correctness and completeness of his/her map on screen (digital version) before requesting a hardcopy printout.
- Operators check the quality of each other's work
- The operator attends to corrections as suggested above if any.
- The division manager oversees and approves the final product.

*Objective 2: Investigate the level of satisfaction from the internal users of topographical data.*

Spatial data quality variables of; accuracy, completeness, correctness and accessibility, which were viewed as the core criteria related to the satisfaction of internal users of TIS data, were investigated through a questionnaire. 30 users, who ranged from professionals, technicians, managers, experts and operators of geospatial datasets, were identified and targeted. These users came from numerous sections such as; Spatial Information and Professional Support (SIPS), Aerial Triangulation and Elevation Capture (ATEC), Orthophoto, Map Data Processing (MDP), Small and Medium Scales and Ancillary Data and Imagery Acquisition (ADIA) . A questionnaire (see appendix 5) was send to all 30 of which 25 responded. Of the 25, 4 came from the orthophoto mapping division (and that number constitutes all orthophoto mapping staff that use data from TIS). The evaluation of each question was based on a 7 point likert scale that ranged from 7 (for very satisfied) to 1 (for very dissatisfied). Responses were captured into an Excel spreadsheet and summarised into figure 5.4 below.

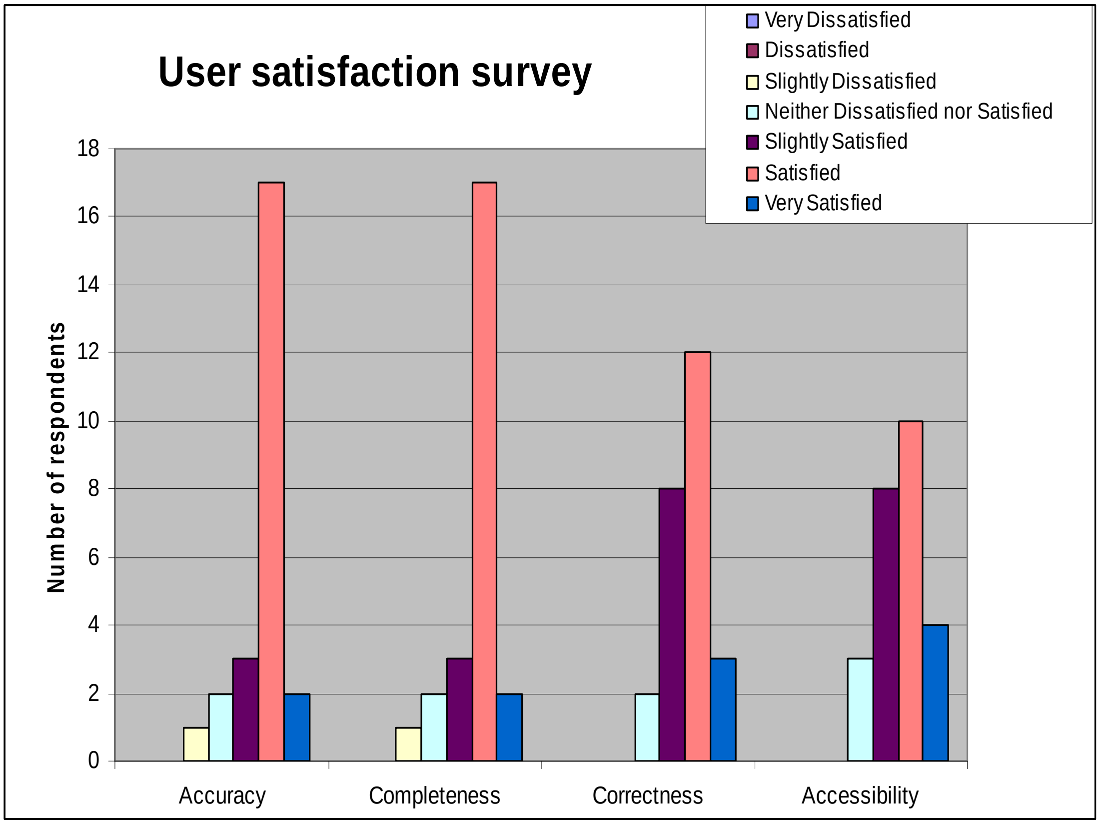


**Figure 5.4: Bar chart showing the overall satisfaction of users.**

From the bar chart, the accuracy and completeness dimensions were evaluated equally across all 7 points of the scale. For both, 22 respondents (88%) were slightly satisfied, satisfied or very satisfied. 1 respondent, in both cases, was however slightly dissatisfied with both accuracy and completeness. Correctness and accessibility had highest numbers of very satisfied respondents (3 for correctness and 4 for accessibility). 23 respondents (92%) evaluated correctness with slightly satisfied or better.

*Objective 3: Conduct a SWOT analysis of CDSM with relevance to the OMS*

From the viewpoint of improving Orthophoto mapping at the CDSM, 6 strengths and 8 weaknesses were derived through internal environmental scanning and presented in table 5.1, while 8 opportunities and 9 threats were generated through external environmental scanning (table 5.2). Based on the feasible Strengths/Opportunities, Weaknesses/Opportunities, Strengths/Threats and Weakness/Threats combinations, a SWOT matrix (table 5.3) of possible strategies, was created.

A discussion of the results of the 3 objectives is presented in section 5.2

**Table 5.1: The internal screening of the orthophoto mapping system of CDSM**

| Strengths (S) | Weaknesses (W) |
|---|---|
| **S1.** Trusted to be the country's foremost supplier of geospatial information and orthophoto maps.<br>**S2.** Has well trained and suitably qualified personnel (Cartographic and Surveying background) in conventional orthophoto mapping methods.<br>**S3.** High level of data security.<br>**S4.** Advanced spatial data management applications.<br>**S5.** Availability of modern data extraction techniques, (e.g. FME, Cute-FTP), reliable file conversion techniques, (e.g. EPS to TIFF or JPEG) and data or file compression techniques (e.g. JPEG, TIFF and MrSid).<br>**S6.** Availability of modern data manipulation software/techniques for orthophoto map generation, e.g. ARCGIS™ , GEOMEDIA™. | **W1.** Silo operations by different sections resulting in lack of a 'whole'.<br>**W2.** Integrity, completeness, accuracy and correctness of the end product is sometimes questionable.<br>**W3.** Supplementary datasets required for orthophoto map production are at times incomplete and of poor quality.<br>**W4.** No structured ways to ensure quality standards are being adhered to and no formal quality management system is in place.<br>**W5.** No policies that regulate production and revision of orthophoto maps.<br>**W6.** Inefficiencies in the planning of orthophoto mapping programs as dead areas (where there is neither growth nor development potential) are sometimes mapped.<br>**W7.** Direct access to the Oracle database is limited to certain software programs and excluding ARCGIS™.<br>**W8.** Film and paper copies are expensive. |

**Table 5.2: The external screening of the orthophoto mapping system of CDSM**

| **Opportunities (O)** | **Threats (T)** |
|---|---|
| **O1.** Monopoly over 1:10 000 orthophoto mapping.<br>**O2.** Implement quality control measures (existing standards documents) to ensure acceptable and user satisfactory end product.<br>**O3.** Develop marketing strategy where clients are given an opportunity to raise their concerns, dissatisfactions and opinions towards the future of the end product.<br>**O4.** Consider the Map on Demand concept, which saves time, labour and cost.<br>**O5.** Consider supplying of value-added products as digital mapping methods come with new opportunities.<br>**O6.** Use of Free open source software (FOSS) and TerraShare technologies may bring down cost in licensing fees and production time.<br>**O7.** Availability of modern data extraction and manipulation techniques makes it possible to consistently achieve the annual production targets.<br>**O8.** New GeoPdf file format enables orthophoto maps to be viewed in different layers as may be required by the customers. | **T1.** Budget cuts due to economic recession.<br>**T2**. File size of digital imagery is very large compared to film-based and thus requires larger file storage.<br>**T3.** Lack of experience in digital mapping.<br>**T4**. No integrated database in place.<br>**T5.** Access to the database is limited to certain software programs that exclude ARCGIS™.<br>**T6.** Level of technical support is uncertain.<br>**T7**. High staff turnover.<br>**T8**. Competition from other quicker means of acquiring imagery and maps e.g. high resolution satellite based techniques (e.g. Ikonos) and google earth.<br>**T9**. Expensive software licensing |

**Table 5.3: The SWOT Matrix**

| | **STRENGHTS - S** | **WEAKNESSES - W** |
|---|---|---|
| **OPPORTUNITIES - O** | **SO - STRATEGIES**<br><br>**S1&01**: Use monopolistic and trusted market positions to improve supply and quality of geoinformation and orthophoto products.<br>**S5&O5**: Use modern data extraction, conversion and file compression techniques to develop and supply value added products.<br>**S2&O2:** Use well trained staff to implement quality control measures that ensure acceptable user satisfaction. | **WO - STRATEGIES**<br><br>**W2&O2**: Improve integrity, accuracy and correctness of end products by implementing quality control measures.<br>**W5&O1**: Develop policies that regulate production and revision of orthophotos to enhance monopolistic advantage.<br>**W6&O4:** Consider use of map on demand to avoid mapping dead areas. |
| **THREATS - T** | **ST - STRATEGIES**<br><br>**S2&T3:** Retrain existing staff in digital mapping.<br>**S4&T4:** Develop integrated databases based on available advanced spatial data management applications.<br>**S6&T9**: Explore upgrading or changing current orthophoto mapping software to cut on cost of licensing. | **WT - STRATEGIES**<br><br>**W1&T1:** Explore holistic operational planning to minimize effects of budgetary cuts.<br>**W5&T7**: Implement staff retention policies and policies to regulate production and revision of orthophoto maps.<br>**W4&T4**: Develop quality monitoring and integrated databases systems to ensure high quality standards. |

## 5.2 Discussion of results

The research analyzed an OMS using; (1) system analysis, (2) client satisfaction survey and (3) SWOT. Under systems analysis, the DFD technique and SDW case tool were used to establish the key processes, data flows and data stores for the orthophoto mapping system at the CDSM and their linkages. From the context diagram (figure 5.1) and lower level (figure 5.3) it appears that; ADIA, ATEC and Map sales are the main suppliers of most data sets required for orthophoto map production at CSDM. In this regard, these 3 seem to be the ideal strategic partner sections/divisions for any quality improvement initiative and/or collaborative planning endeavor that Orthophoto Mapping wishes to undertake. Such collaboration would promote integrated initiatives and reduce silo-based approaches. Furthermore, most of the data flows from these 3 terminators affect, at a lower level, the unprocessed data extraction and map production processes. These 2 internal processes should therefore be central participants in any suggested collaborative initiative with the 3 external entities listed above. As in the (Wing & Maloney, 1994) and Karamouz *et al.* (2003) studies, systems analysis has been used in this study as an underlying framework for additional analysis. The client satisfaction survey (in objective 2) was subsequently carried out on one of the data stores (TIS), which was 'exposed' from the system decomposition in objective 1.

Results of the client satisfaction survey (figure 5.4) appear to show that the problem of quality, highlighted at the beginning of the research, is not as wide spread as was previously thought. This could be because of the 25 respondents who participated in the user satisfaction survey, only 7 were in map making and 4 of these, were from Orthophoto Mapping. The rest; 4 from ADIA (map compilation), 2 from Network adjustments, 2 from Survey services, 3 from ATEC and 5 from Map Sales, were mainly users (and updaters) of specific data sets in the TIS. Thus, being users and producers of the same data sets, there could have been an element of bias in their evaluation of their own data sets. The results therefore suggest that current TIS data quality (in terms of accuracy, completeness, correctness and accessibility) is generally satisfactory for most users except Orthophoto Mapping, which was associated with lowest scores in the user satisfaction survey.
The other map-making divisions; Medium scale (2 respondents) and Small Scale (1), appear to be ok with current data quality because their accuracy requirements are more relaxed.

Under the SWOT, concern for TIS data quality (mainly from Orthophoto) was registered again through the 3 quality related weaknesses; (W2, W3, W4) identified in the internal environmental scanning (table). These weaknesses (together with the responses from the user satisfaction survey) suggest that quality requirements for Orthophoto Mapping could be different compared to other divisions. In this regard, 1 opportunity was identified in the external environment while 3 strategies were built in the SWOT matrix (table 5.3) to improve data quality related deficits.

# CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

## Introduction

This chapter presents the conclusions of the research and proposes some recommendations based on the objectives pursued in Chapter 1. First the conclusions are presented and then recommendations are tabled. The concluding paragraph of this chapter outlines the relationship between the suggested improvement tools and the objectives of this research. It is through this paragraph that scopes for further research on other mapping series components are indirectly articulated.

## Conclusions

Using the three approaches of system analysis, user satisfaction survey and SWOT, the Orthophoto Mapping system (OMS) of the Chief Directorate of Surveys and Mapping in South Africa was analyzed. Systems analysis was used to analyze the OMS in terms of its data flows, data stores and processes. The data flow diagramming technique and SDW case tool were used to decompose the OMS into 3 system diagrams; a Context, top level and lower level. 8 terminators (organizations that supply or receive data) from the OMS were identified together with their data flows (see context diagram figure 5.1). The top-level diagram was created by decomposing the context into 2 key processes; unprocessed data extraction (process 1) and cartographic enhancement (process 2). All data flows appearing on the context were accordingly connected to the relevant process at the top level. A subsequent decomposition of process 1 was then carried out, resulting in a lower level system diagram (figure 5.3) were two key data stores; TIS and the shared drive, were shown. Through the systems analysis, the OMS's processes, data flows and data stores, and their links have been shown. Based on the system diagrams, a client satisfaction survey was then carried out on TIS, in the second objective. The TIS was chosen after taking into consideration the numerous data flows that flow into and out of it (figure 5.3). A questionnaire was developed and a survey was carried out to assess the level of satisfaction of users of TIS with the accuracy, completeness, correctness and accessibility of TIS data. Out of a possible 30 users, 25 participated in the questionnaire-administered interview. The results (figure 5.4) showed that all users (except orthophoto mapping) were generally satisfied with the 4 variables assessed. Following the user satisfaction survey, a

SWOT analysis (objective 3) of the OMS was done to determine the internal strengths and weaknesses as well as external opportunities and threats. 6 strengths, 8 weaknesses, (table 5.1) and 8 opportunities and 9 threats (table 5.2) were recorded. These strengths, weaknesses, opportunities and threats were then used to develop a SWOT matrix were several strategies for OMS improvement were suggested (table 5.3)

The research has demonstrated the use of 3 separate key concepts in analyzing an OMS. These approaches when combined give a holistic and broader analysis of the production system side of OMS (through system analysis' data stores, data flows and process), the user's view (through user satisfaction analysis with TIS data store) and the challenges that the OMS experiences from its internal and external operational environment (SWOT analysis).

**Recommendations**

Based on the objectives pursued, the case study and results obtained for each objective, the following recommendations can be drawn:-

- ✓ A complex system such as Orthophoto Mapping System can face numerous operational challenges which may need to be analyzed in a structured manner. In this research, 3 approaches have been used, dictated by the challenges at hand (fragmentation, lack of goal sharing, lack of understanding of common and individual needs). However, these approaches are not the only possible combinations. It is recommended that OMS facing similar challenges could use some or all of the approaches as a start for analyzing their specific cases.
- ✓ A number of strategies have been developed based on the SWOT (see the SWOT matrix on table 5.3). Implementation of some of these strategies can be considered taking into consideration the resources and priorities of the CDSM.
- ✓ The user satisfaction and SWOT have shown that the Orthophoto mapping's accuracy requirements are not met in the current system. It is recommended that such needs be reviewed with the relevant data custodians in an attempt to improve the requirements.

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# APPENDIX 1

**Interview: 12th August 2008**

**Mrs Judith Velemani and Mr Yalezo Rasonti**

**(Chief Industrial Technicians: CDSM)**

1. *What are the core data sets of Orthophoto mapping?*

   Answer: Contours, Spot heights, names, Trig beacons, Power lines, and Boundaries.

2. *Where are these datasets stored and in what format?*

   Answer: They are stored in a shapefile format and Rectified images are stored in a TIFF format. All shapefiles are stored in Oracle database.

3. *How are they accessed?*

   Answer: All shapefiles in Oracle Database are accessed through FME Workbench and the imagery on the AMASS is accessed via CuteFTP™.

4. *What are the common daily problems that come with the datasets?*

   Answer: i) Getting incorrect data from the contractors.

   ii) Data with topology problem especially when the job has got heavy contours.

   iii) Names dataset is sometimes not updated which needs mapmakers to rely on hard copies for annotation which could cause problems because even the hard copies are 20–25 years old meaning there could be a lot missing, i.e. new development in that old copy.

   iv) Another problem would be the time the managers take to replace people who leave the organization.

# APPENDIX 2

**Interview: 23rd July 2008**

**Mrs Mariana French**

**(Deputy Director: Cartography)**

1. *What is the correct criterion that is supposed to be the driving factor behind choice of orthophoto map coverage?*

   Answer: Available budget, NIMAC inputs, government priorities and vintage of the current orthophoto maps.

2. *Is it always possible to follow this criteria and if not what are the other alternatives?*

   Answer: No, sometimes we are driven by the availability of the supplementary datasets like DEMS, relief data and rectified imagery in order to push for targets.

3. *Do the alternate methods always work in favour of the planned mapping program?*

   Answer: Not always, sometimes they force diversion from the planned program as they can be in contrary with response to question 1 above.

# APPENDIX 3

**Interview: 21st September 2008**

**Mr Steve Jansen**

**(Chief Industrial Technician: Ancillary Data & Imagery Acquisition)**

1. *What is the role of your division in the datasets housed in the TIS?*

   Answer: Updating the feature class called names/text with emphasis on non-descriptive attributes.

2. *How are these features stored in the database?*

   Answer: Oracle uses tables that store such information's geometry, attributes and indexes.

3. *Who do you rely on regarding the verification of the names and do you have a conducive working relationship with that body or institution?*

   Answer: It is supposed to be the South African Geographical Names Council (SAGNC) and we are not getting any support from this council as they do not respond to our request on verification of these names, especially place names.

4. *Who are the other institutions that helps/supply you with relevant data to pursue this task?*

   Answer: National Departments of Health, Education, Water Affairs, City Councils, South African Police Services, STATSSA etc.

5. *Are there any problems related to such donors or data received from them and please explain?*

   Answer: Yes, accuracy and format of the data received is problematic and can be tied to the fact that people in these institutions have little knowledge of the technicalities of dealing with spatial information because they are from different backgrounds.

6. *What are the driving factors behind your planning of areas to be mapped or flown?*

   Answer: Age of the current map and the rate of development are the core drivers.

# APPENDIX 4

**Electronic mail interview: 2nd October 2008**

**Mr Marc Machlaglan**

**(Control Industrial Technician: Map Compilation)**

1. *Who is responsible for the integrity of the data in the TIS?*

   Answer: The Map Data Processing Division (MDP) is responsible for the administration and therefore the integrity of the TIS database. Other divisions supplying data are also guided by these rules, as listed below. This ensures quality standards are meet within there divisions. MDP is mealy the administration of the data.

2. *What are the measures of ensuring this integrity?*

   Answer: The following standards/measures are employed to ensure the Topological and Attribute integrity are of the spatial data housed in the CDSM Oracle Database Topographical Information System (TIS).

Topological Integrity of Spatial Data

Introductions

Symbology to be used in illustrations

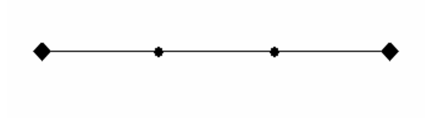
Terminal vertices

Normal vertices between terminal vertices

Line Features (Geometry) defined:

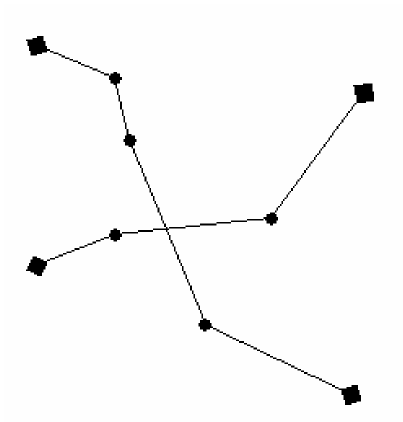
All linear features are described as either **line** or **polyline**. A linear feature consists of terminal vertices, commonly referred to as nodes, and normal vertices in between the terminal nodes. A **line** feature consists of two terminal vertices only and a **polyline** feature consists of two terminal vertices and other vertices in between:

Line Geometry

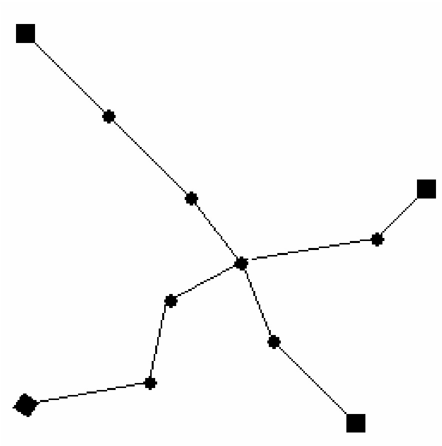


Polyline Geometry

Connectivity, Line geometry:



Invalid connectivity (missing node at intersection)



Valid connectivity (node at intersection)

3. *Who are your clients?*

Answer: Cartographic Services: Medium Scale, Small Scale and Sales Marketing

# APPENDIX 5

## CLIENT SATISFACTION QUESTIONNAIRE

The core business of Topographical Information System (TIS) database of the Chief Directorate of Surveys and Mapping (CDSM) is to collect, maintain and store topographical data for use by its clientele of geospatial information. You have been identified as one of the users or custodians of this topographical data and therefore requested to take a few minutes of your time and give feedback on the following questionnaire. Please note that in order for the author to make effective analysis of the outcomes you need to be as frank and as honest as possible. The questionnaire is designed to rate the level of satisfaction of CDSM users of the TIS dataset in terms of its quality variables as listed in the questionnaire below.

***Also, note that the responses captured in this questionnaire will be used solemnly for the author's academic purposes and will not by any means be used for other purposes***

| | | Very Dissatisfied | Dissatisfied | Slightly Dissatisfied | Neither dissatisfied nor satisfied | Slightly satisfied | Satisfied | Very satisfied |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Questions** | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **Accuracy** | How satisfied are you with the **positional** accuracy of TIS dataset that you use for your mapping activities | | | | | | | |
| | How satisfied are you with the **attribute** accuracy of TIS dataset that you use for your mapping activities | | | | | | | |
| **Completeness** | How satisfied are you with the TIS datasets completeness of the captured features in relation to the ground or reality (this refers to over completeness or incompleteness) | | | | | | | |
| **Correctness** | How satisfied are you with precise portrayal of features of spatial datasets in the TIS that you use for your mapping activities (this refers to reliability and currency of the spatial datasets) | | | | | | | |
| **Accessibility** | How satisfied are you with the accessibility of TIS dataset (this includes knowing the path to the dataset, who the dataset custodian is, data format, cost etc.) | | | | | | | |

Any other comments or explanations: