A Conversion Strategy to Improve the Quality of Cadastral Map and to Support the Registration Process: Indonesian Case

Wahyu Sari Sabekti
February, 2010

A Conversion Strategy to Improve the Quality of Cadastral Map and to Support the Registration Process: Indonesian Case

by

Wahyu Sari Sabekti

Thesis submitted to the Faculty of Geo-information Science and Earth Observation (University of Twente) in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation, Specialisation: Land Administration

Thesis Assessment Board

Chairman	: Prof. Dr. J.A. Zevenbergen
External examiner	: Dr. Ir. M.J.P.M. Lemmens
Supervisors	: Ir. C.H.J. Lemmen
	: Dr. Ir. H.T. Uitemark
Member	: Ir. M.C. Bronsveld

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
ENSCHEDE, THE NETHERLANDS

Disclaimer

This document describes work undertaken as part of a programme of study at the Faculty of Geo-information Science and Earth Observation. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the faculty.

Abstract

Key words: cadastral map, map conversion, digital map, map renovation

The rapid development of technology, social changes, globalization, and economic growth related to land, cause changes in the cadastral trend (ELayachi and Semlali, 2001). Nowadays, it is not only used for land registration processes or fiscal and legal purposes but more in supporting the management of land and land use, and facilitating sustainable development (FIG, 1995). In order to achieve its purposes, the cadastral system must provide reliable, accessible and advanced information related to land.

With regard to this condition, the performance of traditional cadastral systems is no longer compatible and adequate (Kaufmann and Steudler, 2001) to achieve the purpose. They are difficult to adjust to all new developments and to meet all user requirements. The traditional cadastral systems are also hard to provide efficient and cost effective services.

As stated in Cadastre 2014 (Kaufmann and Steudler, 2001), automation is recognized as a suitable tool to improve the performance of cadastral systems. The automation processes can be attained through computerization. Through computerization, faster speed on acquiring, storing, retrieving, and disseminating data can be achieved, and it also provides the basis for quality control. The other benefits of computerization are accessibility of wide area network and provide the possibility of data manipulation used in data analyzing and modelling.

The existing conditions of cadastral maps in Indonesia are far away of being so called accurate, complete and up-to-date. They were established by BPN using different methods and scales causing the different qualities of cadastral maps. Moreover, as stated by Winoto (2009), the number of land parcels registered and titled is 24.5 million land parcels out of the number of 84.5 million land parcels all over the Indonesian territory (including forest areas). Among the 24.5 million land parcels, 40% of the maps they are still paper based maps and databases (non-digitized) and also still broadly loosely-connected each other. Meanwhile, there is an expectation on building National Spatial Data Infrastructure (NSDI) where cadastral maps as the basis of this system; hence the cadastral maps have to be in digital environment with a uniform structure such as uniform in data quality.

In order to have cadastral map data in digital environment, there should be data conversion from analogue to digital format. Basically, there are four methods of data conversion: (1) manual digitizing, (2) scanning (heads-up digitizing and automated vectorization), (3) coordinate geometry (COGO), and (4) conversion of the existing digital.

As the aim of this research is to design a conversion strategy of cadastral map data from analogue to digital and also to analyze its implementation to provide an accurate, complete and up-to-date data of cadastral system, hence the investigation of the existing data conversion that can be applied for Indonesia is going to the main concern of this research and the selected method should be minimal loss of data quality, low cost and minimal time.

Map conversion is not only limited to make cadastral map available in digital format but more than that the digital cadastral map has to be accurate, complete, and up-to-date. Due to this there is a need to improving the existing cadastral maps through map renovation. The purpose of map renovation is to improve the quality of cadastral maps either from geometric or semantic specification (Salzmann, Hoekstra et al., 1998) so that they can be used nationwide. Hence a frame work for map renovation as apart of map conversion is going to be built for this research.

Acknowledgements

First of all I would like to thank GOD for His blessings and protection over me so that I can finish my thesis.

I would like to express my gratitude to Christian Lemmen and Harry Uitemark for their support during my thesis period. Thank you for the inputs for broadening-up my knowledge.

I would like to thank my family to always cheer me up and to fully support me to complete this thesis. I love you all.

Special thank to my all of BPN employees at KPKM for their cooperation and to all the respondents during data collection for this thesis. Hopefully our wish for better land administration service in Indonesia will come true.

I would like to give my acknowledgment to all my friends that I cannot mention them one by one. Thank you for being with me and always supporting me.

The last, I would like to thank my classmates in Land Administration course 2009 for giving me a great experience. It would be my pleasure to know you all.

Table of contents

List of figures

List of tables

List of abbreviations

BAKOSURTANAL	:	Badan Koordinasi Survey dan Pemetaan Nasional (National Coordinating Agency for Survey and Mapping)
BAL	:	Basic Agrarian Law (Undang-Undang Pokok Agraria/UUPA)
BPN	:	Badan Pertanahan Nasional (National Land Agency)
CAD	:	Computer Aided Drafting
COGO	:	Coordinate Geometry
DI	:	Daftar Isian (Form List)
DLS	:	Department of Land and Survey
EDM	:	Electronic Distance Measurement
GCPs	:	Ground Control Points
GIS	:	Geographic Information System
GML	:	Geographic Markup Language
GNSS	:	Global Navigation Satellite System
GPS	:	Global Positioning System
ICT	:	Information and Communication Technology
ISO	:	International Organization for Standardization
KaBPN	:	Kepala Badan Pertanahan Nasional (Head of National Land Agency)
KKN	:	Kolusi, Korupsi dan Nepotisme (collusion, corruption and nepotism)
KPKM	:	Kantor Pertanahan Kota Makassar (Makassar Land Office)
LADM	:	Land Administration Domain Model
LAP		Land Administration Program
LIS	:	Land Information System
LOC	:	Land Office Computerization
LSA	:	Least Square Adjustment
NIB	:	Nomor Induk Bidang (Parcel Identifier)
NSDI	:	National Spatial Data Infrastructure
OGC	:	Open Geospatial Consortium
PBB		Pajak Bumi dan Bangunan (Land and Building Taxation)
PMNA/KaBPN	:	Peraturan Menteri Negara Agraria/Kepala Badan Pertanahan Nasional
	:	(Agrarian Ministry/Head of National Land Agency)
Pusdatin	:	Pusat Data dan Informasi (Data Centre and Information)
PP	:	Peraturan Pemerintah (Government Regulation)
RO	:	Research Objective
RRR	:	Rights, Restrictions, and Responsibilities
RTK	:	Real Time Kinematics
R2V	:	Raster to Vector
Sat Nav	:	Satellite Navigation
SDI		Spatial Data Infrastructure
SIGNAS	:	Sistem Informasi Geografis Nasional (National Geographic Information) Systems
SIMTANAS	:	Sistem Informasi Pertanahan Nasional (National Land Information and
	:	Management Systems)

SOI	:	Survey of Israel
SPOPP	:	Standar Prosedur Operasi Pelayanan Pertanahan (Standard Operational
	:	Procedure)
TM3°	:	Transver Mercartor 3 degree
TS	:	Total Station
UML	:	Unified Modeling Language
UTM	:	Universal Transverse Mercartor
WGS	:	World Geodetic System
XML		eXtensible Markup Language

1. Introduction

1.1. Background

The rapid development of technology, social changes, globalization, and economic growth related to land, cause changes in the cadastral trend (ELayachi and Semlali, 2001). It is known that the cadastre is an information system consisting series of map or plans showing the size and location of all land parcels including text records that describe the attribute of the land (UN-ECE, 1996). It is used for land registration processes, fiscal and legal purposes, supporting the management of land and land use, and also facilitating sustainable development (FIG, 1995). In order to achieve its purposes, the cadastral system must provide reliable, accessible and advanced information related to land.

With regard to this condition, the performance of traditional cadastral systems is no longer compatible and adequate (Kaufmann and Steudler, 2001). They are difficult to adjust to all new developments and to meet all user requirements. The traditional cadastral systems are also hard to provide efficient and cost effective services.

As stated in Cadastre 2014 (Kaufmann and Steudler, 2001), automation is recognized as a suitable tool to improve the performance of cadastral systems. The automation processes can be attained through computerization. Through computerization, faster speed on acquiring, storing, retrieving, and disseminating data can be achieved, and it also provides the basis for quality control. The other benefits of computerization are accessibility of wide area network and provide the possibility of data manipulation used in data analyzing and modelling. It also simplifies the space required for data storage (Dale and McLaughlin, 2000).

The most important cadastral activity is the cadastral updating process. This process consists of daily revision of cadastral information and cadastral map. Based on that condition, paper (analogue) maps are not sufficient anymore regarding to maintain and keep it up-to-date. In addition, analogue maps create complexity in data integration with other existing geo-information data. Consequently, data analyzing and decision making processes based on analogue cadastral map are also very difficult to conduct (Kumar, 2007).

Due to the drawbacks caused by analogue cadastral maps, digital maps are required. The digital cadastral maps are an essential component of modern cadastral systems. The advantages of digital cadastral maps are (IAAO, 2003): eliminate tedious/repetitive manual work, accelerate the land registration process and improve data quality, easiness in data sharing, maintaining/updating, and data integration, data protection, and a base of the development for e-land registration.

As mentioned before, one advantage of digital cadastral maps is data protection. Analogue maps have high risk in data storing in terms of natural disaster, fire, and missing/damage due to human activities. Generally known, on December 26, 2004, Indonesia was struck by a tsunami. It caused many losses for Indonesian people, not only to National Land Agency/Badan Pertanahan Nasional (BPN) itself. Many essential documents including maps and legal documents were lost in that tragedy. It can be imagined, how much difficulties might have been faced by BPN to trace the history of land right for interested societies/parties. This illustrates the limitation of analogue format to assure data security. Therefore, it is important to exploit the potential of digital data to assure its security, whilst a proper back-up process is also need to be done. Expensive digital data acquisition can be avoided by digitalising existing analogue data.

In order to digitalize analogue data, a conversion process is required. It is possible to improve existing cadastral maps by translating them into digital form using appropriate procedures. Improvement of cadastral maps is necessary to satisfy the changing demands of users, make them compatible with the Geographic Information System (GIS) environment and create transparency in services with the accessibility of data for all users.

1.2. Problem Statement

The current cadastral maps in Indonesia were established by BPN using different methods and scales and have different qualities, not to say imperfection. In principal, cadastral map in Indonesia was drawn in several scales such as 1: 500 and 1:1.000 for built-up/urban area, 1:2.500 for rural area, and 1:5.000 and 1:10.000 for plantation/forest area. In case of data sources, the cadastral maps are acquired with different techniques like field survey using tape and compass, Global Positioning System (GPS) or theodolite, aerial photogrammetry, digitizing, and satellite imageries. While the coordinate that used are: local coordinate system and national coordinate system (Transverse Mercator 3° (TM3°)). Moreover, most of them are in analogue format. It is emphasized by (Winoto, 2009) that the number of land parcels registered and titled is 24.5 million land parcels out of the number of 84.5 million land parcels all over the Indonesian territory (including forest areas). Among the 24.5 million land parcels, 40% of the maps they are still paper based maps and databases (non-digitized) and also still broadly loosely-connected each other.

Meanwhile, cadastral maps play important role in land registration as evidence to give certainty to the land owners. As evidence, a cadastral map should depict legal boundaries accurately and these maps should be secured in terms of data storage, thus it can be used anytime without any worried of loosing it. Due to this condition and considering the important of cadastral maps, therefore BPN needs to convert its analogue cadastral maps to digital format.

Methods for data conversion are various with their own advantages and disadvantages, specifications or requirements such as the requirement of input data. Thus in selecting which one is suitable for Indonesia, a minimal loss of data quality, minimal cost, and time spent should be taken into account by BPN.

1.3. Motivation

As stated in Agrarian Ministry/Head of National Land Agency (KaBPN/Kepala Badan Pertanahan Nasional) regulation No.3/1998 concerning the enhancement of efficiency and quality of services to the public related to land registration, this study addresses the improvement of the quality of cadastral system in Indonesia which is part of land registration in terms of accelerating the land registration processes. KPKM has been chosen as case study. At the end, it is expected that the result of this study can be implemented for other land offices of BPN.

1.4. Research Objectives

The main objective of this study is to design a conversion strategy of cadastral map data from analogue to digital and also to analyze its implementation to provide an accurate, complete and up-to-date data of cadastral system.

Next to the main objective mentioned above, there are secondary objectives need to be achieved:
1. To examine the existing condition of cadastral maps concerning registers and map data: up-to-date-ness, accuracy, completeness, and scale.
2. To examine the available data conversion approaches.
3. To evaluate and assess the data conversion approach that suitable for converting cadastral map data of BPN.
4. To estimate the costs needed.
5. To develop an implementation strategy of map conversion for KPKM.

1.5. Research Questions

According to the research objectives, some research questions have been addressed as follows:

General Question:

What is the suitable conversion strategy for improvement of cadastral map data and registration process?

Sub-questions:

Table 1: Research sub-questions

Research Objectives (RO)	Research Questions
RO1	1. How is the existing condition of cadastral map data and registers? 2. What are the major factors that define the quality of cadastral map and registers?
RO2	3. What are the available data conversion methods?
RO3	4. What are the parameters to define the best approach of data conversion? 5. What quality improvement methods are available? 6. How to complete cadastral map data? 7. What are the workflows to organize the available method?
RO4	8. What are the cost factors that will impact the conversion method implementation?
RO5	9. Which available conversion and renovation methods can be suitable for KPKM context?

1.6. Methodology

1. *Literature Review*.
   The research begins with literature review, where it is very important here. Before defining the research problem, relevant scientific literature has been reviewed. Further it will be used for

defining assessment criteria. Identification of data requirements before the field work, data analysis, and validation of the result will also be supported by this method. Furthermore, the idea to carry out the case study will be guided by the insight acquired here. For the purpose of this research, scientific literature such as journal articles, books, etc., and policy documents including research/project reports on land reform in Indonesia will be used. It will be done by carrying out literature study related to:

- Modern Cadastre
- Land Administration System in Indonesia
- Map digitalization
- Conversion techniques
- Cost Analysis for map digitalization
- Quality control of map digitizing.

2. *Preparation for Data Collection*.
   In this phase, the steps taken are identifying what kind of data required for this research, such as data about the existing condition of land registration and cadastral map data, data about organizational structures, human resources, users' requirements of digital cadastral map, registration processes, time and cost required for a process. Based on the type of data identified, some questions for questionnaire survey and interviews will be prepared.

3. *Data Collection*.
   In data collection, there are three methods to collect the desired data:
   - *Textual data from literature review.* The desired data in this context are data associated with conversion methods, quality framework of data conversion, and policy framework on map digitalization which can be obtained by study from the available literature.
   - *Questionnaire and Interview*, since this research will not be performed by fieldwork, therefore questionnaires and interviews are conducted to attain the desired data. Questionnaire will be disseminated to users from KPKM, such as the customers, bank, real estate agency, and employees of KPKM itself.

4. *Data Management*.
   The idea of data management is to cluster or classify the data obtained from the method mentioned above, such as questionnaire, interview, and textual data from literatures. The objective of data management is to simplify the data in order to make data analysis efficient.

5. *Data Analysis*.
   The two sets of data collected from the questionnaires and literature review will be analysed in two phases. First, the text data from literature review related to data digitalization and conversion strategy will be analysed to formulate an effective and efficient conversion strategy. The main concern in this analysis will be the cost, time, accuracy, feasibility with the ground situation. In the second phase, the data collected from the questionnaire and interview will be analysed to investigate the user requirements and user's satisfaction level.

6. *Developing a new strategy.*
   Based on the results acquired from data analysis, a new strategy, which can be appropriate and suitable for KPKM will be developed.

1.7. Thesis Structure

Chapter 1: Introduction
This chapter consists of research background, problem statement, research objectives, research questions, and methodology.

Chapter 2: Literature Review
This chapter presents a literature study which supports this research. This consists of a literature related to cadastre and land registration, role of cadastral maps, data conversion methods, cost-benefit and role of surveying and mapping.

Chapter 3: Cadastre in Indonesia
This chapter presents cadastral system in Indonesia in terms of its current condition concerning cadastral map data. Further it discusses the legal framework of cadastre in Indonesia, its current practice, and the issue of building National Spatial Data Infrastructure (NSDI.).

Chapter 4: The Methodology of Map Conversion
This chapter describes the method to build and select the methods of map conversion.

Chapter 5: A Framework for Map Renovation
This chapter presents a framework for map conversion in Indonesia based on the justification related to user requirements concerning data quality, cost and time needed for map conversion, and organizational structure.

Chapter 6: A Case Study
This chapter presents an implementation strategy of map conversion for Kantor Pertanahan Kota Makassar (KPKM).

Chapter 7: Conclusions and Recommendations
It consists of the conclusions of the research and the recommendations for the next study (a pilot project).

2. Literature Review

2.1. Introduction

This chapter is intended to provide some current and relevant literature to support this research. It is started with an illustration of cadastre and land registration. A description of the important of cadastral maps and their role in Land Information System (LIS) is presented here. In addition, to play such an important role, cadastral maps have to be in digital format; therefore literature related to methods to convert data from analogue to digital is presented. In order to perform such project, cost estimation is always needed to make judgement and set up priority; therefore what should be considered in performing cost analysis is discussed. In the last section, it presents the role of surveying and mapping in providing cadastral data records.

2.2. Cadastre and Land Registration

Cadastre and Land Registration system are the core components of cadastral system or land administration (Bogaerts and Zevenbergen, 2001). They described that the land registration is a public register in which the documentation effecting interests in land are kept. This is the official legal registration of properties such as land, buildings, and apartments, of legal right and rightful claimants. On the other hand, they also illustrated that cadastre can be considered as an access channel to the land registration in which it is derived from input data of the land registration documents. These data are registered in registers and on maps, or currently they are stored in administrative and geographic database.

Nowadays, cadastre and land registration system are changing tremendously. It is caused by global drivers, like sustainable development, globalization, urbanization, economic reform and technology (Williamson and Ting, 2001). The aim of cadastre and land registration system is to serve society related to access lands. The system provides them legal protection regarding to the ownership in terms of security to exploit their land, such as: investment and land transaction (selling/buying land) (Bogaerts and Zevenbergen, 2001). However, in practice, there are many failures which can be seen from the ongoing system. As argued by van der Molen, P (Van der Molen, 2002), the existing system does not always support society at an appropriate level and it is also badly maintained. Sometimes the system is far from up-to-date in which it cannot cope with the changes, such as changes in tenure, value, and use by spontaneous/unplanned or planned development. This is also justified by Zevenbergen (Zevenbergen, 1999); he argued that cadastre and land registration procedures are sometimes slow, expensive, and also bureaucratic in such a way, they escort to higher transaction costs because of the complexity of current legal procedures.

2.3. Cadastral Maps

In most countries, cadastral maps are an essential element of land administration (Williamson and Enemark, 1996). A cadastral map is a map that gives information about the shape, boundary, location, and parcel number. The importance of cadastral maps is to support land tenure systems which protect land rights through recognition and recording. They are also used to support effective land markets which allow land rights to be traded effectively and efficiently, such as buying and selling, mortgaging and leasing. It can be seen how important cadastral maps is as a part of infrastructure of information related to land. These maps are the core component for developing and establishing LIS (Larsson, 1991).

In order to meet and support LIS, there is a requirement for digital cadastral maps. As stated in (ELayachi and Semlali, 2001), the important element of any modern cadastre is the digital cadastral maps. By using digital cadastral map, the data will be easy to be manipulated, shared, and up-dated in the system. The base of LIS is a uniform spatial referencing system for the data in the system, which also facilitates the linking of data within the system with other land related data. From that statement it can be said that LIS plays significant roles in land management and supporting the sustainable development.

In order to support LIS, the existing analogue cadastral maps have to be presented in digital format. There are several methods to acquire digital maps (Cichocinski, 1999):

- Converting analogue maps to digital format through map digitizing. Initially, maps are scanned to get the raster image and then further steps are taken to get the vector data. This method will be discussed further in the next section.
- Calculating the survey records such as (parcel boundaries, building corners, and other topographic features) by geodetic calculating programmes. These points are automatically generated as vector data and then can be used directly for creating digital maps.

One that needs to be noticed in the improvement of the existing cadastral maps is that the quality of improvement has to be taken into account. The parameters of quality improvement of cadastral maps are positional accuracy, completeness, attribute accuracy, consistency, and up-to-dateness (Salzmann, Hoekstra et al., 1998).

2.4. Map Conversion

As stated in GIS dictionary (http://www.support.esri.com), data conversion is the process of translating data from one format to another format. Basically, there are four methods of data conversion (Montgomery and Schuch, 1993) (Dangermond, 1988): (1) manual digitizing, (2) scanning (heads up digitizing and automatic vectorization, (3) coordinate geometry (COGO), and (4) conversion of the existing digital data.

2.4.1. Methods of Data Conversion

2.4.1.1. Manual Digitizing

This technique is used to convert data from hard-copy (analogue) maps to digital data (United Nations, 2000). The operator manually traces the map features (mainly lines) from the hard-copy maps using a mouse device. In this case, maps are taped on the digitizing tablet and then directly converted into vector data files, following a sequence of three phases: calibration, digitizing, and correction of errors. This method minimizes the total hardware/software investment. On the other hand, it is labor-intensive, thus it can be expensive. However Ingersoll (Ingersoll, 1994) argued that it is a proven method and that is the reason why many of the most experienced and productive data-conversion teams use it.

2.4.1.2. Scanning

Digitizing using scanning can be divided into two types: *semi-automatic* and *automatic* digitizing, depending on operator interaction within digitizing processes (Montgomery and Schuch, 1993).

- Semi-automatic digitizing procedure is similar with on-screen digitizing. The operator selects the features that need to be converted and then the system traces the features to the nearest intersection and converts them into vector presentation.
- Automatic Vectorization. Using this method, process, symbols, text, and lines can be recognized automatically with assumption that the available maps comes from a good raster map image. It uses automatic pattern recognition, optical character recognition, and vectorization software. The steps taken on this method are: scan, vectorize, and edit. Mendes (Mendes, 1995) argued the use of semi- or fully automated solutions, at the moment, is possible only to convert unambiguous documents. In general, cartographic documents are too dense and complex to be submitted to a fully automated digitizing. Nevertheless, in some situations, it is feasible when followed by a clean-up of the results that will supplement what the automated algorithm did not find and will correct what was not found accurately. Currently, this method is not widely used.

2.4.1.3. Coordinate Geometry (COGO)

This refers to a data conversion process in which digital maps are created from data that are taken from field survey (Dangermond, 1988). These data usually consist of line length and direction, and point locations. All of those data are relative to the location of certain key features such as ground control points and survey monuments.

2.4.1.4. Conversion of the Existing Digital Data

Recently, there are a wide variety of spatial data, including digital maps that are openly available from a wide range of government and private sources (Dangermond, 1988). Data from Computer Aided Drafting (CAD) systems are commonly used in a GIS. Due to this commonly there are GIS software offer in the market to transform it to GIS environment. Considered the purpose of this research is to convert data from analogue to digital, therefore this method will not be included in the next discussion to choose the best method for map conversion.

2.4.2. Types of Data Sources

The initial step to be noticed in map conversion is to know the types of data sources for map conversion. This will determine what kind of techniques to be used as input and how to process them. The general sources for spatial data are:

- hardcopy or analogue maps;
- aerial photographs;
- remotely-sensed or satellite imagery;
- point data samples from surveys or data from field measurement; and
- existing digital data files.

2.4.3. Map Standard and Accuracy

All maps, in this case cadastral maps, in order to be useful, they must correctly represent real world entities both geometrically and geographically to some measurable degree (Devillers and Jeansoulin, 2006). Standards provide rational for how spatial data may be used by defining to what degree the data represent the real world, or in this case how accurately they depict property boundaries. Standard in terms of map projection, scale, or the accuracy of production plays an important role when spatial data especially cadastral map data are going to be used in GIS environment. Using the same standard, it will simplify the combination of cadastral map data with other spatial/geographic data such as thematic map (rainfall, density, soil type and land classification maps); in which it will generate important information for land use planning or environmental analysis.

Table 2: Data quality elements and sub elements (ISO/FDIS 19113:2002) (http://www.isotc211.org/)

No.	**Data quality element(s)** Sub element(s)	**Description**
1.	**Completeness** Commission Omission	Presence and absence of features, their attributes and relationships. Excess data present in a data set Data absent from a data set.
2.	**Logical consistency** Conceptual consistency Domain Consistency Format Consistency Topological consistency	Degree of adherence to logical rules of data structure, attributes, and relationships. Adherence to rules of the conceptual schema. Adherence of values to the value domains. Degree to which data is stored in accordance with the physical structure of the data set. Correctness of the explicitly encoded topological characteristics of a data set
3.	**Positional accuracy** Absolute or external accuracy Relative and internal accuracy Girded data position accuracy	Accuracy of the position of features. Closeness of reported coordinate values to values accepted as or being true. Closeness of the relative positions of features in a data set to their respective relative positions accepted as or being true. Closeness of girded data position values to values accepted as or being true.
4.	**Temporal accuracy** Accuracy of a time measurement Temporal consistency Temporal validity	Accuracy of the temporal attributes and temporal relationships of features. Correctness of the temporal references of an item (reporting of error in time measurement). Correctness of ordered events or sequence, if reported. Validity of data with respect to time.
5.	**Thematic accuracy** Classification correctness Non-quantitative attribute correctness Quantitative attribute correctness	Accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships. Comparison of the classes assigned to features or their attributes to a universe of discourse (e.g. ground truth or reference data set) Correctness of non-quantitative attributes. Accuracy of quantitative attributes.

In the context of map conversion, data quality issues are positional accuracy and completeness of the spatial data (MASGISS, 1999)(United Nations, 2000). Thus these two factors become the main concern in which they determine the strategy in selecting the best method of conversion.

2.5. Cost-Benefits

(Dale and McLaughlin, 2000) says that with the ongoing cadastre and land registration system, in terms of maintaining and keeping it up-to-date, it requires high investment. The source of investment could be from the government or other institutions, such as World Bank. To obtain intended investment, usually it needs data for evaluation. Thus, cost-benefits analysis has an important role as a tool for making judgements and setting priorities (Dale, 2005). It will prevent a waste of unnecessary investment and become a guideline for a judgement or decision making whether an investment should be made or not.

There are several steps that can be taken as considerations when performing cost-benefit analysis as following (Larsson, 1991):

- *Specifying the current situation*. What is the current system, how does it work, and what are its shortcomings? These questions are necessary to be answered in order to define the starting point of the assessment.
- *Defining the proposed of new system(s)*. It is suggested to illustrate precisely the current and desired system, to make it easier for evaluating the effects of the changes.
- *Expressing the benefits in verbal term*. It defines what kind of advantages can be obtained from the system applied in wider context, such as for the sustainable development.
- *Evaluating the benefits*. It is started by analyzing the strength and weakness of the proposed system.

In addition, user requirements should be taken into account as a part for analyzing (Dale, 2005). As one aim of the establishment of new system(s) is to serve customers, it is important to investigate the characteristic and degree of what people require, which is helpful to identify potential new data sets that can support their needs related to land information. From this information, it can be used for evaluating the costs needed for storing and updating and also what are the potential benefits that can be expected from it.

2.6. The Roles of Surveying and Mapping

Surveying and Mapping are approaches for establishing cadastral records. Cadastral surveys are mainly concerned with the setting out and recording all points for mostly defining property boundaries (Dale, 2005). Indeed, there are various techniques that can be used in which each of them has their own characteristics related to costs, accuracy, and inherent advantages. Of course, the applied techniques are adjusted with the need or purposes for which the survey is carried out in the first place. For instance, if the cadastre is conducted for supporting land titling, it should be established in accordance with the same general standards that have been determined. This does not mean that all the areas that are being surveyed must have the same precision. It is because there would be different requirements for performing survey in the city centres and the rural areas.

Generally known, techniques in surveying can be utilized for the purpose of cadastral renewal, (cadastral up-dating) such as field survey techniques and air survey methods. Through photogrammetric techniques, these are powerful tools for documenting, interpreting and surveying large area. They can be a good choice for accelerating the survey records instead of ground surveying, in terms of time spending and cost saving. They are widely used to increase the density of control points and also to measure the property boundaries. The other important advantage using these techniques is that whatever being recorded, they can be seen clearly on the aerial photographs in which it is useful in feature identification such as land use, and boundary demarcation.

Since there are various techniques that can be used to obtain the cadastral data, the results might also be presented in various kind of data type with various qualities. Consequently, the requirement of a uniform quality for cadastral surveys is essential. This is the responsibility of the central surveying authority to establish such framework for uniform data quality. The framework of data quality is rules, standards, and basic principles for the examination and evaluation of basic material; how the quality of spatial and text data is to be improved; and how new data are to be obtained and then overlaid with the current data.

2.7. Conclusion

From the literature study as performed in this chapter, it shows that cadastre and land registration have been changing tremendously in line with the development of technologies. As cadastral maps become a foundation for LIS, indeed cadastral maps have to be in digital format. Due to this requirement, there are several methods have been presented to convert paper based maps into digital format such as manual digitizing, scanning, COGO, and conversion of the existing digital data. Detail comparison of the three methods will be presented in section 4.4.1.

3. Cadastre in Indonesia

3.1. Introduction

This chapter discusses cadastral system in Indonesia and its current condition, including the purpose of cadastral system in Indonesia and its legal framework. This chapter is more focus on physical activity such as surveying and mapping and its element related to physical data resulted from those activities (spatial and textual documents). With regard to a great demand to build Spatial Data Infrastructure in Indonesia where the cadastral system plays an important role, it also becomes a concern of this session. Some efforts that have been taken by Indonesian government is also described here.

3.2. Legal framework

3.2.1. The Basic Agrarian Law (BAL)

The foundation of legal framework of cadastre system in Indonesia is the Basic Agrarian Law (BAL) that was enacted in 1950 ruled by law number 5/1960. It determines the purpose of cadastre system in Indonesia. Cadastre in Indonesia is a legal cadastre with negative system within the registration of titles system. It means that the certificate of land title is valid as the strong (not positive or absolute) evidence. As long as it is otherwise inversely proven by the court, then the certificate of land title is the strongest evidence. Furthermore, as stated in article 19 BAL (UUPA); the purpose of cadastral system in Indonesia is to guarantee the security of tenure or juridical assurance of land ownerships. It is conducted by the government of the Republic of Indonesia through land registration. The activities in land registration contain (a) surveying, mapping, and booking the lands; (b) registration of titles and also transfers of those titles; and (c) issuing the letter of evidence of land title called certificate that is recognized as strong evidence.

3.2.2. Regulations related to Land Registration

With regard to the description above, the outline of Basic Agrarian Law is only main matters and basic principles. The implementation of this law is governed into other laws, government regulations and other legal decrees or regulation. The specific regulations to support BAL in administering cadastral system in Indonesia especially for land registration are:

- Peraturan Pemerintah No. 10/1961 (Government Regulation/PP No. 10/1961)
- Peraturan Pemerintah No. 24/1997 (Government Regulation/PP No. 24/1997)
- Peraturan Menteri Negara Agraria/Kepala Badan Pertanahan Nasional No. 3/1997 (Regulation of Agrarian Ministry/Head of National Land Agency/PMNA/KaBPN No. 3/1997)

PP No. 24/1997 is a replacement regulation of PP No. 10/1961 concerning Land Registration in Indonesia. It was established because the land registration resulted by implementing PP No.10/1961 did not give a satisfied result. Of the approximately 55 million parcels of land rights were eligible to be registered, only approximately 16.3 million of which were registered. The basic legal provisions in this regulation were not enough to give possibility for implementing land registration in a short time with a satisfied result. Considering this situation and in order to give better support of national sustainable development by providing legal certainty of land parcel(s), it was necessary to make improvements in provision governing the land registration by establishing PP No. 24/1997.

Moreover, PP No. 24/1997 is an affirmation of the things that have not been clear in the PP No. 10/1961. It consists of ten (10) chapters in which it includes the understanding of land registration itself, the principles and purposes of land registration, which in addition to provide legal certainty as mentioned before; it is also intended to collect and present a complete information of physical and juridical data of a certain land parcel. It also stipulates the procedures of data collection related to land ownership.

In order to implement the provisions in PP No. 24/1997, BPN established Peraturan Menteri Negara Agraria/Kepala Badan Pertanahan Nasional No. 3/1997 (PMNA/KaBPN No. 3/1997). This regulation regulates the technical procedures of land registration, such as the detail requirements of surveying and mapping for land registration and land.

3.3. Surveying and Mapping

As mentioned before in chapter 2 the surveying and mapping play important role in establishing cadastral records. Cadastral surveys are mainly concerned with the setting out and recording all points for mostly defining property boundaries (Dale, 2005). Surveying or cadastral survey in Indonesia is related to the measurement of land rights, especially for the parcel measurements. The measured parcels are then mapped in the cadastral maps and registered in land books. Mapping and land booking is the continuation of cadastral surveys to create tenure security and for implementing land administration in Indonesia. Therefore in the next discussion, it will discuss the technical part of surveying and mapping.

3.3.1. Ground control points (GCPs)

GCPs play the role as a national reference framework for surveying and mapping in Indonesia. These points are needed for mapping land parcels where size, area, and other dimensions of them can be identified precisely and accurately. Static Global Positioning System (GPS) is used to observe these points in order to get precise coordinates.

The GCPs can be divided into five (5) levels, namely: GCP of *order 0*, *order 1*, *order 2*, *order 3*, and *order 4*. For GCPs *order 0* and *order 1*, the organization that responsible to provide and carry out surveying and mapping of those GCPs is *Badan Koordinasi Survey dan Pemetaan Nasional* (BAKOSURTANAL). Others are carried out by BPN with the following division: *order 2* and *order 3* are done by the headquarter office, although for *order 3* it can also be delegated to the province offices; and for *order 4* it is commonly conducted by the land offices. The technique used to measure *order 2* and *order 3* is through GPS while for *order 4* by carrying out terrestrial measurement with tying it to the GCPs of *order 3*.

3.3.2. Spatial Reference System

As a reference point, GCPs have to be in national coordinate system so all mapping objects can be mapped in the uniform system to create a seamless map. There are two national coordinate system applied in Indonesia: Universal Transverse Mercartor (UTM) used by BAKOSURTANAL as its system projection; while with regard to the article 3 PMNA KaBPN No. 3/1997, the national coordinate system used by BPN is Transverse Mercator 3° (TM3°) as its system projection. In TM3° system projection, Indonesia is divided into 16 zones. In addition the geodetic datum used for both coordinate systems is the same, namely World Geodetic System 1984 (WGS 84). Therefore, there should be coordinate transformation from UTM to TM3°, if BPN uses BAKOSURTANAL coordinates as a reference and vice versa.

3.3.3. Surveying and Mapping of Land Parcels

By the establishment of GCPs, the measurement of land parcels can be done by tying up all measurements to the available GCPs. These measurements can be done through terrestrial, fotogrammetric or other techniques. Terrestrial measurement is performed by using theodolite and other measurement tools such as: tape, electronic distance measurement (EDM), GPS receivers, and so on. While for the fotogrammetric technique, it uses data from aerial photos. Mapping as a result from fotogrammetric firstly should be determined ground control points to bring it to national coordinate system and the measured all land boundaries that were identified from the image maps.

Moreover, all land parcels that have been measured then are mapped in cadastral base maps. However in practice, not all areas covered by GCPs, therefore for these areas, the measurement are done by using local coordinate system. Lack of the availability of GCPs adversely influences cadastral mapping system since no reference to unify cadastral map among local offices to support national land information system.

3.3.4. Parcel Identifier (Nomor Induk Bidang/NIB)

NIB is a unique number given to a certain parcel that have been defined its legal boundaries and mapped in cadastral maps for book keeping or land registration purpose. This number is used as a primary key in land registration to relate and identify the legal and physical data. It consists of 13 digit numbers where the first eight digits is a code of province, regency, district, and village; and the last five digits is the number of a parcel.

3.4. Elements of Physical Data

Indonesia's cadastral system typically consists of the following elements:

a. Physical data, it includes textual and spatial components. The textual component is the land register which identifies land parcel data and its information, such as owner's name, address, and other identities and attributes, neighbourhoods, and other related information. While spatial component is the cadastral maps that illustrate all land parcels graphically in line with the registered title (textual and juridical elements) with use of NIB as a unique parcel identifiers and number of map sheets.
b. Juridical data is the land register that recognizes land parcel data and its information including RRR (rights, restrictions, and responsibilities), durations, kinds of legal documents and legal proofs, and other legal related data.

However, this section will mainly focus on the physical data as one of the objectives of this research that is concerned with the current condition of registers and map data.

3.4.1. Spatial Documents

As mentioned above, the main concern of surveying and mapping is for establishing cadastral records. Related to that, the next paragraph discusses several documents as a cadastral record produced by surveying and mapping in Indonesia in which they are play role in registration process. All of the documents mentioned below refer to the description given in the articles of PP 24/2997 related to spatial documents.

3.4.1.1. Cadastral Base Maps

As stated in article 1 point 14 PP No. 24 /1997, cadastral base maps is a map that contains GCPs and topographic features, such as river, road, building and physical boundaries of land parcels. These maps are made by using scale 1:1000 and 1:500 for built-up areas (urban areas), 1:2500 for agriculture areas (rural areas) and 1:10.000 for plantation areas. These maps must have planimetric accuracy greater than or equal to 0.3 mm on the scale of the map (article 17 point 1a PMNA KaBPN No.3/1997). Therefore, in order to know the accuracy it is usually done by checking the distance at which points that easily to be identified in the field and on the map. As mentioned before, these maps could be in national or local coordinate system depends on technique used for measurement. Referring to article 16 point 4 PP No. 24/1997, cadastral base maps are a base map to make cadastral maps.

3.4.1.2. Cadastral Maps

Cadastral maps are made to obtain information about the shape, boundary, location and parcel identifier of each land parcel that has been measured, as well the presence of buildings on it if necessary for registration. The cadastral maps show all land parcels graphically corresponding to the registered title (textual and juridical components) with unique parcel identifiers and number of map sheets (article 1 point 15 PP No.24/1997).

3.4.1.3. Field Sketches

Every measurement of land parcels, not only mapped in the cadastral base maps but the filed sketches of land parcels have to be made also. Field sketch is a document depicting a parcel or more parcels and its surrounding (neighbour boundaries) and data record of measurement such as distance, angle and azimuth or direction. Field sketches are used for boundary reconstruction (article 30 PMNA/KaBPN No.3/1997).

3.4.1.4. Parcel Map

Parcel map is a map generated from mapping of one or more parcel(s) with a certain scale where it depicts legal boundaries of parcel(s) (PMNA/KaBPN No. 3/1997 article 1 point 6). This map is used for announcement of physical data before establishing certificate of a certain parcel. Parcel map is mapped in cadastral map for registration.

3.4.1.5. Map Plan

Map plan is a document that contains the physical data of a parcel in which it is shown as a map and its description (article 1 point 17 PP No. 24/1997). All parcels that have been surveyed and mapped in cadastral maps must be made its map plan for the registration purpose by citing information in cadastral maps. For areas that haven't provided by cadastral maps, the map plan is cited from the measurement. This document is attached in the certificate.

3.4.1.6. Land List

Land list is a document in which it is a list that contains an identity of parcels with a particular numbering. Parcel(s) that have been mapped or given a unique parcel identifier in the cadastral maps are registered or booked in the land list. The purpose of land list is as book keeping (article 21 point 1 PP No. 24/1997.

3.4.2. Textual Documents

As mentioned before, textual documents is the land register which identifies land parcel data and its information, such as owner's name, address, and other identities and attributes, neighbourhoods, and other related information. These are done by recording all registered land parcel in order to administer land registration in form lists (Daftar Isian/DI). Every change in spatial documents should be followed by changing in textual documents (in this case in form list). The DI(s) involved in surveying and mappings are as given in Table 3:

Table 3: Form list (DI) for surveying and mapping

No.	Form List (DI)	Description
1.	DI. 103	List to record field survey data (distances, bearings, and angles).
2.	DI. 107	List to record field sketches.
3.	DI. 203	List for land list to give NIB.
4.	DI. 204	List to record names of the applicants
5.	DI. 311 A	List to record cadastral map
6.	DI. 312	List for land rights type to give number to every land right

3.5. Standardization

In order to improve the performance of its land registration, BPN established a standard for its services called Standar Prosedur Operasi Pelayanan Pertanahan (SPOPP) as the Standard Operational Procedure. It was established in 2008, this standard also consists of legal foundation, pre-requirement, work-flow, time spent for a specific land service, and service fee. Another standard established by BPN is spatial data standard for digital mapping using DXF format. This standard is limited to layer and entity standard. The DXF format was chosen because most of BPN surveyor and mapping staff familiar with CAD software.

3.6. Current Condition of Cadastre in Indonesia

This section discusses current condition of cadastre in Indonesia related to cadastral map data. It covers general overview of cadastral system, the technical issues concerning the different purposes of cadastre system applied by different organizations, and its effects on the development of National Spatial Data Infrastructure (NSDI), and several improvement efforts that have been done for cadastre in Indonesia.

3.6.1. General Overview

As already mentioned before, the aim of cadastre system in Indonesia is to guarantee the security of tenure or juridical assurance of land ownerships. It can be achieved by having a complete administration related to land parcel. Cadastral map as a physical data in which it records the legal boundaries of parcels and related to its legal status, becomes important in supporting land administration in Indonesia. The advantages of having complete cadastral maps are: giving better security tenure, useful for taxation and multipurpose cadastre, ensure fair land taxation and transparent revenue sharing between central and local government, avoid double certificate issuance, provide important information for land use management and planning, and support for decision making related to land.

3.6.2. Current Condition of Cadastral Map in Indonesia

Basically, cadastral maps in Indonesia is drawn into five scales: 1:1.000 and 1:500 (for built-up or urban areas), 1:2.500 (for rural areas), and 1:5.000 or 1:10.00 (for plantation or forest areas). A Cadastral map consist information of cadastral boundary of parcels, a unique parcel identifier (NIB), street name and other topographic features as an orientation in the field such as road and river. Below is the example of cadastral map in Makassar.

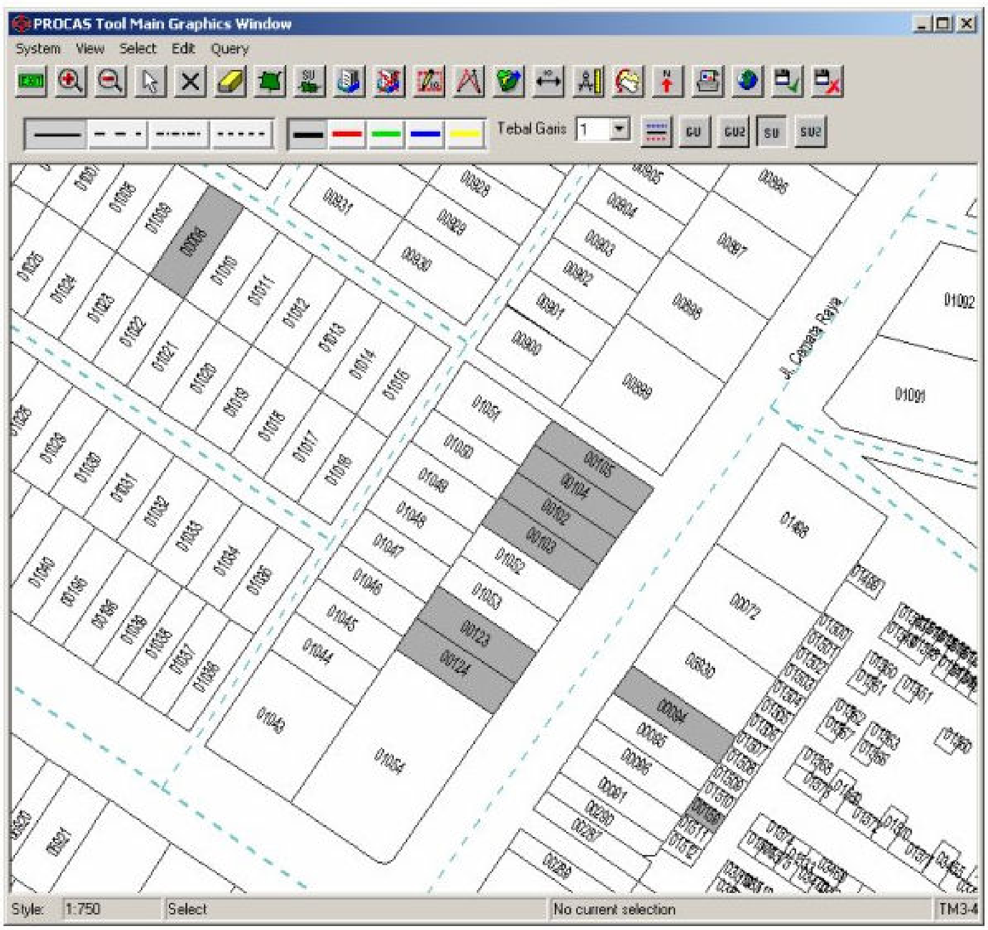


Figure 1: Cadastral map in Makassar (http://map.bpn.go.id/indexmap.html)

Based on the scale and PMNA/Ka BPN No. 24/1997 article 17 point 1b, which states that tolerance limit of field survey is 0.3 x map scale, tolerance limits of measurement for each scale can be given as following:

Table 4: Tolerance limit of field survey

Area	Scale	Tolerance
Urban area	1:500	0.15m
	1:1.000	0.3m
Rural area	1:2.500	0.75m
Plantation/forest area	1:5.000	1.5m
	1:10.000	3m

3.6.3. Cadastral Mapping and Registers

As in article 17 PP. 24/1997 concerning land registration, it states that survey and mapping are performed to collect and process the cadastral data especially physical data (point 1). The activities of survey and mapping consist of (point 2): (1) generating cadastral base maps, (2) establishing cadastral boundary of parcel(s), (3) survey and mapping of parcel(s) and generating cadastral maps, (4) generating land list, and (5) generating map plan.

Cadastral mapping for land registration purpose is conducted in local level or land offices. Cadastral maps are made after performing a field survey. Every surveyed parcel has to be made its parcel maps for announcement purpose before establishing certificate, and then it has to be drafted in cadastral maps. Figure below gives a description of surveying and mapping in terms of cadastral mapping.

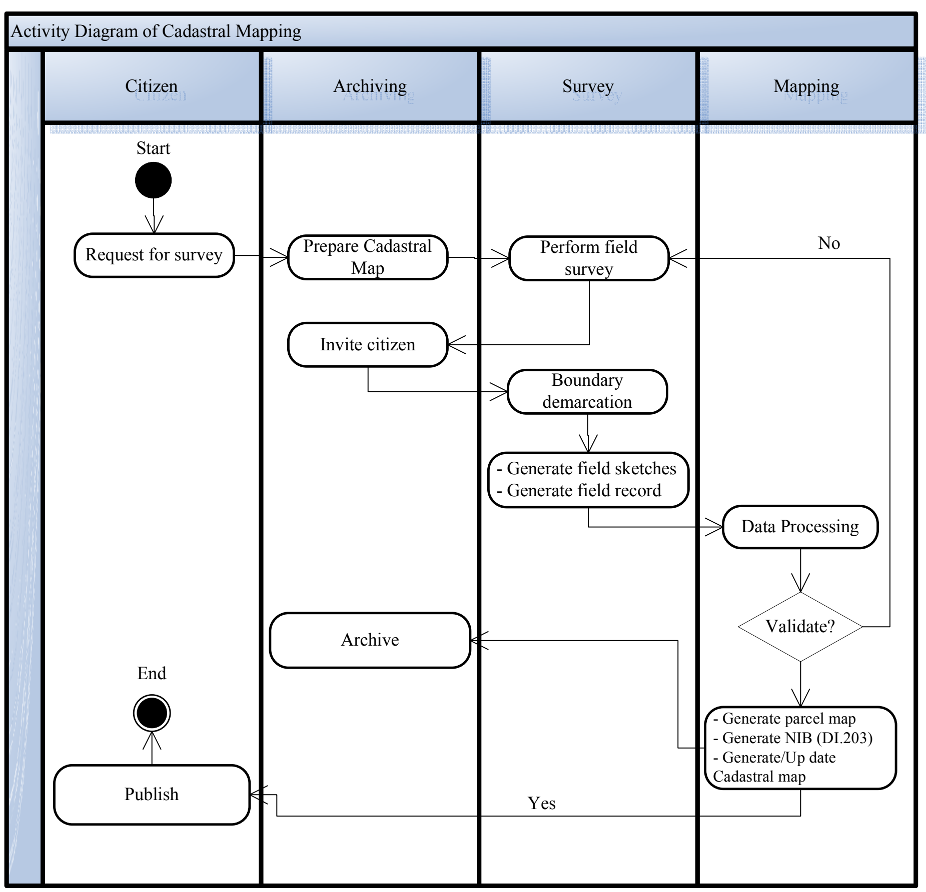


Figure 2: Activity diagram of cadastral mapping

The cadastral map should depict the legal situation of parcels. To keep it as up to date as possible, every change of parcel(s) caused of land transaction such as subdivision/merging of parcels (as presented in Figure 3) should be updated and registered in the physical documents, including spatial and textual documents. In such case, updated physical data is done by drawing the changes in field sketches, map plans, and cadastral maps in terms of changes in legal boundaries and its parcel identifier. These changes are followed by doing book keeping in the textual documents, which in this case is done in a form list called Daftar Isian (DI) and in the land book. The DI that involved here are DI. 203, DI. 204 and DI. 312. The aim of this book keeping is to keep track all changes on parcel(s).

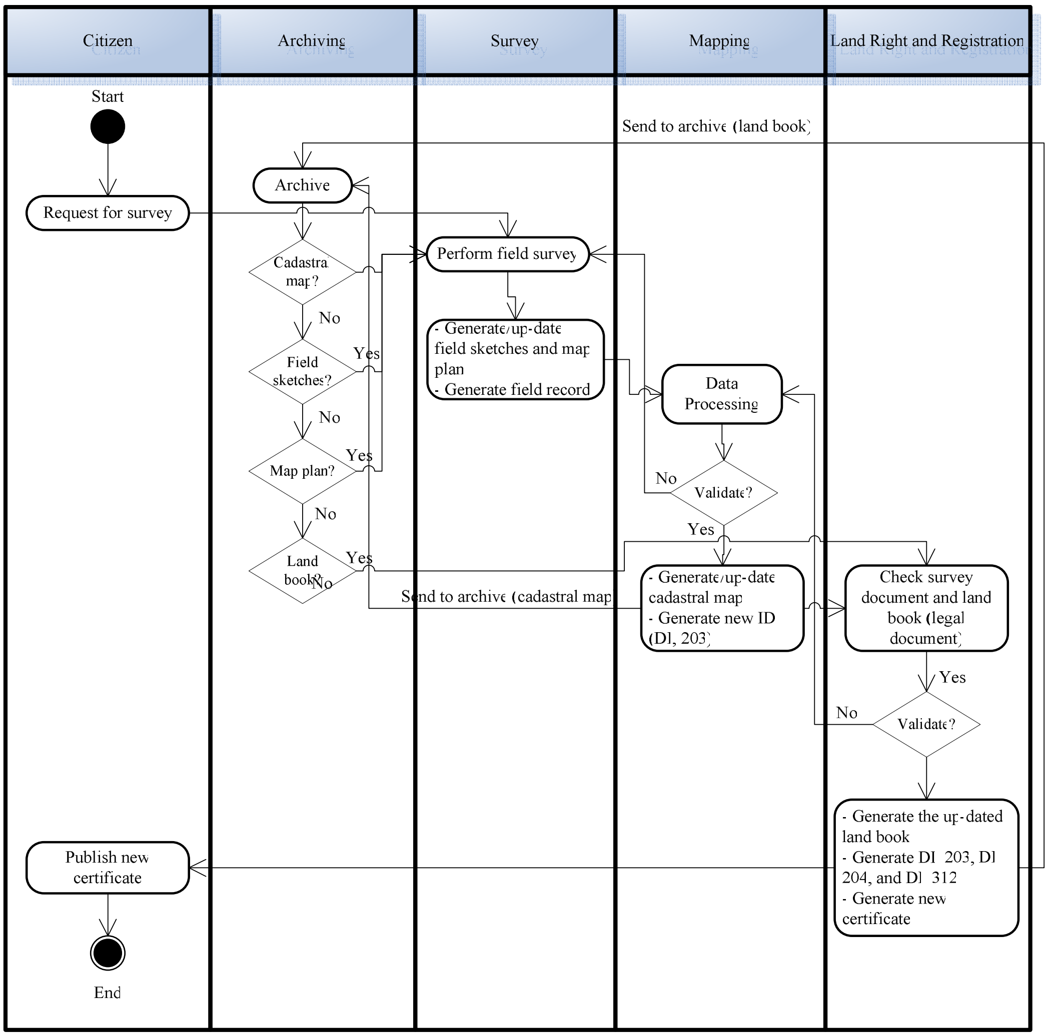


Figure 3: Activity diagram for subdivison/merging parcel

3.7. Technical Issue

There are two cadastre systems in Indonesia (Achmad, 2004): (1) fiscal cadastre conducted by the Directorate of Land and Building Taxation (Pajak Bumi dan Bangunan/PBB), the General Directorate of Taxation, and Ministry of Finance and (2) legal cadastre is managed by BPN. They perform the same activities in cadastre but for different aims. These activities resulting in the existing of vast amount of data with various formats, such as different coordinate and system projections, different

\parcel identity number, and also different accuracy and precision of surveying and mapping. These different formats hamper the data integration and data exchange. As shown in figure 4, the diversity of data generates independent systems where spatial data as a base for those. Meanwhile, there is a great demand for building National Spatial Data Infrastructure (NSDI) to serve different interests from the stakeholders, customers, and also to support sustainable developments.

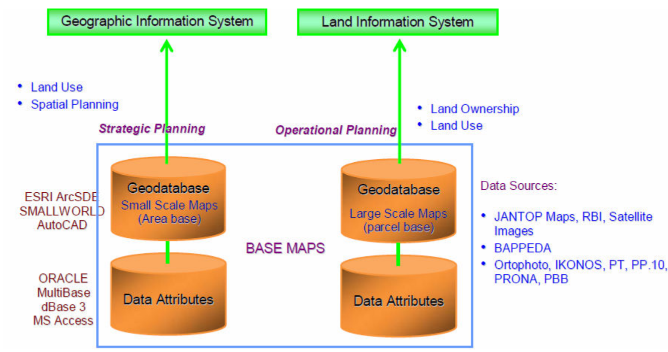


Figure 4: Current condition of spatial data arrangements (Achmad, 2004)

The expecting condition of a NSDI in Indonesia is that there will be data integration between National Geographic Information Systems (SIGNAS) and the National Land Information and Management Systems (SIMTANAS) as shown in figure 5. This new system will allow and support the government to perform land resource management and administration, giving better services to public effectively and efficiently with avoiding duplication of works and wasteful of unnecessary investment. It also allows the government to work transparently and also encourage people by providing easiness of using the system and increase public participation.

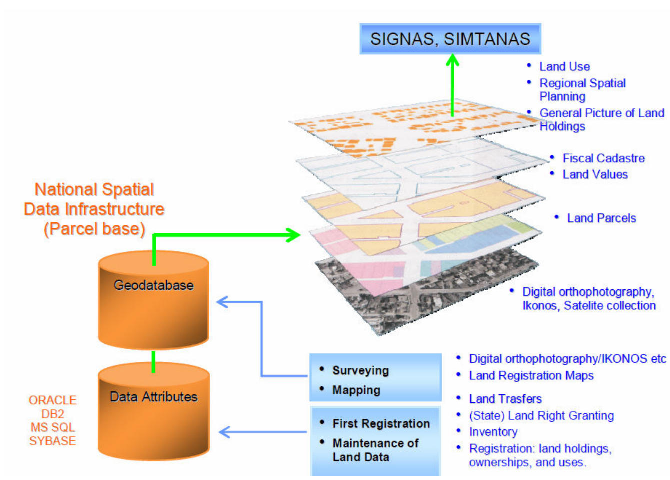


Figure 5: Expecting conditions of a NSDI (Achmad, 2004)

Further expectations in gaining spatial data integration from sources to achieve NSDI are as follow:

- To give a complete, accessible, clear, and comprehensive information related to land,
- To lead and to improve better land management and policy,
- To avoid repetition of works,
- To reduce land disputes,
- To support disaster management by giving early warning system,

- To simplify in making statistic data collection and for its reporting,
- To create an efficient in data storage, time consume in data queries, and number of human resources required,
- To accelerate state incomes through land taxes,
- To support SIGNAS-SIMTANAS, e-Government, and e-Conveyance, and e-Commerce, comprehensive spatial planning, and
- To support and facilitate the coordination between stakeholders and institutions.

Consequently, there must be spatial data in digital format as the basis foundation of the system and a standard of its spatial data structure and also framework for data integration, such as standardization in data acquisition, storage, and maintenance, and the person(s) or institutions who role in the systems. In addition, the hindering factors as mentioned above like the readiness of human resources in terms of capabilities and the financial investment must be taken into account concerning the costs that will be needed to provide the infrastructure.

3.8. Improvement Effort of Cadastre in Indonesia

3.8.1. Land Registration Project

There have been many projects held by government incorporated with other organizations such as World Bank to accelerate land registration in Indonesia. In 1991, the World Bank recommended a long term program to emergence an efficient land market and alleviating social conflict over land right. The Land Administration (LAP) was implemented on 1994 and in general it improves social and economic status more than 1.8 million households through security tenure to land and property (Heryani and Grant, 2004).

However, there are still many parcels that still remind unregistered and it becomes big issue in Indonesia. Based on (Bappenas, 2007) related to land registration data, land registration in Indonesia only covers 37.5 million registered parcels out of total estimation parcels in Indonesia which is about 85 million parcels or equal to 44%. Referring to (World Bank, 2005) Indonesia has the relatively low rate in the number of registered parcels compared to other countries in South Asia. For instance in Thailand and Philippines, the registered parcel parcels in both countries reached almost 80% and 60% in the year 2005. The big challenge for accelerating the land registration comes from the availability of cadastral base maps which cover the whole Indonesian territory.

3.8.2. Base Mapping Project

Since 1960, when the Agrarian Act was issued, only less then ten percent of the total area of Indonesia has been mapped by the scale of 1:10.000, 1:2500 and 1:1000, only 90,000 km^2 out of 1.900.000 km^2 (Bappenas, 2007). It consists of forested area (51 %), plantation (37 %) and dense populated area (8 %). In 2007 Indonesian government launched Agrarian Reform program. One of the objectives of this program is to measure and register the whole land parcels in Indonesia within less than 20 years. Due to this program, it has pushed the government to produce cadastral base map with suitable scale covering. These maps are used as a basis for cadastral survey and land. In addition, in 2006 BPN has formed a new deputy to speed up the availability of large scale base map for cadastral and land registration called Deputy of Surveying and Mapping.

Due to this condition, a scenario has been set up, such as the technology used for data acquisition. In this case aerial photographs and satellite imageries with various spatial resolutions can be used. However, the aerial photographs as the most favourable solution are the most expensive technique. Thus satellite imagery can be the answer for affordable cost, fast and large coverage related to data acquisition for base mapping.

As data obtained from Deputy of Surveying and Mapping related to the current condition of base mapping condition in Indonesia, satellite imagery with a suitable resolution of the entire land surface of Indonesia will have to be collected for the next 3-5 years. Starting from year 2003, satellite imagery covering almost 30 percent of the area (550.000 km^2) had been purchased. It consists of imagery with 0.6m resolutions for Java, Bali, NTB and NTT and 2.5m resolutions for Sumatra and Sulawesi. The plan is to complete cover the whole territory with base maps in the year 2010. The raw images are then distributed to each provincial office to be used and processed.

3.8.3. Land Office Computerization (LOC) Project

For supporting land administration in Indonesia, every land office in each city/regency manages centralized parcel-based land administration in which the processes are mostly run manually. The data is still paper-based and maintained manually, requiring large storage space and storage risk is relatively high. The need to increase the capacity and quality of services is to give a fast service, affordable, and accurate in anticipating the increasing application of land registration. Therefore, land computerization was introduced in BPN environment in 1998 to store cadastral data. This project was established with purposes: to create a good land administration in Indonesia, to improve and speed up the land services, to improve the quality of land information, to create a reliable land information system, and to facilitate the easiness of land parcel data maintaining in digital format and to save the storage space (http://locsupport.wordpress.com/2007/11/14/sekilas-tentang-loc/).

Since LOC has been introduced, there are 42 out of 437 regency and municipality land offices and 15 out of 33 provincial land administration offices running a Land Office Computerization (LOC) projects, but they are still partly manual (source: Indonesia cadastral template).

3.9. Conclusion

A general overview of cadastre in Indonesia and its current condition has been presented in this chapter. As the aims of cadastre system in Indonesia is to guarantee the security of tenure or juridical assurance of land ownerships; hence a complete land administration related to land is necessary. In addition, with a great expectation to build NSDI in Indonesia where cadastral data as the basis for this system; therefore there is a need to improve the performance of the cadastral system and several efforts that have been taken are presented in 3.8.

4. The Methodology for Map Conversion

4.1. Introduction

This chapter discusses a strategy to select the best method for cadastral data conversion. In selecting a method, there are several factors that should be taken into account and they are presented in one of sections in this chapter. The requirement of each method is also described here. It is created based on literature study from many sources which compare between the available methods. Furthermore in map conversions itself, there are processes that have to be performed in order to get a good structure of spatial data of map conversion. In the last section, it gives a discussion concerning the chosen method.

4.2. The Influencing Factors

As mentioned before in chapter 2 that there are four basic techniques in data conversion which are manual digitizing, heads-up digitizing, automatic vectorization, and conversion of the existing digital data. The last method will not be used as the reason given in 2.4.1.4. (MASGISS, 1999) and (Montgomery and Schuch, 1993) emphasize that there are several factors influencing the choice of the available methods of data conversion such as (1) availability and quality of the source maps, (2) availability of the specialized software, and (3) the requirements for quality and completeness of the data vs. the cost of the project.

4.2.1. Availability and quality of data sources

As already stated in section 2.4.2, there are several types of data sources with their own quality. The quality is defined by the condition of the original data before being converted. For instance: analog maps are in poor condition or have error that may not be in a form that can be scanned (Dangermond, 1988).

Before initiating the process of conversion, evaluating the availability and quality of existing maps is crucial to do first, because it is used to determine which conversion is going to be used. In order to know which one is suitable, (Donahue, 1994 in MASGISS, 1999) introduced a method to know the existing condition. The method is by answering several relevant questions as given below:

1. Were the maps originally generated from deeds, field surveys, and subdivision of parcel(s)?
2. Do the original cadastral and parcel maps meet the GIS accuracy requirements?
3. Have the maps been maintained regularly?
4. Do the current maps visually edge match?
5. Are the current maps drafted at an acceptable scale?

Based on those questions, if most of the answers are “NO”, it is necessary to recompile the analogue maps before starting conversion process or select a method that does not require analog maps as data sources.

4.2.2. Availability of the specialized software

The availability of specific software also determines the conversion method that is going to be used. Inversely, the selection of a certain method needs a support for specific software as well. Nowadays, mapping and GIS software commonly are equipped with digitizing tools either for manual and heads-up digitizing. Moreover they also prepared with tools to insert point from field survey using COGO. Meanwhile, for automatic vectorization, it needs specialized software called raster to vector software (R2V).

4.2.3. Quality and Completeness of Data vs. Cost

The decision of higher quality leads to higher cost for the desired data (El-abedein, 2000). Data without any quality information however are without any value. For most data, it is possible to find out information about their quality that is often implicitly defined or stored in a meta-system.

Data quality here is related to accuracy and completeness of cadastral maps resulted from data conversion. Accuracy in which the parcel position is more or less close to the reality in common sense or within tolerance. While completeness, is that the map gives complete detail of cadastral map features such as cadastral boundary of parcel(s), buildings and street names (Salzman, Hoekstra, et. al., 1998).

4.3. The existing Map Conversion Project

There have been many projects of map conversion around the world. For instance in Department of Land and Survey (DLS) in Jordan, DLS held a project to build Jordan Digital Data Base by converting its analogue maps to digital format. This project had started in 1995 to 2000 with a target to convert 18.000 map sheets. In order to achieve its goal, the techniques used for data converting were heads-up digitizing and automated vectorization. The scenarios that had been set up were: (1) preparation such as hardware (computers, printers, plotters) and software, (2) data inventory and examine its paper quality, (3) scanning, digitizing, and vectorization, (4) coordinate transformation, (5) edge matching, (6) data integration. According to this project the accuracy of maps resulted from such this process is given in table 5:

Table 5: RMSE tolerance in different scales (Alostah and Alkhatib, 2005)

Table 1 / RMSE tolerances in Different Scales	
Scale	RMSE (in cm)
500	5.08 -- 10.16
1000	10.16 -- 20.32
1500	15.24 -- 30.48
2000	20.32 -- 40.64
2500	25.40 -- 50.80
5000	50.80 – 101.60
10000	101.60 -- 203.20
20000	203.20 - - 406.40

The aim of examining the paper quality is to determine which method should be used for conversion. If the maps are in bad quality therefore heads-up digitizing is implemented where there are many folds; and inversely. In addition, to complete its coverage maps with features, in this case parcels

COGO was applied. Hence after digitizing process, the absent parcels which available its parcel records, by using COGO, these parcels were added to the maps.

The same condition had been faced by the Survey of Israel (SOI) as a department which has responsible to administer land in Israel. SOI had a project to build a GIS based cadastral database (Gavish and Benin, 2009). Data that are used for this system are acquired from digitizing project. Digitizing project was started in 1991 to 2000. Approximately around 15.000 cadastral map sheets had been digitized using manual digitizing technique. This technique also used in Egypt to convert its cadastral map data (El-abedein, 2000). Using this technique, the maximum accuracy that is given is 20cm.

4.4. Matrix Requirement

Based on the illustration concerning the factors influencing in selecting the map conversion method (section 4.2) and based on literature study about the available conversion methods (section 2.4.1), matrix requirement is developed as given in Table 6 and Table 7 to compare each method. The data sources are (United Nations, 2000), (Alostah and Alkhatib, 2005), (MASGISS, 1999) (Davis, 1996) and (Goodchild and Kemp, 1990).

Table 6: Matrix requirement for each conversion method

	Manual Digitizing	Scanning		COGO
		Heads-up	Automatic	
Availability	Analogue map Aerial photograph Satellite imagery	Analogue map Aerial photograph Satellite imagery	Analogue map Aerial photograph Satellite imagery	Field record, land book
Quality of paper map	Can be applied for map in poor condition	Can be applied for map in poor condition	Paper map should be in pristine condition	-
Software Specialization	No (most of GIS software is equipped by digitizing menu)	No (most of mapping and GIS software is equipped by digitizing menu)	Yes (R2V software)	Yes (COGO software)

Table 7: Scoring matrix comparison for each method

	Manual Digitizing	Scanning		COGO
		Heads-up	Automatic	
Data Quality	4	3	2	1
Time	2	3	4	1
Labor	2	3	4	1
Cost	2	3	4	1

1: Very high 2: High 3: Medium 4: Low

4.4.1. Analysis Matrix

1. Availability of data sources
   Manual Digitizing, Heads-up digitizing, and automatic vectorization are conversion methods which need hardcopy maps such as analog map, aerial photograph, and satellite imagery as their

data sources. Only COGO which does not need hardcopy map as data sources, its data sources are field record which contains record of geometric distances and angles from control points of parcels.

2. Quality of paper map

   Manual and heads-up digitizing method can be applied for maps even in a bad condition. Automatic vectorization requires a hardcopy map in pristine condition where it is only a few folds of paper. Many folds of paper maps will cause false recognition where they will involve a large amount of editing processes. Meanwhile, COGO does not need paper map as its data source.

3. Software specialization

   Most of mapping and GIS software that is offered in the market, such as AutoCAD and ArcGIS is equipped with digitizing tools and COGO software. Thus for manual, heads-up digitizing, and COGO, they can use that software application. However, for automatic Vectorization, it needs specific software called raster to vector (R2V)

4. Data Quality

   Among the available conversion methods, COGO is considered to be the best technique to give an accurate result (MASGISS, 1999). It is because the data sources are derived directly from the field survey record which depicts the real situation of parcels in the field. On the other hand, manual Digitizing gives a low data quality among the others because the data quality resulted from this method depends on human factors. This method relies on human intervention where it influences the result, which is inconsistent due to varying operator conditions, stress, and fatigue. Meanwhile, the data quality resulted from heads-up digitizing is higher than manual digitizing, although this method also depends on human intervention, however the error is reduce with other supporting tools like scanning and zooming. R2V also makes useful of scanning but its software helps to perform the digitizing process in which it reduces the error of human factors. Human involve in this process in the case of editing after vectorization process. Further, this argument is supported by literature study given in section 4.2 in terms of accuracy given by each method (digitizing and scanning).

5. Time

   COGO is considered to be the most time consuming methods compare to the others because not all field records give complete information. For instance, not all parcels have property boundary descriptions or the information could just be wrong. Consequently, field survey is often necessary to collect the missing information or verify the existing documentation (MASGISS, 1999). Many researchers said that from the three approaches of digitizing techniques, the faster technique is automatic vectorization because the software application (R2V) is supporting the digitizing process (Goodchild and Kemp, 1990) (MASGISS, 1999). Moreover between manual and heads-up digitizing, heads-up is faster because of on screen scanning and digitizing processes. This facility helps the operators to perform the work easier and reduce time needed.

6. Labor

   Because field survey will quite often done using COGO, therefore this method is considered to be the labor intensive, and then follow by manual digitizing, heads-up digitizing, and automatic vectorization. Manual digitizing is tended to be labor intensive, but the labor is needed only for digitizing process, not like COGO which requires labor for data processing and also for field survey. Meanwhile, because of software application for automatization, automatic digitizing becomes a method with less labor.

7. Cost

Derived from labor and time needed, the more time and labor needed, the highest the cost is required. Hence from point 5 and 6, it can be said that COGO is a costly technique than the others, and then followed by manual digitizing, heads-up digitizing, and automatic vectorization.

4.5. Cost Factors

Data conversion is usually both lengthy and expensive. As stated by Mendes (1995) to estimate the costs needed for map conversion is required to avoid failure in running the project. In estimating the cost, the factors that are influence or involve in a project have to be considered. As in (Montgomery and Schuch, 1993), they describe that the main factors influence in estimating the costs are costs for the personnel who involve in the project and costs for the procurement or renting hardware and software. These two factors give a considerable influence the map conversion project even though there are another costs factors that also influence, such as costs for mobilization such accommodation and transportation.

4.6. Advantages and Disadvantages

Based on the description of the available conversion method above, the advantage and disadvantage of each method can be summarized as following

Table 8: Advantages and disadvantages of conversion methods (MASSGISS, 1999)

Conversion Method	Advantages	Disadvantages
Manual digitizing	• Ability to correct errors or distortions in the original maps at the time of data capture. • Highly reliable human recognition of map objects. • The ability to interpret ambiguous or incomplete information and select the relevant required information at the time of data capture.	• The process is labor intensive and therefore very time-consuming and costly. • The quality of results is highly dependent on the operator experience. • The results may be inconsistent due to varying operator conditions, stress, and fatigue.
Scanning 1. Heads up Digitizing	• Reduce human errors in digitizing	• Need for manual pre-processing
2. Automatic Vectorization	• Could be very fast and cost effective • Relatively inexpensive • Provides a very accurate representation of the analog map • Easy	• False recognition of different features and text • Editing could be very labor intensive • The analog map needs to be in a pristine condition with minimum extra features and annotation
Coordinate Geometry (COGO)	• Provides an excellent positional and dimensional accuracy. • Provides a check on the closure (should start and end at the same point) and surveyed area of each parcel. • It is not necessary to have a hardcopy parcel map.	• The most time consuming method • Very labor intensive • Very costly • Deeds for all parcel must be accessible

4.7. Technical Issues of Map Conversion

Map conversion involves activities of pre-processing, conversion process, and post processing. Pre-processing is a process of selecting the best method for map conversion as mentioned before. Conversion process is a process that should be taken into account during data conversion and this will be explained in the next sections below. Post-processing is a process taken after map conversion. It is more to make use of the spatial data after map conversion called map conversion. This part will be discussed in chapter 5.

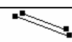
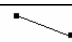
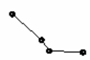
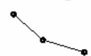
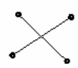
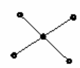
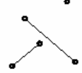
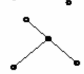
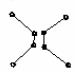
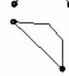
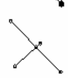
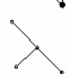
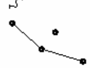
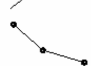
4.7.1. Georeference

Georeference is the process of determining the relationship between the digitized coordinate with real world coordinate (United Nations, 2000). It is an important factor in map conversion after digitizing to register or convert the digitizer map coordinates to the real world coordinate. Georeference can be performed in two ways (MASGISS, 1999): (1) registration to a coordinate system or (2) registration to a base map.

4.7.2. Errors Editing

Errors are often occurred during digitizing and scanning process. In table 9, it shows types of error in digitizing and scanning. In order to correct these errors, most of software mapping and GIS application is supported by tools to recognize errors and to clean up them. These errors should be corrected to create a clean map in order to build topology of map.

Table 9: Error indicated in digitizing process (AutoCAD system manual)

Before Map Cleanup	After Map Cleanup	Description
		Duplicates
		Short Objects
		Crossing Objects
		Undershoots
		Node Cluster
		Pseudo Nodes
		Dangles or Overshoots
		Linear Object Simplification
		Zero-Length Objects

4.7.3. Topology Construction

Topology is defined as the rules of geometry in a space that guarantees the integrity of spatial data (Davis, 1996). For instance, in topology, a parcel is drawn as a closed polygon. Commonly, one of information that users mostly want to know is about the area of a parcel in terms of land transactions. The relation between area and topology is that the topology gives an easy way to calculate the area needed. Thus users can define the price or how they should have to pay/buy for a piece of land (land market purpose) based on the area calculation.

4.7.4. Attribute Assignment

The result of building topology is the creation of a feature attribute table for each theme. This way, attribute information is associated with points, lines, and polygons that describe features in the real world. In this approach to data integration, called the geo-relational model, spatial features are usually linked with their attributes by means of a common spatial key. Different sets of attribute information are stored in different tables, and the relevant information for a given set of spatial features is accumulated by relating (or joining) two or more tables of information (Davis, 1996).

4.8. Discussion

Basically, from all the available methods of data conversion that have been presented in previous sections, all methods can meet the standard accuracy for cadastral maps in Indonesia as mentioned in Table 4. However, in selecting the methods are not only based on the data accuracy that can be given. As given in Table 7, it can be ranked from the most labor intensive, the most time consuming, and the costly, hence COGO is in the first place, followed by manual digitizing, heads-up digitizing, and then automatic vectorization .

As mentioned in section 1.2 the considerations to choose the suitable methods for map conversion in Indonesia are a minimal loss of data quality, minimal cost, and time. Therefore automatic vectorization is a method that meets those requirements. However, the requirements of data sources for this method are that paper maps should be in a good condition. If not, the project using this method might not run effectively and efficiently concerning that there are many folds or in a bad condition, it requires much time for editing. Concerning that not all the available cadastral maps in Indonesia are not in good condition; consequently this method could not be the best choice for map conversion. On the other hand, it uses specific software called R2V where it needs high skilled operators for operating this software than others. Such this condition requires more times for training and/or the institution have to pay more for it.

While automatic vectorization still has weakness, then investigation continued to heads-up digitizing as in the second place. Heads-up digitizing tackles the weaknesses of automatic vectorization. As mentioned in Table 6 this method can be applied for map in bad condition. This ability is also owned by manual digitizing; however it is faster because of scanning process and its convenience to perform digitizing on-screen with the facility of zooming. Further, the software is easy to find out, because many mapping and GIS software are equipped with tools for digitizing such as AutoCAD and ArcGIS unlike automatic vectorization. In addition, commonly BPN employees are familiar with AutoCAD software, where it is proved by the standardization for digital map using DXF file as one of AutoCAD files.

On the other hand, a complete cadastral map is necessary in map conversion. It depends on the information depicted on the maps that are going to be converted. All methods will give information as it is in paper-based maps. Usually, information in cadastral maps are lost because of bad quality of paper-based maps, usually comes from bad maintenance and their age. Therefore the maps are not in a good shape such as torn or folded. However, from the available digitizing they can be used mutually to give complete information. In some cases, after digitizing or scanning process, there might be missing information such as cadastral boundary of parcels or maybe incomplete attribute. It can be completed using COGO concerning its data sources using field record which not only data of bearing and distance but also the legal situation of parcels.

In addition, in conversion process, the rules in map conversion process have to be taken into account. These have to be defined to create such a good structure of spatial data such as geo-referencing, errors editing, topology construction, and attribute assignment. This is important to make valuable of these data.

4.9. Conclusion

The method to select the best technique for map conversion has been presented and one method has been chosen for Indonesia, which the choice falls to heads-up digitizing with the consideration presented in 4.7. However, in map renovation there are important processes that should be followed in order to provide a reliable spatial data from converting process even from the structure or the quality. Hence a framework is required to get such those data and it will be presented in the next chapter.

5. A Framework for Map Conversion

5.1. Introduction

Cadastral map conversion is much more than converting cadastral map data from analogue to digital format. It consists of activities such as map renovation and harmonizing of parcel area after and before renovation. This is done to make use digital cadastral map data by improving its quality in terms of geometric accuracy and updating the existing cadastral database. Thus the quality issue becomes important and developing a quality model to unify the quality description of cadastral map data is necessary.

This chapter discusses such issues as mentioned before to give a description in performing map renovation to improve Indonesian Cadastre in terms of its cadastral maps. Furthermore, this chapter presents the role of GPS in cadastral boundary survey in order to accelerate and complete the information of land parcels because not all parcels have been measured and mapped in cadastral maps; how digital cadastral data become important nowadays and how to prepare the institution or the available human resources (who involve in this process) to be ready for this. In the last discussion, it will present the workflow of map conversion.

5.2. Map Renovation Methods

The purpose of map renovation is to improve the quality of cadastral maps either from geometric or semantic specification (Salzmann, Hoekstra et al., 1998)so that they can be used nationwide. Every country uses different methods to renovate their cadastral maps with regard to the availability of data sources. This section presents, the existing methods of map renovation applied in different countries in section 5.2.1 and section 5.2.2. The consequences of map renovation for the Indonesian cadastre will be described in section 5.2.3.

5.2.1. Map Reconciliation

India, Korea, and Egypt use the same method as in the Dutch Kadaster for map renovation, called *map reconciliation* (Song, 2008). Map reconciliation is performed by reconciling boundaries of cadastral maps and topographic objects whether they are coinciding with each other. A condition for using this method is in its availability of topographic maps with high accuracy. The advantage of this method is minimal cost, because the surveying information (field sketches) is used sparsely. Only for a difficult case, this surveying information can be used for the improvement process. The weakness of this method is that it takes time or to check one by one whether the boundaries are coincide or not.

The procedures based on map reconciliation can be summarized as given below (Table 10). There are several steps can be taken regarding the availability of data sources in field.

Table 10: Map renovation process (reconciliation wise)

Topographic map / Cadastral map	Available	Not available	Description
National coordinate system (analogue)	Edge matching – Adjustment – Interpolation – Reconciliation	Edge matching – Adjustment – Interpolation – Map updating from field sketches, new digital measurement, aerial images	After digitizing, edge matching, interpolation and local adjustment need to be performed. Topographic map is used for the improvement process, if it is not available, it can be done by using terrestrial data, field sketches or aerial images.
Local coordinate system (analogue)	Coordinate transformation – Edge matching – Adjustment – Interpolation – Reconciliation, input digital terrestrial data	Coordinate transformation – Edge matching – Adjustment – Interpolation – input digital terrestrial data or data from aerial images	The procedure is similar with procedure above; only in this case it needs coordinate transformation.
Digital	Reconciliation with topographic maps and/or digital terrestrial data	Input data: field sketches, survey register, aerial images and/or digital terrestrial data	There is no digitizing, edge matching and transformation procedure. The cadastral data that can be used for improvement process are topographic maps and/or field sketches, if it is available.

Annotations:

1. Coordinate transformation: is a conversion from one system to another, in order that the maps use the same coordinate system, in this case national coordinate system used in each country like in Indonesia using WGS 84 as its geodetic datum and UTM as its national coordinate system.
2. Edge matching: is a simply procedure to adjust the position of features that extend across typical map sheet boundaries. The analogue-to-digital conversion is conducted in a map-sheet basis, so it is necessary to match the edges before proceeding to the next conversion step called edge matching.
3. Adjustment: it is done after coordinate transformation for further quality improvement of cadastral maps by performing least square connection adjustment. The quality indication is useful especially for maps where this quality information is missing.
4. Interpolation: is to maintain the homogeneity of the cadastral maps after transformation and/or adjustment process. It is intended to eliminate the discontinuities of points by interpolating the residuals in the connection points of maps.
5. Reconciliation: is a reconciliation process between a topographic map and a cadastral map to find out whether the boundaries of these maps coincide with each other.

5.2.2. Boundary Connection

Renovating cadastral maps based on boundary connection is suitable on the condition that the available data are field survey data (distances and directions) and cadastral boundary database. Countries which apply this method are Croatia and Australia (Rolae, 1998). They renovate their maps by incorporating cadastral maps into information acquired from field survey methods or from mutation. The necessity of this method is to establish a homogeneity control point network using GPS technology to bring all the existing cadastral maps to national coordinate system.

5.2.3. The Consequences of Map Renovation for Indonesian Cadastre

As many users request for a better accuracy of cadastral maps, sooner or later cadastral map renovation is required for Indonesian cadastre. Those two methods as mentioned before can be applied in Indonesia because of the similarity in the available data sources included in map renovation process. In order to perform this using both methods as mentioned before, there are several consequences that have to be met such as:

1. Completing the ground control points (GCPs). A current study shows that only about 5% the existing land data of total area of Indonesia is based on maps and GCPs. It means that many cadastral maps use local coordinate system where they need to be renovated. The GCPs are needed as a base of local control points that will be used for the transformation process in digitizing process. However, by using GPS infrastructure there would be no need of GCP and traditional measurement.
2. Completing cadastral base maps. Since 1960, when the Agrarian Act was issued, only 5% of the total area of Indonesia (approximately 1.900.000 square Km) has been mapped by the scale of 1:10.000, 1:2500 and 1:1000. This map is important as a base for improvement process of cadastral maps. To meet the need of completing cadastral base maps (Sumarto, et. al., 2008), BPN sets a strategy with making use of satellite imageries for mapping forest, plantation, rural, and sub-urban area. For built-up or urban area, aerial photographs are used considering the need of high accuracy in this area. It was started in 2007 and it is expected to complete within 3-5 years.
3. For area where topographic maps are not available for improvement, field data becomes necessary; therefore field measurement using new technology is required to support renovation process. These measurements can contribute in the case of big discrepancies.

5.3. Data Quality Model

The quality of spatial data in terms of cadastral map data is crucial for its effective use, as its role is to provide information related to shape, boundary and location of land parcels. Many users require for good accuracy of cadastral maps especially for supporting other cadastral surveys (e.g for determining new location for new area development) (Williamson and Enemark, 1996). Since cadastral maps are acquired from different sources with different techniques for data collection, knowing its data quality becomes necessary. Data quality model is necessary to unify quality descriptions and to make use of spatial data related to cadastral maps.

Because every measurement will always contain of errors, an adjustment is required to correct those errors. These errors can be random errors, systematic errors, and blunders. Random error is arbitrary; it always occurs in measurement and can be predicted in size and sign of the error. Systematic error follows a mathematical or physical law and can be corrected (e.g calibrating measurement equipment to reduce systematic error). A blunder is an error due to human factors, equipment and nature interference.

5.3.1. Factors influencing in the Quality of Cadastral Maps

Factors influencing the geometric accuracy of cadastral maps are (Salzmann, Hoekstra et al., 1998):

1. Data acquisition and data processing techniques. The precision is dependent on several factors such as the techniques used (e.g digitization, field survey, and photogrammetry), the processing and conversion of the data and the precision of the source material. In map renovation, where

existing geometric information is used, the quality of the source material (e.g. the existing digital map) has a major impact. The relative precision due to data capture and data processing is called *acquisition precision*.

2. The precision with which a point or an element can be pointed out in the field. In mathematical terms: the precision with which an element in the terrain can be modeled as a mathematical quantity (e.g point or line). This precision called *identification precision* and it is obvious that it depends on the type of point.

5.3.2. Least Square Adjustment (LSA)

Since every measurement always contains errors, adjustments are required is required to identify errors and improve the quality of measurement. The concept of LSA is that the sum of squares of residuals measurement is minimized (http://webhelp.esri.com); this is a method of measurement correction. LSA consists of two elements: the mathematical model and the stochastic model. The mathematical model is a set of relations between the measurements and the unknown coordinates. The stochastic model shows the expected error distribution of the measurement.

The advantages using LSA are (Wolf and Ghilani, 1996):

- A complete statistical analysis of the results can be made after adjustment
- It can give information related to the degree of accuracy of a measurement whether it meets standard tolerance of measurement or not; thus it is useful to make a decision whether the measurement should be repeated or not
- It can detect blunder and correct it.

However, there are several challenges when aplying LSA such as:

- It involves a complex mathematical model.
- It needs a LSA program to execute a process and large capacity of computer to process and store data.

5.4. Harmonization of Legal and Renovated Parcel Area

The main issue that usually arises after map renovation process is area differences between legal area and calculated area. These are a consequence of quality improvement of cadastral maps related to its geometric accuracy. However, these differences do not influence its legal area. The legal area as a legal identity will stay the same. As is suggested by (Song, 2008) and (Kumar, 2007), in most cases the area differences are not informed to the general public. This is done by considering the possible reaction such as a fear of loss among them. They would feel confused knowing that their parcels have been reduced. This in fact will lessen the trust of public to the institution.

5.4.1. Control Quality Procedures for Harmonization`

Indeed the differences between legal and calculated area after renovation are not just left without any a quality control check. Therefore, there is need for a standard tolerance for differences that arise. The methodology used for quality checking is based on the concept of confidence limit (Song, 2008). If X percentage confidence limit is Y square meter, it means X percentage of area will have difference in legal and calculated area less than Y square meter. For instance, If a 98% confidence limit is proposed than in 2% of cases a resolution of differences is required. Harmonization of the differences will be first tried by confronting them with field records. If it is not possible, the fieldwork as a last option will be conducted.

As introduced by (Lemmen, 2003), the permissible different in area can be calculated using a function as following:

$$Tolerance(m^2) = q\sqrt{a}$$

Where: q: a constant and depend upon the quality of the cadastral maps.
a: area (m^2) in units of 100 m^2.

To be noted here, to get survey result closer to the reality, it is advised that constant 'q' may be calculated for different scales (Song, 2008). As in Dutch Kadaster, the value of constant 'q' corresponds to 1, 0.5 and 0.1 for respectively rural, urban and city center.

5.4.2. Calculation of 'q'

The function above will help to get the value of 'q' during map renovation process generated from original dataset. Moreover, the value of 'q' may be chosen by trial and error, based on confidence limit criteria or by percentage of cases needed to be investigated in the field. The value of 'q' can be calculated using a simple table (Table 9) presented below (Song, 2008) and (Kumar, 2007):

Table 11: Calculation of 'q'

S No.	Parcel No.	Legal area of parcel in m^2 (A1)	Calculated area of parcel in m^2 (A2)	$\lvert A1 - A2 \rvert$ absolute difference (d)	$q = \frac{d}{\sqrt{A2}}$ in 'm'
1 2 . .					

However in practice, like in Korean case, after conducting some calculations to find out the area tolerance, there are many parcels which its area is above the defined tolerance. In this case, it needs more practical researches to define a new possible value to minimize this problem.

5.5. Role of Hardware and Software in Map Renovation

The development of infrastructure in terms of hardware and software is necessary to support and execute map conversion process; thus the process will be simpler and faster. In addition, they should support optimized procedures to improve the efficiency and the productivity.

There are many GIS software and mapping systems offered in the market. For instance AutoCAD Map and ArcGIS; AutoCAD Map was created by Autodesk and combines CAD functions with GIS analysis. On the other hand ArcGIS is an integrated collection of GIS software products that provides a standards-based platform for spatial analysis, data management, surveying and mapping. Further, in choosing software for map conversion process the software has to support all technical aspects (e.g. all kind of adjustments and transformation) and procedures.

5.6. Data Acquisition for A Complete Cadastral Map Data

As described by Winoto (2009) concerning the condition of cadastral parcel in Indonesia, there are about 85 million parcels in Indonesia of which 45% have been registered, but most of these registered parcels are not yet mapped in cadastral map. In addition, there are still many parcels out there which are not yet surveyed and mapped. A complete cadastral map with the presence of parcel data is important to improve land administration system in Indonesia in order to give certainty in the relationship between people and their land.

5.6.1. Role of cadastral boundary survey in the process of land transfer

Nowadays, the societal need for land transaction is increasing. Therefore, it is expected participation from the government to support land market by giving security on land transaction. It can be done by applying land registration and cadastral system. It means that all documents engaged in transaction on the land markets should be eligible for public inspection. Thus the registers and cadastral maps should give an exact description concerning the relation between persons with his/her land and land right; or in other words which persons are entitled to which object of land, and by which land right. Due to this need, the cadastral boundary survey forms a crucial part of the system.

Like many other countries, Indonesia is a country which has a high number of land transactions. In order to support land market by providing security for land transaction, through one of BPN's strategic plans, BPN plans to register all land parcels within 18 years or less (Winoto, 2009). It means that in one year it should be more or less 3 million parcels to register. However, as mentioned before not all parcels have been surveyed and registered in cadastral maps. Thus BPN needs a new method to complete its cadastral mapping and to support map renovation process through field survey data.

5.6.2. Role of GPS Technology in Cadastral Boundary Survey

Many techniques have been used to support cadastral mapping such as conventional techniques using Total Station (TS) and aerial image using photogrammetry. Using TS is considered time consuming and fairly difficult to operate it. Aerial image needs further process to be used in supporting cadastral mapping, such as rectification and digitizing.

Currently technologies are developing to support and accelerate cadastral boundary survey such as the use of GPS technology. GPS is a U.S. space-based global navigation satellite system (GNSS). GNSS is the standard common term for satellite navigation systems (Sat Nav) that provide independent geo-spatial positioning with global coverage. Real Time Kinematic (RTK) GPS, one of operational GNSS has been used for a variety of different surveying applications and the use of this technology for cadastral work is becoming commonplace. Many researches have been conducted related to this whether the use of GPS technology is qualified for cadastral boundary survey or not, compared to the conventional techniques (Total Station).

The results of these researches give more positive than negative results. Such as in Dutch Kadaster (Wakker, et. al., 2003), where an investigation had been performed focused on three factors: the technical aspects of the survey, the ergonomical aspects and economical aspects. The results of the survey are that 25% of the surveys can be done more efficient using GPS compared to the conventional technique. From ergonomical aspect where the applied science of equipment designs, as for the workplace, intended to maximize productivity by reducing operator fatigue and discomfort.

The result is that the surveyors were pleased with GPS because it allows them to organize a survey in a more flexible way. It also gives surveyors a positive feeling of working with modern technology. The last but not the least, using GPS technology is slightly more expensive compared to Total Stations; therefore it will increase the investment. Nevertheless, considering the positive affect of cadastral survey, it is worthy for investing on this technology.

Furthermore, it is emphasized by the results of research conducted in Inverell, New South Wales (Veersema, 2004). From this research it was concluded that the technique of RTK GPS will be able to deliver results and accuracies equivalent to those expected from a traditional Total Station survey, with the benefit of reduced cost and improved productivity for the surveyor.

5.6.3. The Consequence using GPS

The national coordinate system of cadastral maps using by BPN is TM 3° with WGS 84 as the geodetic datum. The geodetic datum is similar with one of geodetic datum used in GPS; however the coordinate system is not similar. Thus the coordinate transformation is fully required to be transformed where it will allow for a seamless workflow in terms of updating the cadastral spatial database based on GPS surveys.

As experienced by Dutch Kadaster to transform its coordinate system to GPS coordinate system (Wakker J.W. et.al., 2003), this coordinate transformation is not yet accepted because of substantial reasons. Because this transformation will transform all coordinate points which have inhomogeneous quality of points; it is apprehensive lead to changes of cadastral spatial data base related to data maintenance. This transformation could result mismatches of certain tangents in which it leads to errors in topology. In addition, for institutions that have been used the recent coordinate system are required to be inform related to the coordinate changes. This is a complex work because it involves data updating process across institutions.

However, thus such of those problems would not be an issue in here concerning that cadastral data from BPN is not yet interoperable with other institutions. Therefore, it would not give a serious problem in Indonesia and GPS technology would be the best alternative in completing its cadastral maps. Related to technical issue such as the system projection, it can be handle by transforming GPS coordinate system to TM3° for cadastral updating process and inversely for the use of coordinate system in GPS environment.

5.7. Product Development

Different users need different products from cadastral data. In case of urban and rural management, a complete record of all land parcels is essential by municipality to manage the land use, infrastructure and assets, and to control development in its areas of responsibility. These are useful to improve livelihood of its citizen by managing its land use and property. Moreover, it is important to protect the environment from threat such as illegal deforestation which can increase global warming and illegal occupancy which can create slum area and land conflict. Another example for professional, such as real estate agencies, they need cadastral data for land and real estate market for monitoring its price.

With current development in Geo-ICT, it can support the existing cadastral system in terms of extending its function (Van Oosterom and Lemmen 2002). The development is related to the development in information system modeling standards, database technology, GPS, internet technology development, wireless communication and acceptance of geometric standards. The requirement of data in ICT environment is that the cadastral data must be in digital format. It is also emphasized by Van der Molen (2009) the availability of digital datasets in land administration organizations, provide opportunities to expand the function of land administration in the society. Through sounds of information management by making use of digital databases, it gives a better opportunity to respond the growing demand for transparent land and real estate markets, for better governance and for the development of e-government service

5.8. Role of Standardization and Land Administration Domain Model (LADM)

Accordingly, with the development of Geo-ICT and the growing need of users' related to geographic information, it is expected that this information becomes accessible for users with different systems. The system needs to be interoperable; thus such organization like ISO and OGC which develop standardization in spatial data exchange is crucial. The examples of OGC standard are XML (eXtensible Markup Language) and GML (Geographic Markup Language) where they are designed to store and transfer geographic information. Thus, using standards with a well- defined security option can improve the communication ability. It is recommendable to use standards in all procedures like data acquisition, management, and distribution of spatial information.

A standardized Land Administration Domain Model (LADM), covers land registration and cadastre in a broad sense, the'multipurpose cadastre' (Kaufmann and Steudler 1998). *The 2nd goal of LADM is enable involved parties, both within one country and between different countries, to communicate based on the shared ontology implied by the model*. It implies that it is crucial to develop standardized information services either in an international context or between countries and within countries or different organizations. LADM presents both legal/administrative and cadastral objects and their relationship. Using LADM, both data are stored and maintained uniformly. This model is flexible to be implemented as distributed set of geo-information system, and most likely the model will be implemented and maintained by several organizations (Sucaya, 2009). Related to data acquisition, LADM accommodates data acquired from different techniques with different accuracy to be used. For this it requires that the coordinate system has to be in national coordinate system.

5.9. Capacity Building

Map conversion process is not only limited to a process of converting data from analogue to digital format. It is a sustainable process in terms of maintaining and managing digital data resulted from this process. In line with a great demand from users for a better accuracy of cadastral product, improvement of digital cadastral data as a next process is necessary. In addition, concerning the development of Geo-ICT and the growing need of users on digital cadastral products of land information system, thus the organizations should prepare the human resources and infrastructure (e.g improving hardware and software, as well providing base maps).

This is a challenge for BPN as an organization administering land administration in Indonesia in which all cadastral data of land administration is important as a basis to build such that system. To perform such process above and maintain this system, it requires a skilled human resource, improvement of the infrastructure such as hardware and software, also a strong institution. Therefore capacity building and strengthening the institution are necessary.

Capacity building is much more than training (Winoto, 2009), it includes the following activities such as:

- Improving physical resources, such as technologies and support facilities.
- Human resources development and training. Transfer knowledge to improve the skill of the available human resources, therefore they are prepare to manage an applying new system.
- Improving the standard of public service and developing quality assurance in the organization. These are aimed to improve public services on land registration, transparency, as a form of government responsibility to the public, and to guarantee BPN's product.

5.10. Workflow of Map Conversion

Based on the explanation related to the continuous activity of map conversion, the workflow of map conversion can be depicted on figure 6.

5.11. Conclusion

A conceptual framework for map renovation has been introduced to improve the quality of cadastral maps due to the diversity techniques to acquire cadastral map data. There are two methods have been introduced to renovate cadastral maps: (1) map reconciliation and (2) boundary connection. These two methods are chosen based on the availability of data that have to be renovated and concerning that in performing map renovation field surveys have to be avoided as much as possible to reduce the costs needed.

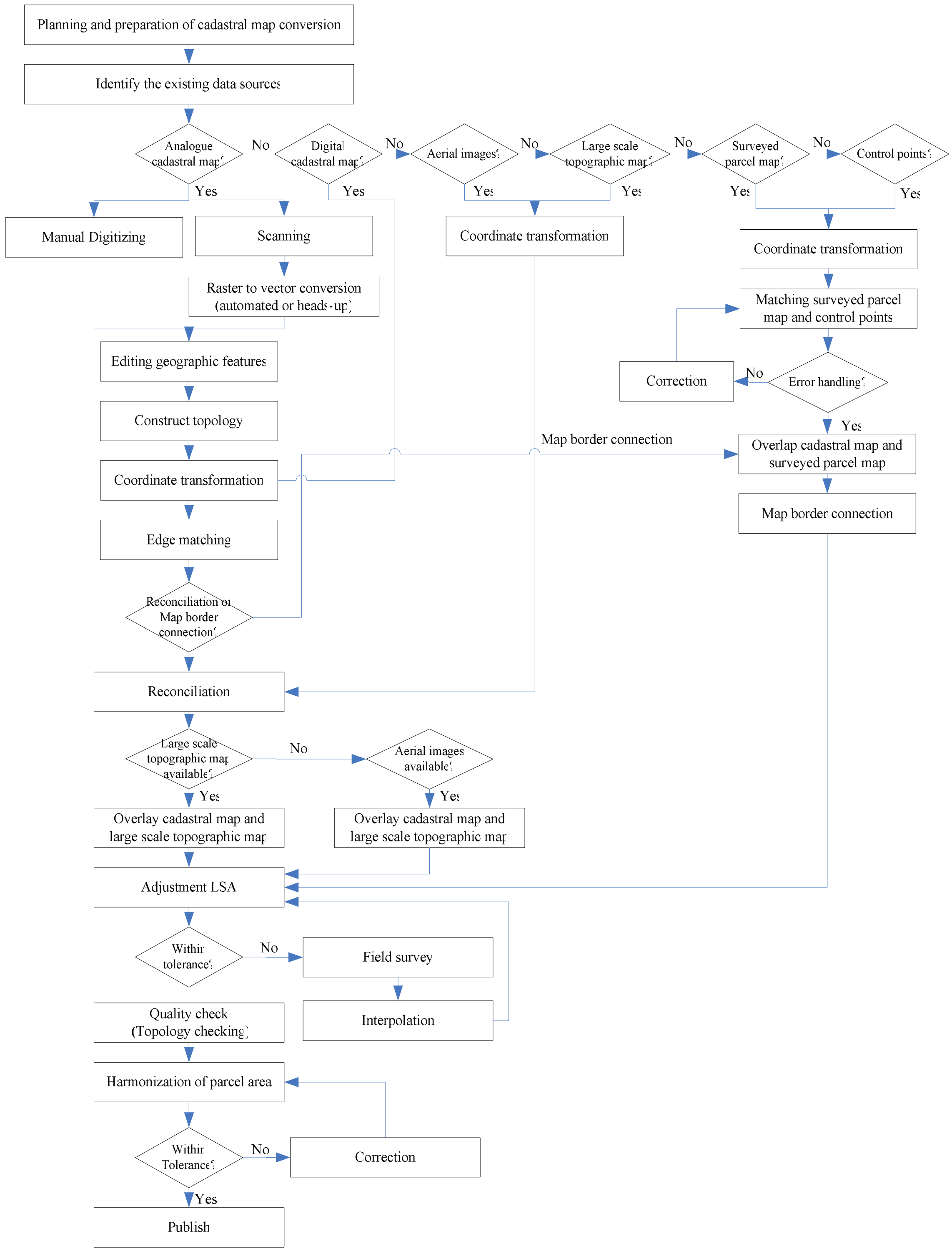


Figure 6: Workflow for cadastral map conversion

6. A Case Study in Makassar, Indonesia

6.1. Introduction

This chapter discusses some impacts of cadastral map conversion and renovation in Makassar and a justification why there is an urgent need to digitize its cadastral maps based on evidence from the field and the users' needs. Users' needs are obtained from questionnaires. Finally this chapter presents the proposed activity of map conversion in Makassar modeled by Unified Modeling Language (UML).

6.2. General Overview

Makassar is located at ° 09'S and 119° 28'E with total area of 203 km^2 and population of 1.25 million people. Makassar becomes one of developing cities in Indonesia as its strategic location to connect areas in Eastern Indonesia, such as Sulawesi, Maluku, Irian/Papua, West Nusa Tenggara and East Nusa Tenggara to others islands. Being a developing city accelerates high investments for business in Makassar. This condition pushes the Makassar government to perform several developments in order to provide facilities for business. Development requires a space (lands). Therefore, the value of land gets higher and it becomes more and more scarce and difficult to acquire. This can be a trigger for conflict over land. With regard to that condition KPKM as a BPN institution, which has tasks to administer land on its area administration, should deliver accurate and reliable information regarding the locations of the existing parcels.

6.2.1. The Existing Condition of Cadastral Mapping

In order to provide security to the land owners, KPKM performs survey and mapping and establishes cadastral maps as a record of the legal boundaries of parcels based on KPKM's legal status. All Cadastral maps in Makassar published by KPKM are drawn in scale 1:1.000 and are obtained using different data acquisition techniques. There are cadastral maps acquired using tape and compass, theodolite, and earlier even using ropes. As a consequence, this leads to diversity in data quality; it caused low accuracy of the existing of cadastral maps.

In 1996/1997, there has been a base map project using aerial images. These maps covers 114 km^2 (56%) of the total area of Makassar. The main objective of this base map project was to accelerate the cadastral mapping in Makassar. Consequently, with the availability of these maps, the Makassar territory is partly served with digital cadastral maps. The base maps are used as a reference to place all the existing parcel boundaries and to place the new surveyed boundaries. This improves the quality of the existing of cadastral maps; it is a map renovation.

By executing such a project, it is expected that KPKM completes its cadastral maps. However, in practice, the existing cadastral mapping is far away from being complete. From the 56% that is expected to have a complete cadastral map, only 30% area is covered by cadastral maps which are available in a GIS environment and 26% are not yet available in GIS (still in progress to complete its mapping using the old aerial photo's from 1996/1997); while the rest (44%) is still paper based.

Obstacles to make a complete cadastral map come from incomplete and not up-to-date registered and unregistered parcels. Obviously, if the problem comes from the unregistered parcels, it means these parcels are not yet been surveyed and mapped. However, from the registered parcels, the problems occur during the plotting where the existing records of parcels, such as surveyed parcel maps, cannot be plotted into the existing maps because there are no control points on these maps thus they cannot be identified and placed in base maps.

Another expectation of having cadastral maps is that they give up-to-date information. However, the existing cadastral maps in Makassar are also far away from being up-to-date. Up to now, since the establishment of cadastral base maps in 1996/1997, these maps are not being up-dated. Even though there is a renewal project of base maps in 2003 using satellite imageries (with 2.5m resolutions), conducted by Surveying and Mapping Department, where the results are forced to be utilized by land offices. Commonly, within those times period (1996/1997 up to now) there are many changes in a certain area such as the possibility changes in land use or the possibility of a new development in particular area where those changes might influence the legal boundaries of parcels.

Related to the available satellite imagery data as mentioned before, these data cannot be used by KPKM concerning the tolerance limit for its mapping is 0.3m. Those satellite imageries in terms of its accuracy are far beyond the tolerance limit 2.5m resolution. Thus they cannot be used for Makassar case either for up-dating or improving accuracy of its cadastral maps.

6.2.2. Issues Related to Cadastral Maps

Furthermore, there are other issues which arise in relation to cadastral maps in KPKM such as:

- Since it is done manually, it takes time to extract data from the analogue maps and to up-date data after survey on it.
- Before 1997, map renewal was done by fixing transparent tracing paper over the analogue maps, and then copying all features on the sheets to the transparent paper. After this, all features were copied from the transparent paper to a new sheet by hand using passer. This process has a negative impact on geometric position of the origin sheets since by doing such process it propagates errors.
- Most of analogue maps are in a bad condition, because the age of the maps and such manual process like re-draw or re-erase. Consequently, the geometric accuracy of parcels becomes diminished and there is loss of spatial information such as cadastral boundaries.
- Many boundary disputes occurred related to inaccuracy of cadastral data because the field sketches being used to reconstruct the boundaries in the field show low quality measurement. In one month there are five to ten reports of land disputes (based on the report of land conflict division).

Generally it can be concluded that, the existing analogue and digital cadastral maps in KPKM are not properly maintained.

6.2.3. Other Cadastral Data

KPKM has other potential data that can be used to complete its cadastral maps such as data parcels from the field sketches and surveyed parcel maps with control points. Related to control points, which established by using GPS technology, 70% of the Makassar area is covered by control points where

10% of them are in bad condition or cannot be traced back in the field. However, the remaining control points still can be used for the improvement process by matching the surveyed parcel maps with the control points.

6.2.4. Human Capacity

The total number of the employees in the Surveying and Mapping Section in Makassar is six (6) persons including the head of section and the head of the sub-section. Thus there are only four persons left who are directly involved in maintaining cadastral maps in terms of performing survey and mapping. As survey is needed to keep the cadastral maps complete and up-to-date where it will renew the legal status of lands and it will record the changes in maps. This number of employees is insufficient to keep the maps as up-to-date and complete. Insufficient capacity generates another negative issue in KPKM such as inequity of services where customers who could pay more, will be firstly served.

6.3. Role of Users

In order to perform digitization process, users' requirements should be taken into account. Those can be used as a parameter to determine whether it is urgent or not to perform digitization. Moreover, the users' requirement can be used to set a priority scale in giving service to users. Figure 7 shows the statistic result of users' requirements related to cadastral maps in Makassar.

There are six important users of cadastral data in Makassar:

1. Private Citizen or general customers: they need cadastral maps to check the parcel area and its owner in terms of land transaction to determine the price.
2. Real-estate agency: this type of users needs information about all types of land and building properties to determine a new location for a new development.
3. Financial Institution (Bank): it requests information about the owner of a parcel including the legal status of the parcel for mortgaging purposes.
4. Court: it requests information related to land or surveying information to support in decision making in land related disputes.
5. Tax department: commonly, the information needed by this institution is information related to buildings and parcels to evaluate taxes of its owners.
6. Provincial organizations such as municipalities, agriculture department and public work department: they need for up to date cadastral maps for planning and designing new projects.

Commonly, the types of information that is needed by the customers are the area of a parcel, the owner name, the legal status of parcel(s), the land use, and other information such as infrastructure.
Each of users needs different information for different parcels.

	PC		REA		FI		C		TD		PO	
	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%
Total number of respondents	20		10		6		6		5		15	
What kind information do you need from cadastral data?	parcel area, owner name, legal status		parcel area, land status, owner name		parcel area, owner name, legal status, land use		parcel area, owner name, legal status, land use		parcel area, owner name		parcel area, owner name, legal status, infrastructure	
Why do you need cadastral data?	- for checking the ownership and its boundary - to determine the price of the land (land transaction/ sell and buy)		- to determine a new location for a new development - to determine the price of the land (land market)		for decision making in terms of financial support to their client (mortgaging)		to support land dispute in terms of decision making		to evaluate and determine taxes		for urban and/or rural management, such as city planning, building permit	
Does the need of digital cadastral maps very urgent to support your work?												
a. very urgent	4	20%	-		-	-	-	-	-	-	6	40%
b. urgent	4	20%	5	50%	-	-	1	17%	2	40%	9	60%
c. not so urgent	12	60%	5	50%	6	100%	5	83%	3	60%	-	-
What are the reasons?	the hardcopy copy is preferable to acquire information such as the cadastral boundaries		hardcopy is most preferable even though digital sometimes necessary if there is used for data manipulation or as a base for its own cadastral survey		to support decision making in terms of financial support, the digital cadastral maps is not so urgent, they need the physical evidence (hardcopy maps)		as an evidence in the court the digital cadastral maps is not so urgent		digital cadastral maps is required in terms of data manipulation or as a basis for other cadastral survey to evaluate taxes		required as a base for other cadastral survey in case there might be an overlay with others spatial data	
Are you satisfied with current cadastral product?												
a. very dissatisfied	2	10%	-	-	-	-	-	-	1	20%	3	20%
b. dissatisfied	10	50%	8	80%	3	50%	4	67%	2	40%	8	53%
c. satisfied	8	40%	2	20%	3	50%	2	23%	2	40%	4	27%
d. very satisfied	-		-	-	-	-	-	-	-		-	-
Are you satisfied with the accuracy of cadastral map data?												
a. very dissatisfied	4	20%	-	-	-	-	-	-	-	-	3	20%
b. dissatisfied	9	45%	8	80%	1	50%	3	50%	3	40%	8	53%
c. satisfied	5	25%	2	20%	5	50%	3	50%	2	60%	4	27%
d. very satisfied	2	10%	-	-	-	-	-	-	-	-	-	-
What products are you expected in terms of cadastral data?	digital cadastral maps and its attributes		digital cadastral maps and its attributes, digital field record, large scale		digital cadastral maps and its attributes		digital cadastral maps and its attributes		digital cadastral maps and its attributes, digital field record		large digital cadastral map scale and its attributes, digital field record, 3D maps, overlay digital cadastral maps with thematic maps	
What services are you expected in terms of cadastral data?	on-line services via internet, mobile services		on-line services via internet		on-line services via internet		on-line services via internet		on-line services via internet		on-line services via internet	

Figure 7: Statistic result of users' requirements related to cadastral

In general, from the statistical data presented in figure 7, user requirement can be categorized as follows:

The characteristic of information needed / The Users	Digital data of cadastral maps	Accuracy of cadastral maps	Completeness of cadastral maps	Completeness of cadastral maps
Private citizen	None	Medium	Low	Low
Real estate agency	Medium	High	High	High
Financial institution (Bank)	None	Low	Medium	Medium
Court	None	Medium	Medium	Medium
Tax department	Low	Low	Low	Low
Provincial organization	High	High	High	High

Figure 8: The characteristic of information needed by the users related to cadastral maps

The characteristics of the information required related to cadastral maps can be explained below:

- Requirement of digital cadastral data. Digital cadastral maps are not always required for all users such as private citizen, financial institution, and court. It is because they use cadastral maps as evidence or supporting document without any spatial data analysis. Therefore, hardcopy maps are preferable. Digital data are highly requested by provincial organization to support spatial data analysis in terms of decision making. In digital format, it would be easier to be performed.
- Requirement of cadastral maps accuracy. The level of accuracy can be varying from one user to another user. It depends on the purpose of using cadastral maps. If it is used as a base for other cadastral survey, therefore accuracy level should be high like in case of private organization and real estate agency. Conversely, if it is used as a document not for a field survey, a high accuracy is not so important. One could get the impression that some respondent want to be negative by saying that the accuracy is too low.
- Requirement of cadastral map completeness. It relates to whether the map is up-to-date or not. Cadastral maps contain information about cadastral boundaries including the administrative boundaries; parcel identifiers; buildings; topographic features and their name, such as road, river, and so on; geodetic control points; features inside the parcel boundaries such as private ditches, private roads; and annotations about transaction of legal rights. This is important for knowing the current legal status of parcels in which it plays an important role for decision making, such as in financial institutions, whether they will give credit or not for their client; in the land market, whether the land transaction can be done securely or not by knowing the true owner of a parcel.
- Requirement of other spatial detail. As mentioned before about the characteristic information in cadastral maps, not all the users need all the available spatial information. If it only serves land registration process, mortgaging, land market, it will only need information related to cadastral boundaries. When cadastral maps are used in multi-purpose role especially for urban and rural management, a complete amount of topographic detail is required such as road, building, and other topographic features.

6.4. Discussion

As lands become important for livelihood, giving accurate, complete and up-to-date information related to land is necessary. It is crucial to give the land owners security of their belonging. Cadastral maps as one of documents to record the legal status of lands have to fulfill such requirements. There is a high expectation of the users for better accuracy of cadastral maps and other products related to cadastral data as presented in figure 8. There is a strong need to make cadastral maps available in digital format. Thus it would be easy to improve its quality in terms of it accuracy and extent the function of cadastral data to serve the society with other products as mentioned in section 5.7. It can be done easily if the cadastral data are in digital format.

In general, the presence of large scale topographic maps or cadastral base maps using aerial photographs in 1996/1997 provides good opportunity for KPKM to improve its cadastral maps. Even though these maps are considered to be out-dated as mentioned in section 6.2.1, the geometric accuracy is still reliable. Further the improvement project of cadastral maps can be done initially by setting up the priority scale. As mentioned before 56% areas are supported by base maps, thus the improvement project can be started here. The map reconciliation can be applied to renovate for these areas are because of the availability of cadastral base maps.

For the rest of 44% area which in paper based using a local coordinate system, map conversion is required to get these maps available in a GIS environment. The map conversion approach that can be use is heads-up digitizing technique as suggested in chapter 4. Because these areas are not covered by base maps, map renovation can be done by matching surveyed parcel maps with the available control points. And then map border connection can be performed by overlaying the digitized cadastral maps surveyed parcel maps that already match with control points.

The available cadastral maps in KPKM use two coordinate systems which are the national coordinate system TM3° and local coordinate system. Thus, there is a need of coordinate transformation into national coordinate system. The map projection and geodetic datum have to be assigned during coordinate transformation in order to make a seamless map. This task is important because maps sheets in different co-ordinate systems have to be assembled. With regard to the location of Makassar at 5° 09'S and 119° 28'E, this city is located in TM3° zone of 50.2.

In order to complete and up-date its cadastral maps, the possible techniques that can be applied in Makassar are aerial photogrammetry, cadastral resurvey using GPS technology, and satellite imageries. However, since aerial photogrammetry is costly to acquire therefore cadastral resurvey and satellite imageries become the best option. There are many types of satellite imageries offered such as Quickbird with 0.6 m resolution (http://www.digitalglobe.com/index.php/85/QuickBird).

The major obstacle to perform such project comes from the insufficient capacity of human resources as mentioned in section 6.2.4. Due to this, KPKM has to be considered the role of external assistance such as private company to support its survey and mapping. However, it needs a further investigation in terms of the requirement and their capability to perform such this project.

6.5. Activity Diagram of Map Conversion

With regard to the condition above, in order to improve its cadastral maps, map reconciliation and boundary connection can be applied in KPKM. The activity of map conversion can be modeled by using Unified Modeling Language (UML), where activity diagram is used to give the complete process of map conversion process as given in figure 9:

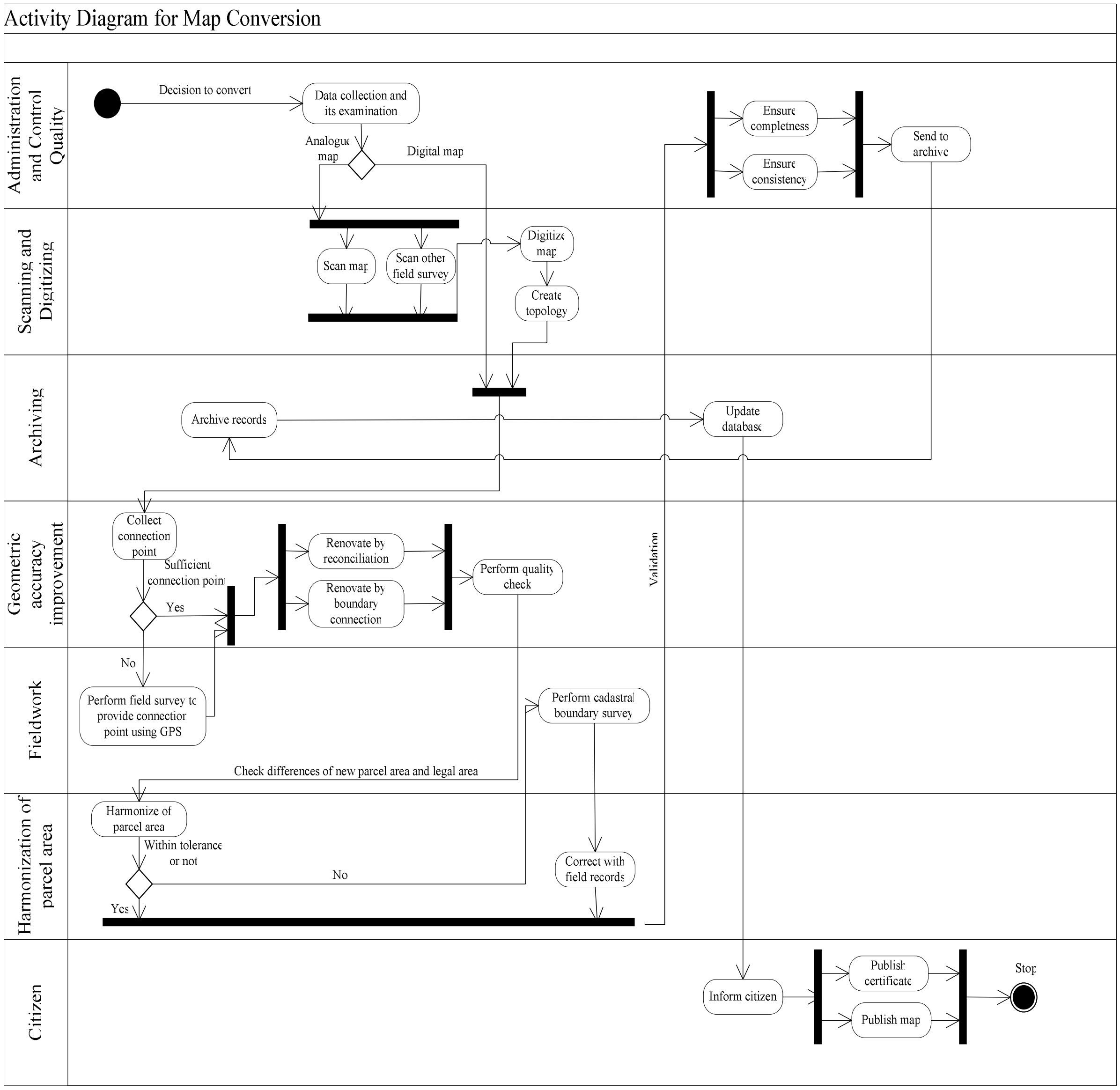


Figure 9: Activity diagram for map conversion

Generally, map conversion process can be divided into six activities: (1) Preparation for conversion such as request for cadastral data collection, (2) scanning and digitizing process, (3) archiving (4) map renovation in terms of geometric accuracy improvement, (5) field survey, and (6) harmonization of parcel area. Those activities and their description can be summarized as in Table 10:

Table 12: The description of map conversion activity

Activity	Description
Administration and control quality	• Perform the initial step of map conversion by conducting data inventory and examining the data collected • Ensure of completeness and consistency the cadastral data resulted from the map conversion process. • Send the result to the archive and publish it to the citizen.

Scanning and Digitizing Process	• Perform data conversion by scanning and digitizing cadastral map data from analogue to digital format.
Archiving	• Inventory, storing, preparing cadastral maps that will be used for field survey, and updating the cadastral database.
Geometric accuracy improvement	• Collect control points used for map renovation process and if it is not sufficient ask for field survey to provide control points, • Perform map renovation to improve the geometric accuracy of cadastral map by map reconciliation and boundary connection. • Perform quality check
Field survey	• Perform field survey to provide coordinates of control points used for map renovation. • Perform field survey for field checking in terms of problem occur during harmonization of parcel area where it cannot be solved using field sketches by conducting cadastral boundary survey.
Harmonization of Parcel Area	• Check the differences between calculated area and legal area. • Make decisions about the difference exceeds the tolerance limits.

The map conversion process is started from the decision to perform cadastral data conversion. It is initialized by performing data inventory to collect the data and examine the collected data. The process will be continued by converting the analogue data to digital by a scanning process which it is not done in KPKM, but it is performed by a private company. While waiting for the result of digitized data, map renovation can already be performed for the digital data and for the surveyed parcel maps. It is done to improve the geometric accuracy of cadastral maps which are obtained from the field survey such as surveyed parcel maps and digital cadastral maps, as well the digital data from scanning and digitizing process. As mentioned before, there are two methods to perform this process: (1) map reconciliation and (2) map border connection. After completing this process, quality check is required to ensure the geometric quality of the spatial data. The consequence of map renovation process is the discrepancy of parcel area before and after the process. The differences should be checked to know whether it is within tolerance or not.

During the map renovation process, problems can occur like in case of quality check and harmonization of parcel area where they require a field survey to solve the problems. However, as such field survey has to be avoided as much as possible, therefore field sketches are important as the first option to solve the problem. If they cannot solve the problems occurred, field survey, as the last option, can be performed. Not all parcels have to be checked one by one however it is done by sampling. Another urgent thing to perform field survey is when the connection point is not sufficient for data processing.

After map renovation, ensure consistency and completeness of spatial data. Ensure consistency to check its data structure, attribute and its relationship; and completeness to check the adherence information of the cadastral maps in terms of parcels, building, street names and other topographic features is required for data integration. The final step is to send the digital cadastral data to the archive and update its digital database and then publishes it to the citizen.

6.6. Conclusion

This chapter has been presented the strong need for KPKM to make all its cadastral maps to be available in digital format. It is determined by investigating the users needs related to cadastral data especially cadastral maps. In addition with the development of Makassar city and such this information is important and concerning on the bad condition of its cadastral maps. Hence KPKM needs to convert and renovate its cadastral maps.

KPKM has opportunity to improve its cadastral maps because 56% of its area is supported by digital cadastral base maps using aerial photogrammetry. The improvement process can be started from this area. However KPKM has a major problem in performing this process, which is that the available human resources are insufficient. Thus the role of external assistance can be taken into consideration in performing this project.

7. Conclusions and Recommendations

7.1. Introduction

The main objective of this research is to design a conversion strategy of cadastral map data from analogue to digital and also to analyze its implementation to provide an accurate, complete and up-to-date data of cadastral system.

In order to achieve the research objectives, a review of the existing methods for map conversion has been presented in chapter 4 and matrix comparison between each method has also been made. The factors that have been compared are the quality of paper map, software specialization, and data quality resulted from each method, time, labor, and costs. Concerning that map conversion is a continuous process involving map renovation, a framework for such process has been developed and presented in chapter 5. As Makassar being a case study of this research, a review of its current condition of cadastral system has been presented in chapter 6. It shows the specific case study to implement cadastral map conversion and renovation.

7.2. Conclusions

In this part, the conclusions are started by answering all the defined research objectives and research questions; and in the last section, it gives the overall conclusion related to whether the main objective has been achieved or not.

There are five (5) research objectives and nine (9) research questions:

1. Research Objective 1: to examine the existing condition of cadastral maps concerning registers and map data: completeness, up-to-dateness, accuracy, and scale. There are two research questions that have to be answered based upon this research objective:

   Research Question 1 (RO1): How is the existing condition of cadastral map data and registers in terms of completeness, up-to-dateness, accuracy, and scale?

   - Completeness. Cadastral maps is called being complete if they contain all parcels. None of cadastral maps in Indonesia is in complete condition. It is emphasized in section 5.6 that there are about 85 million parcels in Indonesia, only 45% have been registered, but most of these registered parcels are not yet mapped in cadastral map. As it is in Makassar 56% of this area is covered by cadastral base maps. By having these maps, 30% area of Makassar has cadastral maps that already been in GIS environment but not properly maintained, 26% are not yet available in GIS, still in progress to complete its mapping, and the rest of 44% area is in paper based (subsection 6.2.1).
   - Up-to-dateness. The existing cadastral maps in Indonesia are far away of being so called up-to-date. The existing analogue and digital cadastral maps are not properly maintained. In case of digital maps there is no updating process for the available cadastral base maps. For instance

base maps using an aerial photogrammetry project in 1996/1997 are not being up-to-date until now, concerning that within those times period there might be possible changes in a certain area (subsection 6.2.1). Moreover, to keep the maps as up-to-date as possible, it requires sufficient human resources to maintain and them up-to-date in terms of performing field survey. However, BPN is not supported by sufficient surveyors. Insufficient capacity like this is happened to KPKM where there are only 4 surveyors to perform this work (subsection 6.2.4).

- Scale. As in PMNA/KaBPN No. 3/1997, article 17 point a, the cadastral maps use scale 1:500 and 1:1.000, 1:2.500, and 1:10.000 for urban/built-up, sub-urban, and rural/plantation area respectively (subsection 3.6.2.)
- Accuracy. The accuracy of current cadastral maps based on PMNA/Ka BPN No. 24/1997 article 17 is 0.3 x map scale (see Table 4: Tolerance limit of field survey). However, in the reality the accuracy such like that does not exist. As long as there are maps produced by inaccurate field survey such as using tape and compass or even ropes where the measurement such like this will derive inaccurate result of cadastral data.

Research question 2 (RO1): What are the quality aspects of cadastral map and why there is a need for map conversion to improve the cadastral maps?

Cadastral maps in Indonesia were established over time by different methods, different coordinate system and scales and have different qualities, not to say imperfections. Many cadastral maps are in analogue format and in bad condition. As the important role of cadastral maps land registration as evidence to give certainty to the land owner, thus the cadastral maps should be secure and should give accurate and reliable information. In addition, there is also a growing demand of information related where this information should be accessible for multiple users.

2. Research Objective 2: To examine the available data conversion approaches. The research question related to this objective is:

   Research question 3: What are the available conversion methods?

   Subsection 2.4.1 shows the existing of data conversion. There are four methods which are manual digitizing, scanning (heads-up digitizing and automatic Vectorization), COGO, and conversion of the existing method. The advantages and disadvantages of each method is presented in Section 4.5

3. Research Objective 3: To evaluate and assess the data conversion approach that suitable for converting cadastral map data of BPN.

   Research question 4: What are the parameters to define the best method for map conversion?

   Subsection 5.3.1 shows the factors that influence in selecting the approach for map conversion. Based on this matrix comparison each method is presented including its description in chapter 4.4. Further in section 4.7, it presents a discussion on which considerations should be taken into account in determining the chosen method.

Research question 5: What quality improvement methods are available?

Map conversion is not just to convert data into digital format but more than that, it is about to make use of the existing digital data. Therefore in section 5.2, it presents methods that discuss on how to improve the quality of cadastral maps and quality assurance by determining the quality of spatial data model (section 5.3) and the issue rising due to this process (section 5.4)

Research Question 6: What is the alternative method to complete cadastral maps?

As mentioned before that cadastral maps in Indonesia are incomplete. In order to complete its cadastral maps, BPN has been set up some scenarios to accelerate its mapping activities. The methods that have been prepared are by using aerial images and satellite imageries with various resolutions (subsection 3.8.2). In addition in section 5.6., it shows that GPS also to be considered as an alternative technology to obtain a complete record of cadastral boundaries for cadastral mapping. Further it illustrates the reason why this technology is compatible concerning its velocity to speed up the work and its accuracy that this technology offered (subsection 5.6.2). However, there are some consequences that should be taken into account by using this technology, but those would not be an issue for countries or institutions where its cadastral system is not yet interoperable with others like in Indonesia (subsection 5.6.3).

Research question 7: What is the workflow to organize the available method?

Chapter 5.10 shows the workflow of map conversion and map renovation.

4. Research Objective 4: To estimate the costs needed.

   Research question 8: What are the cost factors that will impact the conversion method implementation?

   Data conversion is usually both lengthy and expensive. Cost factors that will impact the implementation of conversion project are costs for the personnel who involve in the project and costs for the procurement or renting hardware and software. These two factors give a considerable influence the map conversion project even though there are another costs factors that also influence, such as costs for mobilization such accommodation and transportation (section 4.5).

5. Research Objective 5: To develop an implementation strategy of map conversion for KPKM.

   Research question 9: Which the available conversion and renovation methods can be suitable for KPKM context?

   Referring to chapter 4 which is related to the selection of the best method for map conversion; with regard to the existing condition of cadastral maps in Makassar, therefore heads-up digitizing can be implemented to convert its cadastral maps data. Further, in terms of improving its quality of its maps, both map reconciliation and map border connection can be applied concerning the availability of data sources for map renovation.

It can be concluded that the main objective of this research as mentioned before has been achieved. As the main objective is to design a strategy for map conversion for Indonesia context, it has been answered in chapter 4 on to how to select the best conversion approach by considering the existing parameters which influence on the selection. As this process is not limited on conversion, but more than that a framework for map renovation as part of map conversion has been presented for Indonesia in chapter 5.

7.3. Recommendations

1. In general, it is recommended to convert and renovate cadastral maps in Indonesia because of the following:
    - To provide a better basis to make the cadastral map up-to-date.
    - To simplify in data maintenance. It relates to the public services where they need a fast process and accurate information. It is very difficult to achieve in conventional way where there are a large amount cadastral data that should be managed and customer satisfaction that need to be full-filled. With help of digital data the process will be faster, transparent, and could give more efficient services for the public in many domains such as land valuation system, land sub-division, boundary fixing administration, and state owned land protection and managing.
    - To avoid damage of the analogue maps. Over time analogue maps would be decreased in terms of its paper quality. This can occur because of its age or bad data storage. Consequently, in many cadastral maps the cadastral boundaries of parcels are vanished out. This can diminish the reliability of official records and degrade the geometric properties of the existed parcel. Moreover, it can cause possibility loss in land markets.
    - To avoid renewal of analogue maps. Besides this process would destroy the geometric position of the origin sheets by redrawing process which can cause inaccuracy of map data, it also takes a long time to perform this process and become a costly process since it is labour intensive.
    - To establish a basis to provide different services. Commonly, different users need different information related to cadastral data. Sometimes they need maps with different scales, charts, survey records, or reports. In digital format, this type of information is easy to be provided depend on their needs.
    - To provide an easy workflow. Since cadastral data are going to be used for many domains and different institutions, the cadastral data should be in digital format to make it easy to be accessed.
    - To provide better data protection. Data in digital format gives higher level ownership security and confidence by protecting ownerships against damage or forgery as well as easiness in data updating and maintenance.
    - Moreover, the availability digital datasets in land administration organizations provide opportunities to expand the function of land administration in society, give good opportunity to respond to the growing demand for transparent land and property markets, for better governance and for the development of e-government service.

2. Concerning the drawbacks of analogue cadastral data which it is not sufficient anymore to full-fill the requirements there is a need of data conversion related to cadastral map data.

3. The map conversion and renovation are recommended to be performed under the following conditions and requirements:
   - It is recommended to use COGO to convert the available cadastral data concerning that it doesn't need hardcopy maps. It can be performed as long as the legal documents give complete information related to parcel(s) and control points.
   - To accelerate the cadastral base mapping to provide large scale topographic maps for the whole territory in Indonesia. However, this activity also should consider the need of every region, whether it is for urban, rural, or plantation/forest area. The types of area determine the needed accuracy level. In case of Makassar as an urban area where it needs high accuracy of cadastral base maps. Aerial photography is considered to be the best way to provide high accuracy of cadastral base maps where it is necessary for improvement process. However, data acquired from satellite imageries still can be applied for rural and forest/plantation area.
   - The quality specifications of the cadastral maps should be clear and the employee should understand the necessary functionalities.
   - Concerning that map conversion process is not only limited in a process of converting data from analogue to digital format. Furthermore, it is a sustainable process in terms of maintaining and managing digital data resulted from this process. Intensive training courses should result for the intended project staff to provide them with a range of necessary technical skill.

4. It is recommended that BPN performs a pilot project for cadastral map conversion and map renovation. As it is a huge project involving many parties and technologies to handle such a sustainable process, the possibility of the involvement of external assistances has to be considered. The option to involve them in this project needs a further investigation.

References

Achmad, C., B (2004). *Building Physical Cadastre: A New Approach for Speeding-up the Land Registration Process in Indonesia*. in: 3rd FIG Regional Conference, Jakarta, Indonesia, October 3-7, 2004. www.fig.net

Alostah Z., and Alkhatib, S., (2005). *Building Jordan Digital Cadastral Data Base (JDCDB) in the Department of Lands and Survey (DLS).*In: FIG Working Week 2005 and GSDI-8: from Pharaohs to Geoinformatics. Cairo, Egypt. April 16-21, 2005.

Bappenas (2007) *Konsep Dasar Pengembangan Kebijakan Pertanahan Nasional*. http://www.landpolicy.or.id/kajian/2/tahun/2007/bulan/08/tanggal/29/id/26. Access date: 02 December 2009.

Bogaerts, T. and Zevenbergen, J. A., (2001). *Cadastral systems : alternatives*. Computers, Environment and Urban Systems : an international journal **25**(4-5). http://intranet.itc.nl/papers/2001/peer_jrnl/zevenbergen_cad.pdf

Cichocinski, P. (1999). Digital Cadastral Maps in Land Information Systems Liber quaterly, the journal of European research libraries, Vol.

Dale, P. (2005). *Land Administration in the UNECE Region : Development Trends and Main Principles*. Economic Commission for Europe : Publications on Human Settlements;140. United Nations Economic Commission for Europe (UNECE). Geneva. p. 104.

Dale, P. F. and McLaughlin J., (2000). *Land administration*. Spatial Information Systems and Geostatistics Series;*9. Oxford University Press. Oxford, 169. pp

Dangermond J. (1988). *A Review of Digital Data commonly Available and some of the Practical Problems of Entering them into a GIS.* In: Peuquet, D. J. and D. F. Marble (1990). *Introductory readings in geographic information systems*. London etc., Taylor & Francis 371 pp.

Davis, B. E. (1996). *GIS : a visual approach*. OnWord Press. Santa Fe, 374. pp

Devillers, R. and R. Jeansoulin (2006). *Fundamentals of Spatial Data Quality*. London. ISTE. 309 pp.

ELayachi, M. and Semlali, E., (2001). *Digital Cadastral Map: a Multipurpose Tool for Sustainable Development*. International Conference on Spatial Information for Sustainable Development, Nairobi, Kenya, 2–5 October 2001. p. 2-5, http://www.fig.net/pub/proceedings/nairobi/elayachi-semlali-TS19-1.pdf.

FIG (1995). *FIG statement on the cadastre*. FIG publication;11. the International Federation of Surveyors (FIG). Belconnen, 22. pp

Gavish, J. and Benin E., (2009). A GIS Based Cadastral Database at the Survey of Israel-Infrastructure for Future Modern, High Accuracy Cadastre. in FIG Working Week 2009: Surveyor Key Role in Accelerated Development. Eilat, Israel, 3-8 May 2009.

Goodchild, M. F. and Kemp, K. K., (1990). *Introduction to GIS : NCGIA core curriculum*. Santa Barbara, California, National Center for Geographic Information and Analysis (NCGIA) 350 pp.

Heryani, E. and Grant C., (2004). *Land Administration in Indonesia*. Land Equity International, www. landequity. com. au/pdfs/LandadminIndonesia. pdf.

IAAO (2003). *Standard on Digital Cadastral Maps and Parcel Identifiers*. http://www.oicrf.org. http://www.oicrf.org

Ingersoll, K. (1994). *Solving Data Conversion Puzzle: Find the Solution that is Best for Ypu*. G1S World, 7(8), 34-38.

Kaufmann, J. and Steudler D., (2001). *Cadastre 2014 : a vision for a future cadastral system*. International Federation of Surveyors (FIG). S.l., 51. pp

Kumar, N., (2007). *Renovating Cadastral Map- An Indian Perspective*. http://www.oicrf.org. www.oicrf.org

Larsson, G., (1991). *Land registration and cadastral systems : tools for land information and management*. Also Farsi language edition available. Longman Scientific & Technical. New York, 175. pp

MASSGISS (1999). *Parcel Mapping Using GIS: A Guide to Digital Parcel Map Development for Massachusetts Local Governments.* Commonwealth of Massachusetts Executive Office of Environmental Affairs Massachussetss Geographic Information System. University of Massachussets. August 1999. http://www.umass.edu/tei/ogia/parcelguide/parcelguide.pdf

Mendes, J. E. G., (1995). *Analogue-to-Digital Data Conversion of Cartographic Documents*. Accepted for publication in Proceedings of the EPMESC V Conference, to be held in Macau, August 1995.

Mendes, J. F. G. (1995). *Cost Estimation for the Conversion of Map-based Land-Use Plans into GIS Databases*. Computers Environment and Urban Systems **19**(2): 99-105. <Go to ISI>://A1995QZ80100003

Montgomery, G. and Schuch H., (1993). *GIS data conversion handbook*. GIS World, Inc. and UGC Consulting. Fort Collins, USA. 328 pp.

Rolae, M., (1998). *Improvement of Cadastre in Croatia*. Institute of Engineering Geodesy, Faculty of Geodesy, Zagreb, Croatia. http://www.geom.unimelb.edu.au/fig7/Brighton98/Comm7Papers/TS50-Miodrag.html.

Salzmann, M., A., Hoekstra and Schut T., (1998). *Cadastral Map Renovation–a Dutch Perspective*. p., www.oicrf.org.

Song, W. H. (2008). *Cadastral Map Renovation : an Analysis of the South Korean Perspective*. International Institute for Geo-Information Science and Earth Observation (ITC). Enschede, the Netherlands. 109 pp.

Ary Sucaya, I. K. G. (2009). *Application and validation the land administration domain model in real life situation : a case study in Indonesia*. International Institute for Geo-Information Science and Earth Observation (ITC). Enschede, the Netherlands. 92 pp.

Sumarto, I., W. R. Idrus, V. E. Jaya, R. Eko, D. K. Gindow, B. Adhi, E. Putranty, E. Pintadi, P. Hadi, Y. Aziz, A. Giyanto, Rahardjo, F. Yeryandi, I. Herawati, F. A. Singagerda and S. Yusra (2008).

Cadastral Base Mapping Activity in Indonesia. In: FIG working week 2008: Integrating Generation, Stockholm, Sweden 14-19 June 2008. www.fig.net

UN-ECE (1996). *Land Administration Guidelines : with Special Reference to Countries in Transition*. United Nations (UN). Geneva, 94 pp.

United-Nations (2000). *Handbook on geographic information systems and digital mapping*. Studies in Methods : Series F;79. United Nations. New York, 197. pp

Van der Molen, P. (2009). *The Evolving Function of Land Administration in Society-CApitalizing on Investments in a Digital Land Register and Cadastre in the Netherlands.* In: 7th FIG Regional Conference: Spatial Data Serving People: Land Governance and the Environment-Building the Capacity. Hanoi, Vietnam, 19-22 October 2009. 13 pp.

Van der Molen, P. (2002). *Dynamic Aspect of Land Administration : an Often Forgotten Component in System Design*. Computers, Environment and Urban Systems : an international journal **26**(5). http://dx.doi.org/10.1016/S0198-9715(02)00009-1 http://intranet.itc.nl/papers/2002/peer_jrnl/vandermolen_dyn.pdf

Van Oosterom, P. J. M. and Lemmen, C. H. J., (2002). *Towards a Standard for the Cadastral Domain : Proposal to Establish a Core Cadastral Data Model*. In: Towards a cadastral core domain model : Proceedings of the 3rd workshop and 4th MC meeting of the COST G9 action : Modelling real property transactions, 10-12 October, Delft, the Netherlands, 18 pp.

Wakker, J. W., Van der Molen, P., and Lemmen, C. H. J., (2003). *Land registration and cadastre in the Netherlands, and the role of cadastral boundaries : the application of GPS technology in the survey of cadastral boundaries*. In: Journal of Geospatial Engineering : Official Publication of the Hong Kong Institution of Engineering Surveyors, 5(2003)1, pp. 3-10.

Williamson, I. and Enemark S., (1996). *Understanding Cadastral Maps*. The Australian Surveyor **41**(1): 38-52. www.oicrf.org

Williamson, I. and Ting L., (2001). *Land administration and cadastral trends—a framework for re-engineering*. Computers, Environment and Urban Systems **25**(4-5): 339-366.

Winoto, J. (2009). *Taking Land Policy and Administration in Indonesia to the Next Stage and National Land Agency's Strategic Plan.* Workshop in The International Federation of Surveyors Forum, Washington DC, March 2009

Wolf, P. R. and Ghilani C. D., (1997). *Adjustment computations : statistics and least squares in surveying and GIS*. New York etc., Wiley & Sons 564 pp.

World Bank (2005). *Doing Business in 2005.*

Zein El-Abedein, H. (2000). *Towards a HomogeneousCcadastral Map in Egypt : Map Conversion Process*. International Institute for Geo-Information Science and Earth Observation (ITC). Enschede, the Netherlands. 36 pp.

Zevenbergen, J. A. (1999). *Are cadastres really serving the landowner?* In: Proceedings of 21st Urban Data Management Symposium : Information Technology in the service of local government planning and management, Venice 21-23 April 1999, Delft, Theme 1, pp. 3.1-3.10. http://intranet.itc.nl/papers/1999/conf/zevenbergen_cad.pdf

Web Reference:

1. Peta Online Badan Pertanahan Nasional (http://map.bpn.go.id/indexmap.html)
2. Indonesia Cadastral Tempalte (http://www.cadastraltemplate.org/countrydata/id.htm)
3. Pelayanan Pertanahan Berbasis Teknologi Informasi (http://locsupport.wordpress.com/2007/11/14/sekilas-tentang-loc/)
4. ISO/TC 211 Geographic Information/Geomatics (http://www.isotc211.org/)
5. ESRI (www.esri.com)