Developing 3D Cadastral Information system for part of 03 kebele, Dire Dawa Administration City, Eastern Ethiopia

By kedir Abdi

A Thesis Submitted to

The Department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Geodesy and Geomatics Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

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Approval of Board of Examiners

We, the undersigned, members of the Board of Examiners of the final open defense by Kedir Abdi Mumed have read and evaluated his thesis entitled "Developing 3D Cadastral Information System for part of 03 kebele, Dire Dawa Administration City" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master's in Geodesy and Geomatics Engineering.

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Internal Examiner	Signature	Date
____________________	____________________	____________________
External Examiner	Signature	Date

Declaration

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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Signature: ________________

This MSc Thesis has been submitted for examination with my approval as thesis advisor.

Name: Dr. Hasan Raja Naqvi

Signature: __________________

Date of submission: January, 2018

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Abreviations/ Acronomys

2D	Two Dimensional
2.5D	Two and Half Dimensional
3D	Three Dimensional
3DCDM	3D Cadastral Data Model
ABS	Australian Bureau of Statistics
ADE	Application Domain Extension
BIM	Building Information Model
CAD	Computer Aided Design
CCDM	Core Cadastral Domain Model
CE	CityEngine
CGA	Computer Generated Architecture
CIS	Cadastral Information System
CSA	Central Statistics Agency
CSV	Comma Separated Values
DBMS	Database Management System
DXF	Drawing Interchange File Format
EC	Ethiopian Calendar
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental System Research Institute
FIG	Internatinal Federation of Surveyor
GDBMS	Geodatabase Managiment System
GIS	Geographic Information Systems
GML	Geographic Markup Language
GPS	Global Positioning System
GTZ	German Technical Support
GUI	Graphic User Interface
ICSM	Inter-governmental Committee on Surveying and Mapping
ID	Identification
ISO	International Standard Organisation
LADM	Land Adminstration Domain Model
MSL	Mean Sea Level
NSDI	National Spatial Data Infrastracture
RRR	Right, Ristriction and Responsibility
UDSS	Urban Development Support Service
UTM	Universal Transverse Mercator

WGS	World Geodetic System

Abstract.

3D property registration has become a vital need in order to optimally reflect all complex cases of the multilayer and multi level reality of property rights and restrictions, revealing their vertical component. But, the current 2D cadastral model does not include multi layer and multi level building. The main objective of this study is to developing 3D cadastral information system for part of 03 kebele, Dire Dawa Administration city. To achieve this objective CityEngine procedural model method has been used for activities of 3D cadastral data to register and visualize the complex reality in 3D. The 3D model was built using different parameters based on input data, derived from Aerial Photographs, 2D cadastral system, questionnaire datasets as well as architectural plans and elevation data . The modelling process consists of data preparation,organization, validation and import into the software model creation using Computer Generated Architecvture(CGA) rules and export for the model created to the web scene. The process resulted in a final 3D model and capable of easy to store, update, search, insert, share, maintain and visualize intended 3D properity. The application and potential of 3D model has been tested by selecting the condominium design types of selected site in which a complex ownership status is established along with approved legal document from Dire Dawa housing development agency and manucipality. The finding of this study show Developing 3D cadastral information system have better for the society and government that related to providing relevant documents regarding to the ownership of house as well as gives useful information for municipality in order to administration land valuation, tax collection and legal purposes. Moreover it is providing relevant information for decision and policy makers with reality of land and decrease corruption or misunderstanding between field observer and office manager. Interestingly, Dire Dawa and other city municipalities should develop and adopt such techniques of 3D cadastre.

Key Words: 3D Model, GIS, CityEngine, Condominiums Building, Dire Dawa city

1. Introduction

1.1 Background

Population is significantly increasing in urban area which results in huge number of land allocating for housing and development activities. This trend has caused a growing importance of ownership of land, which has changed the way humans relate to land. This changing relationship necessitated a system in which property to land is clearly and indisputably recorded. such a system is referred to as a ‘cadastre’ although many systems with different names are instituted world-wide, which fulfill (more or less) similar tasks, such as cadastral registration, cadastral system, land registry, land registration, land administration, property register and land book.

There is no unique form or definition of a cadastre exists. In (Dowson and Sheppard, 1952) it was noted that: “It is impossible to give a definition of a Cadastre which is both terse and comprehensive, but its distinctive character is readily recognized and may be expressed as the marriage of (a) technical record of the percolation of the land through any given territory, usually represented on plans of suitable scale, with (b) authoritative documentary record, whether of a fiscal or legal nature or of the two combined (multipurpose), usually embodied in appropriate associated registers.”

In principle, this thesis follows the description of a Cadastre as it is given in the FIG (International Federation of Surveyors) Statement on the Cadastre (FIG, 1995): “Cadastre is normally a parcel based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes such as valuation and equitable taxation, legal purposes such as conveyancing, to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection.”

Cadastre is an official record both in urban and rural land property usually maintained to register location, ownership, land value and attributes of land in a given jurisdiction, state or country. There are two models of cadaster to manage the land and its property which are called 2D and 3D cadastre. Cadastres that are equipped to show the geometry of parcels (2D) and to represent the legal status of these parcels (ownership information) are called

2D cadastres without elevation and partion building and 3D cadastral registration can apply to register one land(one parcel) and many overlapped property owned by different owners.

In developing countries the application of urban cadaster is very difficult due to the tendency of city (town) official to use land (parcel) for their benefits illegally and lack of awareness of cadaster, improper plan of city or towns, lack of technical human power, financial and etc. Lack of instrumental technology in land delivery leads to increases case of corruption, bribery and favoritism by the town and city officials (Aldridge and van Velten, 1997).

Ethiopia is one of the developing countries which are being challenged with above state problems. Currently, in Ethiopia principles for recording overlapping interests in land are fragmented and not available in a cohesive and integrated way. Historically, 2D systems managed interests in land and property. Traditionally, 2D cadastres were designed to assist in land taxation, real estate conveyancing, and land redistribution. It also help to provide those involved in land transactions with relevant information and help to improve the efficiency of those transactions and security of tenure in general. They provide governments at all levels with complete inventories of land holdings for taxation and regulation. To prove this problem some works has been started in some urban region of Ethiopia by introducing the 2D boundary parcel registration and it is expected to solve the problem when it is completed the 2D registration system. These urbans include Mekelle,Adama, Awassa, and Bahir Dar which are selected from the four major Regional States in Ethiopia. UDSS/GTZ played the leading role in promoting cadaster in the four mentioned towns the system in urban centers from those Mekelle 90%,Adama 95%, Awassa50%, and Bahir Dar 75% completed, since the project is going on for more than 8 years as report(DHV Consultants ,2013).

Today, the information is also increasingly used by both private and public sectors in land development, urban and rural planning, land management, city space management, and environmental monitoring (FIG, 1995).Even though, these 2D cannot manage the increasing number of the sector and 3D property rights, restrictions and responsibilities in current situation. Therefore, different countries have been working and set different conferences to share their knowledge and experience about land adminstration system supporting 3D representation. The ability to maintain 3D information relating to property interests and make it available through the land administration systems will provide important benefits at government levels, at the public level where it will assist management of the economy of 3D land development, security of tenure and community engagement (Rajabifard et *al*., 2012).

The Population of Ethiopia increasing which results in huge number of land allocating for housing and development activities. To secure this, the government of federal democratic republic of Ethiopia and private sector are design to develop town vertically as much as the capacity of the city permitted. Due to this policy, condominium houses, commercial buildings and real estate building are constructing throughout the towns of the country. This construction surface boundary will be registered in 2D cadaster where the condominium building situated and the information of houses are text registered with regard to its 3D property units. There are many problem in multi level and multi layer registration in 2D cadastre espacialy in condominium. The challenge is how to register overlapping and interlocking constructions and how to register the property situations above and below the surface in cadastral registration as that registered information in one parcel area only by means of a cadastral system in which ownership rights are accurately designed and guaranteed can prosperity be achieved. In order to register and visualize the complex reality in 3D cadastre. Esri's City Engine 2014 modeling software has been used, which is specialized in the generation of 3D urban environments, transforming 2D GIS Data into Smart 3D City Models **(**Tsiliakou, 2013). City engine for the selected and organized database has been used to develop the system and proto type implementation of the 3D cadaster been developed based on the 3D procedural modeling (CGA rule file). To achieved through the arrangement of geometry, attributes and rules or algorithms.

This research shows the 3D cadastral system is the solution to overcome the challenges of registration and updating of the interlocking and overlapping property units using modern technology for our country especially for multi layer and multi level building to property management.

1.2 Statement of the Problem

The designed urban cadastre in Ethiopia including Dire Dawa City does not include multi layer and multi level in Cadastral System.The problem is how to register overlapping and interlocking constructions and how to register the property situations above and below the surface in cadastral registration as that registered information in one parcel area epecialy in condominium. Due to these problems income tax return, growths of land management, security of housing and land transactions are very poor in Ethiopia((Daniel,2006).

For instance, Addis Ababa housing development agency census of each condominium houses from 2-28 March, 2016, it is found 3231 houses were illegally transferred. Moreover, 127 houses were rented by neighbours and 94 houses were closed i.e. missed to transfer (Broadcasting, "news," 2016). The similar problem or trend in Dire Dawa City and other cities especially condominium houses which requires a clearly designed and protective technological mechanism that can register for their 3D properties.

Hence,3D Development cadastre is more solution and put enormous pressure on current land administration system equipped with the cadastre that are only able to maintain 2D spatial information.

The need to conduct this research their is no any 3D cadastral information systems for this study area even current 2D cadastral registration have no real property boundary (Source, Dire Dawa municipality).Therefore, this research concerned on developing 3D Cadastral system using GIS and city engine procedural model to resolve problem for multi level and multi layer houses in Dire Dawa Administration City, particularly in kebele 03.

1.3 Motivation

Like most developing countries in Ethiopia, cadastral surveying technique still supported by traditional methodologies. Hence, the output from this kind of methodology is apparently measurement based identification of the parcels .For instance, cadastral survey was undertaken in the four regional state (Oromia, Amhara, SNNP &Tigray) with traditional methods in the first, second and third level of certification. But, the size of the plot was determined either using ropes or relying on knowledge of the number of 'timads' of a plot. In addition, the plot is described by naming the neighbour on the N, E, S and W. Thus, in none of the regions still produced a full-fledged cadastral map and not even a valuable sketch that could be distributed as a certificate to the owner of the parcels of the land. So, in general the initiation of the research is to perform the following activity:

- To change tradition methodologies of land recording to modern computerized system (3D).
- To create awareness about 3D cadastral system.
  - Possibilities to query graphic objects in a virtual environment.
  - Visualisation of 3D spatial queries in a virtual environment.
  - virtual reality navigation and exploration of 3D worlds.
  - possibilities to visualise outcomes of queries in different file formats.
  - provision of moderate means to edit data over the 2D and visualise the change.

1.4 Research Questions

In considering the research problem the key research questions were formulated as follows:

- What objects should be registered in 3D cadastres?
- How the model selected to develop 3D cadastre?
- What makes the 3D cadastral information system sufficient?

Using these research questions as the basis for exploring 3D cadastral systems, the following research objectives were formulated to achieve the research question.

1.5 General Objective

The main objective of this study is to develop 3D cadastral information system for part of 03 kebele, Dire Dawa City Administration.

1.5.1 Specific Objective

To achieve the research questions and main objective the following specific objectives were considered:

- To identify spatial data and non-spatial data.
- To model 3D interface of building and dimension with their respective textures using Computer Generated Architecture code (CGA code).
- To evaluate the parcel of land and its property (3D object) in one database system that representing both spatial and attribute information for better retrieve, storage and queries on web page.

1.6 The Significance of the Study

Cadastral information system needed for different purpose in government, private and society such as for land valuation, tax collection and legal purpose, for providing relevant information for decision and policy makers on land, land boundary disputes between neighbours, emergence services and socio economic indicators.

In general the study has different significance for society and government in different way for example:-

- Providing the society with relative documents of the owner ship of land will enable society too clearly known the owner ship and avoid conflict between land owners.
- The study has a great importance in providing information, suitable for land administration and land tenures for specific area.
- Increasing countries economy revenue through lawful taxation returns.
- Decreasing misunderstanding and corruption between organizations.
- This research used as reference for municipality, student who want to do further research on 3D cadastre.
- Overall this study provides a prototype and quality parameters pertaining to cadastral system models and data which can be afforded by the municipalities in developing countries efficiently

1.7 The Scope of Study

This research was focused to developing 3D cadastre which to links the ownership, the object to be owned and the extent of the right of the owner by integrating database, in City Engine and ArcGIS for 3D modeling of multi-level buildings limited to legal and physical cadaster at Dire Dawa City. Which was demarcated by frameworks determine the needs and possibilities for 3D cadastral information system. These frameworks are linked to each other in the following.

To collect data required such as socio economic data, spatial data, data about object size, shape and types of software required to model this research project. In order to extract the building footprint from Architectural, structural Plans and Aerial photograph then integrate floor wise socio-economy data with building footprint. Modelling 3D floor wise condominium and in cooperating texture to buildings and its facilities using CGA code, in order to register the parcel of land and its property (3D object) in one database system that representing both spatial and attribute information for better retrieve and storage on web page. Finally, Rendering and analysis frame work, including smoothing morphing and other process to make final result.

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1.8 Organization of the Thesis

This thesis was organized into five chapters: The first chapter contains introduction, where the background, statement of the problem, objectives of the study, research questions and significance of the study discussed. The second chapter focuses on review of related literatures. The third chapter was description of the study area in terms of location and topography. This section also elaborates conceptual models, source of data, and software used and methodologies applied to achieve the desired objectives with details of the data sources. In the fourth chapter process, results and discussion was provided and finally last chapter provides conclusion and recommendations based on results and discussions presented.

2. Literature Review

Land is the platform for all economic, political and social activities of mankind. Therefore, knowing the land in its totality is very important. In order to study the natural resource and the conditions of these resources, proper surveying and preparation of maps is needed. The Cadastral system and land registration without cadastral surveying and cadastral mapping will be incomplete. A cadaster and cadastral map unless otherwise constantly updated loses its validity (municipal development partnership-ESA, 2006).

Israel is one of the countries which face high pressure on the use of land. This has promoted developments for a 3D cadastre. Therefore, in Israel for the past five years several studies have started on 3D cadastres (Benhamu and Doytsher, 2002; Forrai and Kirschner, 2003).

A decade ago there was no country in the world having an operational Cadaster including the Legislation, 3D survey plans/ mutation plans, 3D Cadastral database, and 3D dissemination. Due to limitation of technological (the spatial DBMS did not yet support 3D volumetric Primitives), legal, organizational and technical i.e. no operational 3D Cadastral system Implementations available. Now, after a decade of more experience with real-world (3D) developments in Israel, other countries also progressing, and an accepted international ISO 19152 standards for Land Administration supporting 3D representations, it is time to realize the 3D Cadaster in Israel. In Israel 3D cadastral system has been applied because the country is relatively small and it has a rapid growing population, the demand on the available land or space is becoming high .So it requires a proper management of land to satisfy the land inadequacy by adapting the available technology which supports 3D cadaster as Proven in some other countries; e.g. China .The development of this LADM country profile is a joint activity involving the Israeli key players: That is, besides the Survey of Israel, also the Land Registry (especially when also considering to register apartments, condominiums in3D), Israel Land Authority (93% of the land in Israel is in the public domain, and ILA is responsible for managing this land), and the licensed surveyors (creating the new 2D and 3D parcel representations)(Belfore, 2002).

The land administration sectors in Australia recognise the importance of having land information in 3D, especially in cadastres. Australia‘s Inter governmental Committee on Surveying and Mapping (ICSM), which includes all land administration authorities in Australia, in its Strategic Pathways and Milestones 2008-2010‘ (ICSM, 2008), identified the 3D cadastre as an emerging trend and supported research into 3D cadastre development.

In April 2013 Cadaster participated in the World Bank Land and Poverty Conference. During this annual conference world leaders and experts from around the world came together to discuss land administration and its importance in combating poverty. In 2013 Cadaster organized study visits for foreign delegations in order to share knowledge and to offer an opportunity to become acquainted with Cadaster. We welcomed delegations from Ethiopia, Bhutan, Cape Verde, Romania and Bangladesh as show figure 2.1.

Figure 2.1: Involvement of Ethiopia in the International Cadastre

In most cases where 3D is compared to 2D, if asked, participants appear to prefer 3D. This preference, especially when combined with the lack of evidence that it is the better solution, is termed naive realism. While we believe that it is important to be aware of research that accounts for human perception and cognition, in this study, we take a literature review approach and elaborate on the utilization of 3D models as reported those who use it and for the purpose they report using it; eventually inferring categories of reported use Publications in the 3D GIS domain regularly list various uses of 3D geoinformation as examples (Ahmed *et al.*, 2014)

2.1 Related Research on 3D Tools and 3D Modeling

There has been a growing interest in representing and analyzing the real world using 3D tools. In particular countries such as The Netherlands's, Israel, Greece, Malaysia, Norway, Sweden, Canada, Denmark, etc., use 3D cadastral data registrations (Valstad, 2005) in addition to their national 2D bases and at the same time they have also been trying to resolve their fundamental technical and legal issues.

However, most of these lists are brief, specific to the paper's focus, and are not necessarily always supported with references. In the past 15 years, only a few researchers have focused on the general applicability of 3D geoinformation for solving industrial and research problems. In a 2000 study, (Batty *et al*., 2000) provide a conceptual study on the use of 3D city models, focused on visualisation and spatial planning. They have segmented the use of 3D city models into 12 categories of industries: emergency services, urban planning, telecommunications, architecture, facilities and utilities management, marketing and economic development, property analysis, tourism and entertainment, e-commerce, environment, education and learning, and city portals. Their list serves as an excellent starting point to re-examine after 15 years.

(Ross, 2010) lists several applications and provides a general taxonomy of 3D use cases: (1) applications that are based only on geometry (e.g., estimation of the shadow); (2) analyses based on geometry and semantic information (e.g., estimation of the solar potential); and (3) analyses based on domain specific extensions and external data (e.g., noise emission calculation).

In a more recent study conducted, (Wong, 2015) investigates the economic value of 3D geo information as an initiative of the Euro SDR 3D Special Interest Group. A part of the work deals with several examples of uses of 3D GIS, which are classified based on areas (domains) and applications. An area (e.g., health) may contain multiple applications (e.g., emergency services, epidemiology).

3D registration deals with maintaining spatial and non-spatial information on 3D objects, which are core as a 3D modeling is being used in different application areas, such as animation, archeology, architecture, engineering and others, (Luan *et al*. 2008) in their research have stated it as a key technique for many researches and applications. Research by (Luan *et al*., 2008) gives an overview of the process of 3D modeling which includes 3D data acquisition, modeling and rendering steps. There are given application possibilities of the 3D modeling as well.

2.2 Cadestre in Ethiopia

Emperore Menilek II, who was signed the country's first Proclamation related to urban lands at the end of 1907, which was started by a French company in Addis Ababa. The land owner was to be provided a certificate referred to as "yerist waraqet" or "rist" paper to be written in Amharic and French, with a map showing the boundaries of the land. But it remained without maintenance for more than 80 years. The Addis Ababa City Administration around 2002 decided to launch a cadastral project initially intended to register all property owners liable for property taxation and collect data that would enable the City Administration to assess a value of a property more realistically. As it has been already stated cadaster as a system is non-existent for most cities in developing countries. This is true for Ethiopian towns and cities. By considering this reality the UDSS/GTZ took an initiative on four selected regional towns to establish their own cadastral system. These include the study Mekelle,Adama, Awassa, and Bahir Dar which are selected from the four major Regional States in Ethiopia. Despite UDSS/GTZ played the leading role in promoting cadaster in the four mentioned towns until now it was not possible to replicate the system to other urban centers in the country, since the project is area. The table 2.1 show the report summarizes the status of the project.

Table 2.1. The Status of Cadaster in the Four Towns of Ethiopia since 2013

City	Start Date	%Complete	Parcel	Status	Remark
Adama	1999	95%		On going due for completion early 2013	Orginal survey stalled now being completed by a private contractor
Bahir Dar	1998	75%		Paused, HR and financial constraints	Some updating with lease subdivisions
Hawassa	1998	50%	20,000	Paused; pending reorganization	New project proposal prepared
Mekelle	1996	90%(Spatial)25%(Aspatial)	35,000	Paused,pending new contrat	New lease subdivision bing added

Addis Ababa, capital City of Ethiopia has witnessed rapid urban expansion over last 20 years. This has pressure on the city's land resource to increase of slum settlement .the Addis Ababa City government has recently integrated program for the development of slum settlement and the development of new house areas both of which requires reliable and consistent systems of real property registration and ownership. To this end Addis Ababa City Administration is committed to securing and clarifying land and property right and promoting land transaction process through registration. Those aims primarily are achieved with up-to-date City cadastral map data and robust geo-database system (zien, 2012).

2.3 2D Cadastre

From the early stages of human settlement, land was undisputedly the primary source of wealth and power. To secure guarantee of land ownership, cadastres have been established and managed in different forms their differences often depend upon local cultural heritage, physical geography, land use, technology, and etc. (Bełej *et al*., 2002).

Traditionally, cadastres were designed to assist in land taxation, real estate conveyancing, and land redistribution. Cadastres help to provide those involved in land transactions with relevant information and help to improve the efficiency of those transactions and security of tenure in general. They provide governments at all levels with complete inventories of land holdings for taxation and regulation. But today, the information is also increasingly used by both private and public sectors in land development, urban and rural planning, land management, city space management, and environmental monitoring (FIG, 1995).

Cadastres that are equipped to show the geometry of parcels (2D) and to represent the legal status of these parcels (ownership information) are called 2D cadastres without elevation and partion building. Land parcel and 2D representation of land parcels are two main properties and 2D cadastres work well where the owner of a parcel is entitled to use the land in the parcel from the centre of the earth to the heavens (villa arrangements) according to law, and building and urban planning regulations as show figure 2.2.

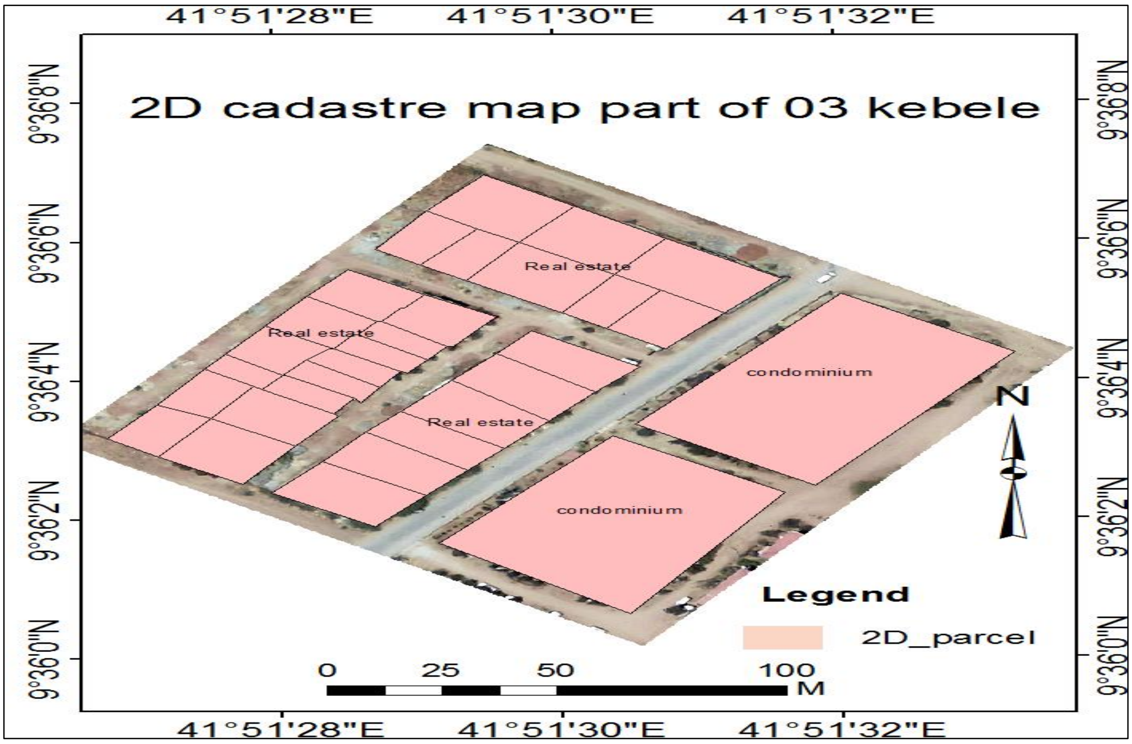


Figure 2.2: Sample Existing 2D Cadastre

2.3.1 Problems of 2D Cadastre

2D cadastres cannot effectively represent the complexities of reality. They are not able to manage and represent land ownership rights, restrictions and responsibilities in a 3D context.

The lack of an efficient and effective three-dimensional solution, limits the ability of the public to visualise and communicate 3D development and the ability of architects, engineers and developers to capitalise on the full potential of 3D title models. It also limits the ability of governments and developers to visualise multi-level developments resulting in increased costs and delays; and the ability of land registries to administer a title registration system that can accommodate these increasingly complex multi-level developments. In these cases, one parcel can be affected by a depth limitation (Figure 2.3) or a restriction can affect the height of any building that might be constructed. In this situation, the user might require a 3D representation of the ownership rights. From this conclusion this 2D cadastre not have effectively and efficiently represent information of cadastre to visualize reality of multi -level and complex building Therefore, The solution of this problem to solve the shortcomings of the current land administration and cadastral system is to develop a 3D Cadastral system that accommodates 3D parcels, incorporates legal and physical information, and is semantically enriched.

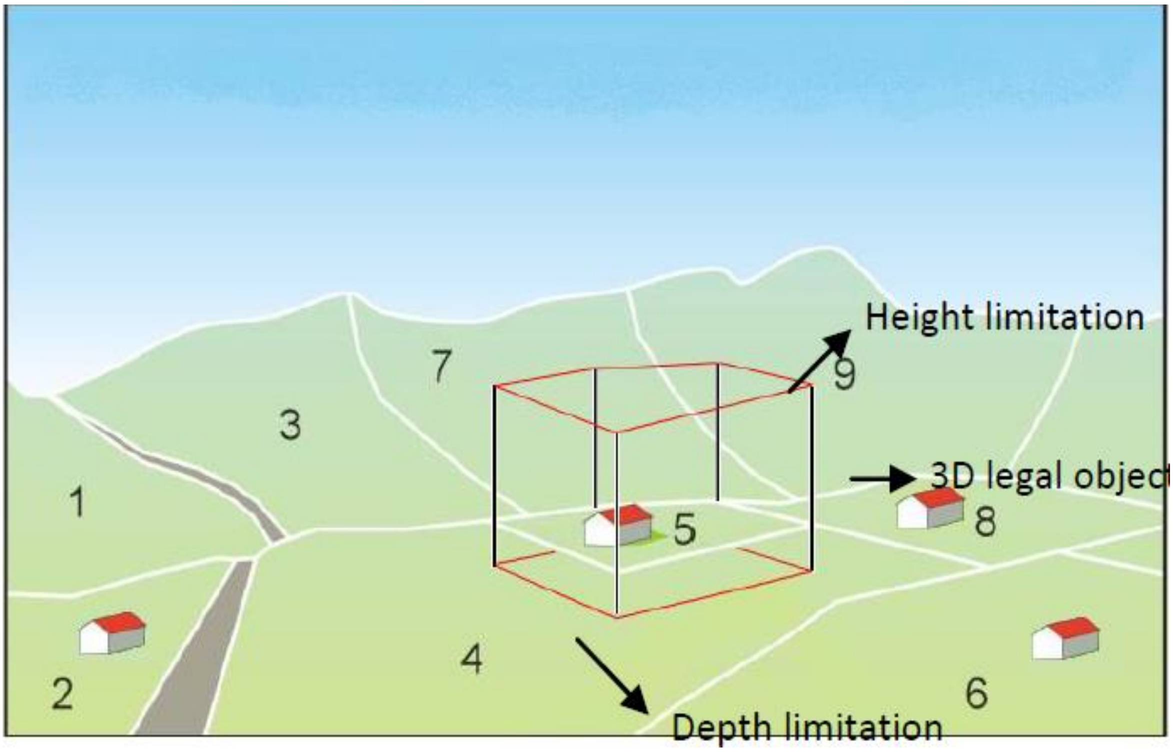


Figure 2.3: Land parcels inadequately represented by 2D spatial extent of boundaries of land related to the rights, restrictions and responsibilities

2.4. 3D Cadastre

There are different ideas about 3D cadastre. Hence, some existing 3D cadastre definitions will be mentioned from various researchers 'points of view before finally defining the 3D cadastre .Some definition of 3D cadastre as follow:

- ✓ A 3D cadastre is a cadastre which registers and gives insight into rights and restrictions not only on parcels but also on 3D property units (Stoter , 2004).
- ✓ 3D Cadastre provides information beyond the typical planar data and can be used to ensure registered rights below & above the land surface. Land use of underground and above-ground parcels, can be thus described, analysed and optimally developed and exploited (Papaefthymiou *et al.*, 2004).
- ✓ The 3D cadastre system will manage the 3D spatial data in strata in the same way the 2D-GIS system manages the 2D spatial data currently. This task can be separated into two parts; the first being 3D cadastral data spatial analysis of 3D parcels and 3D objects, and the second is 3D digital visualisation. 3D registration deals with maintaining spatial and non-spatial information on 3D objects, which are core topics of 3D GIS (Stoter and Ploeger, 2003 & Even-Tzur, 2004).
- ✓ A modern cadastral system should always reflect the existing status of all property

rights, including private and public properties. This provides better means for a rationalized management of the built environment, including regulations of legality of use or economic applications (Dimopoulou *et al*., 2006) the variation between these definitions are the result of different attitudes towards cadastres. However, most of the definitions purely reflect the legal portion (registration) of 3D cadastres and neglect integration of physical counterpart. Therefore, 3D cadastre is defined in this research as: 3D cadastral registration system defines with the same longitude and latitude but different owners, titles, size and found at different elevations piled in one parcel area.3D cadastre is a tool in a land administration system to digitally manage and represent stratified rights, restrictions, and responsibilities (legal models) and their corresponding physical models such as buildings, utilities, on, above or under the ground surface in 3D. A 3D Cadastre has the capability to capture, store, edit, query, analyses and visualise multi-complex properties and frame works with a documented set of standards. The 3D cadastral registration can apply to register one land(one parcel) and many overlapped property owned by different owners. Therefore different countries has been working and set different conferences to share their knowledge and experience about land adminstration system supporting 3D representation.

2.4.1 Need of 3D Cadastre

The world‘s population is being urbanised: the majority of people now live in towns and cities (UN-FPA, 2008). These increasingly urbanised populations will predominantly live in multi-level, multi-purpose, highly engineered, high-rise developments. Rapidly expanding vertical cities and their populations will experience a range of new environmental, social and economic challenges (Hillman, 1983). It is essential the infrastructure is in place to model and manage these new 3D environments (UN-FPA, 2008). This infrastructure should include verified, authorized, repeatable, engineered information about 3D environments, not just the surveyed external boundaries of structures and parcel boundaries that appear in two-dimensional drawings. The problem of creating efficient and accurate spatial representation of people‘s rights, restrictions and responsibilities in buildings and infrastructure above and below ground is shared by all cities of the world, irrespective of the level of development.

The third dimension of height in land information systems facilitates subdivision of space into strata legal property objects capable of being owned by different entities and used for unrelated purposes while facilitating management of the entirety. This creates separate legal property objects above or under the original property parcel or unit. The most typical objects located above the surface are apartments or buildings registered as separate property (Rajabifard *et al*., 2012).

Increasingly, construction below or above the surface, such as tunnels and platforms used as foundations for buildings and so on are also treated as 3D objects in a land subdivision process(Stoter, 2004). In some jurisdictions, networks such as telecommunication lines, water pipes and gas supply grids, and communication systems may also be registered, either within the land registry (as has been proposed in The Netherlands) or in a separate register (as for high-voltage power lines in Norway). 3D cadastres can also include interests related to trees, vegetation, minerals, hydrocarbons, as well as water (Bennett *et al*., 2005; Rajabifard *et al*., 2006 & Kalantari *et al*., 2008). Factors that highlight the need for 3D cadastres include an increase in property values, escalating numbers of overlapping transport routes, proliferation of utility infrastructure including cables and pipelines, management of complex natural environments alongside built infrastructure, and emergence of useful 3D technologies for design, planning and management.

Also, in current land information system data models, the third dimension is usually inadequately modelled as a 3D tag linked to the parcel record (Stoter & Oosterom, 2003). The increasing complexity of modern cities demands that modern land administration systems include heights and capacity to visualise inter-relationships between structures and uses for sustainable management (Wallace & Williamson, 2004).

Overall, the basic needs for the 3D cadastre are to:

- ❖ Explicitly register 3D space to which 3D rights apply.
- ❖ Have good accessibility to the legal status of 3D properties, including 3D spatial information as well as public law restrictions.
- ❖ Identify significant land and buildings subject to flooding (especially those in CBD high value and high impact areas).
- ❖ Identify parcels that cross other parcels.

- ❖ Support high value infrastructure‖ that should be 3D and height enabled‖: CityLink, Melbourne, Australia (http://www.citylink.com.au/).
- ❖ Support new style high-rise and low-rise buildings and developments: Queen Victoria Building, Melbourne, Australia (http://www.qvb.com.au/).
- ❖ Support infrastructure beyond land parcels: infrastructure assets and their position require heights. For example, above ground transmission and electrical wires should be mapped in the cadastral maps.

2.4.2 Benefits of 3D Cadastre

The ability to maintain 3D information relating to property interests and make it available through the land administration systems will provide important benefits at government levels. Its greater benefits lie at the public level where it will assist management of the economy of 3D land development, security of tenure and community engagement (Rajabifard *.et al*., 2012).

Building data show a trend of strong growth in approvals for residential dwellings in inner city areas of many Australian cities (ABS, 2009). Implementation of a 3D land and property information system potentially provides significant long-term benefits and savings for the community in the land development processes as more than 50 percent of land development proposals involve height allocations. A clear understanding of 3D developments through computer visualisation will help reduce misunderstandings and disputes between developers, owners and managers, and the public. At the same time this will improve the ability of authorities, such as local government and utility companies, to effectively plan large multi-unit developments such as shopping centres, bridges and tunnels. Access to comprehensive and integrated land and property information in 3D will modernise processes of land and property development in our cities and prevent confusion, administrative friction and disputes during decision making.

Currently, in Ethiopia, principles for recording overlapping interests in land are fragmented and not available in a cohesive and integrated way. Historically 2D systems managed interests in land and property effectively. These flat systems cannot manage the increasing number of 3D property rights, restrictions and responsibilities in our country. The fast growing populations and pressure to integrate facilities on, above and under the surface of cities and natural environments demand the introduction of a holistic approach to managing the third dimension in Ethiopia. The availability of 3D spatial land information systems will enable governments to effectively respond to the fast growth of Ethiopia‘s cities. Benefits of 3D cadastres and their potential needs persuade scientists and land administration authorities to develop and implement the 3D cadastre. Different aspects should be considered to successfully develop a 3D cadastre. But, All cadastral attempts in Ethiopia are depending on 2D Cadaster. No official effort and proposal is sugested to apply 3D cadastre in Ethiopia.

This research shows the 3D cadastral system is the solution to overcome the challenges of registration and updating of the interlocking and overlapping property units using modern technology for our country especially for condomineum and high raise building to property management.

2.4.3. 3D Cadastres and Models

It is important to realize that for registration, for storage/validation and for dissemination different models (all based on the shared ISO LADM semantics) may be needed and different types of users are involved.” The formal definition a 3D parcel is defined as the spatial unit against which (one or more) unique and homogeneous rights (e.g. ownership right or land use right), responsibilities or restrictions are associated, as included in a Land Administration system”.The modeling aspect includes the question of which spatial (esp. height) and temporal information should be used and how different types of users may interact (i.e. produce, archive, edit, analyze, and visualize, edit) with 3D-Cadastre? The 'users' belong to various categories; they range from professionals (which can be further subdivided in notary, real estate brokers, banks, water boards, utility companies, municipalities, cadastral employees, surveyors, etc.) to citizens (with various capabilities of owners/users).

2.4.4. 3D Cadastres and SII

The registration of legal objects (cadastral parcels and associated rights) and their physical counterparts (e.g. buildings or tunnels) result into two different, but related data sets, which can be very well accessed together via the Spatial Information Infrastructure (SII, sometimes also called SDI). This is already true in 2D, but even more so in 3D. By also showing some physical objects for reference purpose, the location and size of the legal objects will be clearer (Benhamu and Doytshe, 2002).

2.4.5. 3D Cadastres and Time

A 4D parcel is defined as the spatio-temporal unit against which (one or more) unique and homogeneous rights (e.g. ownership right or land use right), responsibilities or restrictions are associated to the whole entity, as included in a Land Administration system. Homogenous means that the same combination of rights equally apply within the whole 4D spatial temporal unit. Unique means that this is the largest spatio-temporal unit for which this is true. Making the unit any larger (in 3D space or time) would result in the combination of rights not being homogenous. Making the unit smaller (in 3D space or time) would result in at least 2 neighbour 4D parcels with the same combinations of rights (Benhamu and Doytsher, 2002).

2.4.6 3D-Cadastres and usability

The graphic user interface (GUI) is an essential aspect when realizing 3D-Cadastres in practice. This includes investigation of interacting with true 3D cadastral data (specific user interfaces: 3D spatial and perhaps temporal aspects via animations or snapshot sliders). The existing quality of successful and popular user interfaces will be the starting point with specific attention for working with the main 3D legal object types (related to underground infrastructure and building/apartment complexes). A true 3D cadastral system with functions should be implemented and applied to demonstrate the possibilities in practice based on 3D visualization. How to distribute the 3D cadastral information (3D parcels and associated rights) to the citizens? How to represent and demonstrate the 3D geographic aspect, on paper (with different viewpoints) or on electronic media (interactive tools based on Adobe Flex or Flash) (Bentley.Edition, 2004;and Benhamu and Doytsher, 2002).

2.5 Technical Aspect of 3D Data acquisition and Processing

Cadaster is only one of the application areas which 3D data can be used. Similar to other application areas deal with 3D data, the main technological challenge in maintaining a 3D cadaster is related to collecting, maintaining, editing, analyzing and visualizing the data. Significant developments are taking place in surveying technology and it is not very difficult to add z-values to the x and y-values of a coordinate-set. Horizontal and vertical reference systems are nowadays integrated (e.g. WGS84/ETRS), GPS-based survey provides z-values, and airborne laser-altimetry (e.g. LIDAR) has become very effective in the collection of elevation data for large regions, and terrestrial laser-scanning is a source of 3D data collection (‘3D point clouds’). Although there are several techniques that can be used for data collection, it may not be sensible to collect the 3D data for cadastral purposes alone. Hence, sharing and multipurpose use of data are important topics that should be given extra caution (Lemmen and It is important also to examine the state of the art with respect to the relevant software. “In the 3D application areas, customized software has frequently been used, because the existing Standard geo-DBMS and GIS/CAD software do not cover the 3D aspects sufficiently**”** (Blaschke and Tiede, 2003).

However, significant progress has been made in the recent years. For example, the DBMSs Oracle Spatial, IBM Informix Dynamic Server (IDS) and IBM DB2 Spatial Extender, can all store the third dimension within their point, line and polygon spatial data-types. However, the geometric functions (area, overlap, buffer, etc.) are still limited to two dimensions, true 3D volume primitives are not available and there is no 3D standard available like the Open GIS simple feature specification for 2D data types. “The geo-DBMS can be considered as the back-end of geo-information processing.” The front-end can either be ‘traditional’ GIS software (strong in analysis) or CAD software (strong in data editing). In general GIS packages support (2D) editing, analysis and visualization, and in many systems 2.5D functionality is added. However, functional support in true 3D is still very limited. “CAD packages on the other hand have supported true3D editing and visualization for many years, but are limited with respect to analysis of information at geographical scales of measurement .In practice, and in spite of the many possible applications, true 3D geo-information processing has not yet made any great breakthrough, because of limited availability of 3D data and standard 3D software”. However, on both fronts the situation is improving rapidly. Some of available software packages (ArcGIS 3D Analyst, ESRI; Imagine Virtual GIS, ERDAS; GeoMedia Terrain, Integraph.Inc etc.) that attempt to provide solution for 3D representation and analysis were evaluated. “This paper concludes that most of these packages can efficiently handle 3D data in the 3D visualization aspect but further progress is still needed for true GIS functionality such as 3D structuring, 3D manipulation and 3D analysis”**.** Consequently, major development has been seen in 3D visualization and editing thanks to advanced computer hardware and graphics achievements. However, 3D functionality is still lacking such as generating and handling (querying) 3D geo-objects, 3D structuring, 3D manipulation and 3D analyses (3D overlay, 3D buffering, 3D shortest route). This is caused by the specific character of 3D data compare to 2D. Bottlenecks are still the 3D object reconstruction, the representation and navigation through large 3D models, editing and organization of the data (Blaschke and Tiede 2003).

2.6 Prototype Implementation

To describe the rights concerning complex situations in 3D we will introduce figure (3D right-figure 4) that contains for every parcel the different height-levels of ownership (z-list). The z-list contains n z-values corresponding to n-1 consecutive ranges associated with the parcel. Redundancy is avoided since only the z-levels are stored in addition to the currently stored data (boundary of parcels). This information is sufficient to generate the representation of 3D right-objects based on the geometry of parcel boundaries. The 3D right-objects are identified by unique numbers that are based on the parcel number concerned.Holders of a 3D right-object can be obtained by the right to which the 3D right object is associated (e.g. a right of superficies). The right-owner of this right (subject) is the holder of the 3D right-object.The height-levels are invariant for every 3D right-object, which means that the upper and lower boundaries of 3D right-objects are defined by horizontal planes. We have considered defining the lower and upper limits in more detail, however the horizontal boundary. More detail registered at the Cadaster makes the Cadaster responsible for the consequences of this information (Jantien *et al.*,2003) as show in figure 2.4.

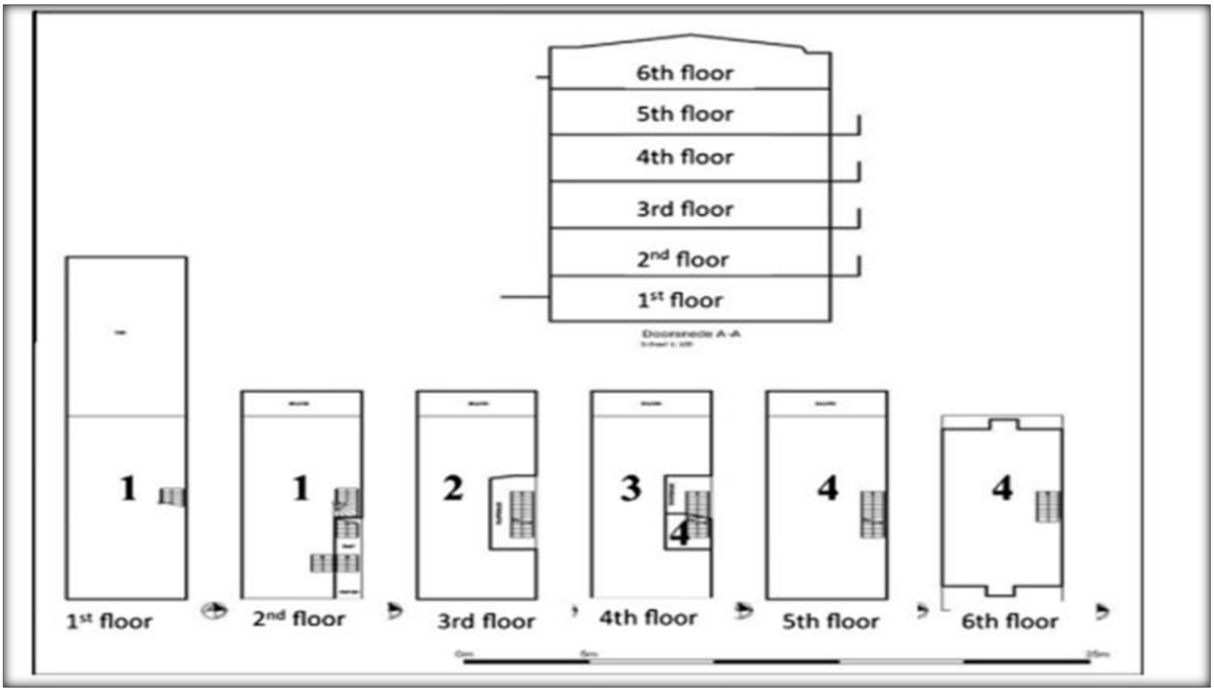


Figure 2.4: 3D Right multi floor in2D cadstre

In practice both sketches and more detailed drawings can be registered in the land registers to show the 3D extent of the limited rights or restrictions. The land register accepts detail 3D representation for the better reflection of the legal situation but (s) he cannot demand this. The format of 3D representation can be horizontal and or vertical cross section(s) bet also a digital 3D Pdf since this fits within the currently used electronic conveyance system. The Netherlands was the first country in the world supporting100% electronic conveyance with this system.

Despite the possibility to register a 3D representation in practice in reference to a demarcated area at location is sufficient. This of course has its risks because the real world at this location can change.In case the deed provides no description of the boundaries at all, the land registration of the deed. Because of reliable and observable reference points often missing, in practice the intension of the involved parties are only verbally described in the deed 3D representations added to the deed often acts as a sketch no legal meaning with respect to the exact locations of the boundary. In theory, the deed can include a representation of boundaries, which are considered legally binding if the parties declare that the boundaries exactly reflect their intentions.In practice this rarely happens, although it is obvious that it would be helpful for both the submitting and the receiving parties if some voluntary best practice based guidelines would exist; e.g. to clarify the situation in the form of 3D representation (Peter *et al*,2010).

2.7 Why CAD Models do not comply a 3D Cadasters

3D data is needed to represent 3D objects in the 3D cadaster. Since 3D data is available with designers, mostly as CAD models, it is a relevant question how this information can be used. Municipalities, the Ministry of Transport and Public Works, and designers were visited in the search for usable CAD models. Based on this research the conclusion can be drawn that CAD models suitable for the 3D cadaster cannot or hardly be found. "The first reason for this is that newly planned objects are mostly still designed in 2D by using linear profiles and cross-sections". Contractors and builders are used to the 2D drawings: understanding 3D drawings would require special skills. The 2D models could be used to construct 3D models that are relevant for the 3D cadaster (as this is the most original source). In this process attention has to be paid to the conversion of local coordinates of the CAD files to absolute coordinates in the national coordinate frame. In the design and building process, 3D CAD models are generated from the designs for visualization purposes. Also those models cannot directly be used for the 3D cadaster. Since CAD models contain much more details than is needed in the 3D cadaster it has to be studied what selections and generalizations are needed to obtain the relevant information such as the outer boundary of objects? When the Cadaster would register the detailed information that is available in CAD models, it would make the Cadaster responsible for this information, which they obviously want to avoid. Furthermore, 3D CAD files can get unworkable large, since mostly they are not made for interactive purposes but to generate movies out of them. Furthermore the relevant objects can hardly be recognized in the "file-based models" and finally 3D spatial data in CAD files contain complex geometries and are sometimes parametrically described. At the moment these data cannot automatically be converted to the primitives that are available in the spatial DBMS, which is used for the 3D cadaster (point, lines, polygons, polyhedrons). Also once the 3D CAD objects will be available as geometries in the DBMS, 3D generalization and simplification is needed to obtain the appropriate information. Although the use of CAD models (2D and 3D) still seems to offer a lot of potentials for the 3D cadaster (information on the third dimension is available in those models), generating relevant information out of these models requires further study. The main reason for this is that experiences have shown that it is a complex process to obtain the needed information (property boundaries in 3D) out of these models. For simple "buildings it might still be straightforward", but for more complex situations (e.g. tunnels) it requires study on basic fundamentals in GIS science (generalization; converting parametrically described geometry to geometry primitives).borate on this solution(Stoter and Ploeger, 2003).

The Public Registers have to be queried to find the plan of division. Another disadvantage of this way of registration is that the plans in the notarial deed are drawn in a local coordinate system (in 2D layers). When coordinates were defined in the national reference system they could be combined with the cadastral map or other geo data (e.g.topographic data). However, the addition of 3D information on the individual apartments in the cadastral system itself would especially enhance (Stoter and Ploeger, 2003).

2.8 The Gaps of the Previous 3D Cadastral Researches

According (Yaron *et al*, 2014) the 3D cadastral problems to be solved from the scientific and technological standpoint, the principal challenge in developing a three-dimensional multi-layer cadastre lies in gathering, processing and managing the three-dimensional data. The third dimension, which does not appear in the current 2D cadastre, necessitates development of new spatial models for managing the subsurface information and linking it to the surface information. The main tasks in the process of defining and establishing the 3D CAD are: Developing three-dimensional models in respect to the cadastre; Study and understanding of the special character of the subsurface cadastre; and, creating links between the subsurface cadastre and the surface cadastre.

According to (Yaron *et al.*, 2014) Due to limitation of technological (the spatial DBMS did not yet support 3D volumetric Primitives), legal, organizational and technical i.e. no operational 3D Cadastral system Implementations available.Nowadays“In the 3D application areas, customized software has frequently been used, because the existing Standard geo-DBMS and GIS/CAD software do not cover the 3D aspects sufficiently” (Biyik, 2007)“CAD packages on the other hand have supported true 3D editing and visualization for many years, but are limited with respect to analysis of information at geographical scales of measurement**”** (Biyik, 2007)**.** So in this research it will use the City engine as customized software. This paper concludes that most of these packages can efficiently handle 3D data in the 3D visualization aspect but further progress is still needed for true GIS functionality such as 3D structuring, 3D manipulation and 3D analysis. “The Registration of Condominiums Law governs the status of the rights of the several property owners at the same land site, and provides a judicial solution of separate ownership on levels. An apartment in a condominium is a separate issue regarding ownership, rights and transactions”**.** So to study or manage those condominium houses; there needs aproper 3D registration system.

3. Materials and Methods

3.1 Description of Study Area

3.1.1 Location

The study area located in Dire Dawa City Administration part of 03 kebele .The Dire Dawa City is located in the eastern part of Ethiopia. Geographically between 9^{0}28.1' N and 9^{0} 49.1' N Latitude and between 41^{0} 38.1' E and between 42^{0} 19.1' E Longitude and by relative location 515 Kilometers to the east of Addis Ababa, 55 kilometers to the north of Harar and 311 kilometers to the west of Djibouti port.

Particularly the study area is located in northwest of Dire Dawa City part of 03 kebele as show figure 3.1. Its particular name is Mariam sefer which includes residential, condominium and real estate buildings**.**

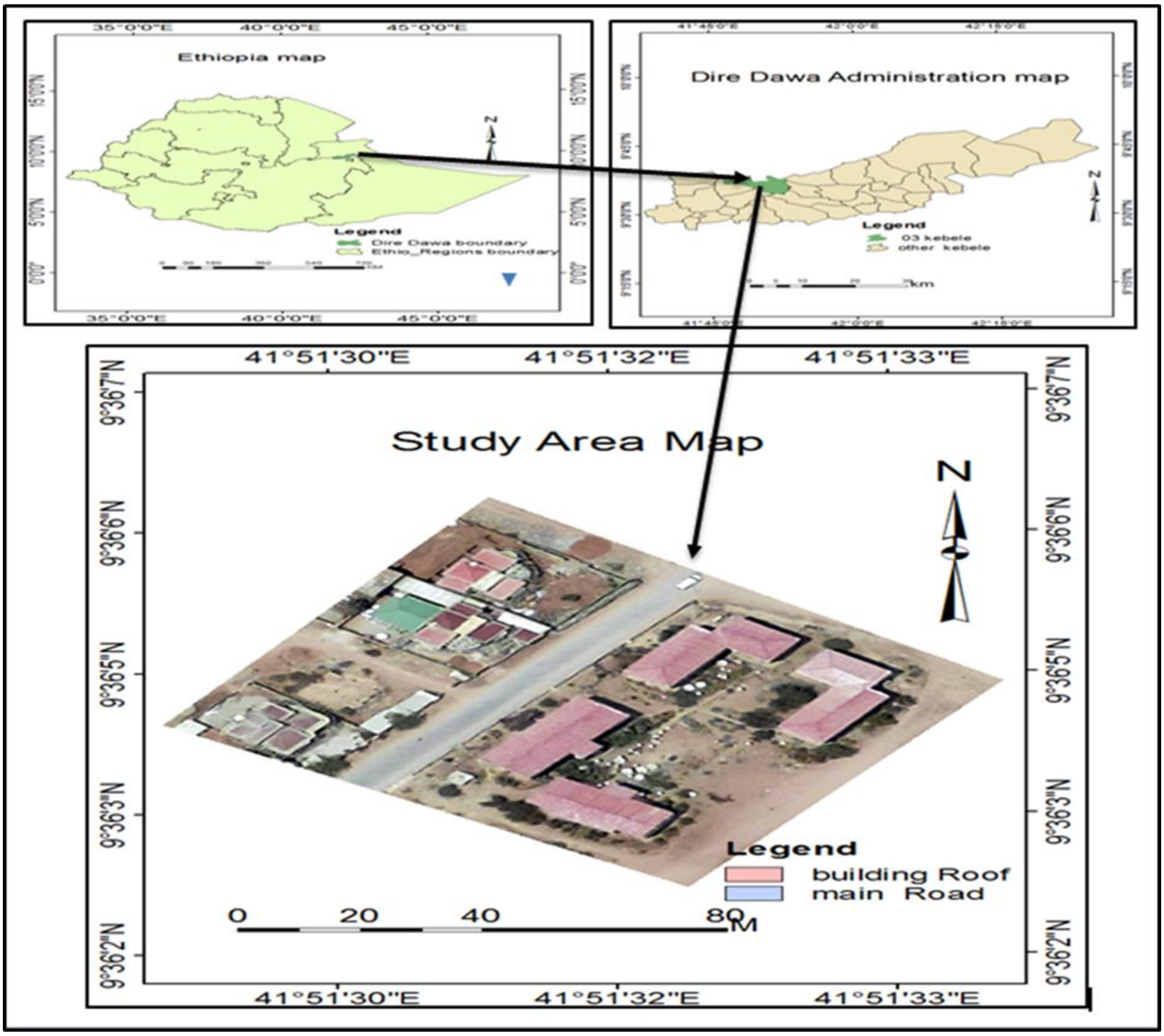


Figure 3.1: Location Map of Study Area

3.2 Current Cadastral Data Model

The aim of this thesis is to develop a 3D cadastre which to manage stratified land rights, restrictions, and responsibilities and their physical counterparts in one environment. In order to develop a3D Cadastre it is required to assess available data model, to explore the theories and concepts of existing cadastral data models and investigate how they manage 3D data. Therefore seven major cadastral data models have been reviewed for this purpose. These data models are the most popular cadastral and land administration data models. They are:

- The core cadastral data model (Henssen, 1995)
- FGDC Cadastral Data Content Standard for the National Spatial Data Infrastructure (FGDC, 1996)
- ArcGIS Parcel Data Model (Meyer, 2001)
- The Legal Property Object Model (Kalantari *et al*., 2008)
- ePlan (ePlan, 2010)
- ISO 19152, Land Administration Domain Model (LADM) (ISO19152, 2012).
- City Engine 2014 procedural data model

These data models were assessed and compared based on selected criteria. The aim was to analyse how they manage stratified RRRs and meet 3D cadaster’s requirements and what data modelling techniques they use to support 3D data.

The criteria were selected in a way to be able to assess the data models from different aspects and provide information on how they manage stratified RRRs. For this reason ten criteria were developed in order to assess these data models as display by table 3.1. They helped to explore each data model.

Table 3.1: Summaries criteria used for comparing above-mentioned cadastral data models

No	Criteria	Description
1	Core objects	What are the core objects of the data model? (person, right, spatial unit, parcel)
2	Basic spatial unit	What are the basic spatial units of the data model? (2D parcel, 3D parcel)
3	Other forms of spatial units	Does the data model have other forms of spatial units? (text-based, point-based)
4	Reference documents	What are the data sources? (survey plans, architectural plans, titles, deeds, mortgage)
5	Applications	For what applications can the data model be used? (Registration, taxation, valuation, planning, etc.)
6	Inclusion of other types of interests	Whether or not other types of interests are considered in the data model? (utility network right, biota right, mineral right)
7	Temporal aspects	Whether or not temporal aspects of interests are considered? (time the right is created or terminated)
8	Management and representation of stratified RRRs	How does the data model render stratified RRRs? (projection on the ground level, 3D primitives)
9	Semantic-level	At what level does the data model support semantics? (class-level, attribute-level, geometry level)

However, most of the current cadastral data models have been developed based on the definition of a 2D land parcel, neglecting the third dimension. Although a few of them support 3D object as a component of the data model. But, they do not use appropriate 3D primitives such as solid geometry to model 3D objects. Solid geometry facilitates 3D representation, volumetric calculation, and 3D spatial analysis.

Secondly, in the context of land and property management, the prerequisite is overlaying 3D physical objects, such as building models, with their corresponding 3D legal objects such as volumetric ownership models (Aien *et al*., 2011).

For this purpose, 3D cadastres should be equipped with integrated cadastral data models that can maintain both 3D legal and physical objects. In this paper, this data model is called 3D cadastral data model and is not based on the definition of 2D land parcels. Use of this data model enables 3D cadastres to serve multiple 3D applications such as land and property management, virtual legal 3D city, housing transactions and land market analysis, land and property taxation, public communication (tools for real estate agencies), city space management (3D land use management), and 3D site location.

The business analysis step provides the requirements to develop a new 3D cadastral data model. Before introducing the 3D cadastral data model which was requirement to develop 3D cadastre summarises the specifications of the reviewed cadastral data modelling that display table 3.2 to select appropriate data model in order to achieve the research question and objective.

Table 3.2: Summarises the specifications of the reviewed cadastral data models

Specificat	Core cadastral data	FGDC model	ArcGIS Parcel model	Legal property object model	ePlan model	LADM model	City Engine Model
core object	Person, Right, Parcel	Agent, Right and Interest, Parcel	Ownership, Encumbrances, Separated Rights	Person, Legal Property Object	Parcel, Document, Survey, Surveyor, Observation, Address,	LA_Party, LA_RRR, LA_BAUnit, LA_Spatial Unit	Person, Right, Parcel
Basic spatial unit	2D Parcel	2D Parcel	2D Parcel	Legal Property Object	2D Parcel	LA Spatial parcel	3D parcel
Other forms of spatial units	N/A	N/A	Vertical parcels	Every object will be treated as a separate Legal Property Object	BuildingFormatLot, Volumetric Lot	Sketch-based, Text-based, Point-based, Line-based	BuildingFormatLot, Volumetric Lot
Reference documents	Transactions evidences, mortgages	Deed,Aerial photogrammetry,Agreement mortgages,satellite images survey	Deeds,survey plans,mortagages	All legal Document	Title, Approval, Dealing,Any other legal documents	All documents providing legal and/or administrative facts	Deed,Aerial photogrammetry,Agreement mortgages,satellite images
Applications	Valuation, Taxation, Security of land tenures, Spatial or physical planning	Model cadastral information , Basis for automating the legal elements	Development of parcel level management, Support parcel level functionality in the GIS environments	Facilitates the land administration system to be more extensible and scalable in terms of new legislations and land-related laws	Eliminate current reliance on hardcopy or PDF plans, Improvequalityofplan data, Improve plan examination processing	Land administration applications	Valuation, Taxation, Security of land tenures, Spatial or physical planning
Inclusion of other types interest	N/A	Mineral rights, Oil rights, Grazing rights, Fishing rights,	Mineral rights, Oil rights, Grazing rights, Fishing rights	Biota rights, Mineral rights	N/A	Utility Network	3D city
Temporal aspects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Semantic level	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description	Class, attribute and physical
Physical objects	N/A	N/A	N/A	N/A	N/A	External databases	External databases

Accordingly, since cadastral purposes (fiscal, legal, or multi-purpose cadastre) can be different in each jurisdiction, different cadastral data models are developed. In order to select it have to fulfill following criteria to a large extent:

- Have been developed based on the definition of 3D land-parcel.
- Integrate physical counterparts into cadastral data models.
- Are semantically enriched.

Most of the cadastral data models such as the Core Cadastral Data Model, FGDC, and ArcGIS Parcel Data Model have been developed based on 2D land-parcels. ePlan and LADM support 3D parcels to model 3D RRRs. However, it has not been fully exercised in ePlan (Cumerford, 2010).And LADM does not use solid geometry (GM_Solid) to represent 3D parcels.Integration of 3D legal and physical objects in these data models would facilitate implementation of the above-mentioned applications.

Therefore city engine procedural model which integrate the legal, and physical object and their interoperability requires semantically enriched information in one environment was select as 3D cadastral data models to achieve the research objective.

3.3. Data Elements of 3D Cadastre

It is important to understand which elements of the 3D cadastre will be considered in 3D cadastral data modelling. To achieve the designed objective, data were collected and organized from primary and secondary Sources.

Primary data were socio economic data collected door to door which used as 3D right Restriction and responsibilities of owner and Interest holder; an interest holder can be a person, group, or an organisation who has certain rights (RRRs) over a particular 3D spatial space. Secondary data were spatial data collected from different organization like Architectural plan, elevation plan from dire dawa project and design offices, Arieal photo and 2D cadsatre from Dire Dawa manucipality.

There fore the primary, and secondary data are used to generate 3D cadastre registration systems of multilayer buildings in Dire Dawa Administration city were summarise as shown table Table 3.3.

Table 3.3 : Data and their sources

Layers(Data)	Format	Scale/ Resolution	Data source	Purpose of the layer
Aerial photo	Raster	15CM*15CM	Dire Dawa municipality	To develop the basic cadastral shape via digitization and to keep the positon via georeferenced
AutoCAD or Archtecturalplan	DXF	1:50 and 1.100	Dire Dawa housingdevelopment agency	To develop the shape and size of the parcel to be digitized
Elevation	Pdf	1:50	Dire Dawa housing development agency	To develop the 3D building
Socioeconomic data	CSV	Door to Door	Questionnaire from the site	To develop the description rights, restriction and responsibility
Photographs	Jpeg	3.264CM*1.836CM	Directly taken from the site by digital camera	To develop the texture and physical appearance of buildings

3.4 Softwares

Softwares used in this study were selected based on procedure their capability to work on the existing problems for achieving the predetermined objectives. Hence, softwares were used as mentioned below.

3.4.1 ERDAS 2014

Used for image processing activities on satellite images for the preparation of mosaicking of the aerial photos.

3.4.2 ArcGIS10.3

This software used to integration of attribute data collected through questionnaire and extracting of the footprint of a building from the Aerialphoto, Architectural plan and the factors that are input to the development of 3D cadastral maps of the individual houses with in multilayer, multi level and multi shape building. Cadastral system should be preprocessed in accordance to the criteria set to develop the registration system of 3D cadastral models. So using the shape and size of the building in AutoCAD, some relevant GIS analyses were undertaken to convert the collected file geo database. finally ,was used to develop the physical appearance for visualization of shaded 3D objects and used to combine the basic shape and the elevation data.

3.4.3 CityEngine 2014

CityEngine has established itself well within the gaming industry since its commercial release in 2008. The software has been used extensively to create highly detailed 3D model of fictional cities and urban landscapes.

In order to register and visualize the complex reality in 3D, Esri's City Engine 2014 modeling software has been used, which is specialized in the generation of 3D urban environments, transforming 2D GIS Data into Smart 3D City Models(Tsiliakou, 2013) table3.4. City engine for the selected and organized database has been used to develop the system and proto type implementation of the 3D cadaster. In city engine the proto type and the implementation of the 3Dcadaster has been developed based on the 3D procedural modeling (CGA rule file). The 3D procedural modeling achieved through the arrangement of geometry, attributes and rules or algorithms.It also, has the option of importing various forms of geographical and architectural datasets such as GIS and CAD, its possibilities of modeling real landscape are quite promising.

Table 3.4: Summarise software required

Soft wares	version	purpose
ERDAS	2014	To mosaic Aerial Photo image
ARC GIS	10.3	To digitaze 2D spatial data
CityEgine	2015	To digitaze 3D spatial data
AUTO CAD	2007	To read archectural plan

3.5 Methodology

This thesis follows a mixed research process that integrates the qualitative approach to explore the deficiencies of current cadastral data models in terms of accommodating 3D information. The case study approach is a suitable method to investigate the current practice of 3D property registration and identify how 3D cadastral systems should be developed to improve the current process. The use of mixed methods can also minimize the weakness of a single approach through the Complementary utilization of the strengths of other methods

In generally the are several methods of creating digital maps depending on the state and validity of available source materials and the accuracy required:

- ✓ The existing analogue maps are scanned and raster images obtained this way are refined and calibrated with use of points with known coordinates. Such a picture, when magnified in a monitor screen enables the operator to construct its precise vector representation.
- ✓ The survey results are processed by means of geodetic calculating programs into a form of a specification of measured points (parcel boundaries bend points, building corners etc.) recorded in digital format. These points are then automatically generated as the vector elements of a graphic file and can subsequently be connected by the operator to create proper objects of a digital map
- ✓ Remote sensing result are processed by means of extracting relevant information from Aerial photograph for specification measurement of boundary, building footprint, boundary parcel etc., to collect spatial data for create digital cadastral map.

The approach adopted in this study in order to reach to the objectives of the study was mixed approach used to increased accuracy of study or evaluation. The process by extraction data from Aerialphoto and Archetectural plan to create the 2D geometry then join the separate attributes to the extracted geo database has been undertaken in ArcMap 10.3 Software package. The extraction of 3D geometry, prepare 3D cadastral system, and 3D cadastral maps with the integration of questionnaire data was developed in ArcScene 10.3 software package. However, the development of 3D data or buildings in these software packages (Arcscene 10.3) was not sufficient to show the complete 3D cadaster with its texture and roofs with appropriate reality of objects it simple used to check parameter of 3D primitives .So Esri’s City Engine modeling software has been used, which is specialized in the generation of 3D urban environments, transforming 2D GIS Data into Smart 3D City Models with necessary tools to fill the gaps of GIS/CAD software packages. The elements that are participating to develop 3D cadastral model should be preprocessed in accordance to the criteria set to develop 3D multi layer cadaster. So the rules or algorithms could be worked out using advanced Esri city engine 2014 software to get the rule derived modification and replacement of shape. The rules in Esri city engine can be developed based on CGA (computer generated architecture). The resulted 3D physical object (building) is created by extruding the elevations starting from each floor up to the next floors of the building situated in different level of elevation .

In this section; going to state the methods which give generally guided for conducting this research. Briefly, to develop the 3D cadastre methodology employed in thesis research consisted of the following flow chart as show figure 3.2.

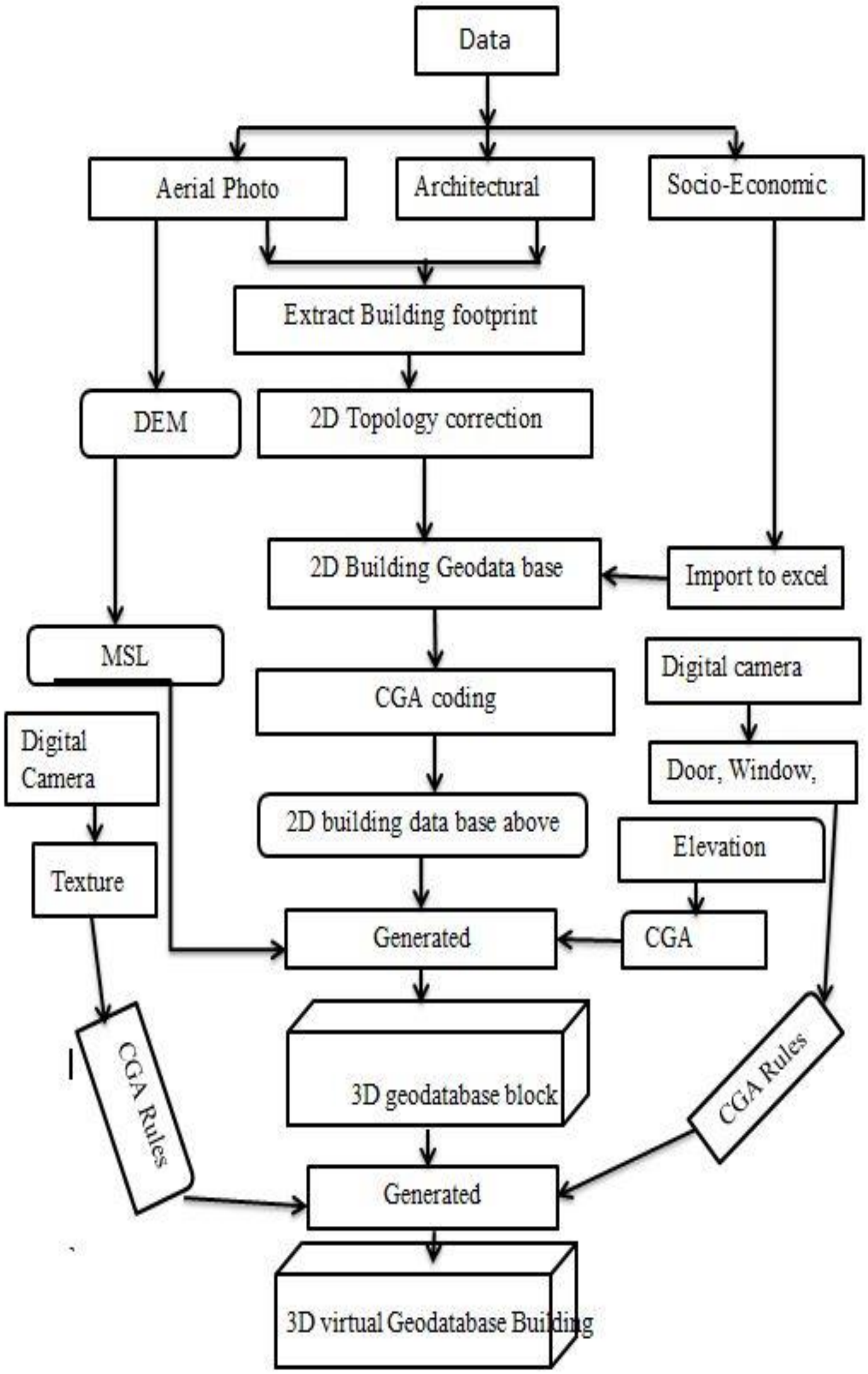


Figure 3.2: Methodological chart Approach

4. Data Processing, Result and Discussion

4.1 Introduction

In order to developing 3D cadastral registration system and model within the integrated platform ,different parameters have been derived from Orthoto(Aerial photo) , as well as, legal documents and architectural plan of the existing buildings which have floor plans, views and sections of buildings of the selected sites or study area and socio-economic data was collected through questionnaires provided with information on the number of floors, purpose of building etc.Finally, 3D cadastral registration system was developed which complete model consists of spatial objects as well as non-spatial attributes integrated within a system, supplying the users with a conceptual analysis of the data and explanation of real phenomena**.** To maintain uniformity of this research Adindan _ UTM _ Zone_37N spatial reference system was followed for raster data as well as vector data in any map throughout this paper.

4.2 Ortho Photo

Orthoto(Aerial photo) of the city which was geo-referenced in the Adindan UTM Zone (i.e UTM zone 37) Geodetic Reference System requred as reference of study area extracted from Orthoto of Dire Dawa City by using soft ware ERDAS version 4.2. for pre processing in ArcGIS to process,and 2D registration system and pre process for 3D cadastral model to integration of the attribute and spatial characteristics as show in figure 4.1.

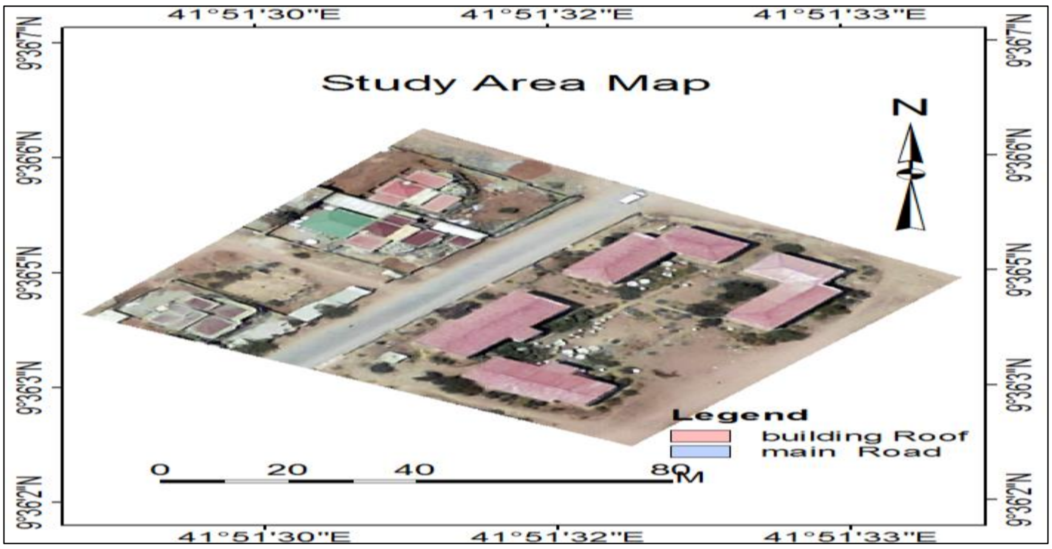


Figure 4.1:study Area generated from Areal photo

4.3 Architectural Plan

Architectural plans or CAD Design of the existing buildings which have floor plans, partion of parcel views and sections of buildings like wall, windows, doors are the core information to organize and shape physcial dimension of building object or spatial data as display in the figure 4.2.

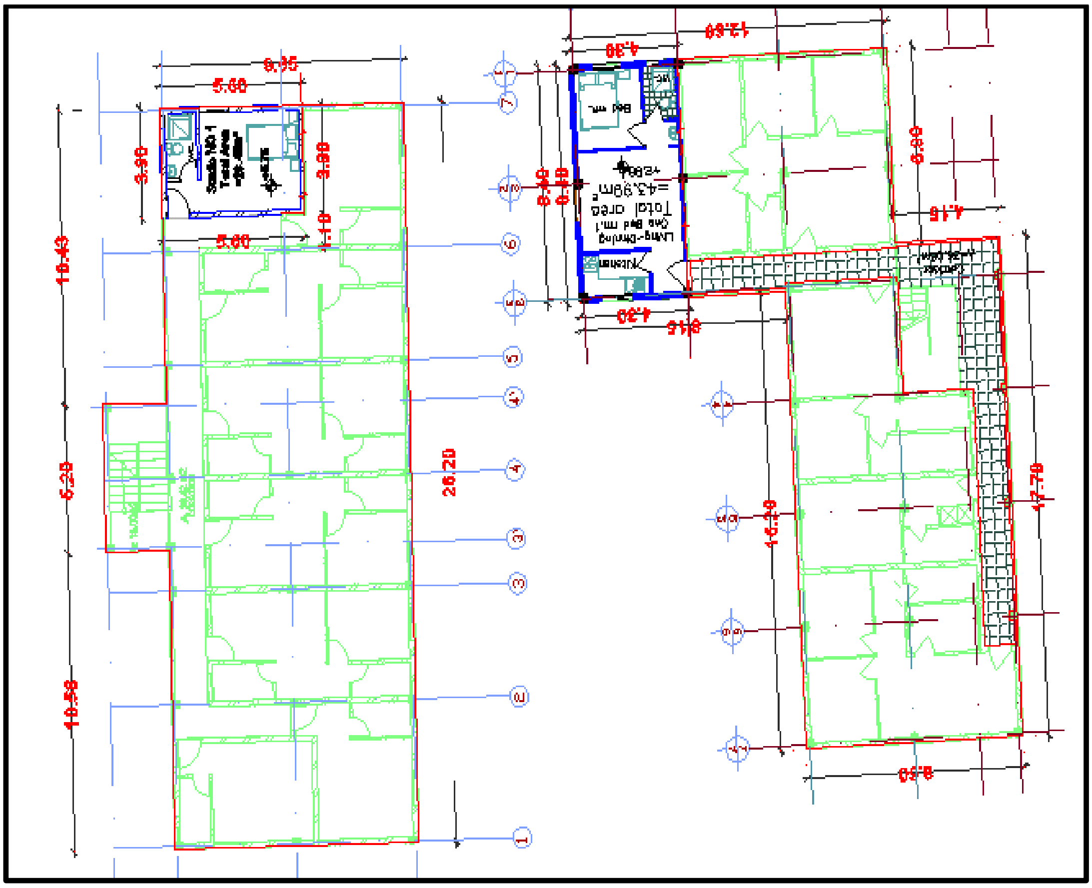


Figure 4.2 : Example of an Illustrative of Building partion from CAD Design

4.4 Generate of Geodatabase

The geographic database (geodatabase) is a core geographic information model to organize a spatial data in to spatial representations. Two types of geodatabase are available under ESRI's ArcGIS package: Personal geodatabase and file geodatabase. In this study, file geodatabase was generated in ArcCatalog to include all the necessary input datasets. In addition to these, a file geo-database is used to protect the data from lost and easy access in the ArcGIS tool. Thus, the extracted building footprint files were imported to the corresponding feature data sets to develop the layers of rest building floors by changing the lower limit of the elevation (MSL) and the raster files were exported as individual raster datasets in the file geodatabase as show Figure 4.3.

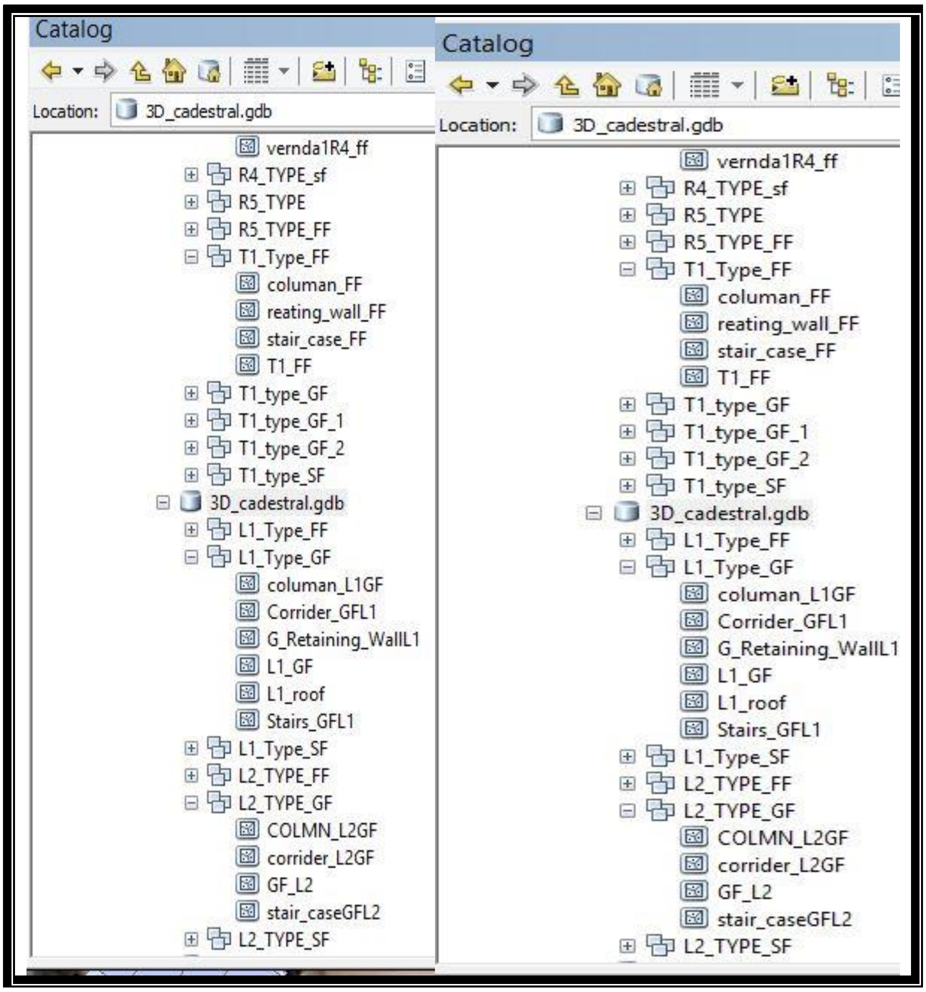


Figure 4.3: Built Geodatabase for 3D Cadastral Modeling and Registration System

4.5 Extraction of Building Footprint

The 3D description of 3D cadastral physical object initially starts with parcel boundaries in 2D. Parcel boundaries are extracted from the Aerial photo by digitizing in the ArcMap 10.3. Depending on the size and shape of the CAD plan of building footprint was extracted from the Parcel boundaries and CAD design by considering the length and direction of building create 2D cadaster. 2D floor plans can also be extracted from CAD plan of corresponding floor can be combined with section plans or with floor height information to define the 3D cadaster corresponding to 3D properties as in show Figure 4.4.

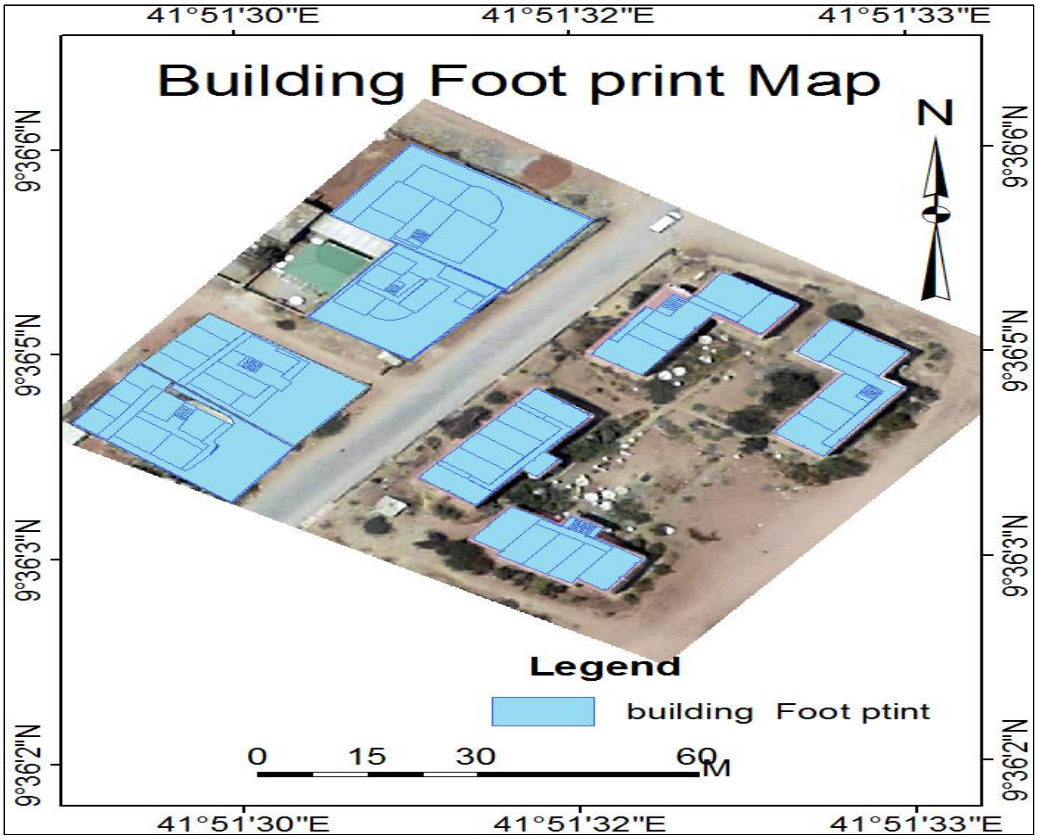


Figure 4.4: Example of an Illustrative Map of Building Foot print

4.6 2D Data Validation

4.6.1 Topology correction

A spatial object is the representation of a real-world object having spatial (topology, size and shape, position and orientation) and thematic characteristics. Topological relationships describe the connectivity, containment and adjacency relationships among spatial objects. These relationships are invariant under topological transformation,such as translation, scaling and rotation (Esther and Stoter, 2004).

There are mentioned and explained issues which should be taken into account when modeling the buildings, for example, overlap (occlusion), gabs and snapping as show figure 4.5 (a) error (b) corrected**.** It is important that the spatial data is checked (validated) when it is inserted in the GDBMS or when it is updated. Valid objects are necessary to make sure that the objects can be manipulated in a correct way, e.g. it is impossible to compute the volume of a cube when the top face is omitted; this would be an open box without a volume.Validating may seem quite easy for humans, but a computer needs an explicit set of rules to check the spatial data. So in this research the following rules were applied to validate features:

1 Have not overlap another area from same layer.
2 Have no gab; a void can’t exist between areas on same layer.

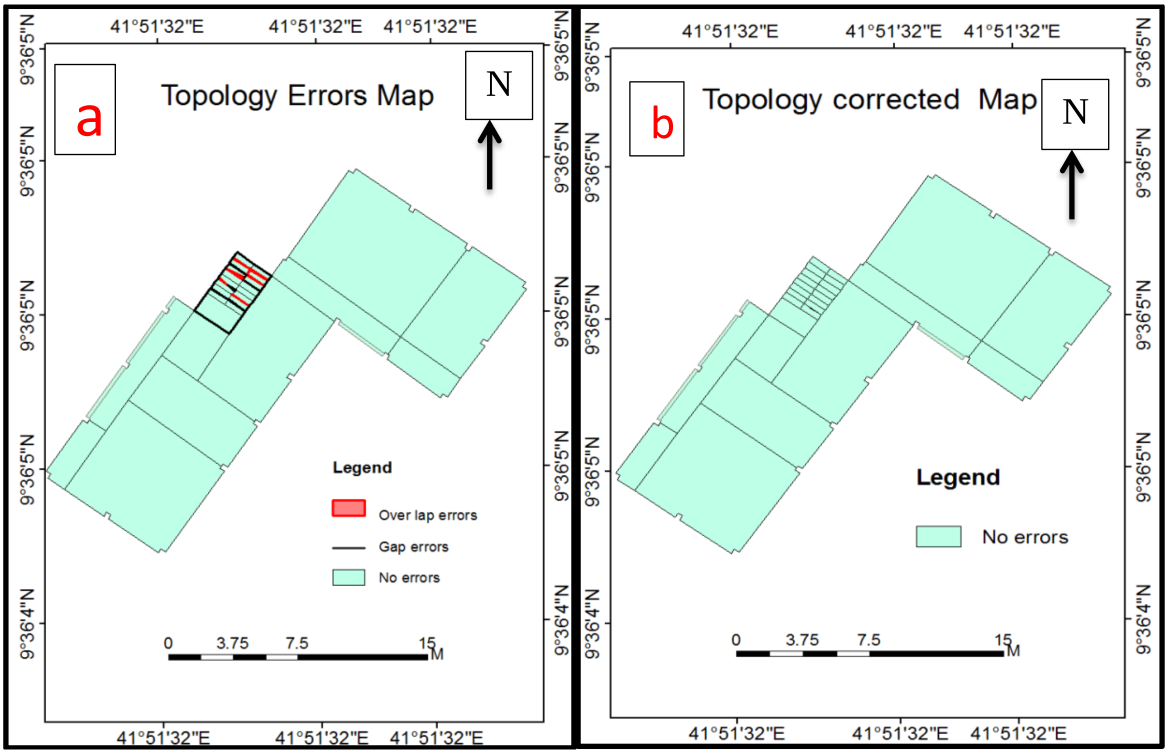


Figure 4.5: (a)The Parcel Before Topological correction (b) parcels After Topological correction

4.6.2 Tolerance

The validation function and some of the 3D functions have a tolerance value as input Parameter. The points that make up the polygon can be slightly out of the flat plane, because of the geodetic measuring methods the finite representation of coordinates in a digital computer. To solve this problem a tolerance value has been introduced. The cluster tolerance is a distance range in which all vertex and boundaries are considered identical or coincident. This tolerance value should not be too large; otherwise invalid objects will be accepted as valid. A good value for the tolerance is the standard deviation of the geodetic measurements. So the cluster tolerance value used in this research is 0.001 meter or 1mili meter which the default value of x y tolerance value as in show figure 4.6.

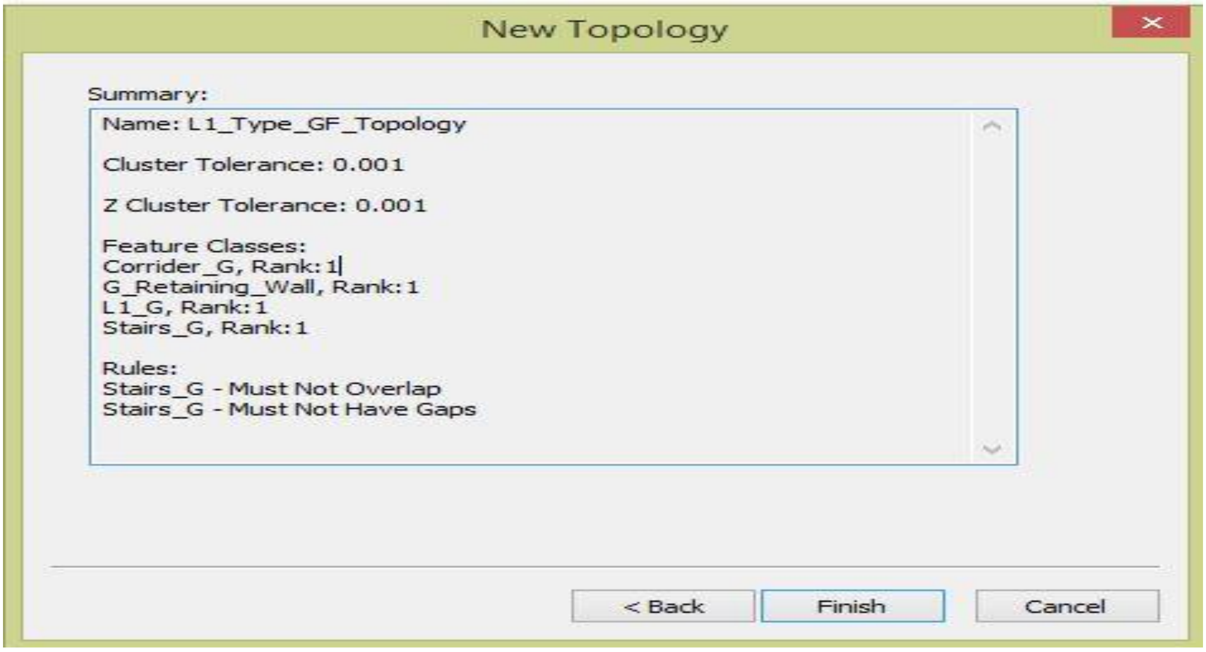


Figure 4.6: Topological Rule,Tolerance Value and Rank on the Feature

4.7 socio-economic Data

The socio-economic data was collected through questionnaires provided with information on the parcel such as , owner ,parcel ID ,Aquistion of land,number of floors, purpose of building etc,shows below Table 4.1.

Table 4.1: Tabular Data Collected from Corresponding 3D Parcels

SHAPE	SHAF	SHA	Owner_Name	owne	City	Kebele	Site	Block_name	Parcel Id	Parcel_name	Floor types	Flats number	Building_use	Family_size
Polygon	24.7	34	mohammed hassen	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE G00/01 343/3	B_E1	Ground fioor	one bed room	Residense	2
Polygon	22.7	35	Abraham Desaleny	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE G00/02 342/2	B_E1	Ground fioor	one bed room	mixed	3
Polygon	30.3	54	kemel abdulay	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE G00/04 345/2	B_E1	Ground fioor	three bed room	Residense	2
Polygon	27.4	45	yetim fixum	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE G00/03 341/3	B_E1	Ground fioor	two bed room	mixed	2
Polygon	20.5	23	Abdi Ibrahim	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE G00/06 342/4	B_E1	Ground fioor	one bed room	mixed	3
Polygon	24.7	34	safi kaso	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE FF00/01 348/2	B_E1	second Floor	one bed room	Residense	2
Polygon	22.7	29	Abdi aliyyii	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE FF00/03 3450/	B_E1	second Floor	one bed room	residence	2
Polygon	30.3	54	tamiruu adunyaa	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE FF00/02 352/2	B_E1	second Floor	three bed room	residence	2
Polygon	27.4	51	hamaziya kialid	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE FF00/04 353/3	B_E1	second Floor	two bed room	residence	3
Polygon	20.5	23	taiba mustefa	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE FF00/05 356/2	B_E1	second Floor	one bed room	residence	3
Polygon	24.6	42	Abdumalik mohamn	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE SF00/01 362/3	B_E1	FIrst_floor	one bed room	residence	2
Polygon	22.7	35	yohanis G/m	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE SF00/03 364/2	B_E1	FIrst_floor	one bed room	residence	2
Polygon	30.3	54	faxuma yuusuf	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE SF00/05 361/2	B_E1	FIrst_floor	three bed room	residence	3
Polygon	27.3	50	kedir mohammad	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE SF00/3 365/3	B_E1	FIrst_floor	Two bed room	residence	2
Polygon	20.5	23	desaleny guuta	lease	Dire dawaCIty	3	maryam sefer	B_E	DD005 03 ms001 BE SF00/4 363/3	B_E1	FIrst_floor	one bed room	residence	1

4.8 Incorporating the Socio-economic Data with Building Footprints

The 3D cadastral data model should not only accommodate 3D RRRs and but,also their association with physical objects. The data model should also represent the spatial extent of 3D RRR. However, visualizing 3D RRRs alone would not adequately assist management of 3D RRRs (Ali, 2011). A complete model consists of spatial objects as well as non-spatial attributes integrated within a system, supplying the users with a conceptual analysis of the data and explanation of real phenomena(Tsiliakou, 2013). The socio economic (non-spatial attributes) were collected from the study area. After the non spatial data has been collected and organized, it was stored in the excel in the format of comma separated Valueszxxx(CSV) to be accepted in the arc map. In this research, to see a comprehensive 3D cadastral data model, it needs an integration of the extracted footprint of every floors of the building in relation to the socio economic data which are collected from the selected sites through questionnaires by providing the same primary key to the MS Access and Geodatabase. As shown in the Figure 4.7 for example the primary key of L1 ground in the excel is ready to incorporate with the primary key of L1 ground in the geodatabase in order to express the full integration of spatial and non-spatial characteristic of the specific parcel within the parcel building of mariyam sefer site.

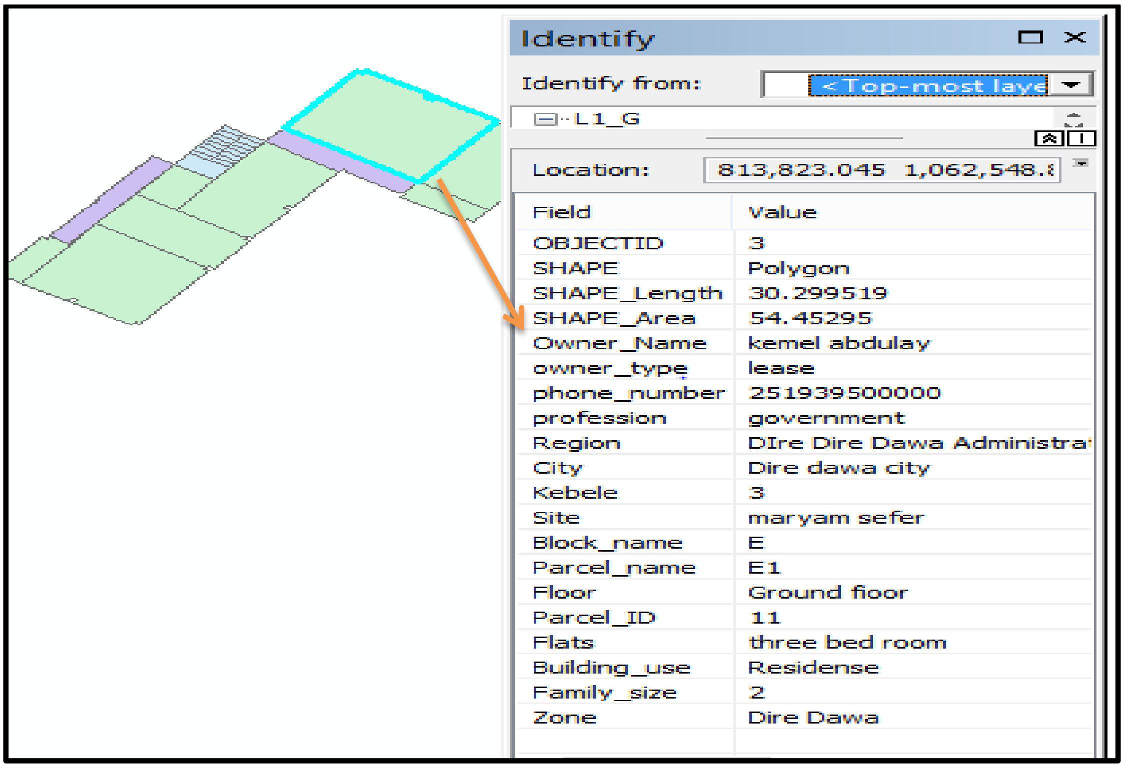


Figure 4.7: Overview of Non-spatial and Spatial integrated within 2D cadastre

4.9 Extruding Building Floor Plans by ArcScene

For every parcel on which limited real rights or apartment rights are registered, a z-list is generated, that defines the upper and lower limits of (limited) rights (and apartment rights) established on the specific Parcel (Stoter, 2004).So for this research, two types column list are prepared in z-list table to define the lower limit used as an initial elevation which is represented as MSL in this table and the elevation which defines the extent (the range b/n the conscutive MSL)of the right from the initial MSL to the upper right of the owner for each parcel as shown in Appendex D. The elevation data are derived from the section plan of the condominium design of that specified building which is found from the housing development agency of Dire Dawa Administration city and real estate as shown in Arcscene extreme of Arc GIS by Figure 4.8 and 4.9.

Figure 4.8: Procedural Preparation of 3D Data in Arc GIS for condominium

Figure 4.9: Procedural Preparation of 3D Data in Arc GIS for Real estate

Finally the layer of the first floor as shown in the Figure 4.8 and 4.9 was extruded from ground floor and so on for any more floors to prepare the 3D cadastral data that are digitized from the aerial photograph. This developed 3D graphical model is not enough to manage the condominium and real estate or any multilayer building of Dire Dawa city because it is merely shown 3D physical objects.So it needs further modeling parameters and procedures to find the efficient 3D cadastral model in more realistic manner. For this reason, Esri city engine has been used to construct a complete 3D cadastral data models and registration system that can handle the spatial and non-spatial data integrated. Generally GIS is used to prepare data that are used for the pre-preparation(pre-process) 3D data which will use as an input for city engine software.

4.10 Esri City Engine Software as a Tool for Procedural Modeling

Procedural modeling in the software Esri City Engine has been mainly used for creating a 3D model of urban areas. The modeling is based on CGA (Computer Generated Architecture) rules first with import data. The user interface of City Engine consists of several windows. A typical modeling session includes as displayed inFigure 4.10.

1. "Scene Editor" window where the user can manage the scene, it is organized in layers.
2. "Rule Editor" window where the CGA scripts are generated. "Rule Editor" can have a text and a graphical view.
3. "Viewport" windows where the generated 3D content is displayed.
4. "Inspector" windows which gives a detailed view editing possibilities of selected objects. Within this window there are object attributes which are spatial and non-spatial descriptions
5. "vertex" windows show the X, Y, Z records. They are classified as information orthogonal coordinate system of the selected object.
6. "Navigator" window where all the files are stored. In this section user can manage and preview files in the workspace as shown.

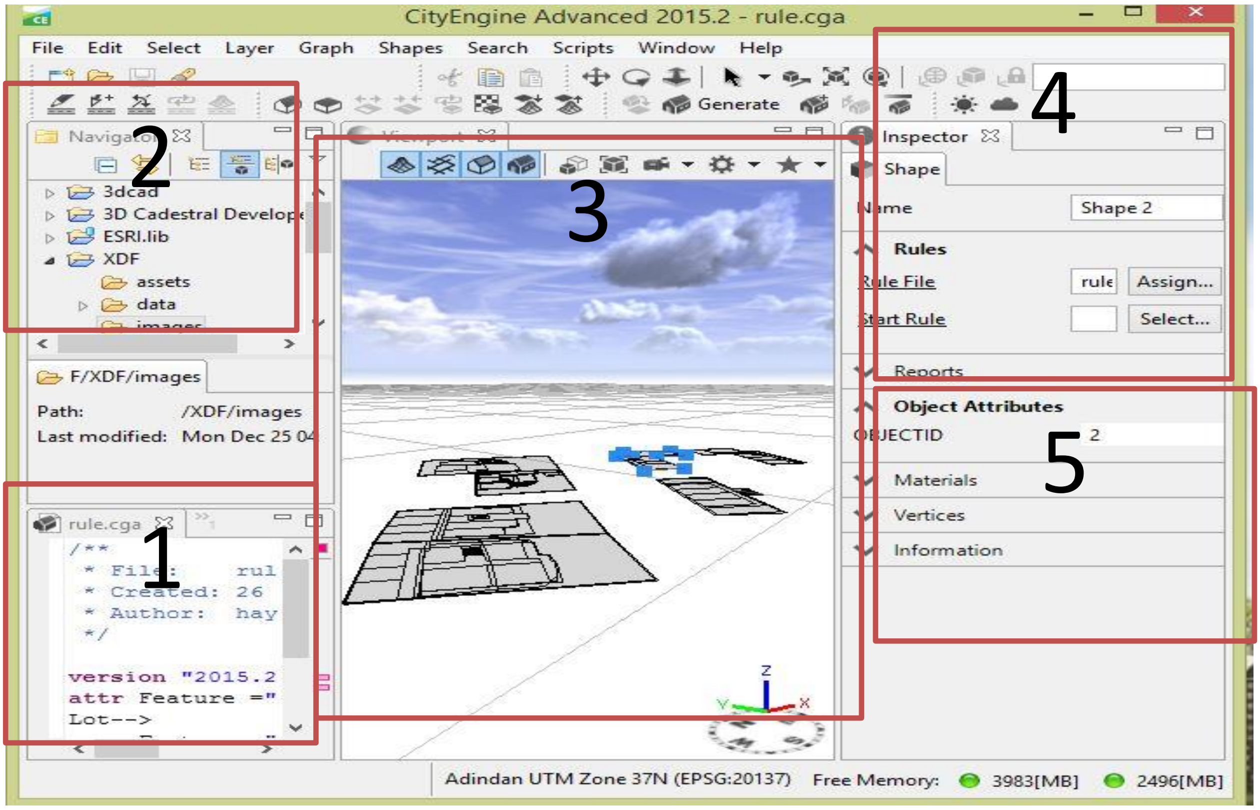


Figure 4.10: Partion of CityEngine Software and import data

4.11Extruding 3D Building by CG A rule file

The scripting language CGA (Computer Generated Architecture) which defines the rules or procedures to create a 3D content is the core of this software. City Engine can be used for the whole procedural modeling development cycle because it includes tools for setting up the scene with pre-existing data, modeling street and lot geometries, writing and analyzing the CGA script files, applying the CGA files to create 3D models and exporting the created models for further processing(Viinikka, 2014).

In this research, it has been prepared 2D data in GIS and import to City Engine as show figure 4.11 (a)) and the CGA rule file to develop a 3D cadastral registration system process in CityEngine software starts with a rule file creation as show in Appendix A .That manage the 3D object of building that show Figure 4.11(b). The rule file also developed to provide texture data which is taken taken photo by the digital camera during ground verification.

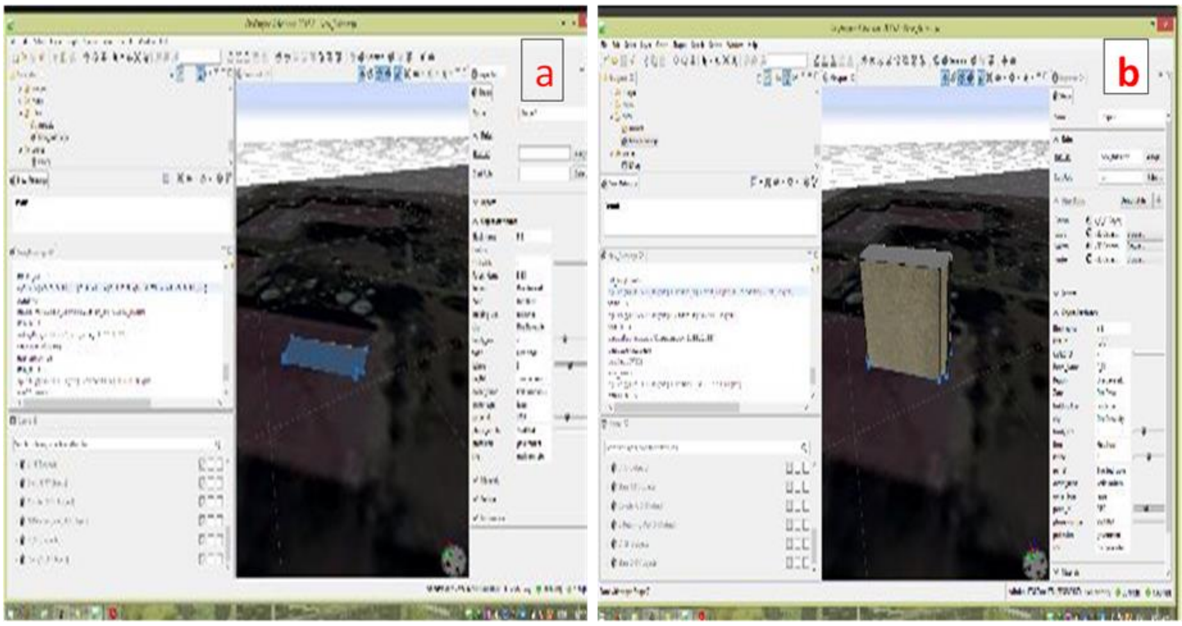
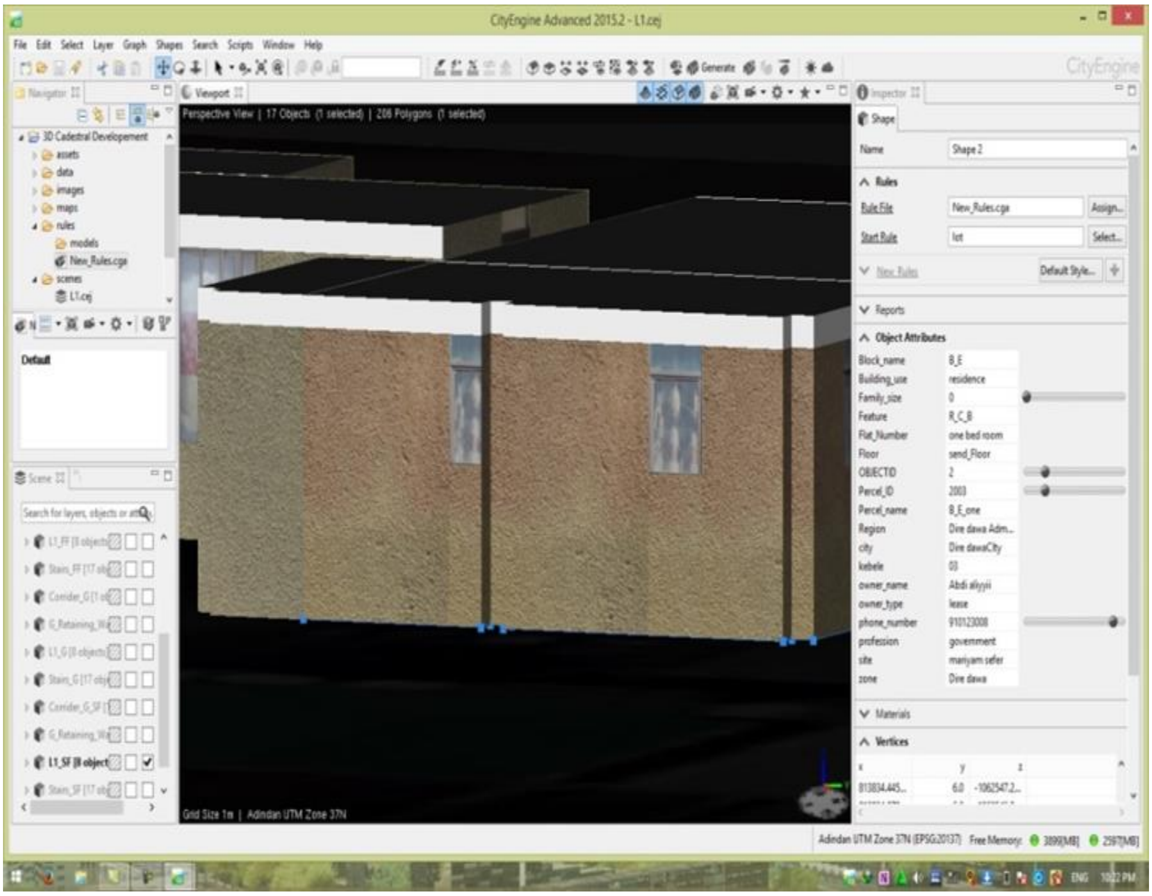


Figure 4.11 : (a) 2D FootPrint (b) 3D Object

4.12. 3D Generating Building Partion

During the developed 3D modeling process different windows and doors of building were created or imported CGA rules to generated fully building partions as show figure 4.12.



1Figure 4.12: Visible 3D Cadastral Registration System with doors,window texture

4.13 3D Data Validation

During the modeling process different errores were created with the generated buildings occurred. For example, too many vertx were created for one building and on the wrong positions, buildings elements were mismatched with the imported windows and/ or doors were created at the wrong position due to unnecessary vertex created during digitization of the Buildings footprints, and problems occurred with creating roof overhangs. Further these problems and their solutions are displayed in the Figure 4.13 a,b and c.

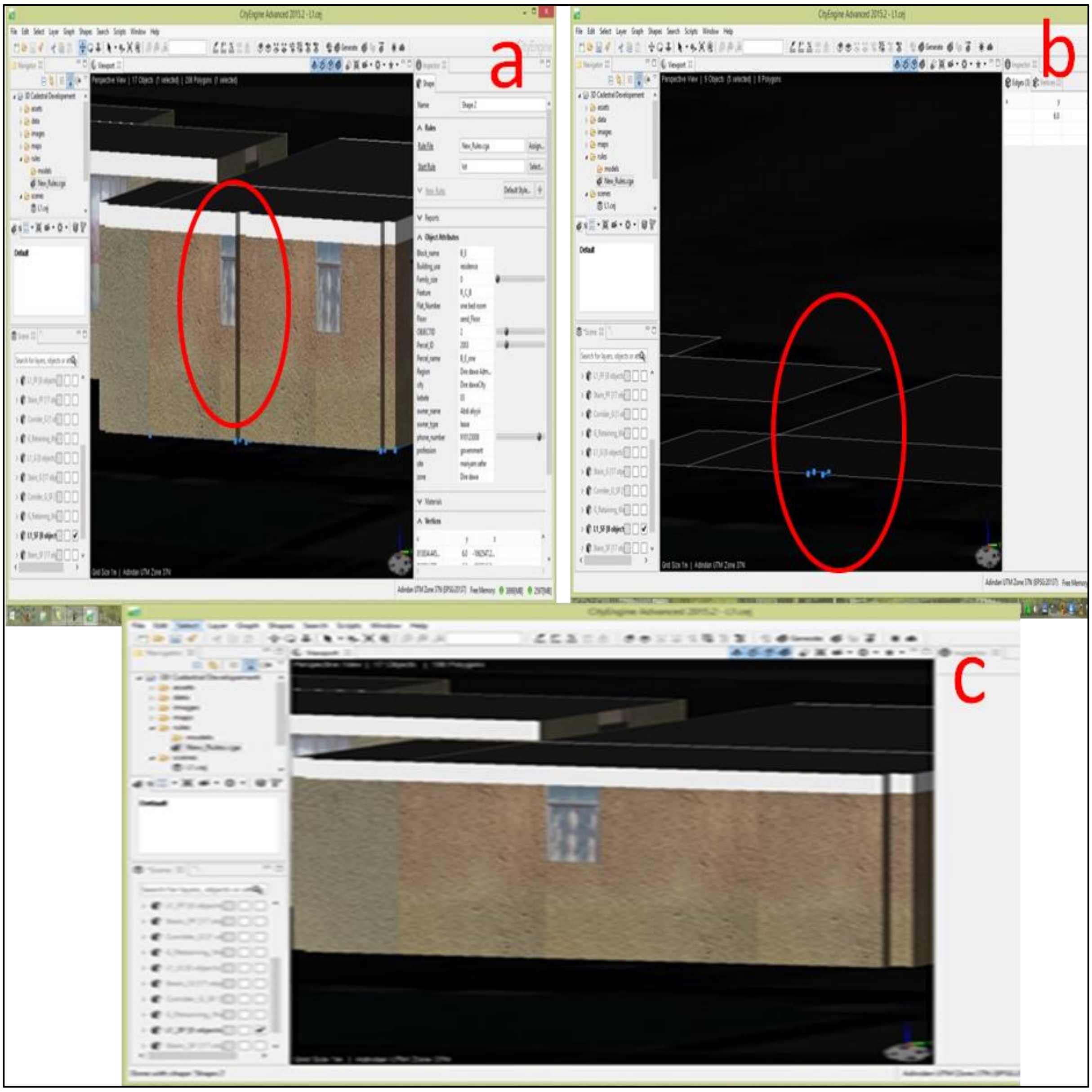


Figure 4.13:(a) 3D Object with Wrong Position of Window, (b) 2D FootPrint Vertex Error Resulted in Wrong 3D Position (C) Validated 3D Object with Correct Position of Window

4.14. Model of fully 3D Cadastre for Building

This research is designed to display the 3D physical object through buildings within those registered associated to their socio economic data with its administrative descriptions as showin the figure 4.14 (a) and (b) .

Figure 4.14: 3D physical object of Buliding with it window,Door and texture(a) Front Side View and (b) Rear side View

4.15 Result and Discussion

This system is used to display general information of (3D) objects that are registered in this building when it is searched using the owner name of 3D objects as shown in Figure 4.15 search by inserting " Kemal Abdulah " who is owner of one houses in this Block or condominium and his house found in ground floor around stair case.

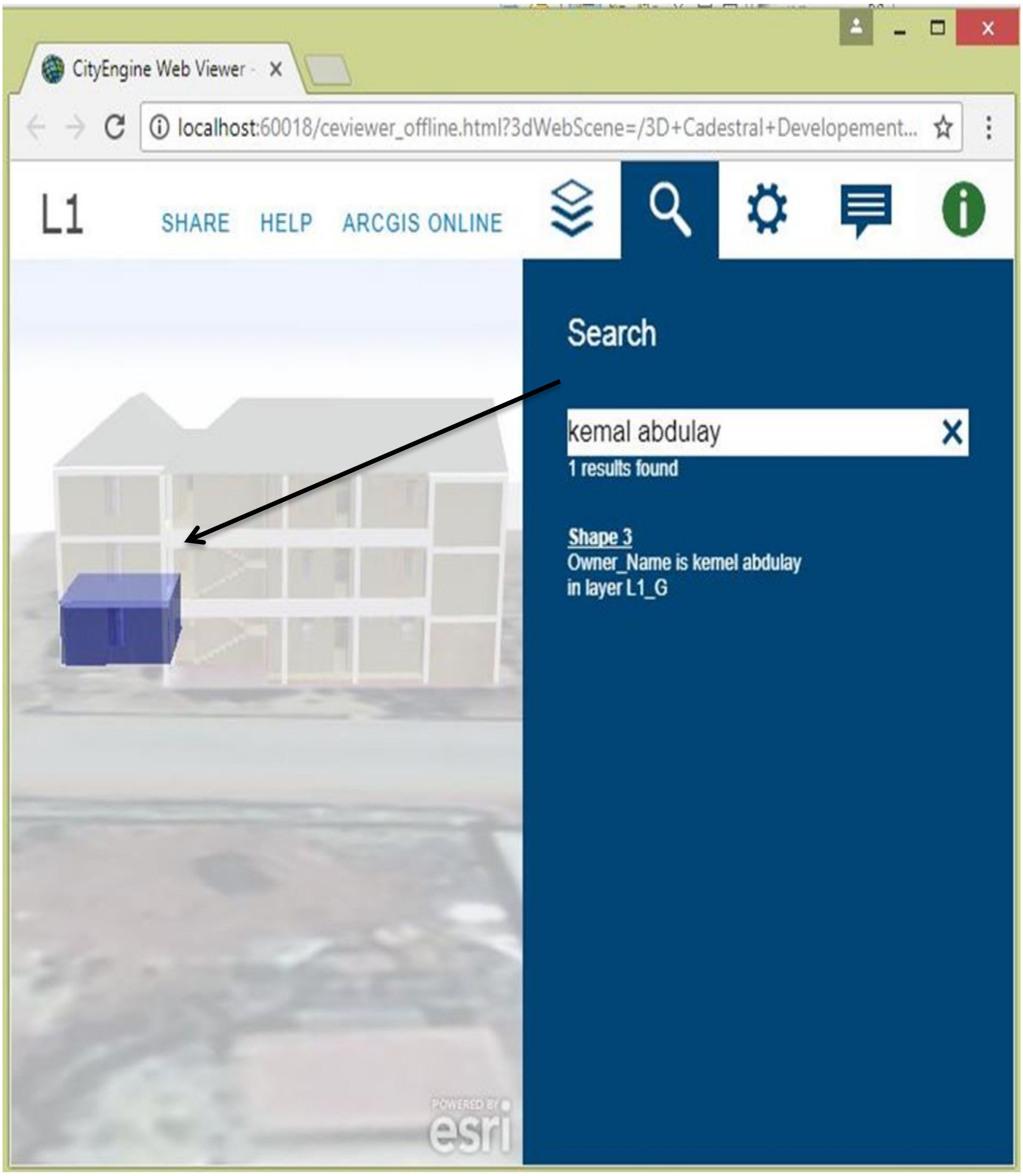


Figure 4.15: general information Kemal Abdulah

That means by visualising or highlight intended 3D properity results and hiding other 3D elements within the building to show result of your question .

This system is used also retrieve a complete information of all the three dimensional(3D) objects and legal objects that are registered in this building when it is searched using the owner name of 3D objects. For example as shown Figure 4.16.

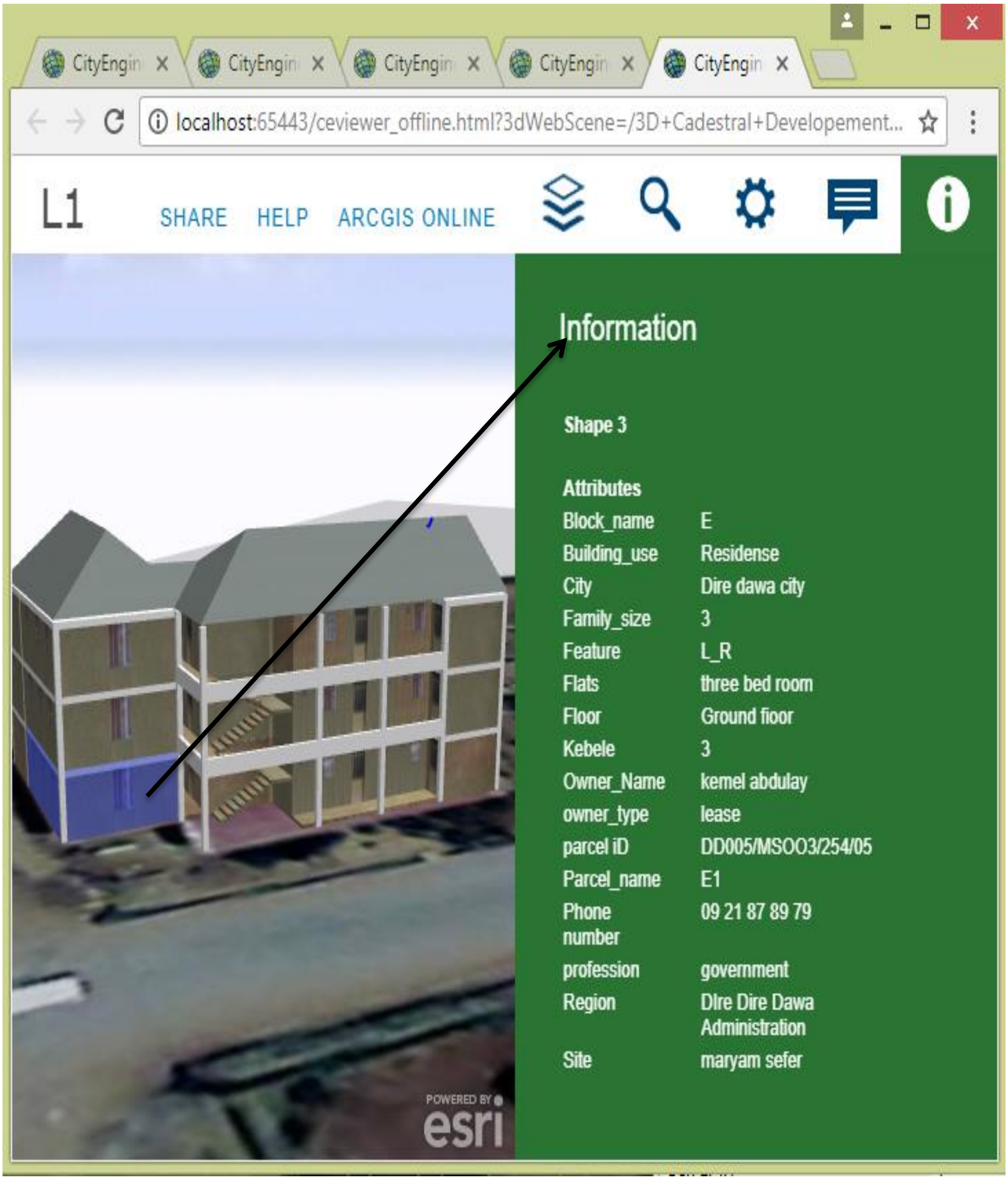


Figure 4.16: Retrieve complete information of Kemal Abdulah

Therefore, figure 4.16 shows the deatil information of kemal Abdulah in terms of 3D legal property and 3D physical proprety with its specific shape, color and location

Also this system is used to display or retrieve information of owner in the three dimensional(3D) objects that are registered in his or her name when it is searched using the owner name of 3D objects.For Example,when to search information of Hamziya kialid, the owner of the 3D objects of Hamziya kialid of two houses in one Building or condominium.That means Hamaziya has house denoted by name shape 5 and Shape 7 in one Building and in same site as Figure 4.17 shows whether the individual(owner) has one or more house by visualising intended 3D properity by hiding other 3D elements within the building .

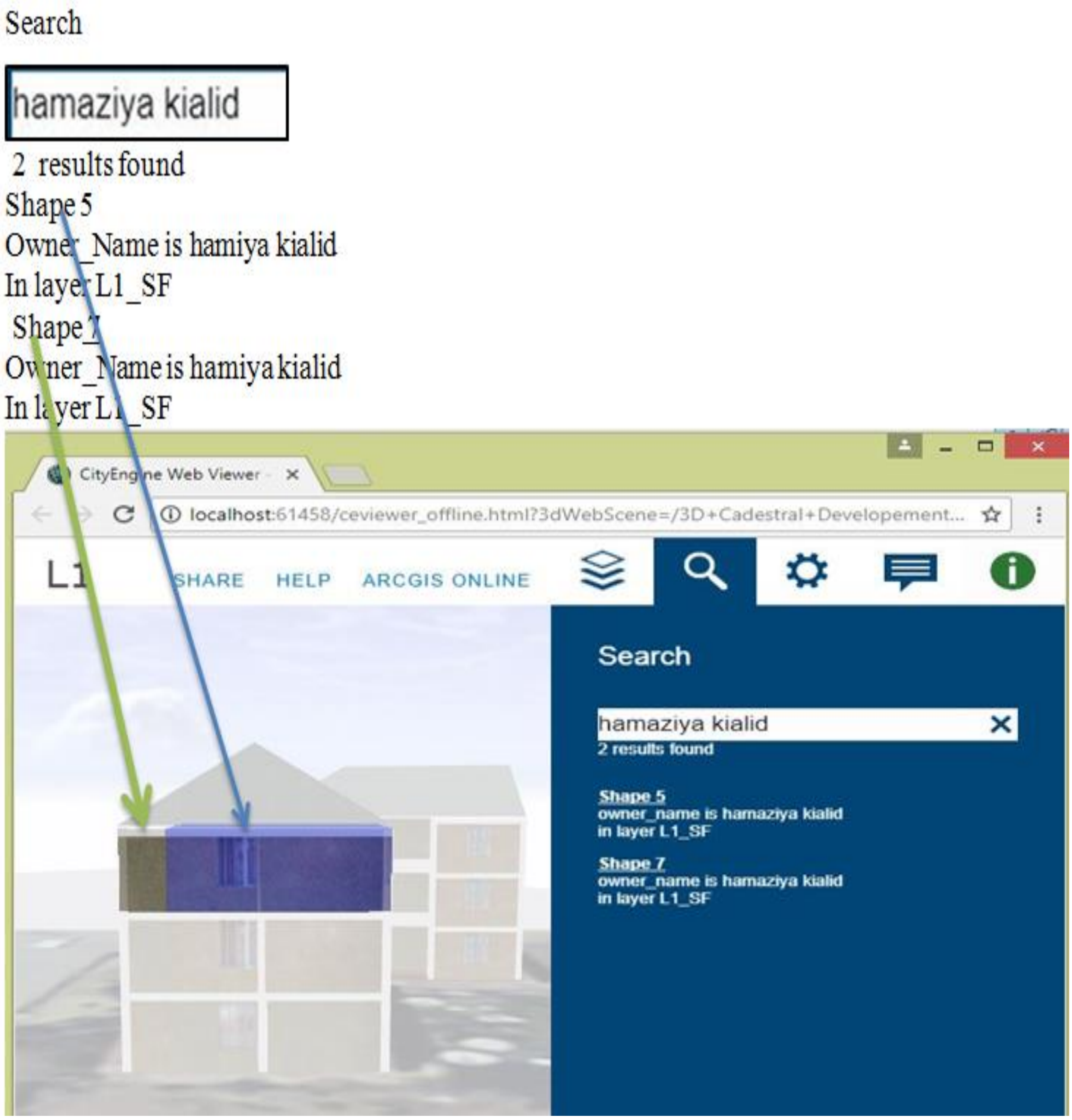


Figure 417:Layer Element of Buildingof one owner has Different house Registered in one System

This system is used to delete and Edit type of information as 2D cadastre. when in three dimensional(3D) objects and legal objects are registered(3D Cadastre) it is possible to the add (create) object and delete object from attribute as shown figure 4.18.

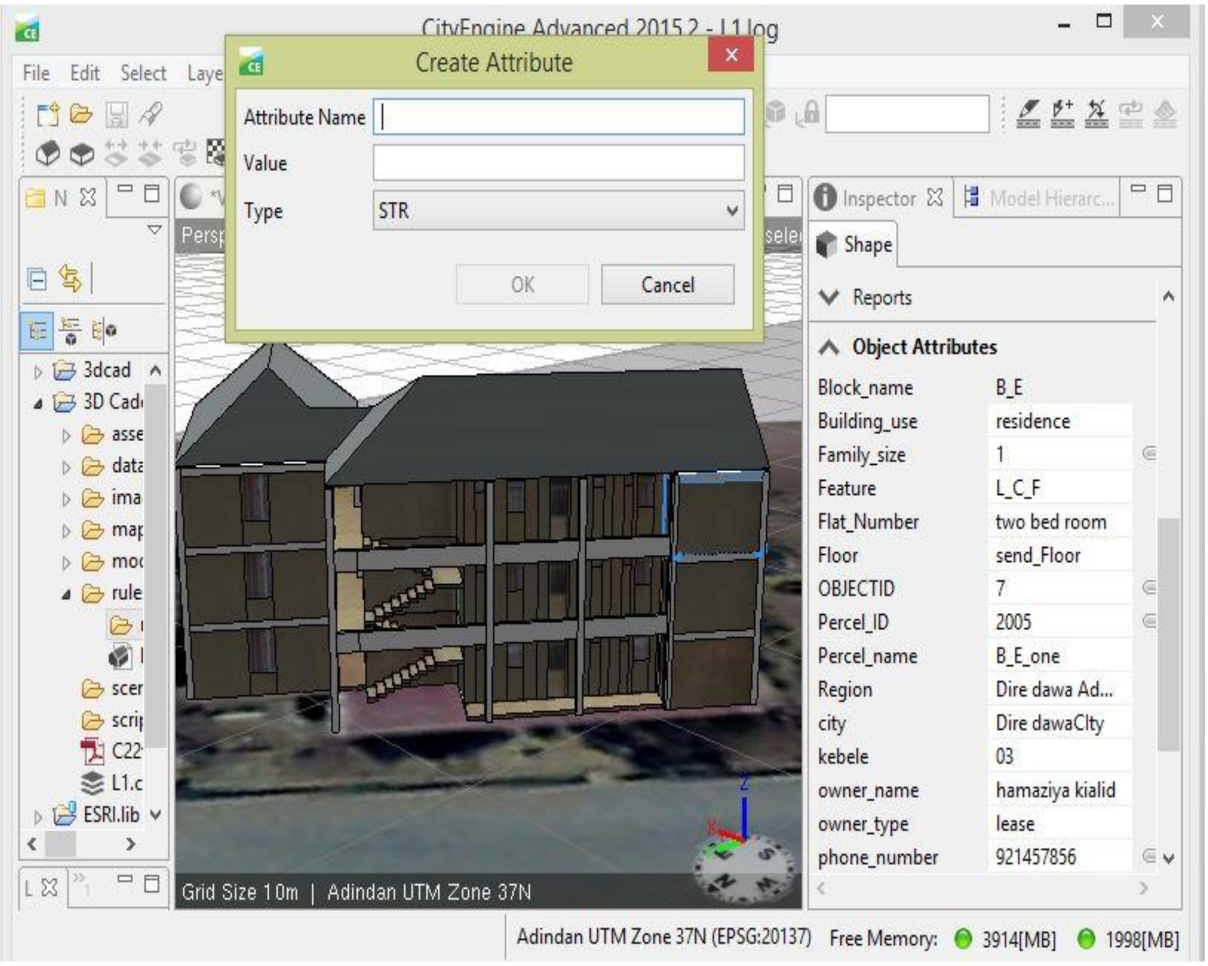


Figure 4.18: how to add and delete information

From this conclused that 3D cadastre has capable of storing, manipulating, querying, analysing, updating and supporting the visualization of 3D property. Therefore, this developed registration system allows the user to interact on the following data base management operations:

- Insert: add new data to the database:
- Delete and :remove data from the database;
- Update:change existing data, and:
- Store and selection

According to (Benoit.*et al.*, 2011) 3D cadaster should be capable of storing, manipulating, querying, analysis, updating and supporting the visualization of 3D property rights, restrictions and responsibilities. which this study agrement with this criteria as display and discuss above figures with results.

Also, 3D aspect should expect in any modern system registration. According to this principle, this research is designed to fulfill this principle. The registration system has two options:

1 The registration system which is allowed to the authorised body can be editable.At this system,when the houses transfered to the user he/she can insert the name and other necessary information or delete the unnecessary in information to/from the associated condominium house as show figure 4.19.

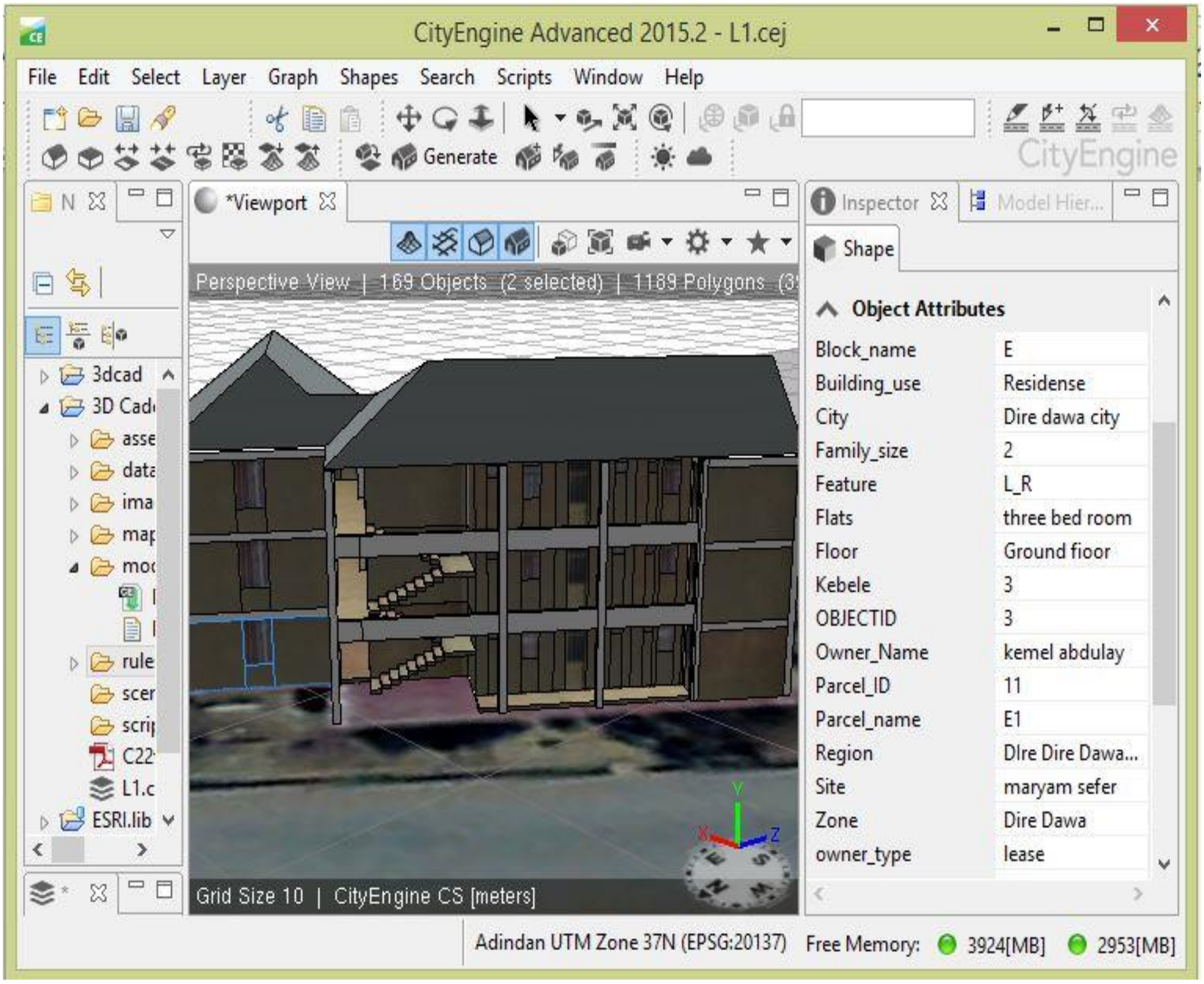


Figure 4.19 where data editable

2 The registration system which is not allowed to the user editable but it quary,visualize and retieve.This is viewed through Esri Web Scene. For Example information of Abdulmalik Mohammed has shown in the Esri Web viewer as shown figure 4.20.

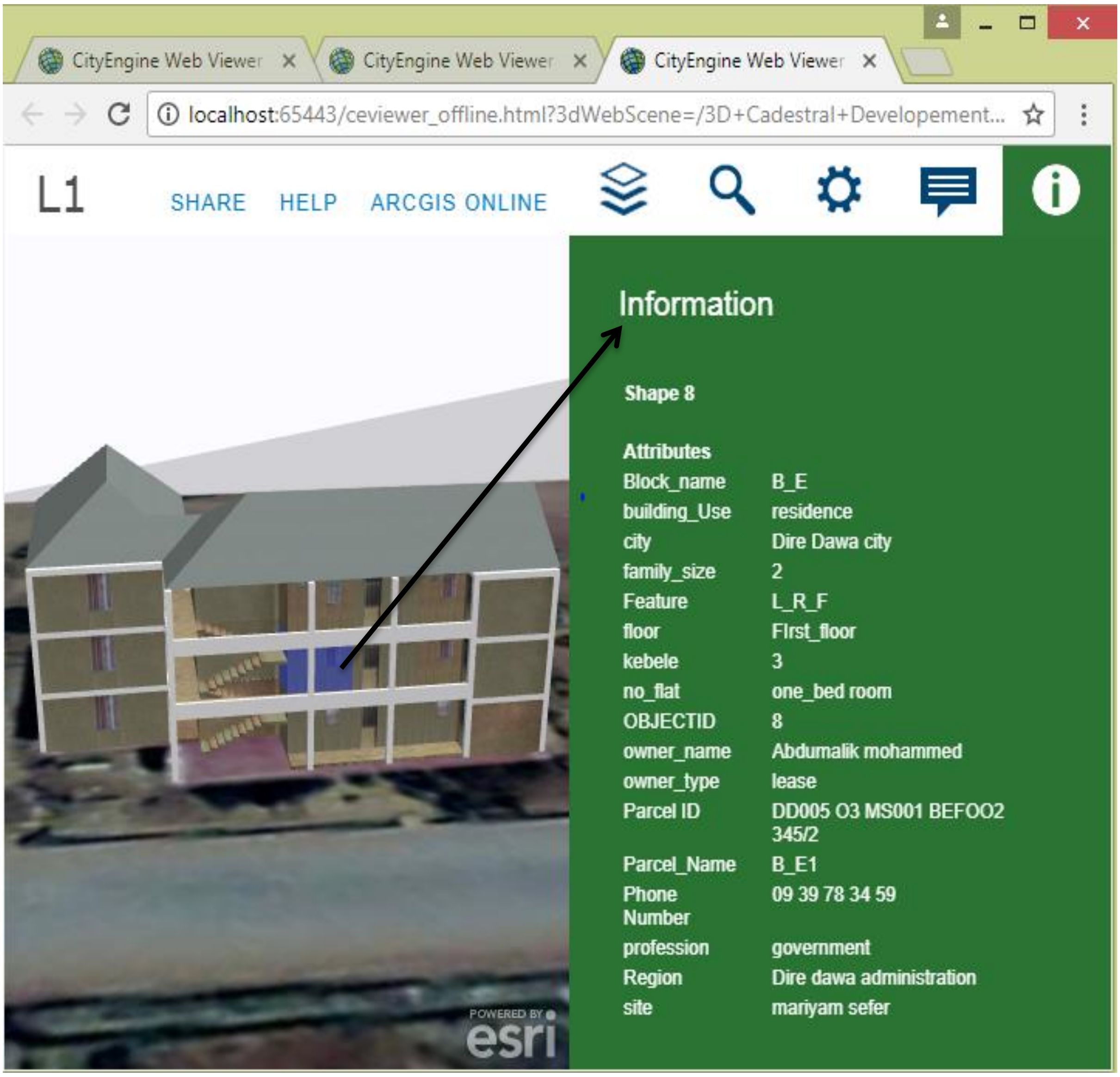


Figure 4.20: web viewer with uneditable information

The result process is exporting of the created 3D model to another 3D application and exported 3D content can be viewed and shared online using Esri Web Scene.

Finally, discussion was highlighted as the first step of implementing a successful 3D cadastre, capable to draw, update, and visualise the 3D legal and physical objects of the 3D cadastre and also fruitful for Land registries and local councils are among users of the mode to management and control multi-layer and multi- level building in cadastral system.

5. Conculsion and Recommendations

5.1 Conclusion

The following conclusions are drawn from the results and discussion presented.

In 3D cadastre application areas, the curent standard geodatabase of ArcGIS and CAD softwares doesn't cover the 3D aspects, so customized softwares packages have frequently used to fill the gap of those softwares.In this study ,CityEngine procedural model based, employed to create 3D multilayer cadaster.

The modelling process started with importing pre- processed data in ArcGIS that means building footprint into Esri's CityEngine procedural model , then by creating Computer Generated Architecture rule files the result was achieved which easy to storing, manipulating, querying, analysis, updating and supporting the visualization of 3D property rights, restrictions and responsibilities with physcical object or reality. As can be seen from the results achieved City Engine procedural model can applied for modelling 3D cadastre of multi layer and multi level building in Dire Dawa city. Morever, this 3D cadastre support for a better mangment of multi layer and multi level buildings that are found in the city.

The modelling what is sufficinty than 2D it has consists export data for created to the web scene which user can be easy to querying, analysis, and visualization of 3D property rights, restrictions and responsibilities with physcical object or reality through out Esri Web Scene.

Finally, data modelling was highlighted as the first step of implementing a successful 3D cadastre, the other technical tolls such as appropriate visualisation platforms are definitely fruitful for implementing the 3D cadastre. Developing platforms to draw, update, and visualise the 3D legal and physical objects of the City Engine model was facilitate the implementation of the 3D cadastres.

Therefore, 3D developments of cadastres assist in managing the effects of 3D developments on a particular extent of land such as apartments, high-rise buildings, and complex infrastructures in land administration into cadastral systems.

5.2 Recommendations

Based on the result of the present study, the following recommendations are suggested for decision makers and future researchers:

The Dire Dawa Administration City integrated land registration system(legal cadaster) project office(manucipality) better to include the 3D cadastral registration system in order to register multi layer and multi level buildings in Dire Dawa Administration City .

The federal and regional housing development agencies should use 3D cadastre in order to managing and monitoring all condominium information of their respective offices in one system and /or the whole condominium of the country(Ethiopia) .

The outcomes of this research highlighted the following directions for further investigation in the future.

- The implement of the City Engine procedural model using CGA base data i.e. means requires lists of Rules to create 3D objects. This information should normally be provided through the Arch CAD. Therefore the implementation of the City Engine model requires changes in the provision of Arch CAD.
- Recently a quiet revolution has been taking place that will fundamentally change managing cities utilising Building Information Models (BIM) and 3D city models (CityGML).The focus of these models is on the physical and functional characteristics of urban facilities. Integration of legal information with physical in these models would maximise the usability of the BIM and CityGMLmodel for 3D cadastre will be the future direction in 3D city modelling.
- Further researchers should be required to validate the model and examine approaches to implementation for underground infrastructure since this research based above the ground surface.

Finally, data modelling process was highlighted as the first step of implementing a successful 3D cadastre; in addition other technical tools that are appropriate visualisation platforms softwares will definitely easy to draw, update, and visualise the 3D legal and physical objects of property will fruitful for implementing the 3D cadastre .

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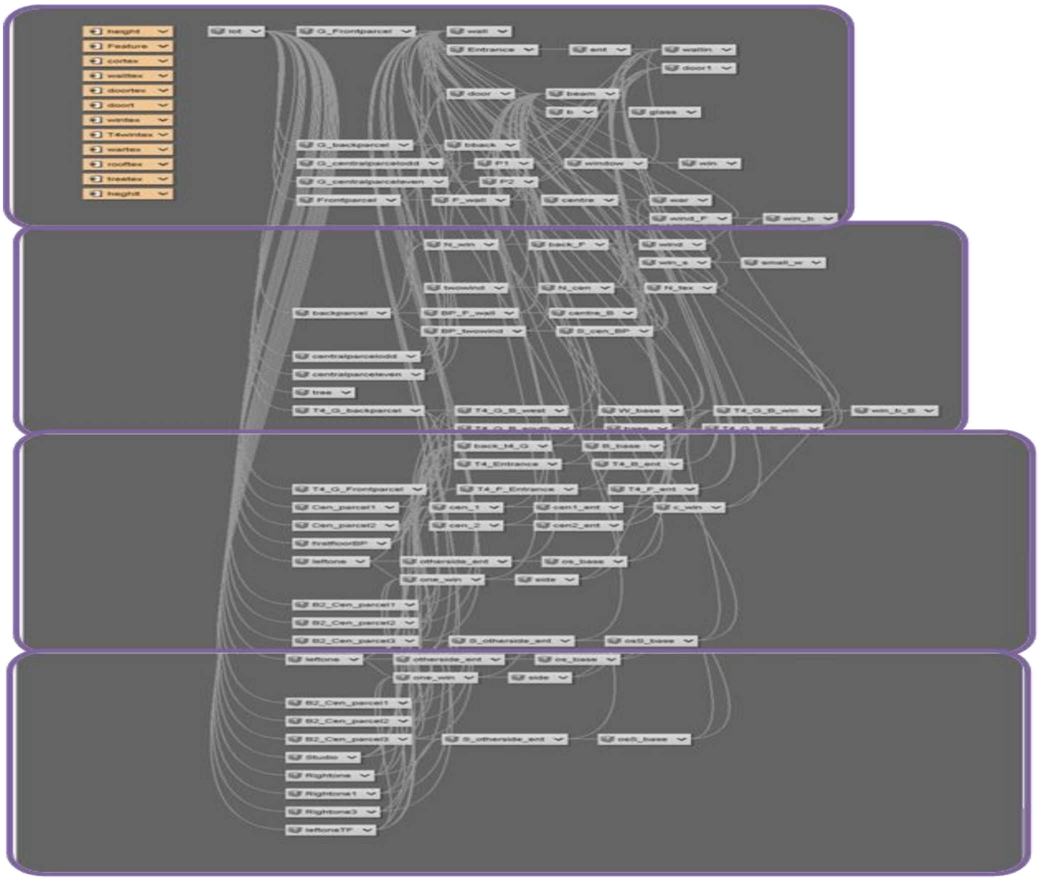
APPENDIX A: A Graphical Representation of Rule Files in a City Engine Software



Appendix B: Rule File for Buildings

```
/**
 * File:    New_Rules.cga
 * Created: 20 Nov 2017 07:43:20 GMT
 * Author:  hayati
 */

version "2015.2"
attr Feature =""
attr cortex = fileRandom("assets/wall/wall*.jpg")
```

-
-
-
-

```
attr walltex = fileRandom("assets/wall/wall*.jpg")

lot-->
case Feature == "column":
extrude(9)
color(1,1,1)
    •
    •
    •
    •
    •

case Feature == "L_R_B" : LRB
case Feature == "L_R" :LR
case Feature == "S_R":roofGable(35)

setupProjection(2,scope.xy,scope.sx,scope.sz)
texture(rooftex)
projectUV(0)

case Feature == "R_C_F": RCF
    •
    •
    •
texture(cortex)
projectUV(0)
case Feature =="retainingwall":
extrude (0.75)
texture(walltex)
case Feature == "stair":
extrude(0.16)
    •
    •
    •
    •
else:
NIL

LCF-->
    •
    •
    •
    •
    •
D_Right-->
setupProjection(0,scope.xy,4,4)
texture(walltex)
projectUV(0)
beam-->
color(1,1,1)
DD-->
split(y){2.7:D|0.3:Beam}
D-->
split(x){~0.3:D_Right|~0.9:door1}
door1-->
setupProjection(0,scope.xy,.85,2.8)
texture(doort)
projectUV(0)
```

```
DD_Back-->
split(y){2.7:D_Back|0.3:Beam}
D_Back-->
setupProjection(0,scope.xy,4,4)
texture(walltex)
projectUV(0)

LCB-->
extrude(3)
comp(f){world.west:DB_Right|world.east:DDB_Left|world.north:DB|world.south:DDB_Back|top:Top|botto
m:Bottom}


DDB_Back-->
split(y){2.7:DB_Back|0.3:Beam}
DB_Back-->

split(x){~1.37:D_Right|1.2:window|~3.5:D_Right}
window-->
split(y){0.9:D_Right|1.9:win|~0.2:D_Right}

win-->
setupProjection(0,scope.xy,1.8,3)
texture(wintex)
projectUV(0)


DDB_Left-->
split(y){2.7:DB_Left|0.3:Beam}
DB_Left-->

split(x){1:D_Right|1.2:window|1.5:D_Right|1.2:window|~1.2:D_Right}

//DDB_Right-->
//split(y){2.7:DB_Right|0.3:Beam}
DB_Right-->
split(x){0.5:D_Right|0.4:win_s|0.2:D_Right|0.75:wind|~5:D_Right}
wind-->
split(y){1.5:D_Right|1.2:win_b|~0.5:D_Right}
win_b-->
setupProjection(0,scope.xy,1.55,1.55)
texture(wintex)
projectUV(0)
win_s-->
split(y){2.3:D_Right|0.4:small_w|~0.5:D_Right}
small_w-->
setupProjection(0,scope.xy,1,6)
texture(wintex)
projectUV(0)

LC-->
extrude(3)
comp(f){world.west:LC_Front|world.east:LLC_Back|world.north:LC_Right|world.south:LC_Left|top:Top|bo
ttom:Bottom}
LC_Front-->
split(x){0.5:D_Right|0.9:door1|1:D_Right|0.5:win_s|~.8:D_Right}

LLC_Back-->
```

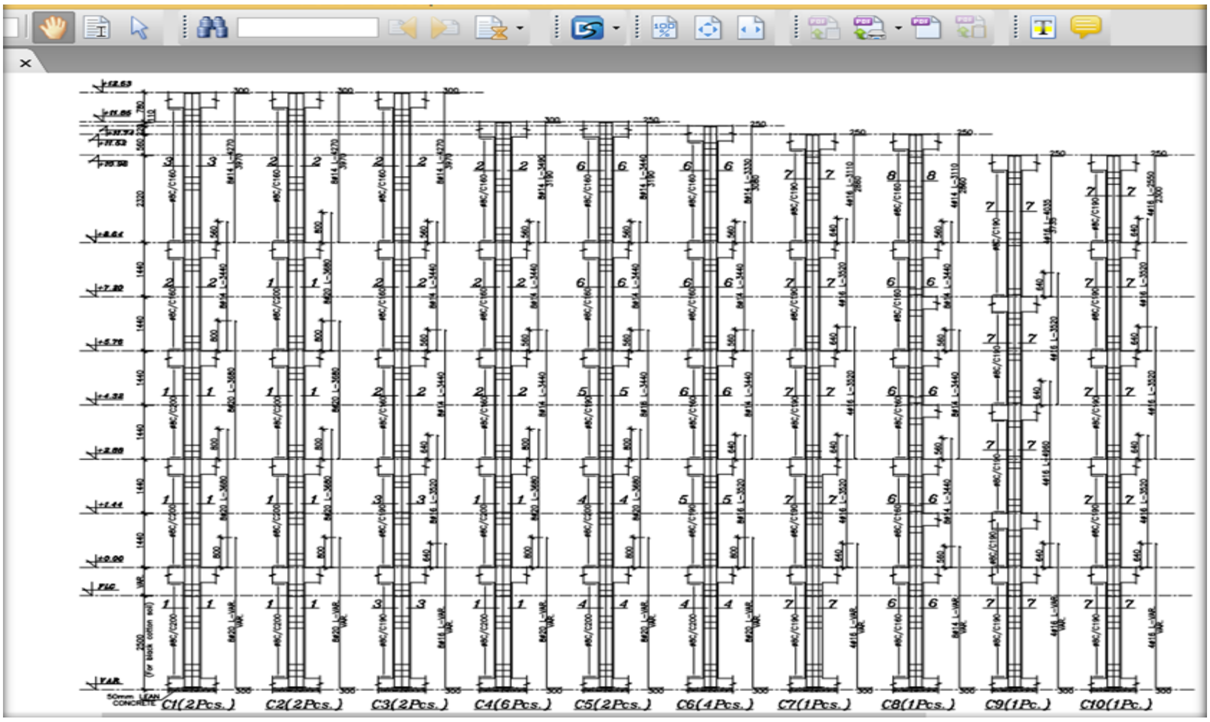
```
split(y){2.7:LC_Back|0.3:Beam}
LC_Back-->
split(x){0.5:D_Right|1.2:window|~1:D_Right}

LRF-->
extrude(3)
comp(f){world.west:LRF_Front|world.east:LRF_Back|world.north:D_Right|world.south:LRF_Left|top:Top|b
ottom:Bottom}
LRF_Front-->
split(x){0.5:D_Right|0.4:win_s|1:D_Right|0.75:wind|~5:D_Right}

LRB-->
extrude(3)
comp(f){world.west:D_Right|world.east:DDB_Left|world.north:LRB_Right|world.south:LRB_Left|top:Top|b
ottom:Bottom}
LRB_Right-->
split(x){~1:D_Right|0.9:door1|~1:D_Right}

LR-->
extrude(3)
comp(f){world.west:LLR_Left|world.east:D_Right|world.north:LLR_Back|world.south:LR_Front|top:Top|bo
ttom:Bottom}
LR_Front-->

split(x){1:D_Right|0.9:door1|1.5:D_Right|0.4:win_s|1.5:D_Right|0.75:wind|~5:D_Right}


LLR_Left-->
split(y){2.7:LR_Left|0.3:Beam}
LR_Left-->
split(x){~1.5:D_Right|1.2:window|~1.5:D_Right}

LLR_Back-->

split(y){2.7:LR_Back|0.3:Beam}

LR_Back-->

split(x){1.5:D_Right|0.75:wind|1.8:D_Right|0.75:wind|1.5:D_Right|0.75:wind|~1:D_Right}

RCF-->

extrude(3)
comp(f){world.west:Door|world.east:Back|world.north:Right|world.south:Left|top:Top|bottom:Bottom}

Door-->
split(x){0.5:D_Right|0.9:door1|0.5:D_Right}

Left-->
split(y){2.7:LR_Left|0.3:Beam}

Back-->
split(y){2.7:D_Right|0.3:Beam}

RCB-->
extrude(3)
comp(f){world.west:Door_F|world.east:Back_D|world.north:Right_D|world.south:Left_D|top:Top|bottom:Bo
ttom}
Back_D-->
split(y){2.7:CF|0.3:Beam}
```

CF-->
split(x){2:D_Right|0.75:wind|2.15:D_Right|~0.5:D_Right}

Right_D-->
split(y){2.7:Right_DD|0.3:Beam}

Right_DD-->
split(x){1:D_Right|0.75:wind|0.75:D_Right|0.4:win_s|~0.5:D_Right}

Appendix C: Section Plan Elevation Data Source



Appendix D: Questionnaire Format

Format Used for Collection of Socio Economic Data and property registration form (door-door and parcel-parcel socio-economic data collection form)

Sheet no___________

Date ______________name of enumerator__________________ supervisor.

1. Owner name: ______________________ Living address ________________occupation (Profession) _________ Company name_________ Tel.no_____________ P.o. box__________ Email ____________ Personal ID_______no/passport__________ No_ Family size________

2. Owner type: □ government □ public □ institution □ private □ unknown/information not available

3 Location: Country____________Region_______Zone _________City _____Kebele________ Street name_________ Subdivision name ________

Blockname/number ______ Lot number__________ Parcel ID_________ House number___________ Parcel area surveyed______________

4. Land acquisition type: □ Free hold □ Lease hold (long term) □ illegal/not registration end of contract (if lease). Date of acquisition_______________________

6. Tax record: Amount of annual tax: □ paid Since ______□ not paid □ information not available if not paid,

7. Building information: Type of structure________Year of construction________ No of room_____ Use of building_____________

8. Encumbrance (charge or claim on the property; like: mortgage, or if any)

9. Boundary conflict: □ Yes □ No If yes with which parcel and why?

____

10. Infrastructure: □ Access road □ Water supply □ Telephone □Electricity/power supply

11 Social infrastructures: school □ health service □. recreation: □ transport mode: □

12 What are the social problems in area: Theft. □. Attack. Prostitution problems □. -police protection/safety problems □.Others (safety).

13 what are your desired services/infrastructures/. :Road. □. -Water. □. Tele. □. Electric. □. Sewerage □.food control drainage □.. If other specify

____

14. Waste disposal: Burning:□.Dumping:□.Municipal service.□

Ifother(specify____

15. Pollution problems type: Air pollution □ Water pollution. : □ Noise pollution: □

If other specify____

12.Certification of the surveyor or the assessor

Name _________________________ Signature________________ Date ______________