بسم الله الرحمن الرحيم

Sudan University of Science and Technology
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Three Dimensional Design of Khartoum Land Terminal

تصميم ثلاثي الأبعاد لميناء الخرطوم البري

A thesis submitted in partial fulfillment of the Requirements for the degree of M.Sc in Computer Science

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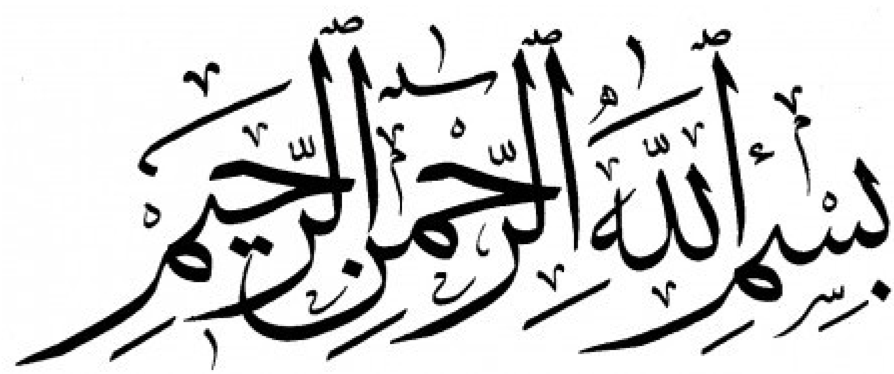


وَقَضَىٰ رَبُّكَ أَلَّا تَعْبُدُوا إِلَّا إِيَّاهُ وَبِالْوَالِدَيْنِ إِحْسَانًا إِمَّا يَبْلُغَنَّ عِنْدَكَ الْكِبَرَ أَحَدُهُمَا أَوْ كِلَاهُمَا فَلَا تَقُلْ لَهُمَا أُفٍّ وَلَا تَنْهَرْهُمَا وَقُلْ لَهُمَا قَوْلًا كَرِيمًا

صدق الله العظيم

(سورة الإسراء، آية 23)

الحمد لله

الحمد لله حمدا كثيرا طيبا مباركا فيه
الحمد لله كما ينبغي لجلال وجهه وعظيم سلطانه
الحمد لله الذي منى علينا بنعمة العقل والادراك والتعلم لكي نستفيد منه
في حياتنا اليومية العملية والحمد لله على ما سخرة لنا من معينات على
إستمرارية الحياة ونعمة التفكر والتدبر في خلقة سبحانه
وتعالي والحمد لله الذي صلى على نبيه المصطفى
وحبيبه المجتبى صلى الله عليه وسلم.

Dedication

I would like to take this opportunity to express my gratitude to all those people who have supported me during this research, and in particular: to my parents for their love and support throughout my life, brothers, sisters, friends and my supervisor Prof. Dr.-Ing. Dieter Fritsch, who suggested the idea that would become the core of my work, and who has been invaluable in every step of the research. And to the teachers of the University of Sudan for Science and Technology, especially teachers of the Faculty of Computer Science and Information Technology.

Abstract

Buildings are the most important objects in urban areas. Thus, building detection using photogrammetry and remote sensing data as well as 3D models of buildings are very useful for many applications such as mobile navigation, tourism, and disaster management.Three dimensional (3D) sensing; the design of objects has become an important area of research in several disciplines.

The objective of this work is to elaborate on the demand and usefulness of three-dimensional modeling, and also, to explore the capabilities of current technologies via a pilot project. and The objective of this research is to three dimensional design of Khartoum Land Terminal and to provide information on all resources within it to assist new passengers, who are suffering for knowing places of offices, halls and how to reached those. In particular we will assist people for not wasting their time in asking how to reach a particular place inside the Khartoum Land Terminal –as this could have a negative effect on the traveling time or the completion of the registration procedure on time.

Therefore, this project is meant for assisting the Khartoum Land Terminal administration development and the provision of passengers. Starting off from this point, different ideas and techniques grew up to make the geographic orientation easier for passengers and guiding them to reach a particular place in due time. For this reason, the need of applying three dimensional visualizations is the true simulation of reality. This project aims to take advantages of a GIS environment to offer a flexible interactive system for providing the best visual interpretation, planning and decision making processes for Khartoum Land Terminal.

المستخلص

المباني هي أهم العناصر في المناطق الحضرية.ولذلك، فإن استكشاف المبنى باستخدام بيانات المسح التصويري وبيانات الاستشعار عن بعد، والنموذج ثلاثي الأبعاد للمباني مفيد جدا للعديد من التطبيقات مثل الملاحة المتنقلة والسياحة وإدارة الكوارث، والاستشعار ثلاثي الأبعاد (3D)وأصبح تصميم الأجسام مجالًا مهمًا للبحث في العديد من التخصصات، الهدف من هذا العمل هو توضيح الطلب وفائدة النمذجة ثلاثية الأبعاد، وأيضا استكشاف القدرات التكنولوجية الحالية من خلال مشروع تجريبي. والهدف من هذا البحث هو تصميم ثلاثي الابعاد لميناء الخرطوم البري وتوفير المعلومات عن جميع الموارد داخل ميناء الخرطوم البري لمساعدة المسافرين الجدد، حيث يعاني المسافرين من معرفة أماكن المكاتب والقاعات وكيفية الوصول إليها، وخاصة المسافرين الجدد. فهم يهدرون وقتهم في الحصول على وسيلة للوصول إلى مكان معين داخل ميناء الخرطوم البري - وهذا قد يكون له تأثير سلبي على وقت السفر و إتمام إجراءات التسجيل في الوقت المحدد.ولذلك، فإن أي خطة أو مشروع تطوير يساهم في مساعدة إدارة ميناء الخرطوم البري وتوفر المعلومات اللازمة للمسافرين.وبدءً من تلك النقطة، نشأت أفكار وتقنيات مختلفة لجعل التوجه الجغرافي أسهل للمسافرين وتوجيههم للوصول إلى مكان معين في الوقت المناسب.ولهذا السبب، جاءت الحاجة إلى تطبيق النماذج التصورية ثلاثية الأبعاد وذلك لمحاكاة الواقع الحقيقي، وإلى الاستفادة من بيئة نظم المعلومات الجغرافية لتقديم نظام تفاعلي مرن لتوفير أفضل التفسيرات البصرية والتخطيط وصنع القرار لميناء الخرطوم البري.

Table of Contents:

Table of Figures:

:List of Abbreviation

Abbreviation	**Definition**
BIM	Building Information Management
CAD	Computer Aided Drafting
CIM	City Information Model
CRP	Close Range Photogrammetry
COTS	Commercial Of The Shelf
DEM	Digital Elevation Model
DTM	Digital Terrain Model
GIS	Geographic Information Systems
LOD	Level Of Detail
LAS	Leaser
LiDAR	Light Detection And Ranging
2D	Tow Dimension
3D	Three Dimension
VRM	Virtual Reality Model
WGS	World Geodetic System
WebGL	Web Graphics Library

Chapter One

Introduction

1.1 Overview

This is the era of computers. Today computers play an indispensable role in sustaining the standard of living. Almost any man-made product that surrounds us has at some point been treated in digital form, whether it is during development, production, marketing, or consumption. In development and production, computers make assisting technologies such as CAD/CAM available, and many products would be impossible to design and manufacture without the help of computers. In marketing computers are used for both creating and publishing product advertisements. For some groups of consumer products, e.g. electronic devices, it is even becoming the norm to order directly from shops on the internet, without having seen the product in real life. The information available online about products is, in many cases, sufficient for the buyer to make a considered decision as to which product to choose. [13]

3D modeling is used in various industries like films, animation and gaming, interior designing and architecture. A wide number of 3D software are also used in constructing digital representation of mechanical models or parts before they are actually manufactured. CAD/CAM related software are used in such fields, and with these software, not only can you construct the parts, but also assemble them, and observe their functionality. 3D modelling is also used in the field of Industrial Design, wherein products are 3D modeled before representing them to the clients.

In Media and Event industries, 3D modelling is used in Stage/Set Design. [25]

Three-dimensional designing technique can be regarded as an electronic attempt to achieve the real-world perception model of human vision, since the real-world environment is strictly perceived in three dimensions by human beings. In this regard, a 3-D designer is capable of presenting any naturally occurring or human-made object in its realistic format, which is the most significant feature of 3-D design technique today. [26]

The 3D reconstruction of buildings has been an active research topic in Computer Vision as well as in Digital Photogrammetry in recent years. Three dimensional building models are increasingly necessary for urban planning, tourism, etc. [23]

In the Khartoum Land Terminal, passengers are suffering from difficulties of knowing places of halls (departure hall, mosque, cafeteria, gates, administration offices, tickets sale points) and how to reach it, especially the new passengers. They are wasting their time in asking a way to reach a particular place inside the Khartoum Land Terminal - this could have a negative effect on the traveling time or the completion of the registration procedure on time.

From this point of view, different ideas and techniques grew up to make it easier for passengers and guiding them to reach a particular place. In this dissertation three-dimensional visualization is applied to make the true simulation of reality.

Three-dimensional (3D) models represent a physical body using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling), or scanned. Their surfaces may be further defined with texture mapping.

3D models are widely used anywhere in 3D graphics and CAD. Their use predates the widespread use of 3D graphics on personal computers. Many computer games used pre-rendered images of 3D models as sprites before computers could render them in real-time. The designer can then see the model in various directions and views, this can help the designer see if the object is created as intended to compared to their original vision. Seeing the design this way can help the designer/company figure out changes or improvements needed to the product. [25]

1.2 Problem Statement

This project will provide answers to the following questions showing the research problem:

1. What are the scope of applying the system?
2. What are the obstacles and difficulties that hinder the system for working properly?
3. What are the goals and the importance of designing a system or applications to represent the geographical areas in three-dimensional models?

4.What is the effect of designing a system or application representing the geographical locations in a three-dimensional representation for the buildings of Khartoum Land Terminal?

5.What is the influence degree and contribution of applying the system on the passengers in Khartoum Land Terminal?

6.What are the techniques to be used in designing three-dimensional systems?

7. What is the importance of using the selected technology in the proposed system?

1.3 Research Hypotheses

In this research, the following research hypotheses are formulated – it is an experiment to reach fast and accurate the 3D models of buildings.

The Khartoum Land Terminal allows passengers to use their resources such as lounges, offices, cafes and other resources. The system facilitates access to and provides some information on these resources, all offered by digital models.

1.4 Thesis Objectives

1. The main objective of a three-dimensional design is to build suitable procedures for Khartoum Land Terminal buildings and thus to serve as tools to make information accessible for

passengers and visitors, who can investigate remotely via Internet the Khartoum Land Terminal without going to the site.

2. It provides information about all resources inside the Khartoum Land Terminal.
3. It explores the capabilities of current technology of photogrammetry and software such as ArcGIS to link the spatial information about the building features and utilities which helps on making decisions.
4. It gives recommendations for restructuring the Khartoum Land Terminal.

1.5 Research Significance

The three-dimensional visualization can be a useful tool in guiding passengers and to reach places inside the Khartoum Land Terminal.

The benefits associated with 3D modeling and visualization include the following:

1. Helps the new passengers to maximize the effective time of doing registration procedures by finding offices rather than spending time in asking.
2. Illustrating features of buildings (e. g. offices, mosques, departure halls and cafeterias).

3. Providing visual support of Khartoum Land Terminal management when they need to make some improvements by adding or modernizing buildings.

1.6 Purpose of Research

The main purpose of this project is to understand the benefits of utilizing interactive, three-dimensional (3D) visualization by designing a 3D model for the Khartoum Land Terminal to assist the passengers, the Khartoum Land Terminal administration, when they need to reach any place inside this important traffic infrastructure.

In addition, the proposed system will be accessible from desktops and smartphones to take advantage of the virtual visualization, at any place and any time. The importance of land Terminals planning focuses on offering 3D real world visualizations, and here the Khartoum Land Terminal main buildings with all semantic information's may serve as best practice.

1.7 Scope

This project is implemented for Khartoum Land Terminal. For the project most of the photos will be collected by smart phone cameras.

The project offers 3D visualization for buildings as well and provides information using a computer.

1.8 Organization of the thesis

The structure of this research is divided into seven chapters as shown below:

- Chapter One:

  This chapter is presenting an introduction containing an Overview, Problem Statements, Research Hypotheses, Research Objectives, and Research Significance.

- Chapter Two:

  This chapter is about Related Work and Literature Review. In detail it covers the Theoretical Framework and Literature Review System Description.

- Chapter Three:

  This chapter is about Methodology and Research Planning – it also reflects the Research Community and Methodology Research Planning.

- Chapter Four:

  This chapter is about System Design: System Requirements, System Analysis.

- Chapter Five:

  Here Experiments and Results are given, especially to mention Testbed Description, Methods Used, Algorithms Implemented, and Results.

- Chapter Six:

  This chapter is about Conclusions, Outlook and Strength of the Thesis, Weakness of the Thesis, Opportunities of the Thesis, and Threats of the Thesis, References.

Chapter Two

Related Works and Literature Review

2.1 Theoretical Framework

As is so often the case with emerging technologies, several different techniques have been developed and deployed to create and represent an urban landscape in three dimensions.

2.1.1 Geographic Information Systems (GIS)

2.1.2 The History of GIS Data

The primary source of the majority of vector data found in today's GIS databases is imagery, **which** was used primarily as a backdrop for digitizing. Whether captured from aerial photography or possibly scenes taken from satellites, layers such as building footprints, roads, and terrain were extracted and the imagery often discarded. The result has been a 2D flat representation of geospatial objects, which, although providing a wealth of information, falls short of the rich 3D perspective, which is more closely matching reality. However, recent technological advances have greatly improved the capability to efficiently extract 3D data from imagery, providing a new source for constructing building models or accurately determining the terrain. These improvements, often referred to as 3D intelligent images, are propelling advances in 3D GIS mapping and driving significant changes throughout the industry. [7]

2.1.3 GIS Definition

A Geographic Information System (GIS) is a computer system for collecting, storing, querying, analyzing, and displaying geospatial data, Geospatial data describe both the location and the attributes of spatial features. For example, to describe a road, its location (i.e., where it is) and its attributes (e.g., length, name, speed limit, and direction) are referred to. A GIS allows the user to manage road data and many other geospatial data, thus distinguishing it from business management systems that deal with no spatial data. [1]

2.1.4 Geospatial data

By definition, geospatial data cover the location of spatial features. To locate spatial features on the Earth's surface, either a geographic or a projected coordinate system can be used. [1]

2.1.5 Elements of GIS

GIS operations usually involve data acquisition, data management, data queries, vector data analysis, raster data analysis, and data display. These operations do not have to be sequential; for example, data display may be conducted for exploring data at the beginning of a project and for presenting results at the end of the project. [1]

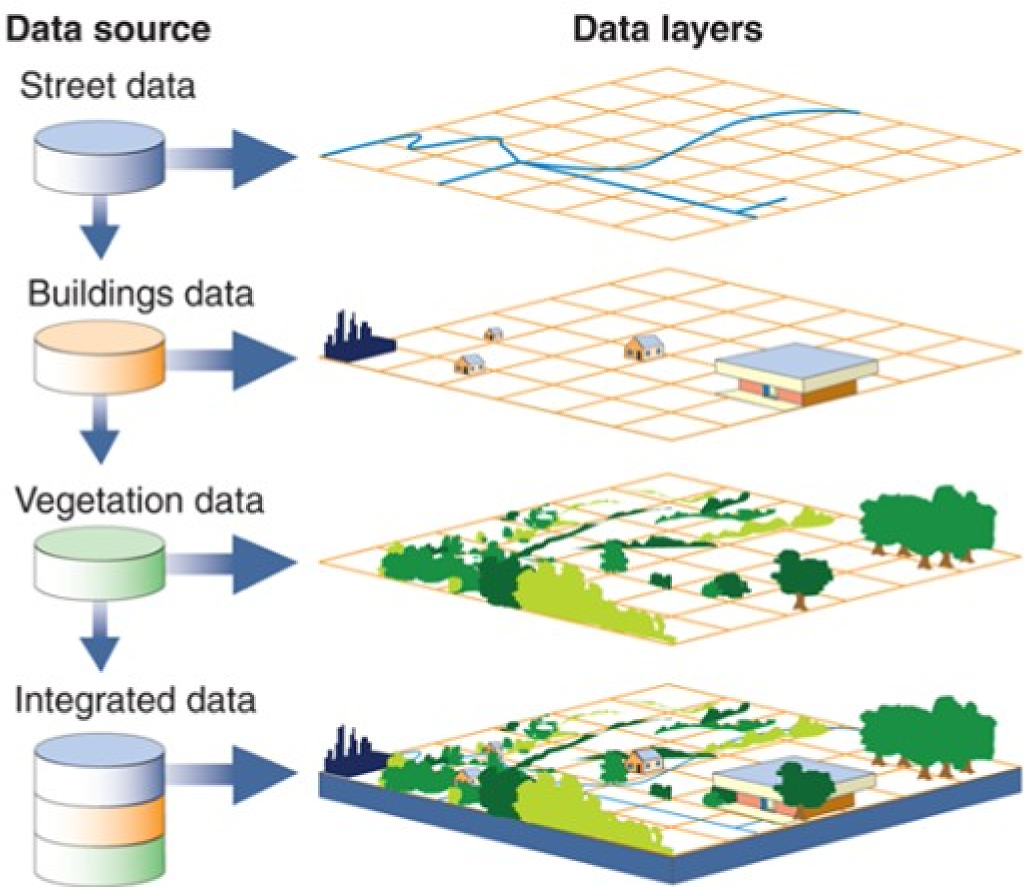


Figure (2.1): GIS Data Layers [20]

2.1.6 GIS Applications

Since its inception, GIS has been important in resource management, land-use planning, natural hazards assessment, wildlife habitat analysis, riparian zone monitoring, and timber management. GIS has also been used for emergency planning, crime analysis, public health, land records management, transportation applications, precision farming, and military operations. Four specific examples of GIS applications are discussed here. [1]

1-Riparian Management

Riparian buffers are strips of land along stream banks that can filter polluted runoff and provide a transition zone between water and human land use. Riparian buffers are typically defined using the buffering tool for vector data. Zimmerman, Vondracek, and Westra (2003) incorporated riparian buffers of 30 m and 100 m in their simulation study of agricultural land-use effects on suspended sediment concentrations in two watersheds. They reported decreases in sediment concentrations with the presence of riparian buffers, especially the 100 m buffer. [1]

2- Site Selection

Site selection of a ski resort, a supermarket, or a landfill must consider a large number of factors. It presents an ideal scenario for applying map overlay, a tool that can combine the locations and attributes from two or more layers in either vector or raster format. In their study of emergency evacuation shelters, Kar and Hodgson (2008) considered the following nine factors: flood zone; proximity to highways and evacuation routes, hazard sites, and health-care facilities; and total population, total children, total elders, total minority, and total low-income in the neighborhood. They chose a raster-based model because it was more efficient than a vector-based model. [1]

3- Response Time to Fires

Many countries have established guidelines for responding to disasters and emergencies such as fires. The response time to fires is the time it takes for the arrival of the fire brigades at a fire scene. Shortest path analysis is the toolfor calculating the response time. A study by Murray and Tong (2009) in Massachusetts (USA) reported that 25% of fires exceeded the response standard of four-minute travel time and, to be able to respond within four minutes to at least 90% of the fires, it would need 180 additional fire stations in Massachusetts. [1]

4- Visual Impact of “Greenhouse Parks”

A “greenhouse park” refers to the clustering of large-scale greenhouses on a single site. Although this clustering can reduce production costs by sharing infrastructure, such as energy, water, and gas facilities, it can impact the aesthetics of the surrounding landscape. Rogge, Nevens, and Gulinck (2008) applied viewshed analysis to a study of the visual impact of a greenhouse park in Belgium and found that it was visible in 39% of the area within a 1200-meter radius of the greenhouse park. They then examined different scenarios in which viewsheds could be reduced through the planting of trees and hedgerows. [1]

2.1.7 Computer Graphics

3D modeling

3D modeling (or three-dimensional modeling) is the process of developing a mathematical representation of any surface of an object (either inanimate or living) in three dimensions via specialized software. The product is called a 3D model. Someone who works with 3D models may be referred to as a 3D artist. It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. The model can also be physically created using 3D printing devices.

Models may be created automatically or manually. The manual modeling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting. [25]

3D Design

The term "3-D design" is a widely used abbreviation for three-dimensional design, incorporated commonly in design procedures associated with computers and other electronic drawing systems. In 3-D design techniques, a designer uses all three axes (x, y and z) to interpret and develop a realistic figure of the desired object.

Three-dimensional designs are usually developed on electronic interfaces, such as computers or other image/video processing machines, using some specially developed common software applications like Photoshop, AutoCAD, Flash, 3-D Studio Max and Maya. Upon development, these designs can be viewed electronically or in the form of printed 3-D objects. [26]

Definition of computer graphics

The term “computer graphics” refers to anything involved in the creation or manipulation of images on computers, including animated images. It is a very broad field, and one in which changes and advances seem to come at a dizzying pace. [3]

Other Definition

Computer graphics is an art of drawing pictures on computer screens with the help of programming. It involves computations, creation, and manipulation of data. In other words, we can say that computer graphics is a rendering tool for the generation and manipulation of images. [5]

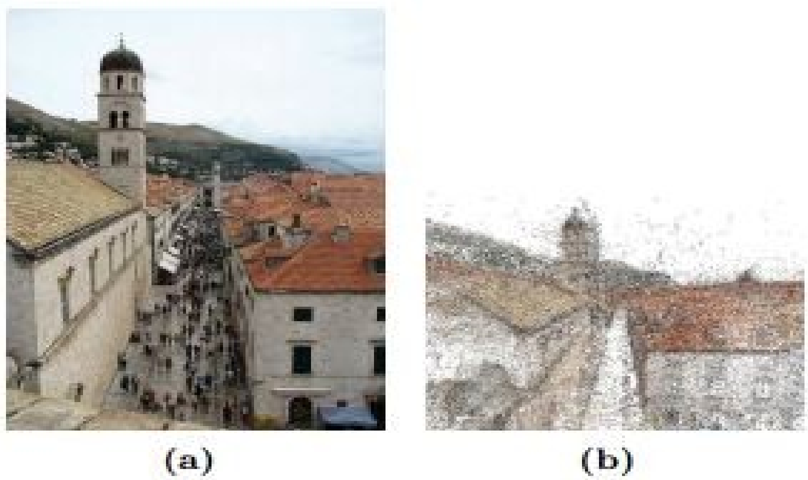


Figure (2.2): A scene from the city Dubrovnik, Croatia is reconstructed from 4,619 images yielding 3,485,717 points.

(a) Original image.
(b) Reconstructed point cloud seen from the same viewpoint. [13]

2.1.7 3D Reconstruction

The proposed methods to reconstruct buildings is implemented separately for each building. Some reconstructed buildings are presented in Figures ((2.3)-(2.6)).[14]

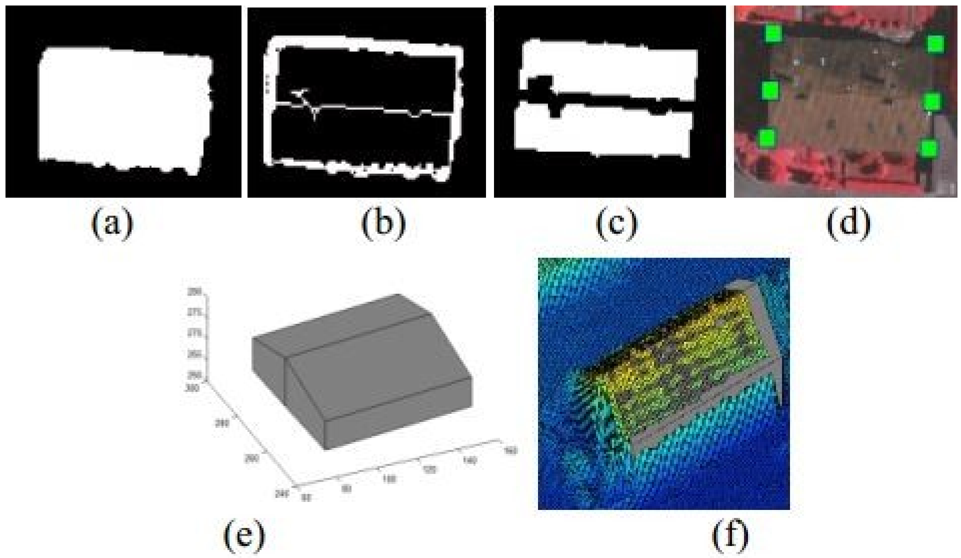


Figure (2.3): The reconstructed building.

(a) Detected parcel.

(b) Ridge line with boundary.

(c) Separated planes of roof.

(d) The roof corners.

(e) 3D model.

(f) Reconstructed 3D model on range image of LiDAR. [14]

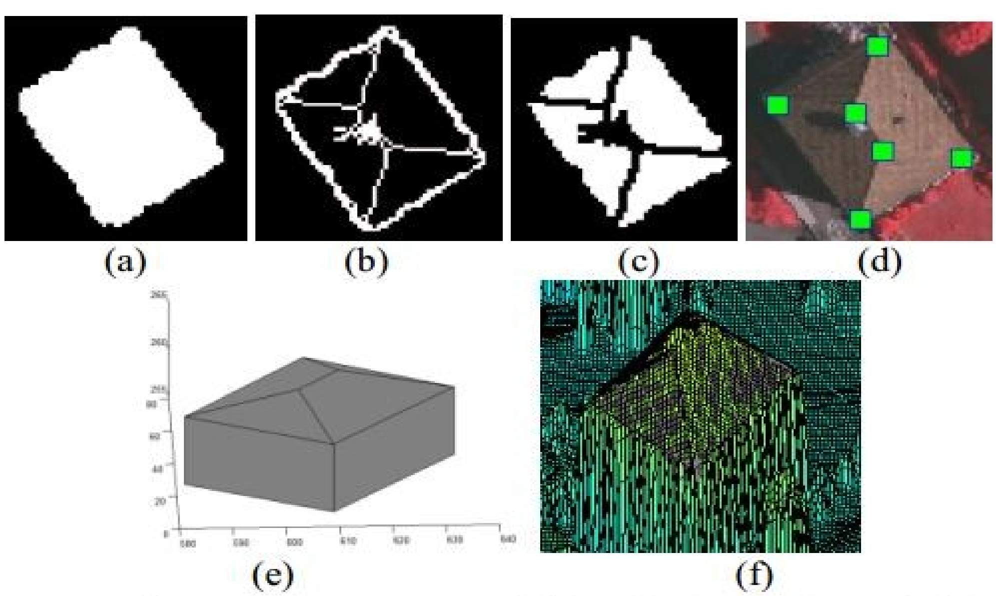


Figure (2.4): The reconstructed building.

(a) Detected parcel.

(b) Ridge line with boundary.

(c) Separated planes of roof.

(d) The roof corners.

(e) 3D model.

(f) Reconstructed 3D model on range image of LiDAR. [14]

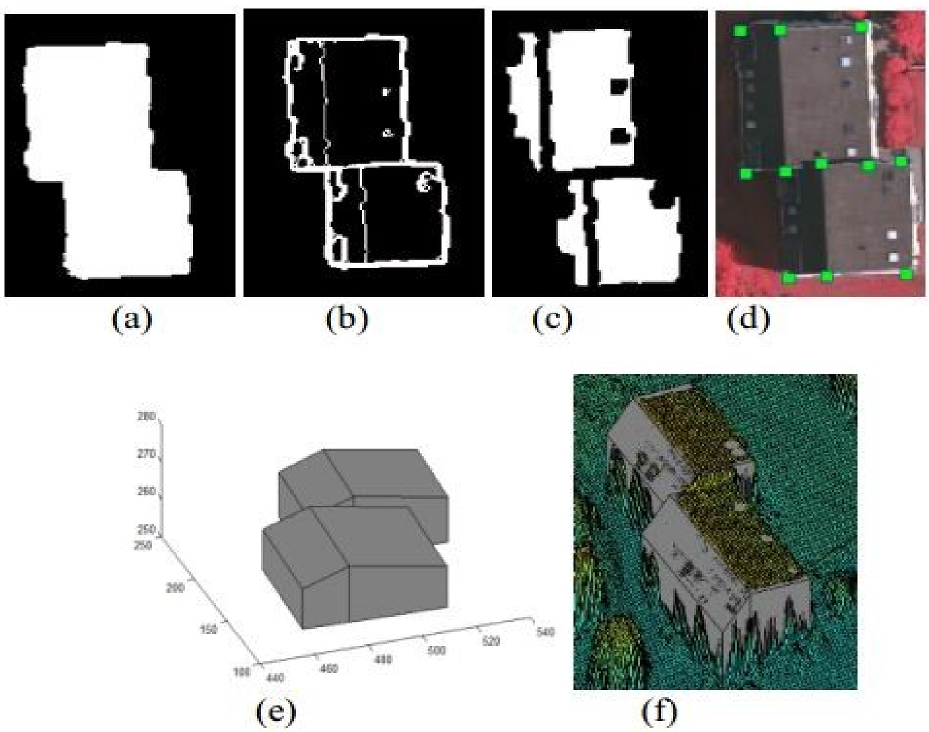


Figure (2.5): The reconstructed building.

(a) Detected parcel.

(b) Ridge line with boundary.

(c) Separated planes of roof.

(d) The roof corners.

(e) 3D model.

(f) Reconstructed 3D model on range image of LiDAR. [14]

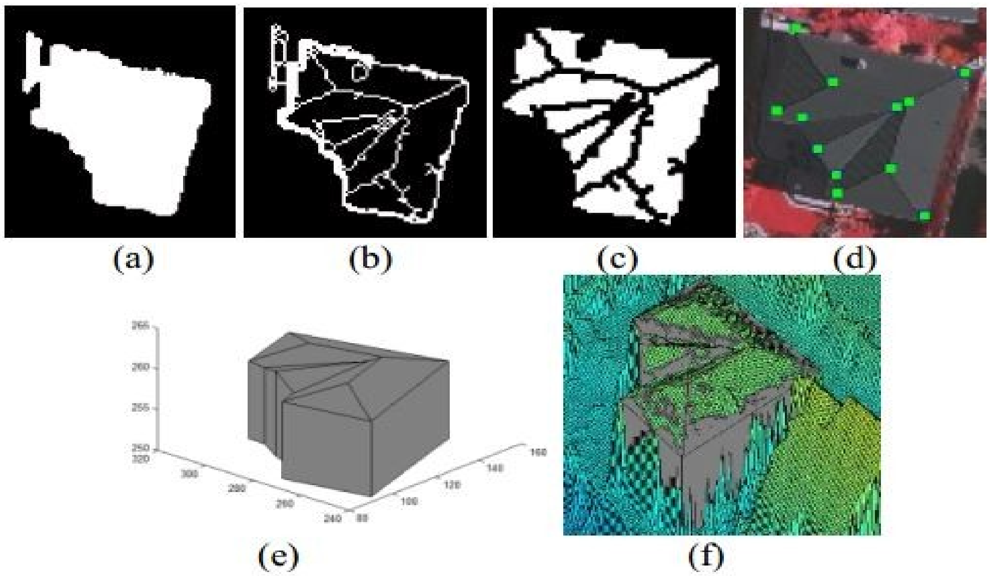


Figure (2.6): The reconstructed building.

(a) Detected parcel.

(b) Ridge line with boundary.

(c) Separated planes of roof.

(d) The roof corners.

(e) 3D model.

(f) Reconstructed 3D model on range image of LiDAR. [14]

2.1.8 Building Reconstruction

In order to separate buildings from the terrain surface and represent them by true 3D CAD models, ground plans are used in addition to the DSM data. For the reconstruction first appropriate building models have to be defined, which are fit to the observed data in the second step. [12]

2.1.9 Building Models

Object recognition or reconstruction, in general, presumes knowledge about the perceived objects by some kind of object model.

A model used for building reconstruction should be able to describe buildings of different complexity and it should permit the representation of geometric constraints during the reconstruction. Object models can be treated as abstractions of real world objects. The most important role played in model definition is the proper balance between the correctness and tractability, i.e. the results given by the model must be adequate both in terms of the solution attained and the cost to attain the solution.

In order to deal with the large architectural variations of building shapes, the utilized model should be as general as possible. In our approach a building is represented by a general polyhedron, i.e. it has to be bounded by a set of planar surfaces and straight lines. Generally, the interpretation of real world data presumes much a priori knowledge or in other words constraints. This can be achieved by applying a very rigid building model, i.e. a model with only a few parameters. Nevertheless, this limits the number of possible building types which can be represented by a single model. We provide the required constraints by the assumption that the coordinates of the given ground plan are correct and the borders of the roof are exactly defined by this ground plan. This supplies sufficient restrictions to enable the reconstruction of buildings without loosing the possibility to deal with very complex buildings.

Two approaches to represent the reconstructed buildings are feasible, boundary representation and constructive solid geometry. The boundary representation (BRep) is probably the most widespread type of 3D representation and already many algorithms are available for computing physical properties from that representation. Spatial objects are defined by their bounding elements, e.g... Planar faces; nodes and edges are defined by intersection of the bounding planes. The topology is additionally captured by a set of relations that indicate how the faces, edges and vertices are connected to each other. In constructive solid geometry (CSG) simple primitives are combined by means of regularized Boolean set operators. ACSG representation always results in valid 3D objects, i.e. in contrast to a BRep no topological check has to be performed in order to guarantee that the object surface is closed. CSG also enables a very compact object representation. Since a CSG can be transformed into a BRep, there are no complete solutions available in the opposite direction. This motivated us to use CSG as primary representation and to generate a BRep on demand e.g. for visualization purposes. Thus the advantages of both representations can be combined. [12]

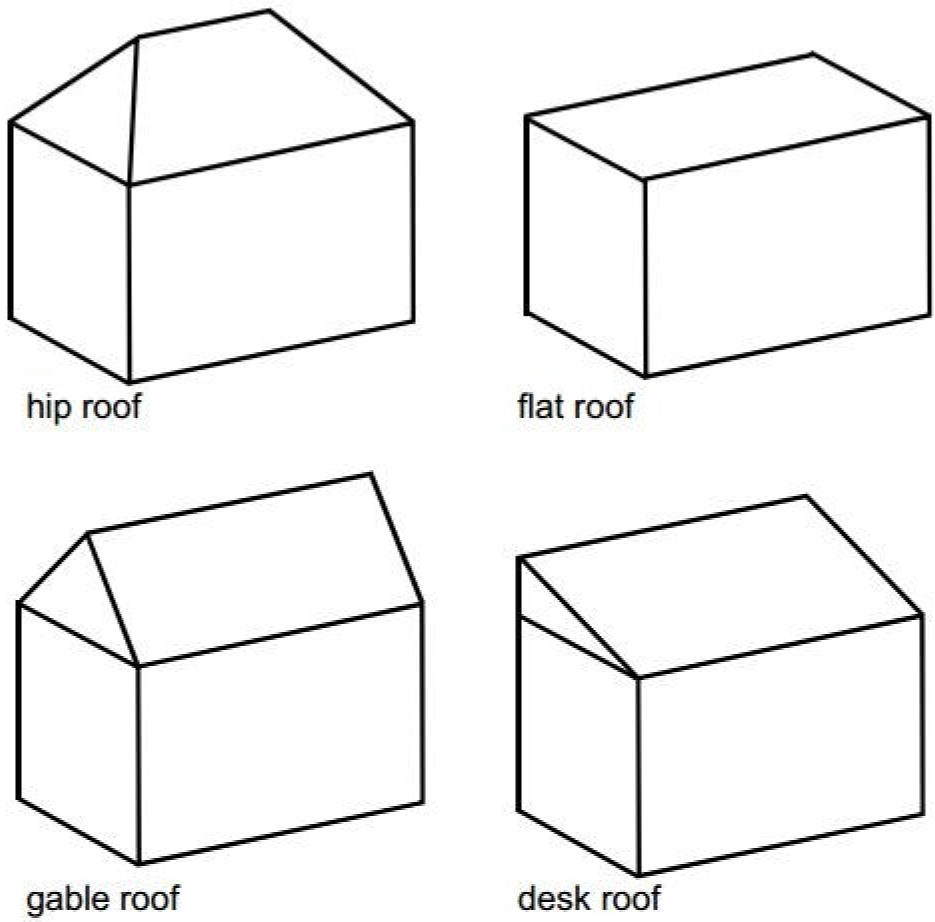


Figure (2.7): Building primitives used for reconstruction. [12]

Similar to (Englert and Gulch, 1996) we utilize a CSG representation which describes each building by a combination of one or more basic primitives. The set of four basic building primitives used for that purpose is shown in Figure (2.7) Each building primitive consists of a cuboid element with different roof types flat roof, pent roof, gable roof and hip roof. [12]

2.1.10 Creating Models

Before deciding how to construct the building models for the 3D urban map, several questions need to be answered to ensure the resultant map will be capable of serving the desired functions. The following should be considered:

- Geographic area? Does your urban map encompass a relatively small or large area, and approximately how many buildings are contained within this area? What is possible, desirable, and feasible for a small area might quickly become unrealistic or impossible for a larger, more densely constructed area.
- Map scale? The answer to this question will impact the level of detail necessary for the building models, where in the past a global or landscape scale was adequate, modern requirements demand city or campus scales.
- Required accuracies? What is important regarding the accuracy of building locations, size, and appearance? More does not always translate into better.
- How will the 3D map be used? Is visualization the primary application, or will spatial analysis be required? Knowing the answer to this question before you begin any construction will likely guide many of your decisions throughout the build-out process and likely influence if a photo-realistic or cartographic approach might make the most sense.
- Future growth plans? Ideally, any project to construct a 3D urban map should consider growth and maintainability—growth and change within the city itself and increased requirements and applications that may not be required or feasible today.

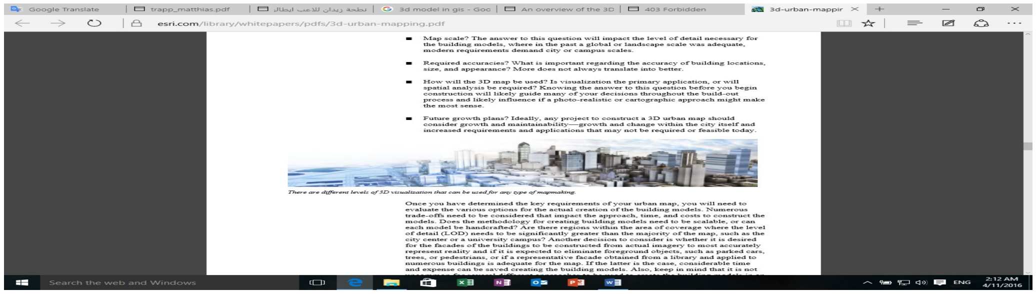


Figure (2.8): There are different levels of 3D visualization that can be used by any type of mapmaking. [7]

Once you have determined the key requirements of an urban map, we will need to evaluate the various options for the actual creation of the building models. Numerous trade-offs need to be considered that impact the approach, time, and costs to construct the models. Does the methodology for creating building models need to be scalable, or can each model be handcrafted? Are there regions within the area of coverage where the level of detail (LOD) needs to be significantly greater than the majority of the map, such as the city center or a university campusor airport? Another decision to consider is whether it is desired for the facades of the buildings to be constructed from actual imagery to most accurately represent reality and if it is expected to eliminate foreground objects, such as parked cars, trees, or pedestrians, or if a representative facade obtained from a library and applied to numerous buildings is adequate for the map. If the latter is the case, considerable time and expense can be saved creating the building models. Also, keep in mind that it is not uncommon for several different approaches to be used to create the building models in an urban map.

The next consideration is whether the sponsoring organization has the expertise and resources to build its own 3D urban map and building models using available products or if outsourcing the project to a service provider might be desirable. Depending on the size of the project's geographic area and/or the number of buildings to be modeled and their required LOD, various options exist. [7]

2.1.11 Photogrammetry

The name “photogrammetry" is derived from the three Greek words phos or phot which means light, gramma which means letter or something drawn, and metrein, the noun of measure. [2]

Photogrammetry is the science of obtaining reliable information about the properties of surfaces and objects without physical contact with the objects, and of measuring and interpreting this information. [2]

In order to simplify the understanding of an abstract definition and to get a quick grasp at the complex field of photogrammetry, we adopt a systems approach. Fig. (2.9) illustrates the idea. In the first place, photogrammetry is considered a black box. The input is characterized by obtaining reliable information through processes of recording patterns of electromagnetic radiant energy, predominantly in the form of photographic images. The output, on the other hand, comprises photogrammetric products generated within the black box[2]. A realistic view of this definition comes to an “old-fashioned” portrait – modern photogrammetry is much more versatile, as commented below.

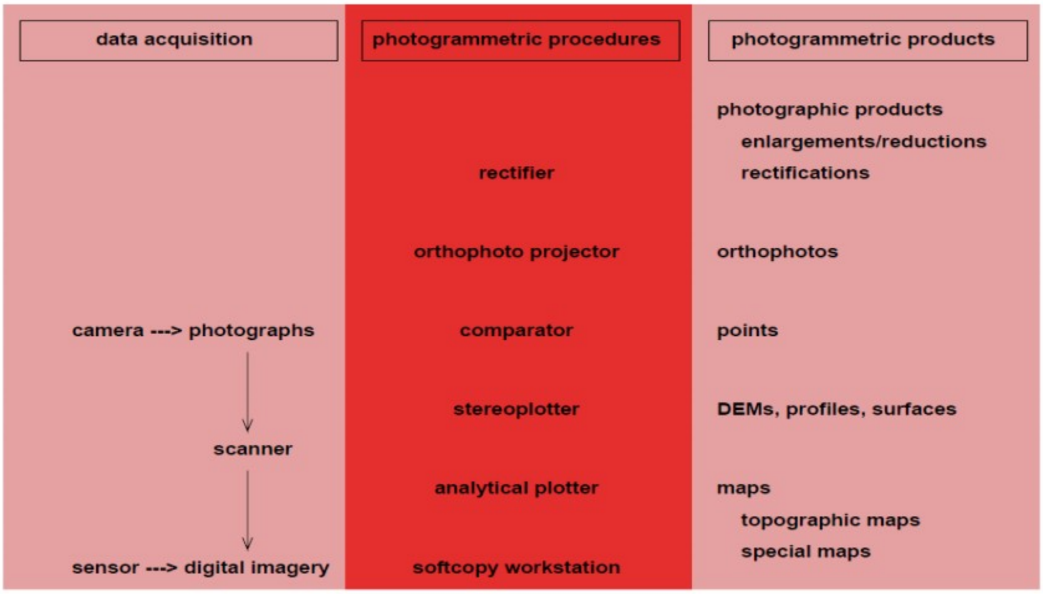


Figure (2.9): Photogrammetry portrayed as systems approach. The input is usually referred to as data acquisition, the “black box" involves photogrammetric procedures and instruments; the output comprises photogrammetric products. [2]

2.1.12 Types of Photogrammetry

Photogrammetry can be classified in a number of ways but one standard method is to split the field based on camera location during photography. On this basis we have Space Photogrammetry, Aerial Photogrammetry, Close-Range Photogrammetry and Mobile Photogrammetry. In Space Photogrammetry photos from satellites in an orbit higher than 600km are taken, providing nowadays Ground Sampling Distances (GSDs) of 0.3m (example: WorldView-3).

In Aerial Photogrammetry the camera is mounted in an aircraft, a helicopter or an Unmanned Aerial Vehicle (UAV) (also called Remotely Piloted Aircraft System, RPAS) and is usually pointed vertically towards the ground. Multiple overlapping photos of the ground are taken as the aircraft flies along a flight path. These photos are processed in a stereo-processing software pipeline (bundle block adjustment or structure-from-motion and Dense Image Matching algortihms) to provide very dense point clouds and thereafter Digital Elevation Models (DEM).

In Close-range Photogrammetry the camera is close to the subject and is typically hand-held or on a tripod (but can be on a vehicle too, which is then called Mobile Photogrammetry). Usually this type of photogrammetry is non-topographic - that is, the output is not topographic products like terrain models or topographic maps, but instead drawings, 3D models, measurements and point clouds. Everyday cameras are used to collect photos for modeling and measuring buildings, engineering structures, forensic and accident scenes, mines, earth-works, stock-piles, archaeological artifacts, film sets, etc. This type of photogrammetry (CRP for short) is also sometimes called Image-Based Modeling. [15]

2.1.13 Photogrammetric Camera

In the beginning we introduced the term sensing device as a generic name for sensing and recording radiometric energy. Figure (2.10) shows a classification of the different types of sensing devices.

An example of an active sensing device is radar. An operational system sometimes used for photogrammetric applications is the side looking airborne radar (SAR). Its main advantage is the fact that radar waves penetrate cloud and haze.

Passive systems fall into two categories: image forming systems and spectral data systems. We are mainly interested in image forming systems which are further subdivided into formatting systems and scanning systems. Image forming systems acquire all data at one instant in time. Scanning systems obtain the same information sequentially for example by collecting scanline by scanline. Image forming systems record radiant energy at different portion of the spectrum. The spatial position of the recorded radiation refers to a specific location on the ground. The image process establishes a geometric and radiometric relationship between spatial positions of the object and image space.

Amongst all of the sensing devices used to record data for photogrammetric applications, the photographic systems with metric properties are the most frequently employed. They are grouped into aerial cameras and terrestrial cameras. Arial cameras are also called cartographic cameras. Panoramic cameras are examples of non-metric aerial cameras. Figure (2.11) depicts an old aerial film-based camera. [2]. It should be mentioned here, that nowadays all aerial photos are collected using digital camera systems, based on CCD and CMOS technologies, but CMOS is the winner considering the progress in digital imaging technologies.

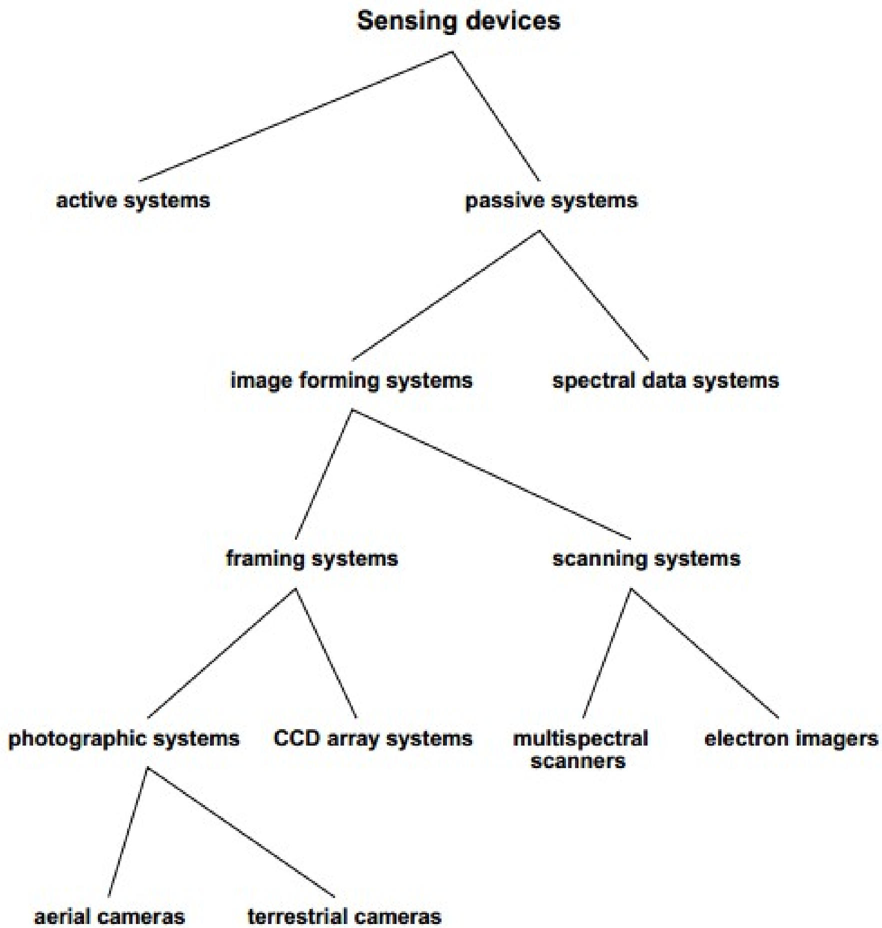


Figure (2.10): Classification of sensing devices. [2]

Figure (2.11): (A) aerial cameras Aviophoto RC20 from Leica. [2]

Figure (2.11): (B) Airborne photogrammetry. [21]

2.1.14 3D Scanning

To reduce the amount of manual measurements that must be taken, 3D scanning techniques may be employed. This also allows taking advantage of user assisted or automatic reconstruction methods, and therefore might save time compared to manual reconstruction. Not all 3D scanning techniques are suitable for scanning buildings, however. triangulation laser scanners and structured light techniques only have limited range, and thus are not suited for larger objects such as buildings. This leaves time-of-flight laser scanning as an option, but such equipment is very expensive. Several scans of the building are necessary, and each scan takes time and may need on-site calibration. Therefore3D scanning is considered an intrusive method in the workflow of a real estate agents. [13]. But with the new developments on terrestrial laser scanning this techn ology is directly competing with photogrammetry, as the devices, such as the Leica BLK 360 are not expensive anymore.

2.1.15 Photogrammetry

An alternative to 3D scanning which also reduces the amount of manual measurements necessary is using photogrammetry. 3D model reconstruction using photogrammetry may also take advantage of user assisted or automatic methods, and therefore is an attractive alternative to manual reconstruction. Image data may be collected using photography or video captures, and the range is not limited to objects of a specific size. As a real estate agent already brings a camera for collecting photographs of the building, using this camera for data acquisition is a simple, cost-neutral solution. Still, reconstruction using photogrammetry requires several overlapping images of the building, so the workload of the real estate agent will increase.

Based on the above discussion it is assessed, that collecting photographs for 3D model reconstruction using photogrammetry is the simplest, and most effective method for data acquisition. Although several photographs are needed in addition to the typical marketing photographs, this data acquisition method does not change the workflow of the real estate agent significantly. Moreover this solution is cost-neutral as opposed to investing in expensive 3D scanning equipment, and little or no on-site calibration is required. An additional advantage of using photogrammetry is that textures for the reconstructed model are available in the captured images, whereas additional photographs would be needed for manual reconstruction or 3D scanning.[13]

2.1.16 Techniques for 3D Mapping

3D Mapping is used for:

1. Robots operate in the three-dimensional world
2. Three-dimensional maps, which support
    - Object recognition.
    - More accurate path planning
    - More reliable localization and data association.
    - Navigation on uneven terrain.

2.1.17 3D Computer Graphics

3D computer graphics are works of graphics that were created with the aid of digital computers and specialized 3d software. In general, the term may also refer to the process of creating such graphics, or the field of study of 3d computer graphic techniques and its related technology. [6]

Today, efficient software packages are available to reconstruct the pose of the camera in an image and then doing an interactive 3D reconstruction of buildings and objects using vanishing line geometries.

2.1.18 Images and 3D Reconstruction

Generally, research about the usage of images is nothing new and takes place in relation to their usage in various contexts, such as engineering, design, architecture or for scientific and research context. Regarding the quality of images as visual signs there are many possible dimensions, such as similarities to a depicted object, visual styles, or creation processes. The use of images in a research related context would not only include functions such as memorization, documentation or communication within projects or of results. Such images would also be important for a solution finding process and related purposes such as information sorting and solution negotiation. Particularly the humanities, and especially archaeology, history of arts, and history of architecture, deal with historic images as sources of reconstruction. Types of sources and their relevance for

3D reconstruction are a prominent topic in scientific literature. But these are not new phenomena: Especially for the reconstruction of architecture, as the most prominent type of objects reconstructed by such projects, a communication via images has had a long tradition since early modern times. [8]

Results of 3D reconstruction are mostly static images, animations, or even interactive visualizations like computer games. An approach to classify is delivered in the Engagement taxonomy by Grissom et al., which differentiates six degrees of interactivity for such visual output. Closely related are questions for information transported by such visualization. Such aspects are theorized by several approaches as, for example, communication theories or visual learning theories.

Especially for 3D modeling and visualization there have been many technological developments during the last years. Generally these inventions are speedily adopted for reconstruction purposes, too. In publications there is a huge bandwidth of technologies described which are used or sometimes “abused” for such purposes, i.e. CAVE-like environments for visualization. In addition, modern technological trends like smartphones or web 2.0 are quickly adopted, as well as current socio-technological trends such as crowdsourcing or mobile computing.

Another trend is to move on from a presentation of static objects to complex and lively impressions of history, involving enhancement of visualization with dynamic elements like crowded places. Other trends are concerned with a presentation of content. This includes an increasing use of interactive Web presentation environments like Google Earth or Augmented Reality technologies as well as a materialization of virtual 3D models via rapid prototyping methods or multi sensual presentation possibilities. [8]

2.1.19 The 3D Mapping Landscape

As is so often the case with emerging technologies, several different techniques have been developed and deployed to create and represent an urban landscape in three dimensions. Some methods can quickly construct photo-realistic buildings but have limited use due to their lack of spatial accuracy or detail. Other approaches rely on accurately constructing each building model individually, which can often make sense when representing a city's important, but this methodology becomes nearly impossible to implement if the goal is to build out a city of 20,000 or more structures. A third alternative often relies on high-resolution remote-sensing data, such as imagery, to define each building's height, volume, and location and often some automation to make the creation of large cities realistic and possible.

To better understand the similarities and differences between the various approaches to 3D urban mapping, it is helpful to review some of the differences between an aerial photograph and a traditional 2D cartographic map. While the aerial photograph is a true picture and may be quite beautiful and realistic looking, it is only possible for the photograph to convey a limited amount of information. The cartographic map, on the other hand, which although somewhat cartoonish looking and not necessarily realistic in many aspects, can be designed to communicate a considerable amount of useful information such as road names, zoning, or cultural boundaries such as city limits. [7]

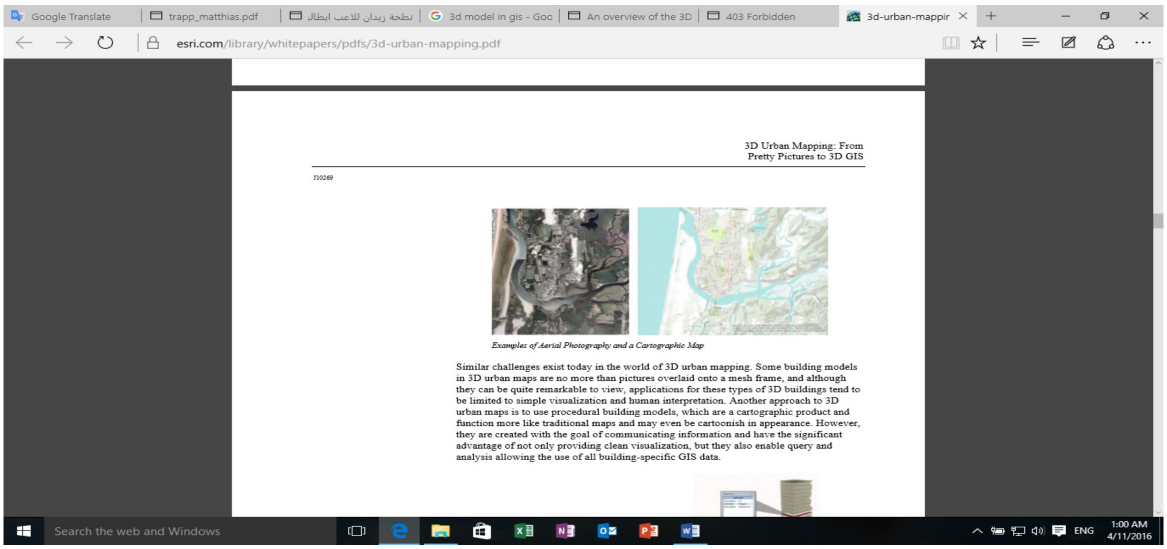
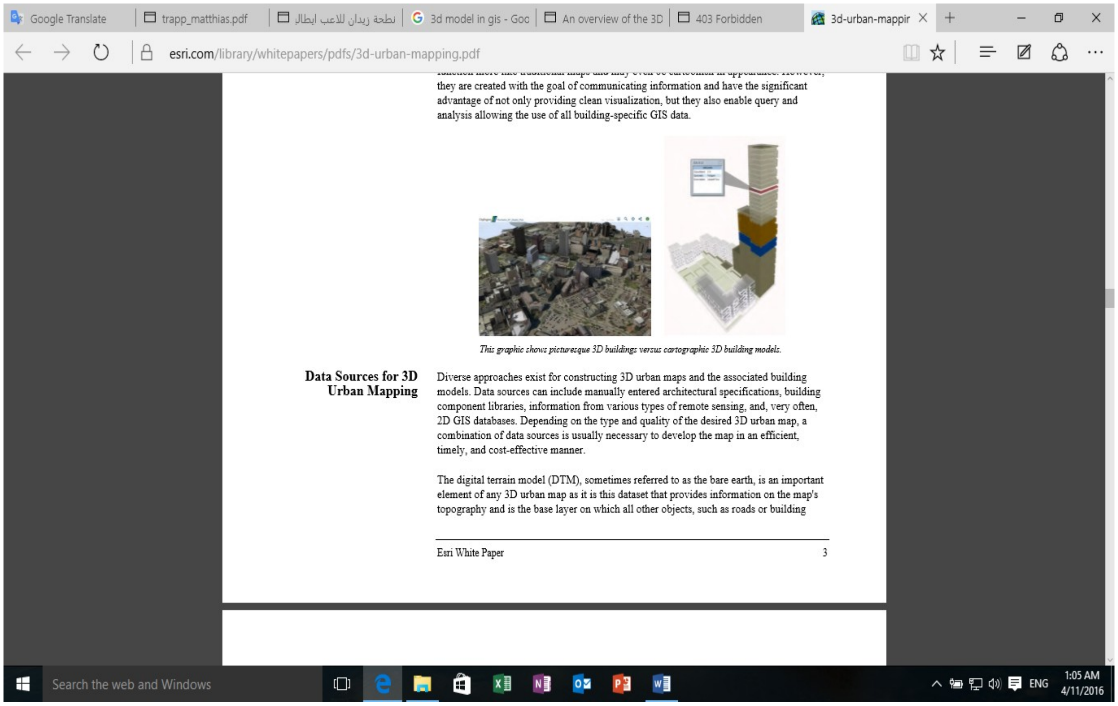


Figure (2.12): Example of Aerial Photography and a Cartographic Map. [7]

Similar challenges exist today in the world of 3D urban mapping. Some building models in 3D urban maps are no more than pictures overlaid onto a mesh frame, and although they can be quite remarkable to view, applications for these types of 3D buildings tend to be limited to simple visualization and human interpretation. Another approach to 3D urban maps is to use procedural building models, which are a cartographic product and function more like traditional maps and may even be cartoonish in appearance. However, they are created with the goal of communicating information and have the significant advantage of not only providing clean visualization, but they also enable query and analysis allowing the use of all building-specific GIS data(see figure (2.14)). [7]


they are created with the goal of communicating information and have the significant advantage of not only providing clean visualization, but they also enable query and analysis allowing the use of all building-specific GIS data.

This graphic shows picturesque 3D buildings versus cartographic 3D building models.

Data Sources for 3D Urban Mapping

Diverse approaches exist for constructing 3D urban maps and the associated building models. Data sources can include manually entered architectural specifications, building component libraries, information from various types of remote sensing, and, very often, 2D GIS databases. Depending on the type and quality of the desired 3D urban map, a combination of data sources is usually necessary to develop the map in an efficient, timely, and cost-effective manner.

The digital terrain model (DTM), sometimes referred to as the bare earth, is an important element of any 3D urban map as it is this dataset that provides information on the map's topography and is the base layer on which all other objects, such as roads or building

Esri White Paper 3

Figure (2.13): this graph shows picturesque 3D building versus cartographic 3building model. [7]

2.1.20 3D Modeling Software

The 3D modeling software is a class of 3D computer graphics software used to produce 3D models. Individual programs of this class are called modeling applications or modelers, 3D models represent a 3D object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling), or by scanning.

2.1.21 Modeling Process

The modeling process contains three types of modeling:

1. Polygonal modeling - Points in 3D space, called vertices, are connected by line segments to form a polygonal mesh. The vast majority of 3D models today are built as textured polygonal models, because they are flexible and because computers can render them so quickly. However, polygons are planar and can only approximate curved surfaces using many polygons.

2. Curve modeling - Surfaces are defined by curves, which are influenced by weighted control points. The curve follows (but does not necessarily interpolate) the points. Increasing the weight for a point will pull the curve closer to that point. Curve types include non-uniform rational B-spline (NURBS), splines, patches and geometric primitives

3. Digital sculpting - There are currently 3 types of digital sculpting: Displacement, which is the most widely used among applications at this moment, volumetric and dynamic tessellation.

2.2 Literature Review:

Extensive research developments have been carried out in the last years. Here a brief excerpt is cited in more details.

Review of Prior Studies:

2.2.1 Workflows and the role of images for virtual 3D Reconstruction of no longer existant historical objects

This is study proposed by S. Münster, Media Centre, Dresden University of Technology, D-1062 Dresden, Germany, and deals with 3D reconstruction of historical objects. Generally, research about the usage of images is nothing new and takes place in relation to their usage in various contexts, such as engineering, design, architecture or for scientific and research context. [8]

For the Methodology and Project Planning the author performed three stages of analysis using widely established methods from social sciences: the first stage was a qualitative content analysis for publications to examine current usage scenarios. The investigation included a sample of 452 journal articles and conference proceedings dealing with 3D reconstruction of historic items. A second stage performs a qualitative content analysis with a sample of another 26 international publications dealing with a reconstruction of no longer existant objects, and a third stage includes four case studies exploring 3D reconstruction projects of historic buildings over time to examine aspects of visual communication and their evolution during a project creation process. [8]

While most investigations focus on certain aspects or theoretical issues of images as sources or as results, there has been no systematic research specifically on roles and functions of images within the 3D reconstruction process and based on empirical findings until now. his main objective was to sketch a current state based on an empirical analysis of recent publications. What are research questions? On the one hand, his research interest was for phenomena visible within such projects. This includes the question for workflows, constellation and media produced. On the other hand, his investigated the role of depictions during the creation process, either as sources or as tools for collaboration or as results.

The results of this study perform a qualitative, explorative research using methods from social sciences. That indicates a possibly subjective decision taking. Moreover, the sample is, in relation to similar investigations, relatively small and based mostly on ex post material and should be further increased. Figure (2.15) demonstrates the workflow until the final visualization. [8]

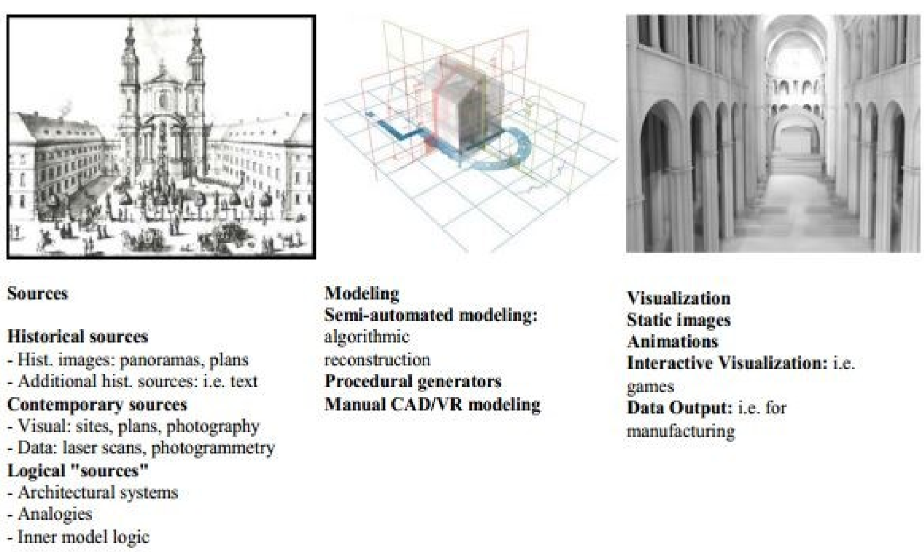


Figure (2.14): Classification Schema: Sources, Modeling, Visualization. [8]

2.2.2 GIS Applications for Building 3D Campus, Utilities and Implementation Mapping Aspects for University Planning Purposes

This is study was proposed by A. Al-Rawabdeh, N. Al-Ansari, H.Attya1 and S.Knutsson, The paper discusses the concept of 3D GIS modeling techniques using a simple procedure to generate a university campus model (real 3D GIS model) which will show the effectiveness of this approach. The 3D GIS model provides access to mapping data to support planning, design and data management. The primary objective is to improve data management (e.g., maps, plans, usage of facilities and services) and to develop methods using 3D spatial analysis for specific applications at the university. [9]

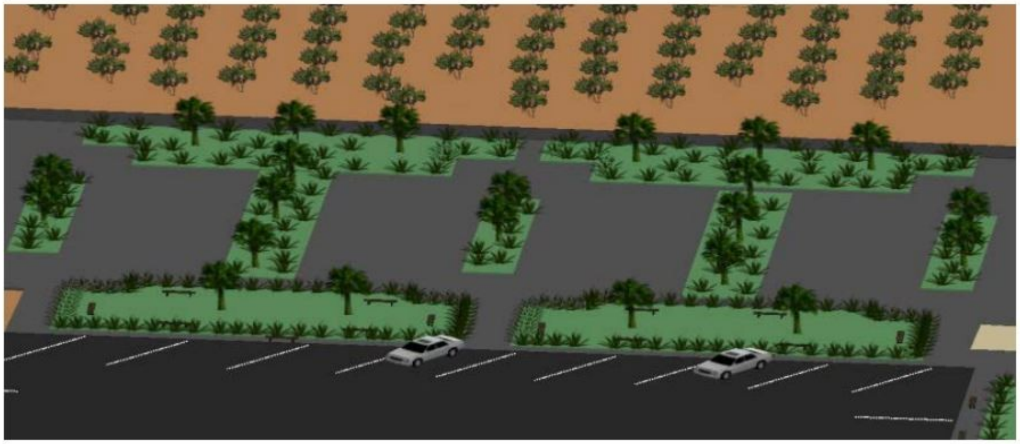
For the Methodology and Project planning the following steps are implemented to build a real world visualization of Al_Bayat University: data acquisition, generation of a 3D model, visualization of the 3D model. Detailed information on these works is presented in the following.

• Existing GIS layers: Layers are groups of features organized into an object called a Shape file. In this study, different vector layers were available from the Department of Maintenance and Engineering inside the l. These layers are: buildings layer, road networks layer and utility layers.

• AutoCAD files (CAD format data) made available from the scanned maps of the area and construction drawings. Raster imagery such as Google earth image for the area of interest;

• Attribute database and documentations related to the park's information. [9]

The results of 3D GIS provide urban designers and planners with a useful tool for modeling and analysis. The 3D GIS application was developed in order to evaluate urban space efficiently and to provide information about urban planning to local communities. The application enables users to visualize complicated urban planning information in the 3D way, to evaluate the allowable capacity of the block and to simulate building plans, as illustrated in Figure (2.16). [9]



(A): Green space 3D models with color texture using 2D vector layer in the ArcScene environment.

(B): 3D visualization: scenario prototype of main campus. (C): Identify tool in the 3D view and 3D campus model with roads networks layer.

Figure (2.15): (A, B, C) Prototype models of 3D visualization. [9]

2.2.3 Texture Mapping and Implementation Aspects for3D GIS Applications:

This study is proposed by Nedal Al-Hanbali, The objective of this research work is to examine the current off-the-shelf software technology to build texture for 3D GIS models using several techniques for various applications. The importance of such trend in city planning is a focus of this work in order to illustrate the effective use of 3D modeling and visualization techniques in the decision-making process to communicate ideas very quickly, which help take better decisions.

And delivers a solution for some applications such as 3D Cadastral mapping, and tourism. [10]

The Methodology and Project Planning In the following are the implementation steps applied to build a true reality 3D GIS model with texture mapping that is implemented for Ki0ng Hussein Park.

- Data Modeling.

- Data Measurements, Processing and Preparation
- Build 3D model.
- Build a 3D GIS model with all relational spatial data base.
- Texture Mapping. [10]

The results was as follows: first the exploration to effectively use a 3D GIS, second modeling in various applications, and third virtual city modeling to build three dimensional GIS models, that allow for 3D spatial analysis for various applications. The approach used in this work presents a simple strategy that is suitable for required spatial applications, and provides more realistic views and virtual reality environments. Moreover, two new procedures to add texture mapping to the 3D objects are discussed and compared. [10]

2.3 System Description of this Thesis

The Khartoum Land Terminal consists of a number of offices and halls, and the presidential offices, halls, and the departures hall. The current project relies on labeling and signs with names of departments and the names of the halls and offices of every building. For passengers during traveling time or arriving time, the Khartoum Land Terminal offers some banners greeting for each building and some information about the departments, halls with pictures.

The main objective of 3D modeling and is to build suitable procedures for Khartoum Land Terminal buildings and thus to serve as tools to make information accessible for passengers and visitors, who can investigate the Khartoum Land Terminal without going to the site.

In addition, the proposed system will be accessible from desktops and smartphones to take advantage of the virtual visualization anytime. The importance of land Terminals planning focuses on offering 3D real world visualization for Khartoum Land Terminal main buildings with its semantic information.

This project is implemented for Khartoum Land Terminal. For the project set-up and implementation a phone camera will collect most of the photos.

The project offers 3D visualization for buildings as well and provides information using a computer.

Chapter Three

Methodology and Research Planning

Overview

This chapter contains headlines, about the community of research (Study Area Khartoum State), and the Methodology and Research Planning. The latter one contains also the selected methodology and techniques.

3.1 Research Community and Study Area

First of all we will discuss the Study Area of Khartoum:

3.1.1 Study Area Khartoum State

Khartoum is the capital and largest city of Sudan and represents the state of Khartoum. It is located at the confluence of the White Nile, flowing north from Lake Victoria, and the Blue Nile, flowing west from Ethiopia. The location where the two Niles meet is known as "al-Mogran" (the confluence). The main Nile continues to flow north towards Egypt and the Mediterranean Sea.

Divided by the two Rivers Nile, Khartoum is a tripartite metropolis with an estimated overall population of over five million people, consisting of Khartoum proper, and linked by bridges to Khartoum North (al-Khartoum Bari) and Omdurman (Umm Durman) to the west. [22]

Location

Khartoum is located in northeast Africa, near the center of Sudan, Its neighbors are Chad and the Central African Republic to the west, Egypt and Libya to the north, the Red Sea to the northeast, Ethiopia and Eritrea to the east, and South Sudan, to the south. The Red Sea washes about 500 miles (800 km) of its northeast coast, and it is traversed from south to north by the Nile, all of whose great tributaries are partly or entirely within its borders.

Khartoum is located in the middle of the populated areas in Sudan, at almost the northeast center of the country between 15 and 16 degrees latitude north, and between 31 and 32 degrees longitude east. Khartoum marks the convergence of the White Nile and the Blue Nile, where they join to form the bottom of the leaning-S shape of the main Nile as it zigzags through northern Sudan into Egypt at Lake Nasser. [22]

The Khartoum Land Terminal includes several buildings management offices, departure halls, access hall, local hall, buses, mosques and others. So, how can we help travelers for the first time to guide them and how they can be supported using modern tools.

3.2 Methodology and Research Planning

The research methodology and project planning can be done well following the selected steps by using ARCGIS applications: Data acquisition, generation of a 3D model, and visualization of the 3D model. In the following the implementation steps required to design a true reality 3D GIS model of Khartoum Land Terminal are explained in more detail.

3.2. 1 Data Modeling

Data Collection is the first task in the pipeline, that means to look for all data of available geospatial databases and attribute data, no matter it is

- Images captured by scanning buildings for dense image matching.
- Point cloud files (Las data format).
- Files available from point clouds for the 3D model construction.
  - Attribute database and documentations related to the Khartoum Land Terminal information.

GIS Data Modeling: This is an important step to define all required geospatial databases including vector and raster classes and their relationship classes based on the defined objectives of the project. This will draft what is required and also missing to build the desired GIS data model. [10]

3.2.2 Data Measurements, Processing and Preparation to build the required 3D GIS.

Data Measurements and Capturing Photos is the process to get in-situ information's about the objects. This means we have to collect

- Stereo images of objects to build 3D models,
- Photos with good colored texture to be used as cover layer later on to build fully textured 3D models – also called Virtual Reality 3D.

Data Processing and Preparations In this process the following steps have to be carried out:

- Build point clouds for the area of interest (here AgiSoft PhotoScan is used).
- Build 3D view of the point clouds (Autodesk 3DMAX and Trimble SketchUp are used).
- Edit captured photos and add texture (MS Paint is used).
- According to the GIS data-model, build 2D layers and also add their attribute data (Esri ArcMap is used).
- Build relational databases within the GIS data model layers (Esri ArcMap and Esri ArcEditor are used). [10]

3.2.3 Build 3D Model

Based on required details and available spatial data and also according to the GIS data model design all the needed features are selected. In the following are the important implemented cases:

Case I: Simple 3D shape geometry. In this case the 2D layer was built and the height dimension was determined either by direct survey measurements or taken from CAD drawings. The 3D model can be built directly in the 3D GIS software environment. The shape appears like 3D block shapes (Esri ArcScene software is used).

Case II: 3D CAD Model is available. In this case, the dimensions have to be verified by scaling it with the built 2D layer and also via survey measurements. The final 3D model is then verified and georeferenced to its exact position on a map (Autodesk AutoCAD and Trimble SketchUp software’s are used).

Case III: Only 2D layer is available. In this case close range photogrammetry is used to build a 3D wire mesh of the required object(s) using the captured stereo imagery during the data capturing step (AgiSoft PhotoScan and Photomodeler software's are used).

Case IV: Some parts are available in 2D and others in 3D. Combination of case II and III is used, but it is very important to use a consistent reference system to merge all 3D objects into one object (Trimble SketchUp software works well in this case). [10]

3.2.4 Build a 3D GIS model with all relational spatial data bases

That corresponds to the 3D model. There are several techniques to insert the built-up 3D models from step 3 within the 3D GIS environment as follows:

The 3D GIS environment in our case is the **ArcScene** environment of the ArcGIS software. The datum for providing a reference base-height for any inserted point, 2D or 3D objects are chosen.

Case I: Simple 3D shape geometry. In this case ArcScene build the 3D model directly using the 2D vector layer with the added height information as part of the layer attribute for each feature in the layer, or added directly as a constant height for all features in the layer. A DTM is also specified as the base-height for all layers.

Case II: 3D CAD Model is available. In this case, if the CAD software has the capability to export the 3D model file into 3D shape file, it then can be inserted directly into the ArcScene environment. Quite often the file can be imported into SketchUp software, where it will be exported into the proper format for ArcScene. It is important to note that complex 3D models should be split as much as possible to smaller objects in order to be able to export it easily into the environment using the geodatabase format. Our practice found, that the best scenario is to use SketchUp software. You can better control your splitted objects since the export formats are geodatabase standards. Also, it is important to georeference the model to its exact position in ArcScene before exporting it.

Case III: Only 2D layer is available. In this case close range photogrammetry such as PhotoModeler orother photogrammetry software such as SOCET SET or Z/I can export the 3D model to 3D CAD model or shape file. Our recommendation is to convert the models to CAD format and then exporting them to SketchUp software and repeat the same as described above.

Case IV: Some parts are available in 2D and others in 3D. A Combination of case II and III is used, but it is very important to use a consistent reference system to merge all 3D into one object (SketchUp software works well in this case).[10]

3.2.5 The Methodology and Techniques

The applications and tools used for this thesis are:

1. **AgiSoft PhotoScan (Version 1.2.5):** Agisoft PhotoScan is an advanced image-based 3D modeling solution aimed at creating professional quality 3D content from still images.

Based on the latest multi-view 3D reconstruction technology, it operates with arbitrary images and is efficient in both controlled and uncontrolled conditions. Photos can be taken from any position, providing that the object to be reconstructed is visible on at least two photos. Both image alignment and 3D model reconstruction are fully automated. [4]

2. **SketchUp Make (Version 16.0.19912 64-bit):** SketchUp is a 3D modeling software from Trimble Navigation Limited that is used by both amateurs and professionals to design and model buildings, furniture, and other geometric structures. The software has a number of classroom applications - including connections to geometry, math, architecture, art, and geography - and can be used for structured assignments or open-ended exploration. Unlike many Computer Aided Design (CAD) tools, SketchUp's interface is simple enough that new users can begin building their own models the day they start using it.

   The Massachusetts Department of Elementary and Secondary Education has partnered with Trimble Navigation to offer school districts a free SketchUp Pro license, giving classroom access to the expanded version of the software and the chance to use the same design tools as professionals. With this license, educators across the state are already working with students on projects that combine rigorous engineering with creative inspiration. While the software is powerful, its interface is relatively simple: teachers find that they can learn it independently, and students derive a sense of pride from the models they have to make quickly. [16]

3. **Esri's ArcGIS (Version 10.4):** ArcGIS Desktop is comprised of a set of integrated applications, which are accessible from the Start menu of your computer: ArcMap, ArcScene and ArcCatalog. ArcMap is the main mapping application which allows you to create maps, query attributes, analyze spatial relationships, and layout final projects. ArcCatalog organizes spatial data contained on your computer and various other locations and allows for searching, previewing, and adding data to ArcMap as well as manage metadata and set up address locator services (geocoding). ArcToolbox is the third application of ArcGIS Desktop. Although it is not accessible from the Start menu, it is easily accessed and used within ArcMap and ArcCatalog. ArcToolbox contains tools for geoprocessing, data conversion, coordinate systems, projections, and more. [11]
   ArcMap will be used to build 2D GIS layers and data models, in addition to ArcScene that provides suitable 3D environments.

Chapter Four

System Analysis and Design

Overview

This chapter describes system requirements, which are subdivided into functional requirements and non-functional requirements, and system analysis with design.

4.1 System Requirements

The system requirements are subdivided into functional requirements and non-functional requirements.

4.1.1 Functional Requirements

This system illustrates the locations of the halls (departure halls) and buildings, it also supports a virtual visualization over desktop platforms to be accessible anytime. Moreover, also the locations of cafeterias are presented, and other facilities. Even locations of mosques and other places of prayer in the Khartoum Land Terminal are identified by defining restrooms and private sections for males and females.

The system aims to provide comprehensive information about all the Khartoum Land Terminal buildings, and above all, the system provides 3D design for the whole place.

It also aims to represent all resources within the Khartoum Land Terminal in a hologram, that means, the system offers real world visualization, helps passengers and administrators viewing the resources inside the Khartoum Land Terminal and administration buildings, It also illustrates locations of landmarks, gates and buildings.

4.1.2 Non-functional Requirements

The system must meet the following requirements, so that we get the best typical visualizations:

Performance

The most important requirement is the performance of the system which includes the following:

- Query and Reporting time: the response time between the mouse action and retrieving object information.
- Response time: also the time of loading the model, which is subject to the screen refresh times or orientations.

Maintainability

The model also has to be updated due to the ongoing renewal of Khartoum Land Terminal buildings.

Availability

The system needs to be available all the time, for every passenger over desktop and smartphone platforms.

4.1.3 Technical Requirements

The following technical system requirements are minimum requirements:

Minimal Configuration

- Windows XP or later (32 or 64 bit), Mac OS X Snow Leopard or later, Debian / Ubuntu (64 bit)
- Intel Core 2 Duo processors or equivalent
- 2GB of RAM

Recommended Configuration

• Windows XP or later (64 bit), Mac OS X Snow Leopard or later, Debian / Ubuntu (64 bit)

• Intel Core i7 processors

• 12GB of RAM

The number of photos that can be processed by Agisoft's PhotoScan depends on the available RAM and reconstruction parameters used. Assuming that a single photo resolution is of the order of 10 MPx, 2GBRAM is sufficient to make a model based on 20 to 30 photos. 12GB RAM will allow to process up to200-300 photographs.

4.2 System Analysis and Design

This section contains two topics - the first is a about Database Design and the second is about Database Transactions.

Shapefiles: A shapefile is an Esri vector data storage format for storing the location, shape, and attributes of geographic features. It is stored as a set of related files and contains one feature class. Shapefiles often contain large features with a lot of associated data and historically have been used in GIS desktop applications such as ArcMap.

4.2.1 Database Design

GIS layers are groups of features organized objectwise and are stored in a Shapefile format. In this project, two-dimensional and three-dimensional layers are used - the software in place for this work is Esri's ArcScene. The model comprises two-dimensional GIS layers, which contain the geospatial data of the objects. In particular these layers are the buildings of Khartoum Land Terminal layers.

4.2.2 Database Transactions

At present we have learned that information retrieval is essentially required, when the users inquire about a particular object by getting a popup message. Thus the data must be well organized. The three-dimensional design of the Khartoum Land Terminal will be visible for each passengers and visitors online for better view and access over desktops and smartphones allowing them to orient the model or retrieve geodata in response of a mouse click. This makes the inquiry process very easy.

Chapter Five

Simulations and Results

Introduction

This chapter contains a full documentation of the main interfaces of the system, which has been ordered according to the implementation using 3D modeling software sequentially.

1

2

3

4

5

5.1 Photogrammetry

Photogrammetry is the science of making measurements from photographs, especially for recovering the exact 3D positions of surface points.

In the following a 3D model of the main Khartoum Land Terminal is created. An excerpt of an aerial photo from Google Maps has been taken illustrating the region and location of Khartoum Land Terminal (see Figure 5.1).

After taking many photos the next step of the study was getting the point clouds of the buildings from a collection of overlapping images using Dense Image Matching. To build the required 2D and 3D GIS information system, some data measurements and processing were applied.

Figure (5.1): Location of Khartoum Land Terminal

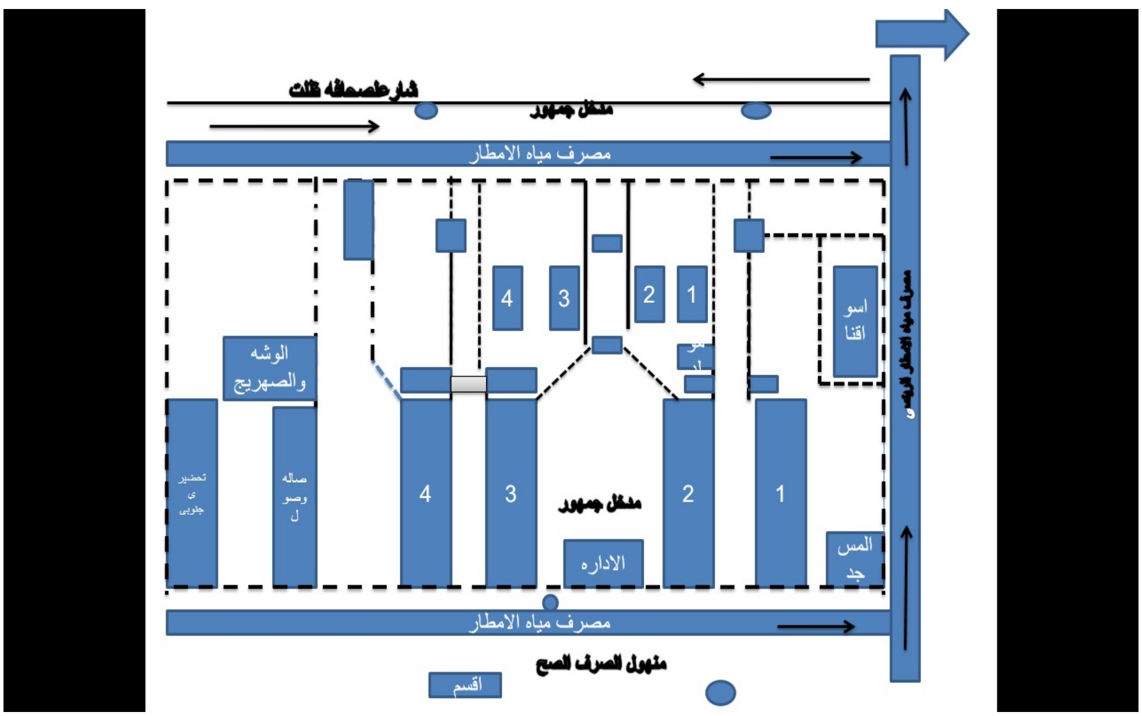


Figure (5.2): The features and buildings in the Khartoum Land Terminal. [24]

A set of overlapping images have been captured panoramically using a mobile phone camera as illustrated in figure (5.3). The basic concept of photogrammetry is the 3D reconstruction by moving the camera positions. This is called in Computer Vision “Structure-from-Motion (SfM)” or “Structure-and-Motion (SaM)”. The point features in overlapping parts are searched automatically by a SfM software and used for a spare 3D point determination in object space. The next step is using the poses of all photos and start the Dense Image Matching process. Here every overlapping – also called homologous pixel – is used for the determination of the disparity image. The disparity image contains the parallaxes along the moving direction to be used for a 3D forward intersection.

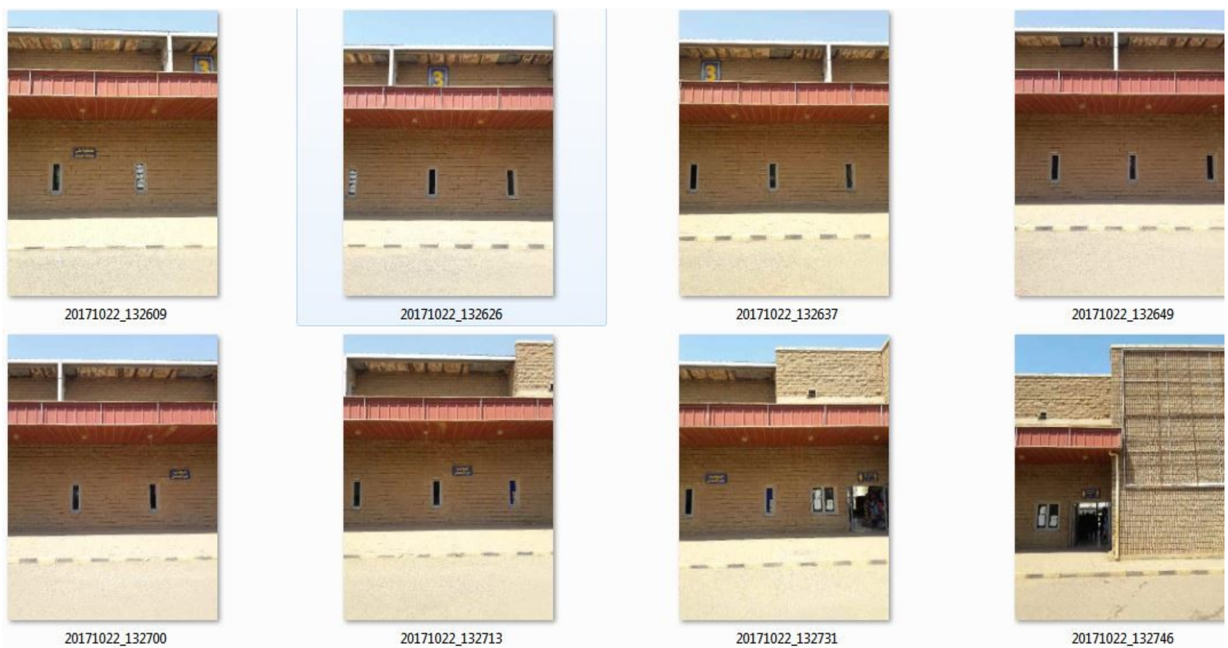


Figure (5.3): (A) a first set of overlapping photos

Figure (5.3): (B) a second set of overlapping photos

It is important to note that the overlaps along the movement and perpendicular to it should be in a range of 80%. The higher the overlap ratio the better is the reconstruction of 3D point clouds.

Figure (5.3): (C) A Third set of overlapping photos

5.1.1 AgiSoftPhotoScan(Version 1.2.5)

First we will give a tutorial to detail the workflow for processing photos into 3D models using Agisoft's PhotoScanPro software. PhotoScan is a widely used application that has made the complex algorithms necessary for processing photos into 3D models accessible through a fairly simple to use graphical interface. (see Figure (5.4).

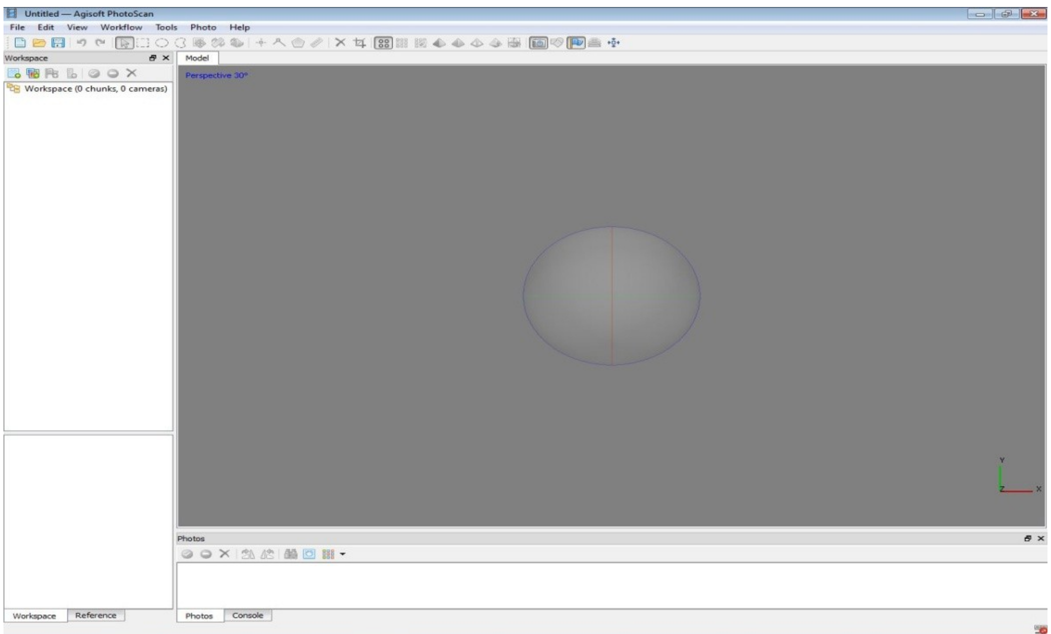


Figure (5.4): The Agisoft PhotoScan Main Window

5.1.2 The AgiSoft PhotoScan Workflow

PhotoScan makes the order of operations easy to follow via its Workflow menu. Basic operations can be accomplished by stepping through the menu and performing each of the following tasks in turn.

- Add Photos (or Add Folder containing all photos from shoot): This first step loads all of your raw images into the software’s interface.
- Align Photos: The first processing step compares the pixels in your photos to find matches and estimate camera locations and a sparse 3D geometry from them.
- Build Dense Cloud: Once satisfied with the alignment, the sparse point cloud (a mere fraction of the total data) is processed into a dense cloud in which each matchable pixel will get its own X, Y, Z location in 3D space.
- Build Mesh: This step connects each set of three adjacent points into a triangular face, which combine seamlessly to produce a continuous mesh over the surface of model
- Build Texture: In the final step, the original images are combined into a texture map and wrapped around the mesh, resulting in a photorealistic model of original object.

In order to improve results there are various options and other tools in the software beyond these basic steps.

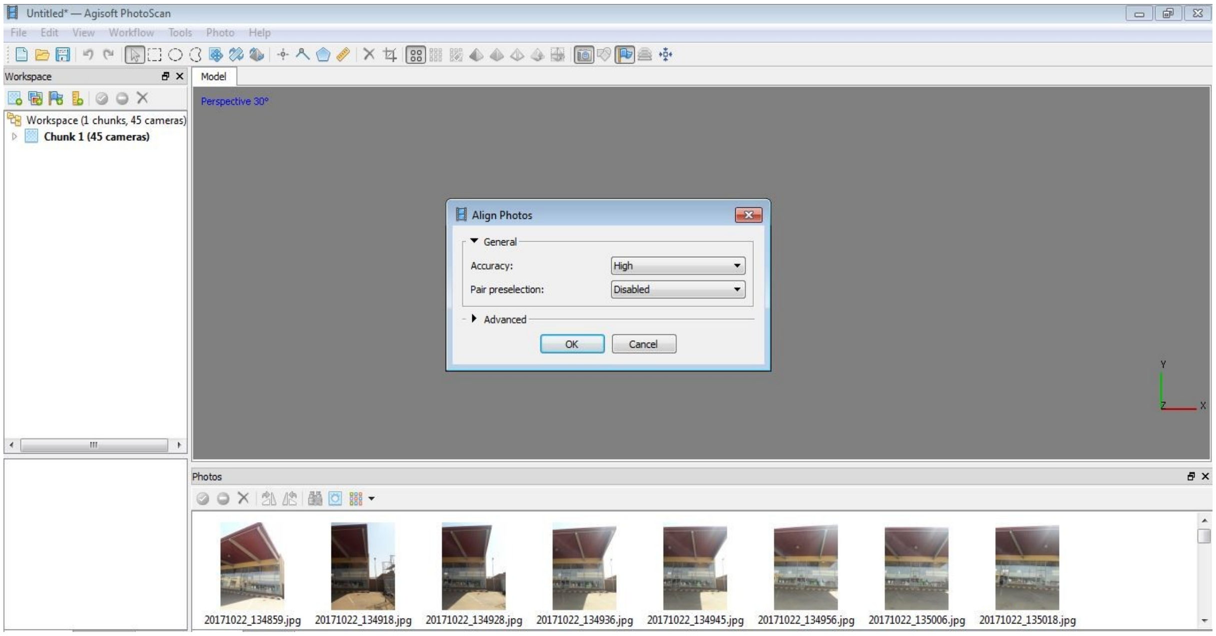


Figure (5.5): (A)Align photos

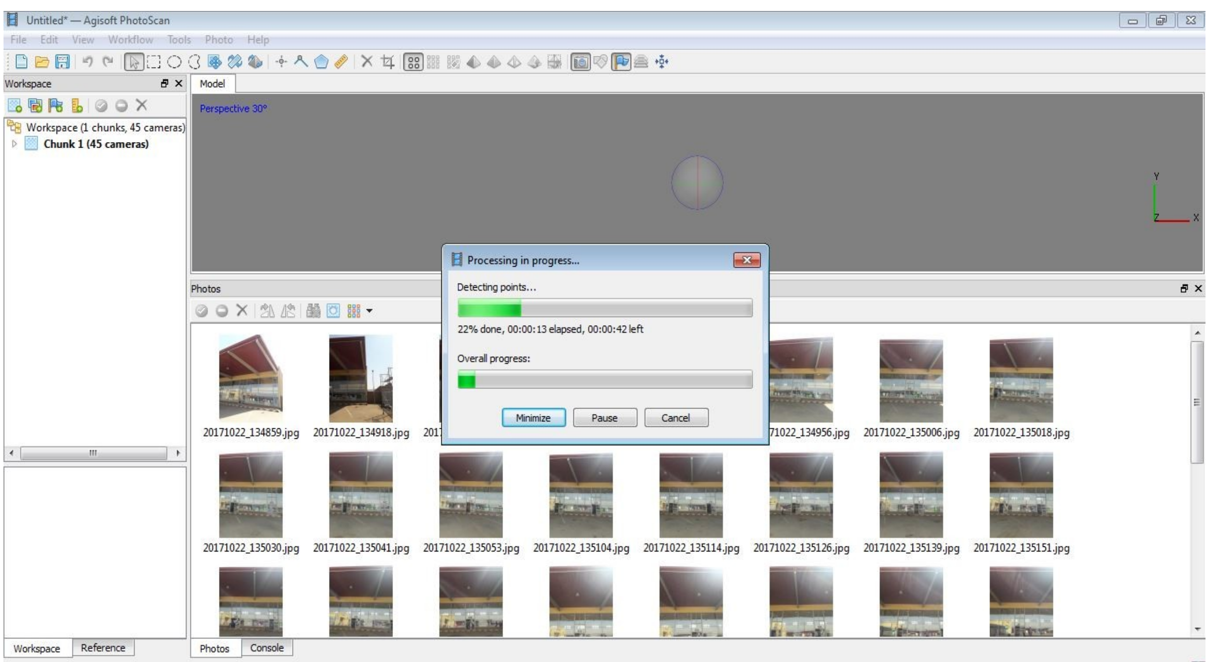


Figure (5.5): (B) Align photos and start with the sparse point processing

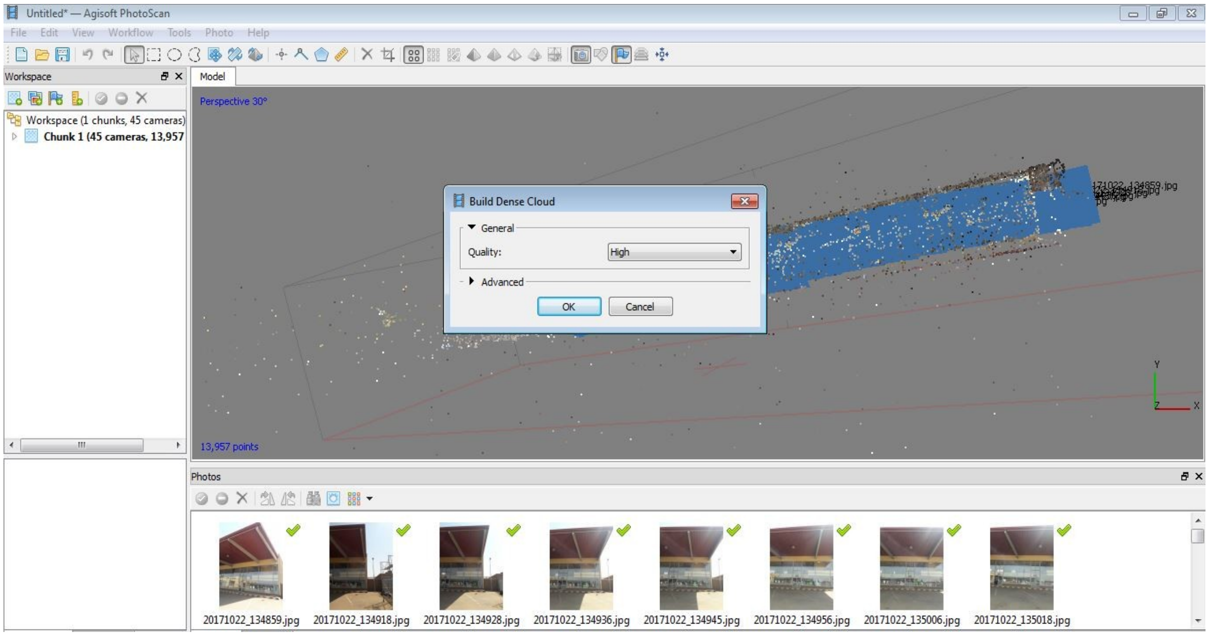


Figure (5.5): (C)Build Dense Point Cloud

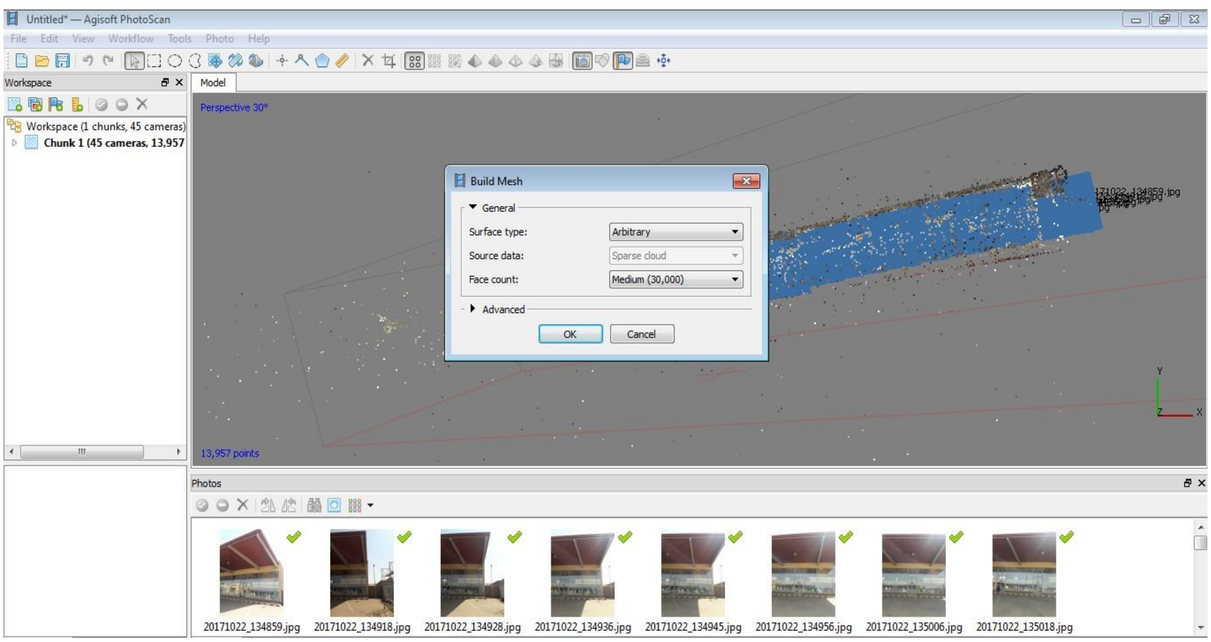


Figure (5.5): (D)Build a Mesh

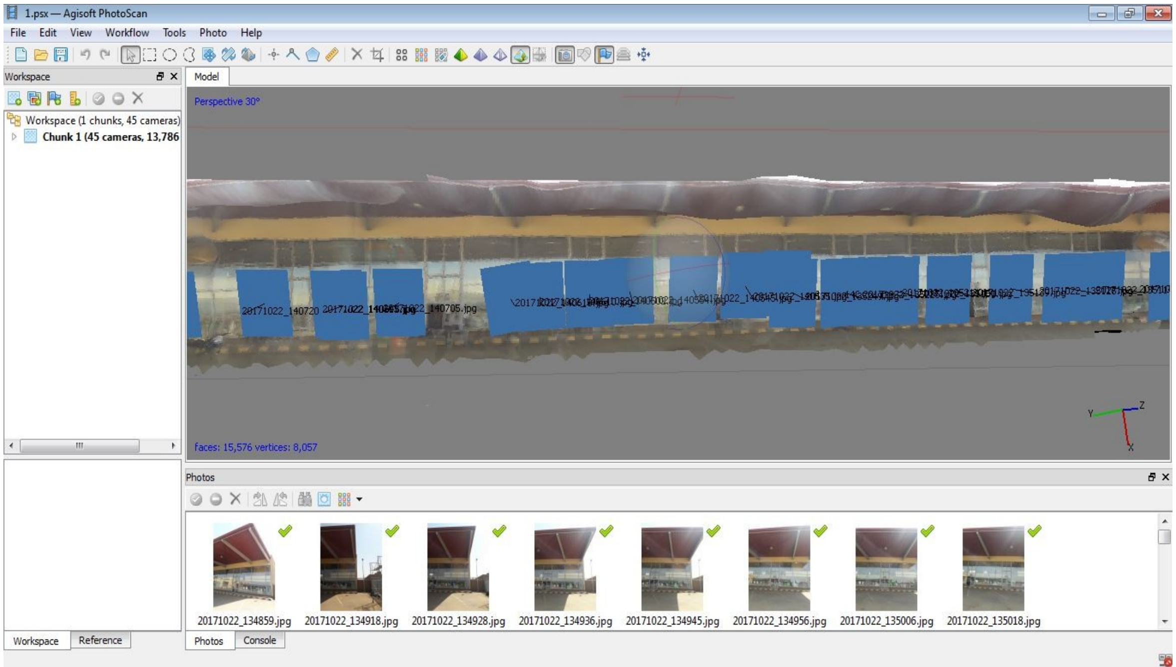


Figure (5.5): (E) Build Textual Point Cloud

5.2 3D Model Design

After getting the clored point cloud containg all the details the design of a vectorized 3D model of Khartoum Land Terminal using Trimble’s SketchUp pro software and Esri’s ArcGIS is the logical follow-up process.

5.2.1 SketchUp (Version 2016)

SketchUp is a 3D modeling program that can be used to create 3D objects in a 2D environment. Whether you plan to model for 3D printing or for other purposes, Sketchup offers all the tools needed to produce professional and quality results even for a beginner.

The SketchUp software works well for texture mapping and allows to customize and duplication of any shape or repeated pattern that can be fitted to various facets, such as windows, doors and openings or special decorations on the surface/sides of a building.

The Undet Extension package was used for importing the point cloud (in las format) files and adjusting objects. This works well with SketchUp (2015/2016 version) as an extension for importing numerous point cloud files, resulting from airborne LiDAR, Mobile Mapping Systems, Terrestrial Scanners, Handheld Scanners or Photogrammetry. The 2nd step was adding texture for the model to be built by customized point clouds. SketchUp's synthetic textures and image textures were used to guarantee better visualization and true virtual reality. This is demonstrated in Figure (5.6).

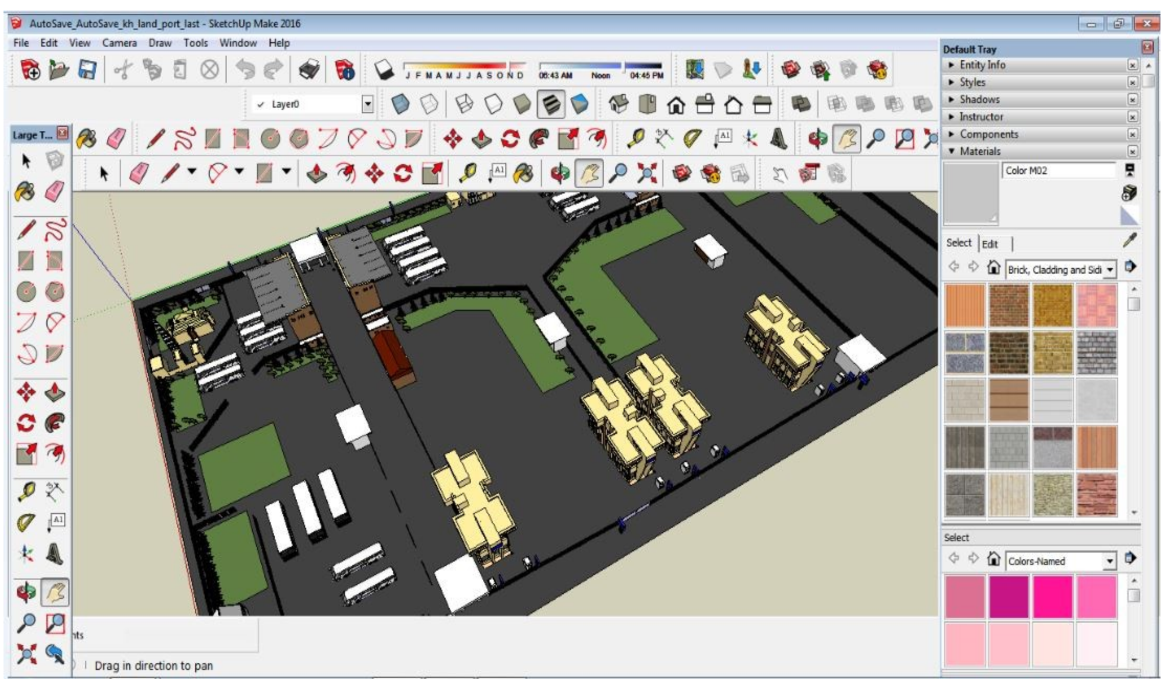


Figure (5.6): (A) 3D Model with Synthetic Texture

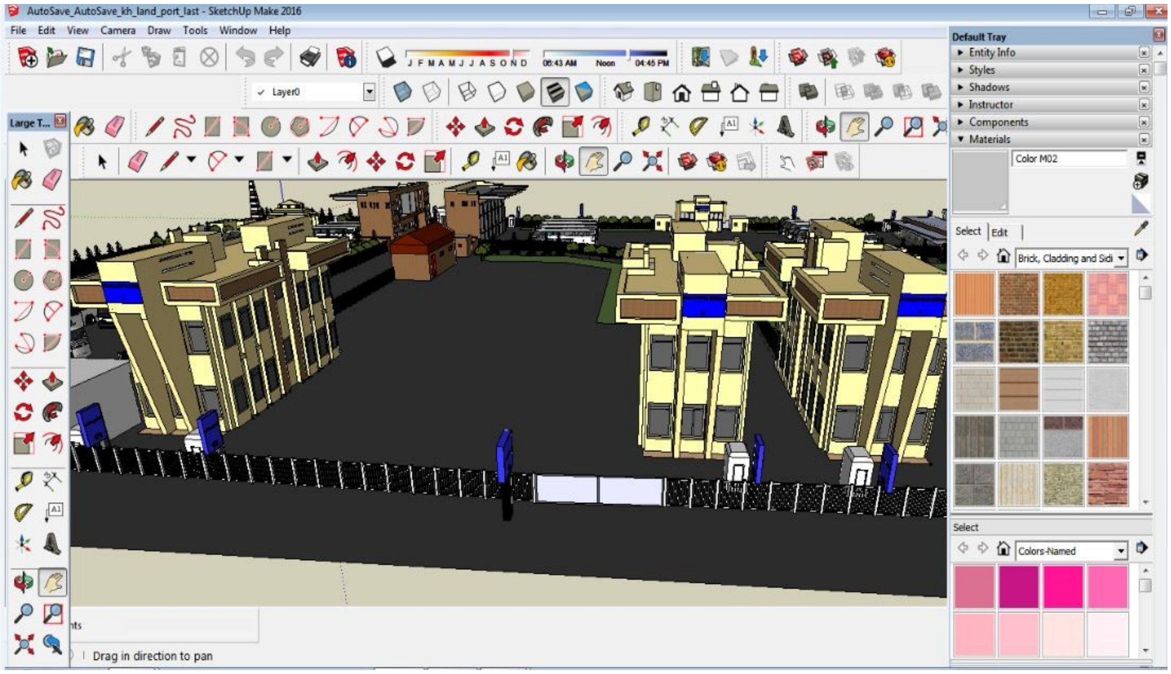


Figure (5.6): (B) a more detailed view of the VR Model with Synthetic Textures.

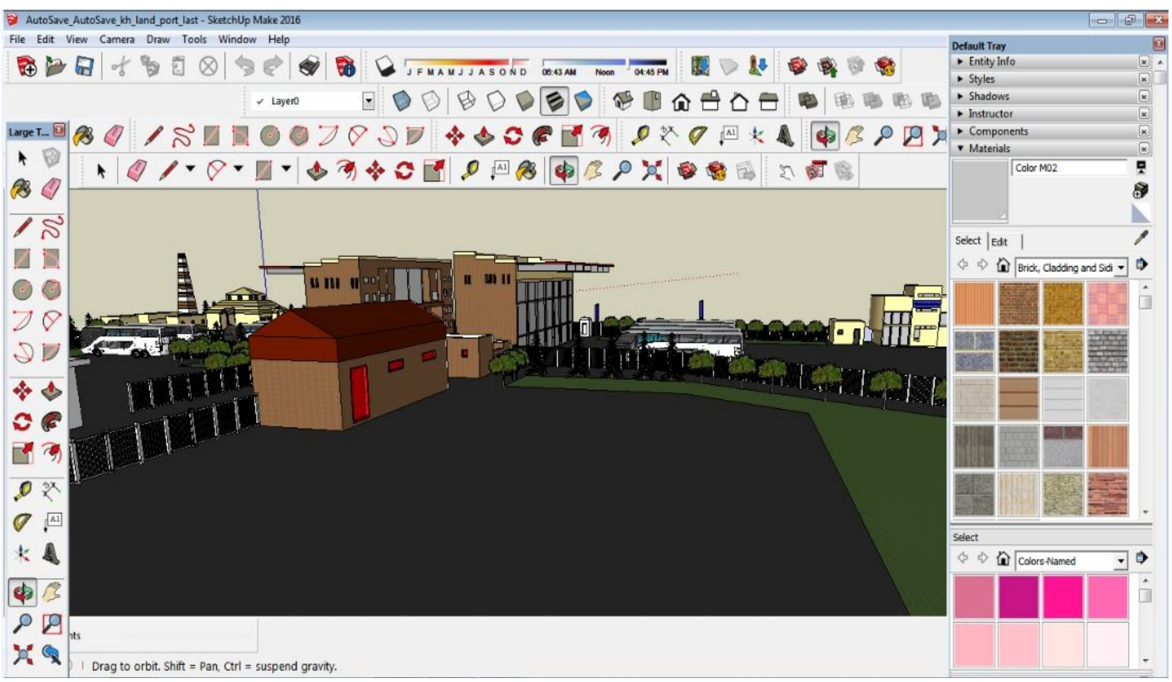


Figure (5.6): (C) a further view

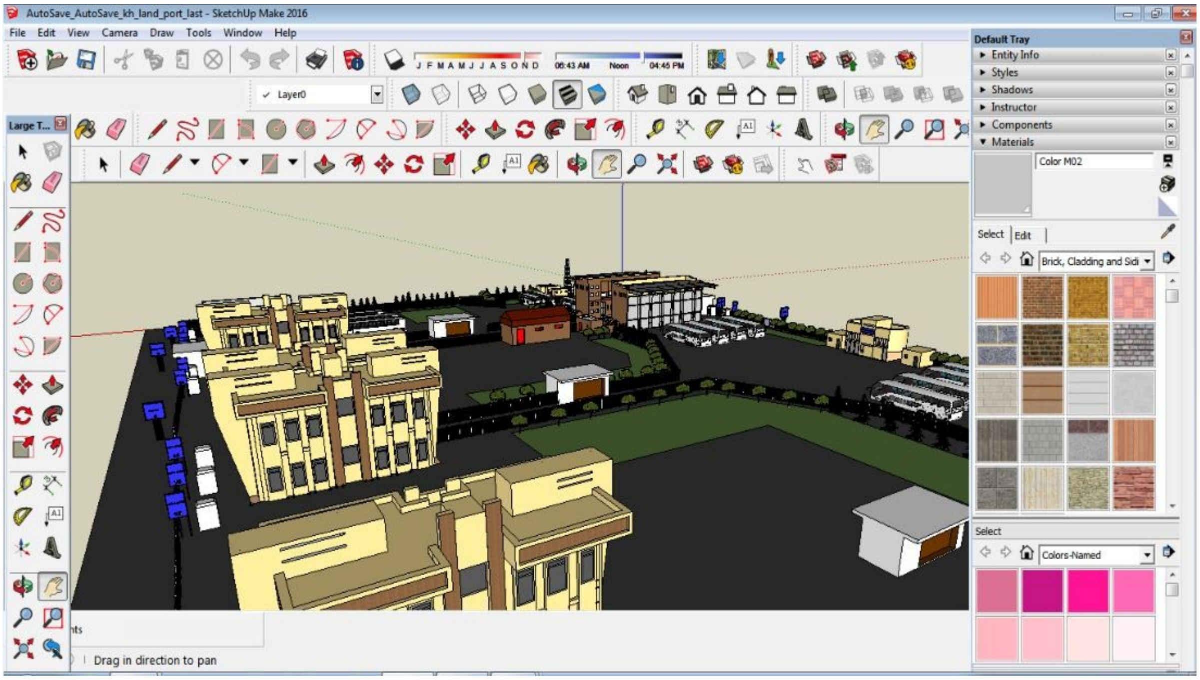


Figure (5.6): (D) a further view

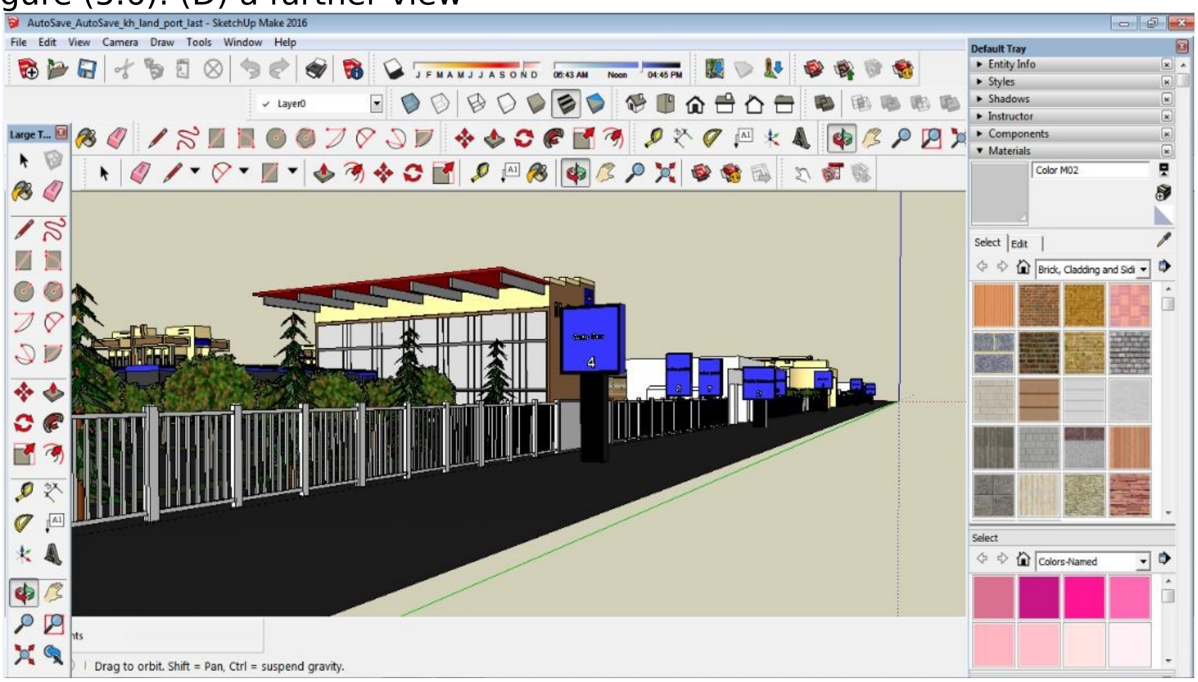


Figure (5.6): (E) a further view

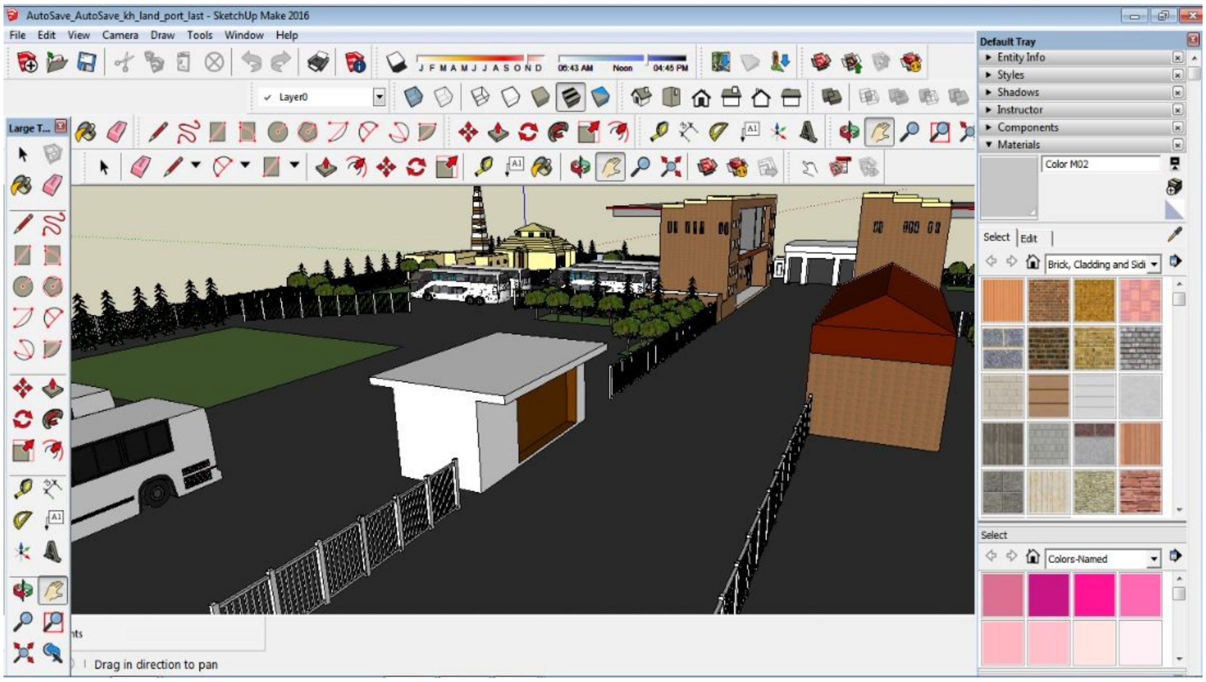


Figure (5.6): (F) a further view

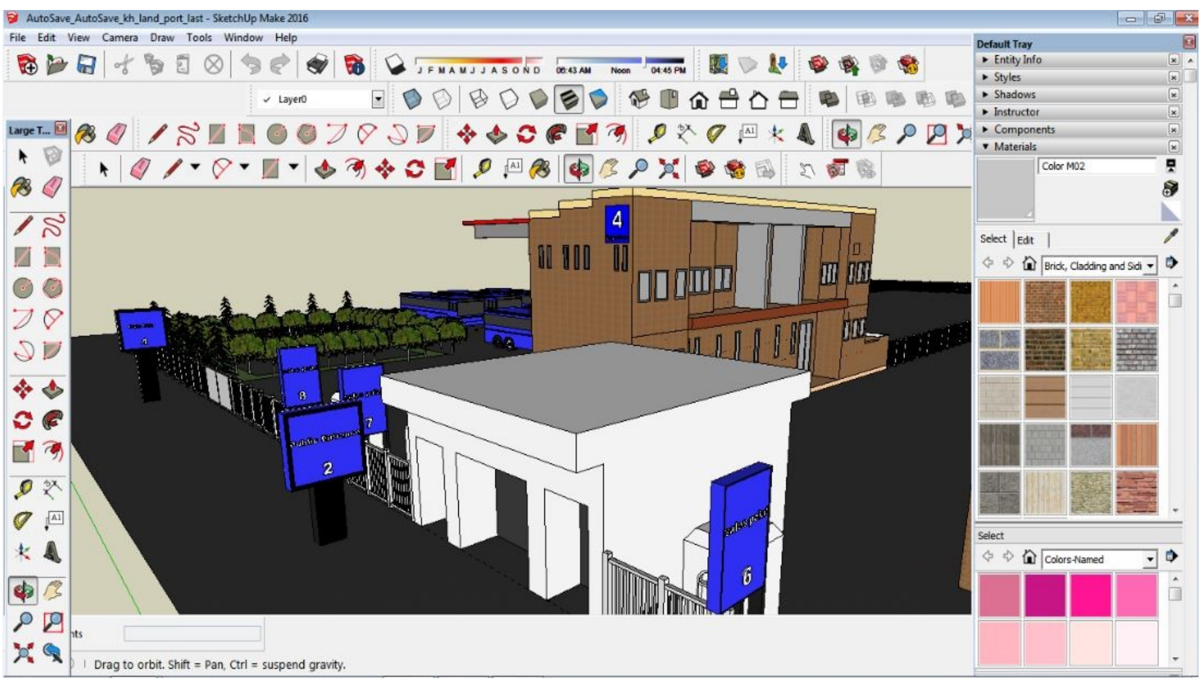


Figure (5.6): (G) a further view

Figure (5.6): (H) a further view

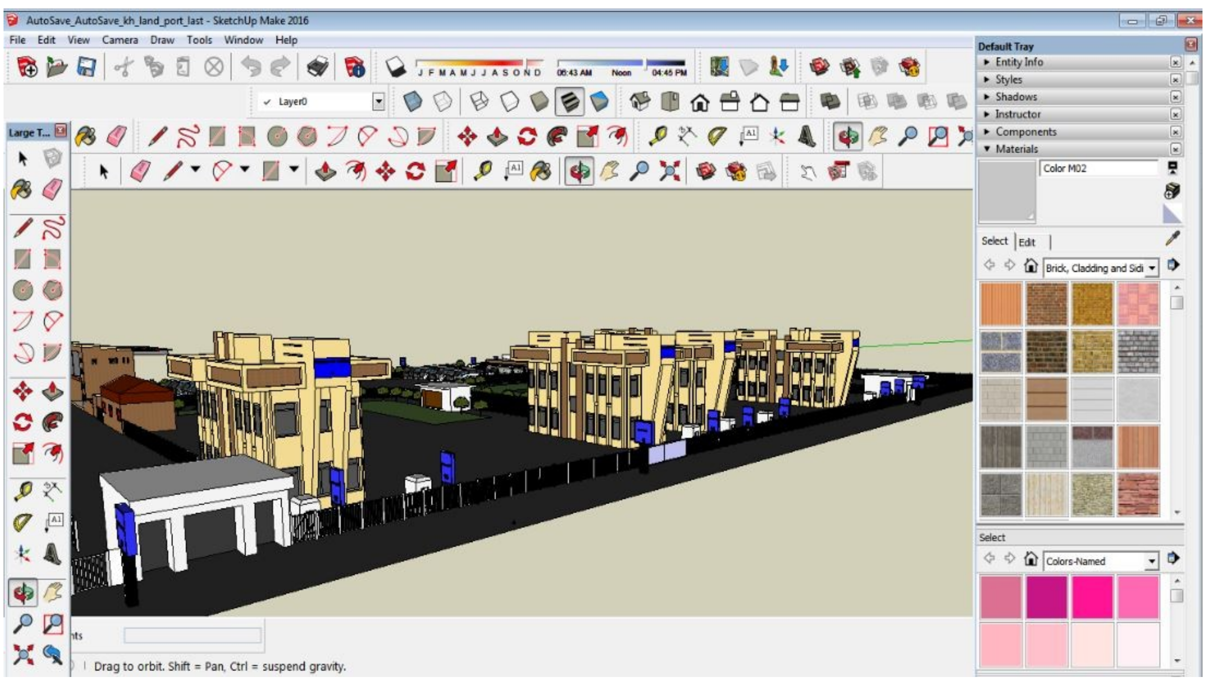


Figure (5.6): (I) a further view

In Figures (5.6):(A, B, C, D, E, F, G, H, I) the Final SketchUp results for Khartoum Land Terminal 3D Model are visualized, seen from different views.

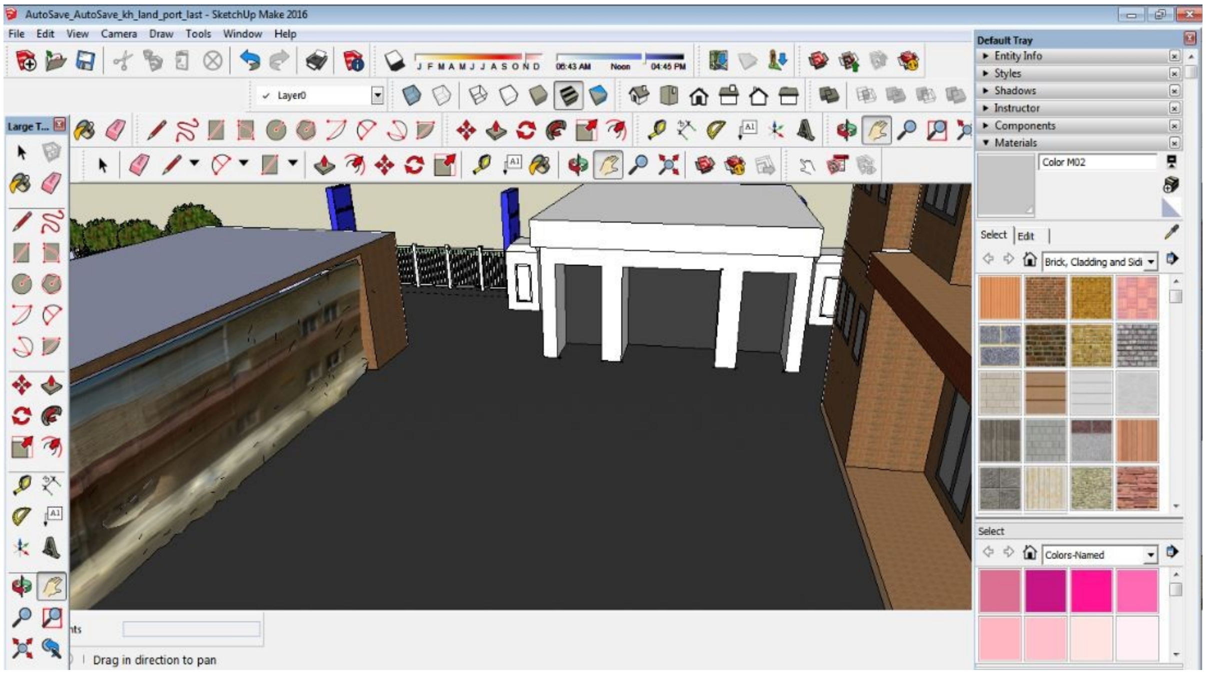


Figure (5.7): (A)

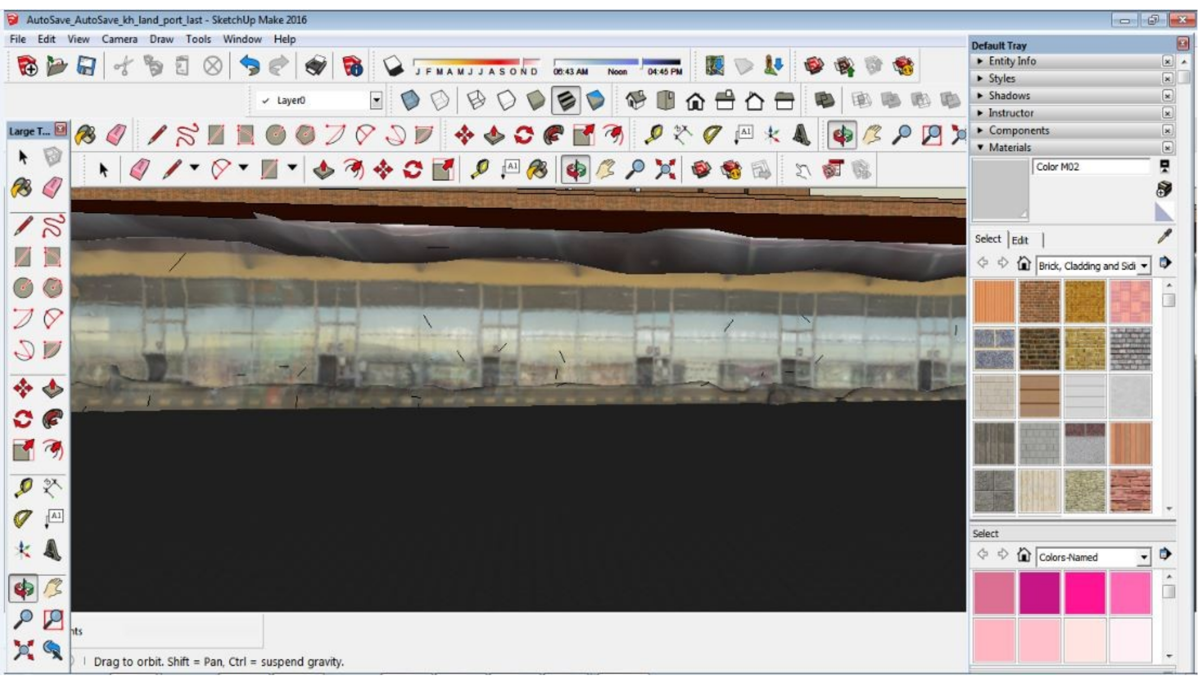


Figure (5.7): (B)

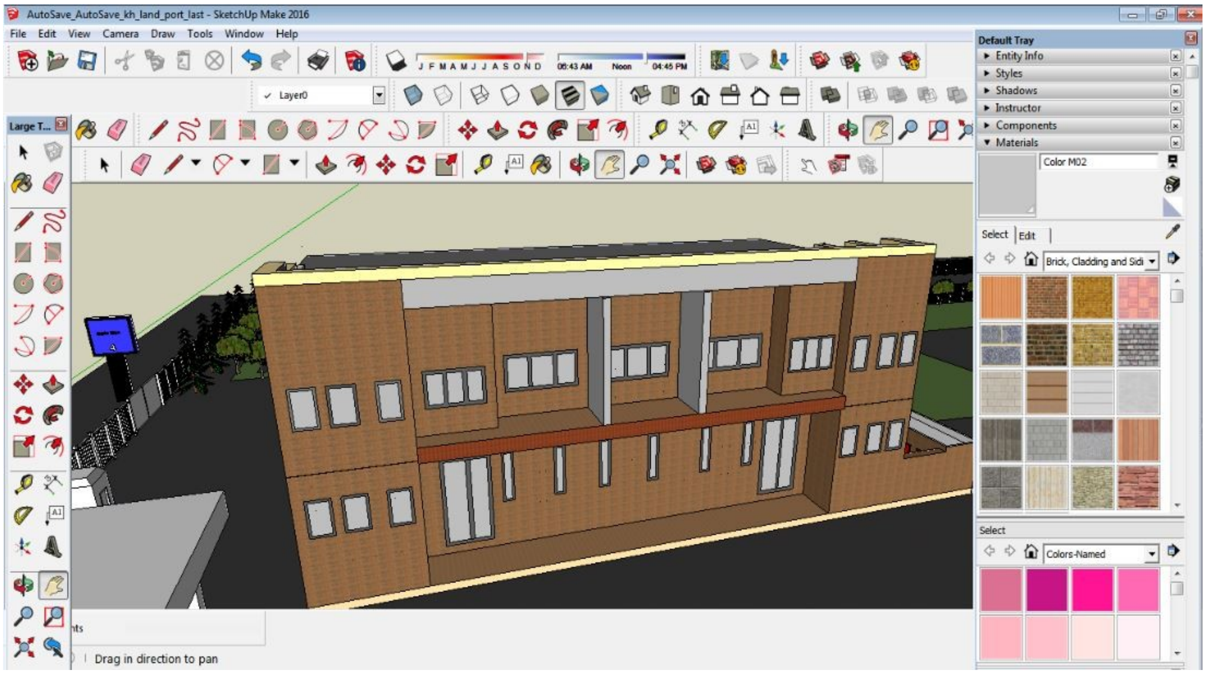


Figure (5.7): (C)

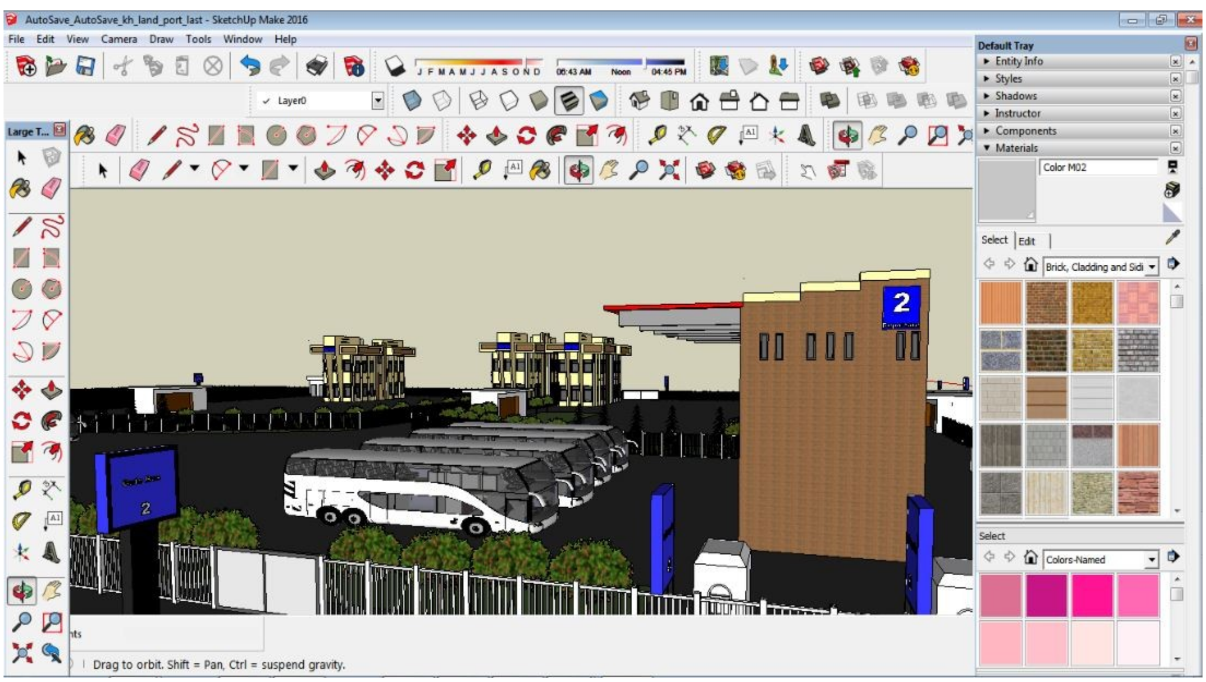


Figure (5.7): (D)

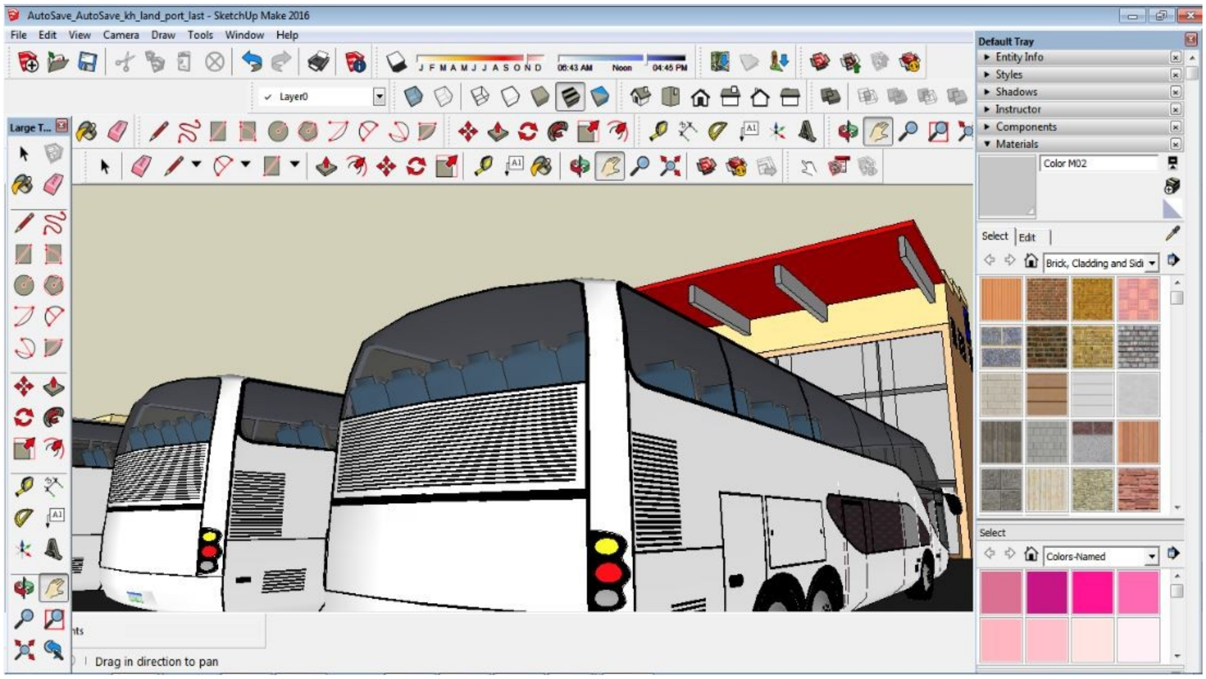


Figure (5.7): (E)

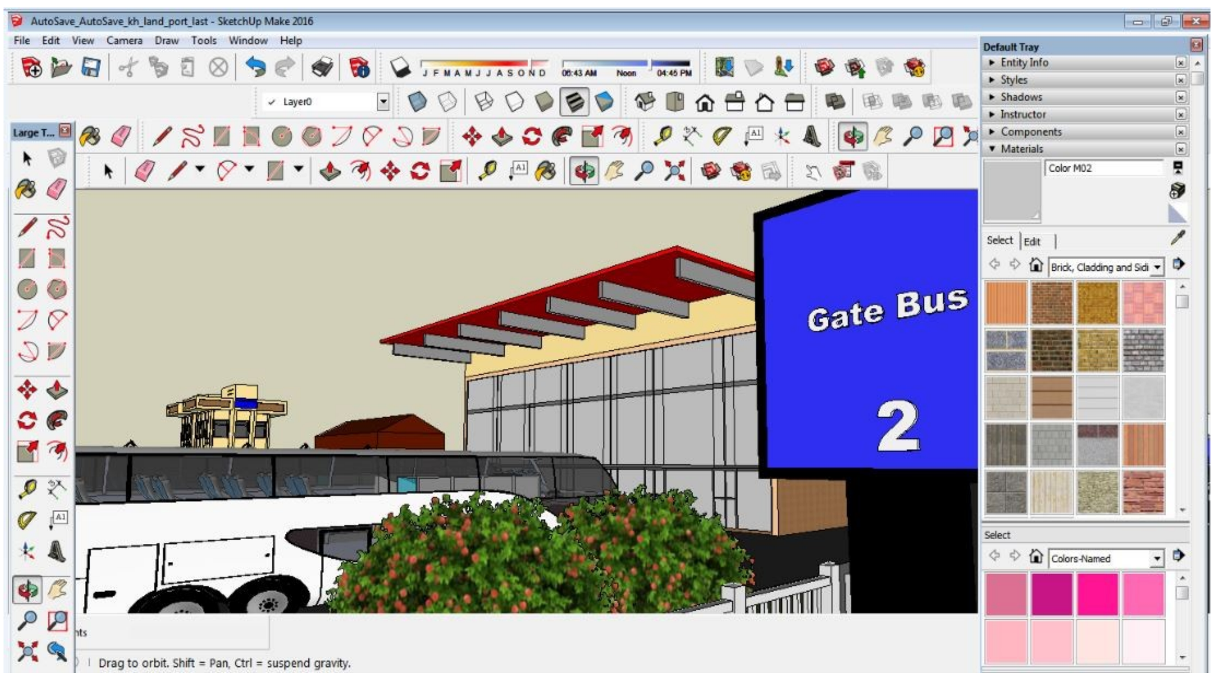


Figure (5.7): (F)

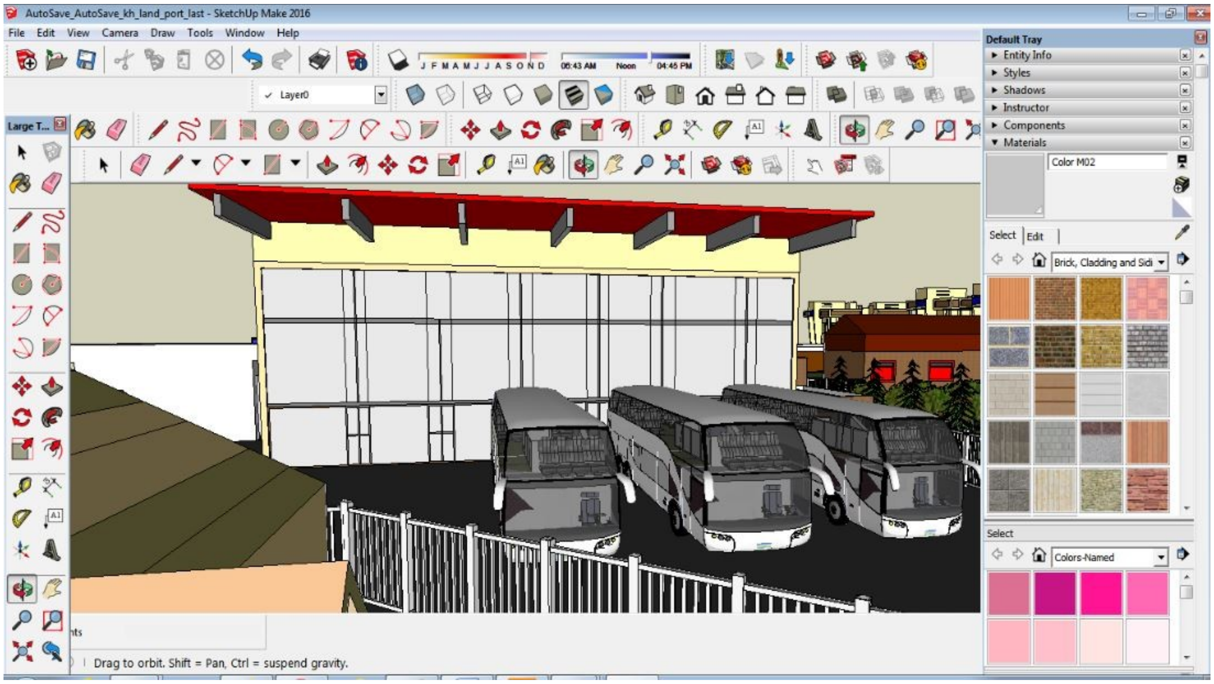


Figure (5.7): (G)

The Figures (5.7): (A, B, C, D, E, F, G) are representing the final SketchUp results for the Departure hall 3D Model, also seen from different views.

A 3D model has been extracted from this phase as a final textured model as shown in Figure (5.6) - (5.7) - the output from this step is a 3D file in *.dae format.

5.2.2 ArcGIS (Arcscene) (Version 10.4)

ArcScene is a 3D visualization application that allows to view GIS data in three dimensions. ArcScene allows you to overlay many layers of data in a 3D environment. Features are placed in 3D by providing height information from feature geometry, feature attributes, layer properties, or a defined 3D surface, and every layer in the 3D view can be handled differently. Data with different spatial references will be projected to a common projection, or data can be displayed using relative coordinates only. ArcScene is also fully integrated with the geoprocessing environment, providing access to many analysis tools and functions.

ArcGIS is one of (COTS) software's, that allow for emitting reality and building 3D geometric, vector and raster layers, and to provide geo-referencing. Analyses help in decision making.

This step is concerned with extruding 3D buildings for 2D building vector layers –The results are 3D models, 3D buildings and the Colleges layer, as shown in Fig (5.8). Here a suitable coordinate system has to be chosen (vertical and horizontal), for which we selected the World Geodetic System WGS 1984 UTM Zone 53N, covering Sudan. Finally the layers had to be converted to shapefiles as illustrated in Figure (5.8),(5.9)(5.10)(5.11)(5.8)(5.12).

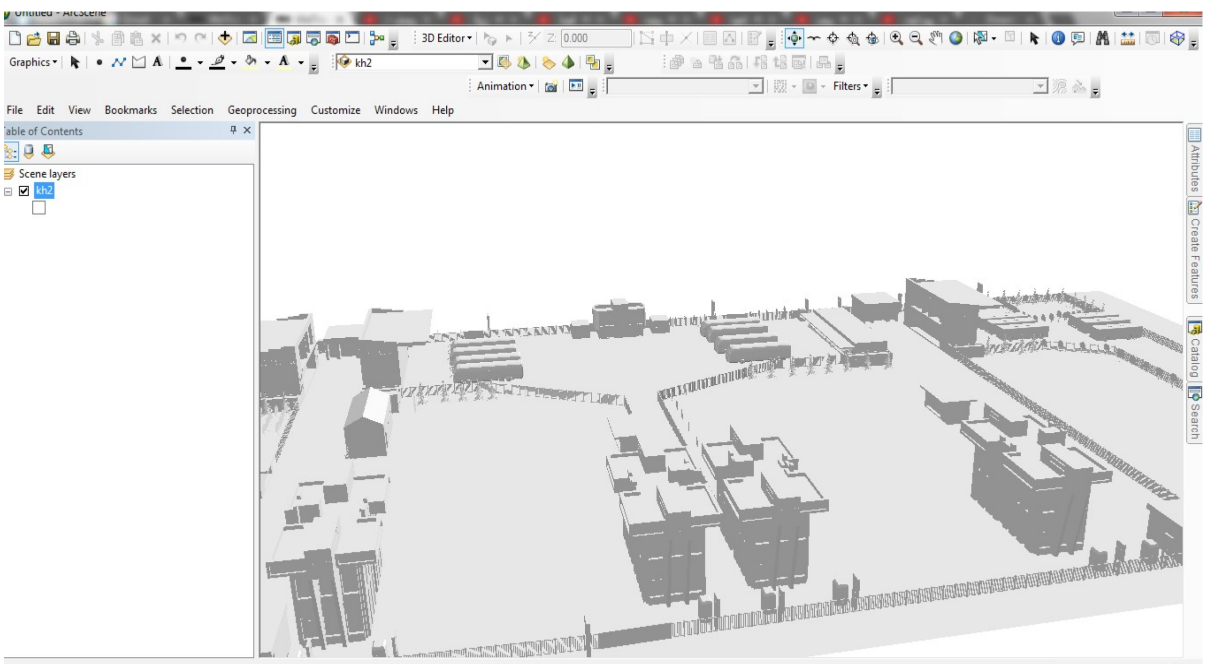


Figure (5.8): Khartoum Land Terminal 3D model, from different views shapefile

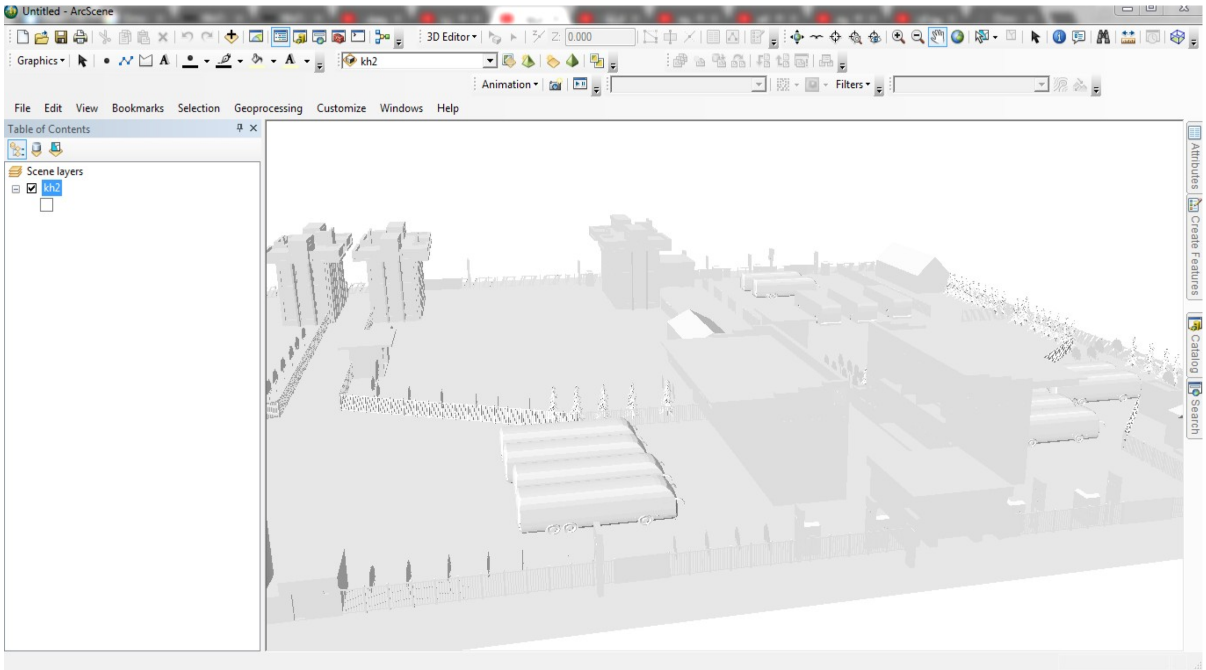


Figure (5.9): Departure hall 3D Model from different views shapefile

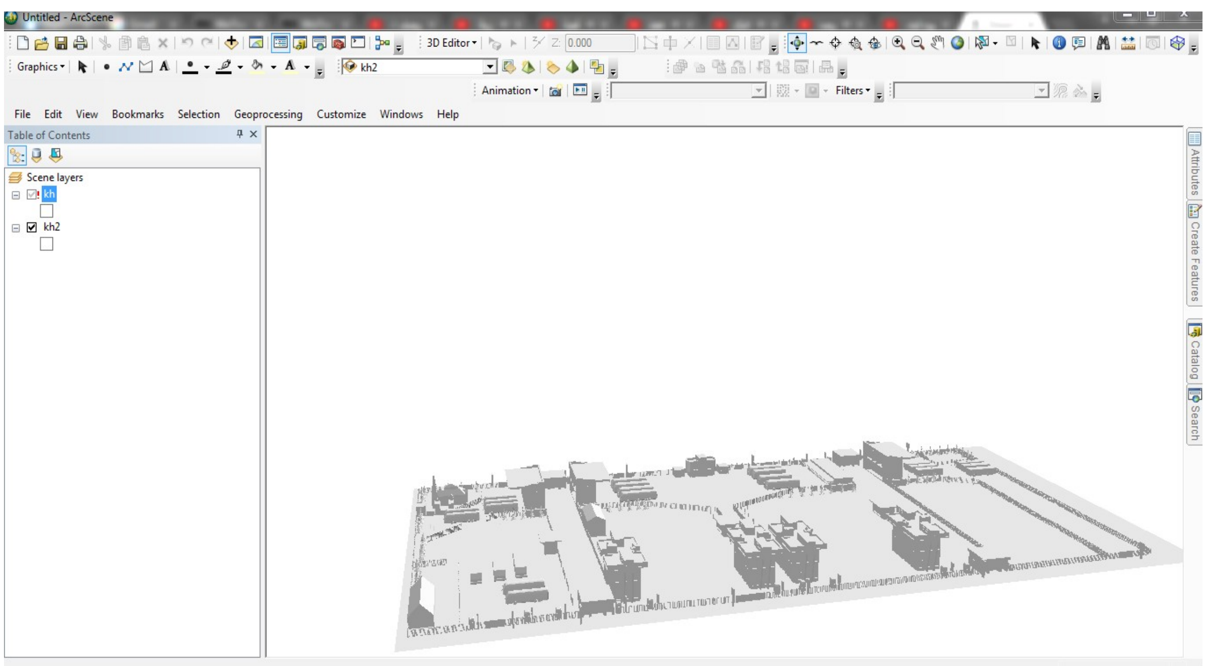


Figure (5.10): Khartoum Land Terminal3D model, from different views shapefile

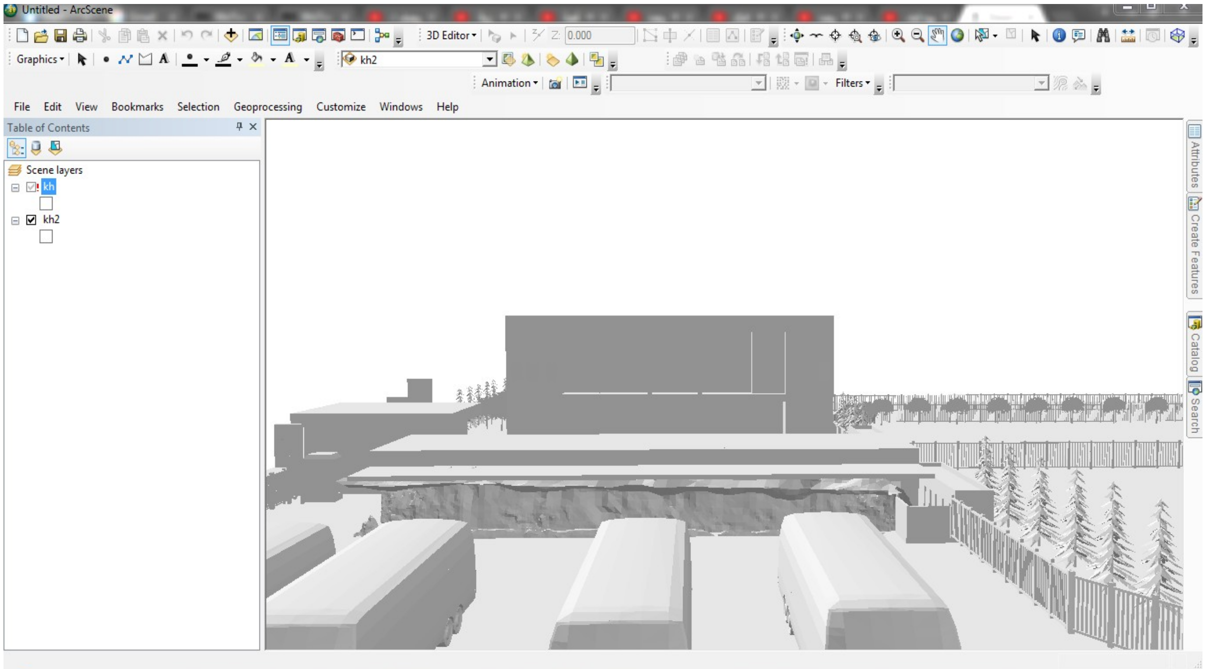


Figure (5.11): Departure hall 3D Model from different views shapefile

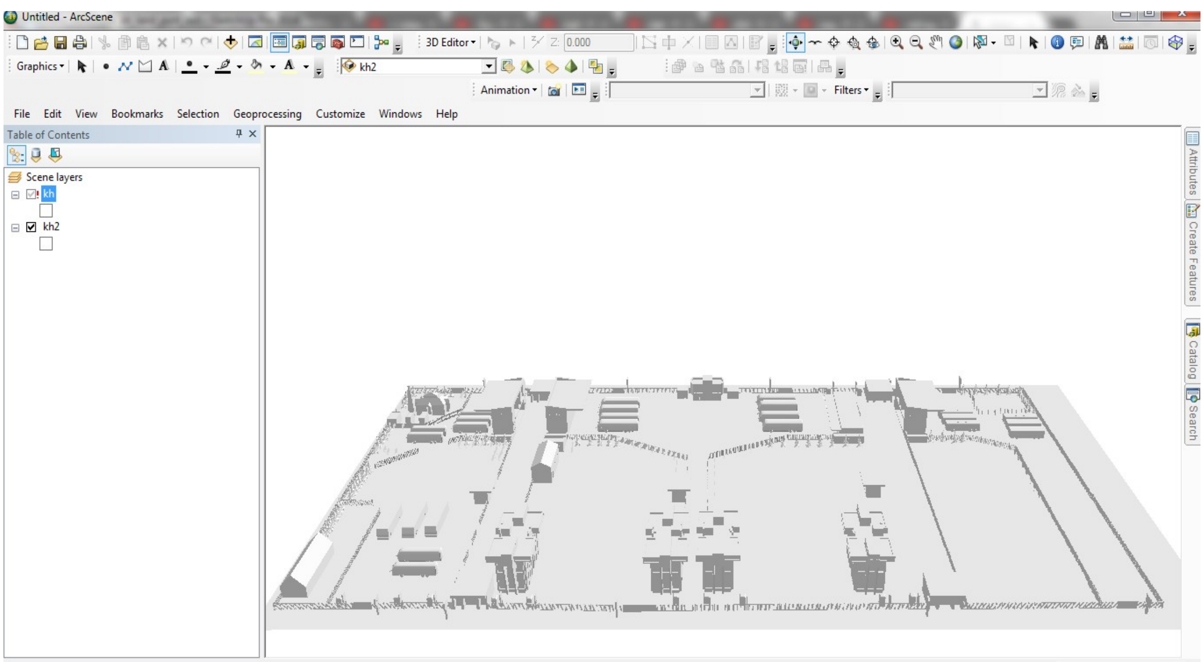


Figure (5.12): Khartoum Land Terminal shapefile

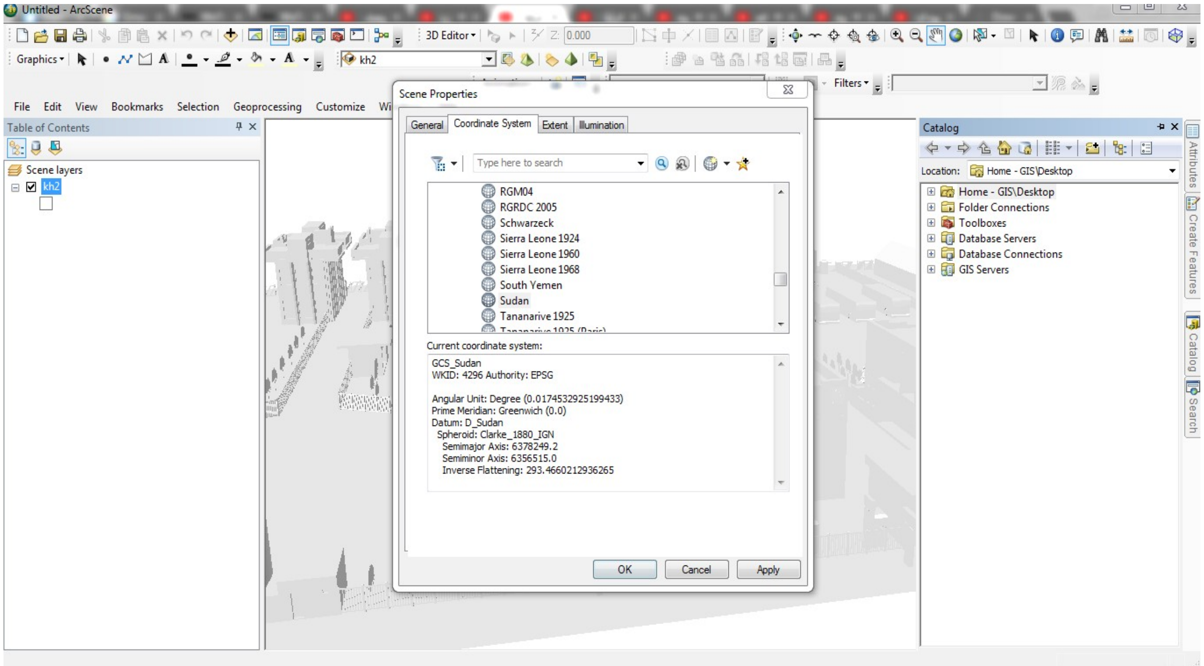


Figure (5.13): Coordinate System Specification.

All these shapefile Figures are given from different views of Khartoum Land Terminal using ArcGIS (Arcscene) (Version 10.4). The last Figure contains the definition of the Coordinate System.

Chapter Six

Conclusions and Outlook

6.1 Conclusions

Recent advances in three-dimensional displays, real-time texturing and computer graphics hardware as well as the increasing availability of rendering and animation software tools have resulted in an increased demand for photo realistic 3D virtual reality city models.

This project describes a method to design of 3D urban environments – the Khartoum Land Terminal.

This work is the result of a research that explores the effective use of 3D modeling in different applications. The thesis demonstrates the feasibility of using a photogrammetry Out-of-the-box software and 3D modeling GIS.

Virtual reality modeling is used for the design of a three-dimensional model of the Khartoum Land Terminal with texture that allows the visualization of virtual reality, and navigations and orientations throughout the Khartoum Land Terminal with geographical data and databases. The approach used in this work offers a simple strategy suitable for the development of realistic views of buildings and introduces an accurate hypothetical reality of the environment. This thesis is mainly intended to use GIS technology to guide travelers in the land Khartoum Land Terminal without wasting effort and time.

3D GIS is considered a powerful tool to solve various issues which modern cities confront.

Further analyses on visual aspects are restricted by the data sources available for this study, for example, to manage large 3D urban databases as well as the automatic database generation. In order to produce good quality and readable output, proper hardware, software and design criteria are required. The design of 3D building model has been an active research topic in recent years. Most approaches have been focused on the design of specific building models: rectilinear shapes and flat roofs. The automation of extraction of buildings from various data sources is a very desirable and challenging yet equally difficult task because of the great number of possible building forms and shapes.

6.2 Recommendations

For more efficient and real views the following suggestions are recommended:

- Take advantages of GPS properties for user positioning.
- Connecting the Land Terminal 3D model directly with the web site to be accessed anytime.
- Utilize GIS modeling for showing high level of building details and features.

6.3 Strength of the Thesis

In the Khartoum Land Terminal project we provide a 3D design of all building elements, including the mosque, the cafeteria, the departure halls, the bathrooms, as well as the entrance and exit gates. Thus it provides information about all resources inside the Khartoum Land Terminal.

6.4 Weakness of the Thesis

The weaknesses of this thesis, Because of the lack of professional training of open source GIS, this thesis could only make a contribution for the 3D outside design of the Land Terminal, The pictures taken from the building were taken by the phone's camera and this is not as high-quality as cameras dedicated to photography.

6.5 Opportunities of the Thesis

Facilitating 3D modeling of an urban environment recent developments have demonstrated that it is possible to represent the urban environment by 3D models. The implementation of the Khartoum Land Terminal in the geospatial environment will help in evaluation of the design proposals both, from employees and passengers.

6.6 Threat of the Thesis

Among the threats in this project is the difficulty of collecting data from public places (images and a map) such as: universities, hospitals and markets, especially pictures because there are a number of people in place, as well as security places, and the government places.

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