Integration of GIS and BIM for Road Construction Management using LRS tools

Dejen Gebregiorgis Gebre

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 Geomatics Engineering (Specialization in Geo-Informatics)

Office of Graduate Studies

Adama Science and Technology University

February, 2023

Adama, Ethiopia

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Advisor (s): Dr Getachew B/Meskel (PhD)

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Declaration

I hereby declare that this Master Thesis entitled **"Integration of GIS and BIM for a Road Construction Management using LRS tool"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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Recommendation

I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled "**Integration of GIS and BIM for a Road Construction Management using LRS tool"** prepared under my/our guidance by **Dejen Gebregiorgis Gebre** submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geomatics Engineering specialization in Geo-informatics. Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr. Getachew B/Meskel (Ph. D)	________________________	________________
Major Advisor	Signature	Date
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Co-advisor	Signature	Date

Approval Page

I/we, the advisors of the thesis entitled "**Integration of GIS and BIM for a Road Construction Management using LRS tool**" and developed by Dejen Gebregiorgis Gebre, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Getachew B/Meskel (Ph.D.)	____________________	______________
Major Advisor	Signature	Date
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Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Dejen Gebregiorgis have read and evaluated the thesis entitled "**Integration of GIS and BIM for a Road Construction Management using LRS tool"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geomatics Engineering Specialization in Geo-Informatics.

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Acronyms

AEC	Architecture, Engineering and Construction
AECO	Architecture, Engineering, Construction and Operation
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
BIM	Building Information Modeling
CA	California
CAD	Computer Aided Design
CGI	Common Gateway Interface
CPM	Critical Path Method
CSV	Comma Separated Value
EGM96	Earth Gravitational Model 1996
ERA	Ethiopian Road Authority
EU	European Union
EUPPD	European Union Public Procurement Directive
GDEM	Global Digital Elevation Model
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
HTML	Hyper Text Mark-up Language
IFC	Industry Foundation Classes
KML	Keyhole Mark-up Language
LiDAR	Light Detection and Ranging
LRS	Linear Reference System
LVR	Low Volume Road
MOOC	Massive Open Online Courses

MoWUD	Ministry of Work and Urban Development
MS	Micro Soft
QR	Quick Response
RFID	Radio Frequency Identification
RIM	Road Information Modeling
TIN	Triangular Irregular Networks
UTM	Universal Transverse Mercator
VPL	Visual Programming Language
WGS 84	World Geodetic System 1984

Abstract

There are many interrelated contributing factors to the inefficiency of a construction projects such as low productivity, low quality of end product, projects time and cost overrun. To overcome such construction project difficulty, we need to focus on the management system of a project. In the last decade, digital transformation has changed a wide range of industrial sectors, resulting in an amazing increase in product quality, productivity, and product variety. The objectives of this paper are to develop an LRS model for the rural road construction as a means of relevant information exchange tool, to develop a geodatabase that can handle an LRS spatial data with its required temporal information and to develop flexible web-based GIS model as a tool to communicate the required information between parties. In order to achieve this objective the following procedures has been followed: organizing information which are used for the model, creating the required geodatabase, modeling an LRS which consider the Z value to attain 3D information, and sharing the necessary information through a web-based GIS application and lastly it recommends how other researchers to go on for further investigation.

Key Words: GIS, BIM, LRS, Web mapping, Centerline, Geodatabase

CHAPTER I: INTRODUCTION

1.1. Background of the Study

Construction is a $1.7 trillion industry worldwide, amounting to between 5 and 7 percent of GDP in most countries. It accounts for a significant part of global gross capital formation –a little under one-third. The sector's role in economic development is undeniable housing, roads, utility networks, schools and clinics are all built assets. (Kenny, June 2007)

Ethiopia has a rich history of magnificent construction endeavors. The ruined palace of Queen Sheba at Yeha, the Obelisks of Axum, the rock-hewn churches of Lalibela, and the Castles of Gondar are few examples of this expertise. With the advent of modern civilization, especially during the late 19Th and early 20Th century, there have been some significant developments in this regard." (Nega, March, 2008) But now, due to many reasons the methods, techniques and technology of construction industry have growing not enough. When we are going to see in different construction sites methods, techniques and technology that is all to be seen are they were used in last decades. No progresses have been seen. Even though, the development of the construction industry in Ethiopia is slow, it plays a key role in the development of the national economy. (Nega, March, 2008)

According to MoWUD, (2006), the interrelationship between the construction industry and the broader economy largely emanates from three of the industry's characteristics namely: The public sector is its major client; It's large size, ability to produce investment or capital goods which contribute significantly to national GDP; and It is a major source of employment, directly and indirectly by its multiplier effect. (Nega, March, 2008)

As long as we do believe in this truth, construction industry should be considered as a pillar for many countries economic determinant factor and also deserve special attention in every structure of the sector.

There are many interrelated contributing factors to the inefficiency of a construction projects such as low productivity, low quality of end product, projects time and cost overrun. (Enku, May 2018) To overcome such construction project difficulty, we need to focus on the management system of a project.

For this reason, every project shall be undertaken based on the well-planned budget and economy, so as to maintain a good economy of the country as well as the construction industry and also has a benefit for every beneficiary.

The amount of information produced in any project from start to finish is massive. At any stage of the project, different types of information are required by various stakeholders in various formats. ((UNECE), 2021)

Building Information Modeling (BIM) is rapidly gaining acceptance in several infrastructure industries, including highway transportation. However, some agencies have begun to deemphasize the term "BIM" in their specifications as it is interpreted in different ways by different people and the focus shifts from the real intent of the term. There is a growing recognition that BIM, as applied to highway infrastructure (referred to in this report as BIM for infrastructure), involves collaboratively delivering capital projects using digital processes that organize and move data and information efficiently through the planning, project delivery, and operation and maintenance phases. The so-called "open BIM processes," which allow data interoperability between various software applications used to design, build, maintain, and operate infrastructure, optimize traditional asset lifecycle management workflows; prevent information loss and duplication; and replace paper outputs and deliverables. Asset owners adopting this modern, digital way of doing business are reaping benefits in terms of cost, time savings, and safety. (Mallela, 2020)

Building information modeling (BIM) is a digital and graphical representation of the physical and functional characteristics of a structure. BIM is a shared knowledge resource for facility information that provides a reliable basis for decisions during its life cycle (from design to demolition). (Mounir Bensalah, 2019)

Building Information Modeling (BIM) is a process and technology that supports virtual design and construction methodologies putting all team members together throughout the entire design and construction process and beyond to the operations in maintenance of the building, during its working life. Typically, BIM is one holistic process using real-time, intellectual modeling software effectively working in 3D, 4D (3D + time), and 5D (4D + cost) to improve productivity, to save money and time in the design and construction phases, and to reduce operating costs after construction. (Enku, May 2018)

BIM as an approach to building design and construction distinguishes it from other technologies. This lies not only on the advantages of 3D parametric modeling, but also the structured information that is organized, defined, and exchangeable. (Enku, May 2018)

In different situation, professionals use and experience different software to manage the BIM integrating with other soft wares.

By applying the BIM method, a much more profound use of computer technology in the design, engineering, construction and operation of built facilities is realized. Instead of recording information in drawings, BIM stores, maintains and exchanges information using comprehensive digital representations: the building information models. (Bayou et.al., 2020)

1.2. Statement of the Problem

An innovative approach to building design, construction and management is gradually being implemented by major countries across the globe. This paradigm shift is referred to as “Building Information Modeling” or simply put “BIM”. (Enku, May 2018) BIM has shown great value in providing solutions to the problems posed by the construction industry. At present, there is a tendency to improve the AEC industry worldwide, to the extent that BIM is being expanded into sectors for which it was not originally designed, such as the infrastructure sector, the implementation of which has posed new challenges. Indeed, the limited availability of libraries of infrastructure components and the difficulty in assigning parameters to object geometries are considered the main obstacles to the use of BIM for transport infrastructure. (Salvatore Antonio Biancardo, 2020)

In Ethiopia utilization of the modern technology has still just on the beginning stage, only restricted in foreign contractors on some mega projects and a few researchers tried to address only in the building sector. Development of BIM in civil engineering applications is fostered by a particular European political situation aiming to improve the efficiency standards of the construction industry. To that extent, the European Union Public Procurement Directive (EUPPD) (EU, 2014) has mentioned that “the 28 European Member States may encourage, specify or mandate the use of BIM for publicly funded construction and building projects in the European Union by 2016. (D'Amico, 2020)

Once considered just for buildings, Building Information Modeling (BIM) is gaining rapid acceptance in several infrastructure industries, including highway transportation. BIM, as applied to highway infrastructure, involves delivering capital projects collaboratively (through the planning, design, and construction phases) and managing services the built infrastructure is expected to provide efficiently using digital processes rather than traditional paper-based processes. ((UNECE), 2021)

Nevertheless, the problem is that the improvement of the industry towards a multidisciplinary collaborative work trend is highly observed in the market rather than the academia. Different researchers have observed that AEC education sector is lagging to implement multidisciplinary collaborative approach which enhances the collaborative, communicative and coordinative skills of the students. (Bayou et.al., 2020)

However, most of these infrastructure projects in developing countries encounter considerable low performance in terms of time, cost and quality. (Ogulana et.al, 2004) and Wubshet (2004) described that many of these performance related problems are recurrent and serious. (Enku, May 2018)

In general, even if the BIM technology progressively forwarding in many developed countries, in the infrastructure sector, still is not satisfactory respect with the building construction sector. In the building construction, sector even different platforms have been developed by different commercial companies those are delivering a professional software to the market, like Esri (ArcGIS Pro supports BIM design files from Autodesk Revit (RVT) and Industry Foundation Classes (IFC) formatted files as ArcGIS BIM file workspaces), Autodesk (Revit application software) and others. Even, their delivery reached up to 7D and beyond for different purpose, But, for the road construction sector, especially for the construction monitoring purpose, still almost null.

Construction is one of the most information-dependent industries. Construction projects, by their very nature, are unique, uncertain, and complex, involving several stages during which a large number of human resources of various specialties interact and cooperate, performing diverse project tasks. Thus, the amount of information and documentation generated and exchanged during the construction process is massive, even on small projects. As construction projects become larger and more complex, an efficient means of information exchange mechanism is needed.

Proper management of construction projects can facilitate the timely completion of projects adhering to the required quality, cost, and sustainability. Methods currently available for monitoring the progress of construction projects include manual recording, satellite imagery, Photogrammetry, Light Detection and Ranging, Global Navigation (Yadhukrishnan A. V., 2015). Satellite System, Building Information Modeling and Geographic Information System However, the management of linear construction projects, for example, road projects require a carefully designed progress monitoring process in place and associated control steps to be taken. Monitoring such projects is challenging due to variable workplaces, remote locations, multiple work-sites required to be monitored at once, and repetitive resources being used (Moselhi, 2011) (Vick S. M., 2016). (Ajwaliya R. J., 2017)Therefore, only some of the methods mentioned above can be efficiently used for linear projects since the other methods either become too expensive, time-consuming or need significant efforts. In addition, the progress monitoring cycle of linear projects could be improved by automating the complete process, which is currently being implemented only for structural components in buildings (Vick S. M., 2016).

Moreover, the use of GIS in linear project monitoring has been limited compared to its use in monitoring other types of construction projects. 4D GIS was used only to consider the effect of surroundings on the project in many cases and for the concept of time and schedules in the monitoring process along with 3D data (Ajwaliya R. J., 2017). Therefore, the potential of using GIS for collecting data related to the work done in road projects and visualization of their progress should be explored.

Due to the many stakeholders and phases involved in a construction project, the fragmentation has led to well documented problems with communication and information processing and has contributed to the proliferation of adversarial relationships between the parties to a project. This fragmentation is also often seen as one of the major contributors to low productivity in construction. Besides large variety of forms and types of project information are required at different stages of a construction project and a wide range of professionals from many disciplines uses this information. The data is extremely dynamic, often changing from day to day throughout the project and there is a continuous cycle of creation, storing, manipulation, transmission, reformatting, application and revision. The time for each cycle can be very short and the consequences of using inappropriate or inaccurate data can be costly and result in unnecessary delay. The efficiency of the construction development and operation cycle depends on the integrity and effectiveness of the information flowing between the client, design engineering, equipment manufacturing, contracting, and facilities management segments of the construction industry (Petimani V. S., 2019).

Currently, an innovative approach to building design, construction and management is gradually being implemented by major countries across the globe. This paradigm shift has shown great value in providing solutions to the problems posed by the construction industry (Petimani V. S., 2019).

At present, there is a tendency to improve the AEC industry worldwide, to the extent that BIM is being expanded into sectors for which it was not originally designed, such as the infrastructure sector, the implementation of which has posed new challenges (Azhar S.). Indeed, the limited availability of libraries of infrastructure components and the difficulty in assigning parameters to object geometries are considered the main obstacles to the use of BIM for transport infrastructure. (Bansal, May 2007)

Cost overrun is one of the most impactful risks in construction projects, and, being such a dynamic and complicated factor, it has been difficult to fully mitigate. While there are many investigations on factors affecting the project cost variations, cost overrun remains the key concern of many projects and companies in construction (Samad M. E. Sepasgoza, 2022)

Due to enormous variance in construction circumstances that might occur in different sites, road construction varies from other building and manufacturing processes. The nature of construction may affect cost overruns, requiring digital tools to monitor, predict, or control the project costs. (Samad M. E. Sepasgoza, 2022)

In the conventional project delivery, design documents are used to estimate the project cost before value engineering may be conducted for the final decisions about the design and alternatives. This process is repeated for alternatives and can be a time-consuming practice. Using new information systems and models such as 5D BIM, all the design options, including the associated costs of each design scenario, can be evaluated concurrently. However, more practice and lessons on how digital tools can efficiently be utilized are needed to enhance the process of cost estimation, which can be helpful in the financial management process. (Samad M. E. Sepasgoza, 2022)

And this paper is aimed to motivate the stake holders to go further to advance knowledge to visualize information for road construction project tracking on its alignment (to deliver information to exchange a project timely status).

1.3. Objectives

1.3.1. General objectives

The main Objective of this study is to develop a BIM for scheduling a rural road construction using an Arc GIS platform.

1.3.2. Specific Objectives

The specific objectives of this research are to:

1. Develop a BIM/RIM for the rural road construction as a means of relevant information exchange tool.
2. Develop a geodatabase that can handle a 3d spatial data with its required temporal information.
3. Develop flexible web-based GIS model as a tool to communicate the required information between parties.

1.4. Research Question

In order to attain the final result, the following questions should be answer:

1. How to develop a BIM/RIM for the rural road construction which is used as relevant information exchange tool to monitor construction progress timely.
2. How to develop a geodatabase that can handle a 3d spatial data with its required temporal information.
3. How to develop flexible web-based GIS model which is used as a tool to communicate the required information between parties.

1.5. Significance of the Study

In highway construction, changes in the project scope will bring enormous impact to the project completion time and project cost due to the size of the project. (A T B Yung, 2020)

The Building Information Modeling (BIM) process has been progressively implemented worldwide in the Architecture, Engineering and Construction (AEC) areas in recent times (D.Amico, 2020). It is well-known that BIM is a conceptual model that allows a parametric approach for storing all the available information related to a specific project within the proposed model. (D.Amico, 2020)

To analyses in depth the multi-aspects of design information for the control of the entire design process and to fulfill requirements of a BIM process, many other dimensions need to be added. (D.Amico, 2020)

Using building information modeling (BIM) in conjunction with emerging technologies for the management of infrastructure can help achieve more reliable, sustainable, and safer performance of the network while decreasing maintenance costs and risks, and at the same time generating considerable revenue for all stakeholders (S. A.Biancardo, 2020)

There are an important number of agents and stakeholders that could benefit from the BIM model's advantages, such as planners, engineers, designers, safety specialists, contractors, risk managers, etc., so there are multiple international initiatives to promote the use of this technology. (Jua, 21)

BIM serves as an intermediary of interoperability among industries" players thereby boosting its popularity among clients (Azhar et al., 2015), GIS on the other hand visualizes and analyses location related issues in geospatial science and natural resource management by integrating different spatial and attribute data and deriving knowledge through diverse spatial analysis tools and modeling modes (Zhu et al., 2018). (Rahman, 2018)

In previous BIM-GIS integration studies, researchers spent a lot of effort on the integration technologies. Various BIM-GIS integration methods are proposed to address different problems (Y.Song, 2017)

For the integration pattern, more than half of the researchers prefer to extract data from BIM to GIS, and others integrate GIS data to BIM systems or integrating both BIM and GIS data on a third-party platform (Y.Song, 2017)

However, BIM-supported analysis and decision making cannot fully satisfy the user requirements of the AEC industry, including the improvement of quality and productivity, decrease of project cost, real-time tracking progress across construction space, ensuring safety, decreasing environmental risks, and effective information update, interaction and management. A primary gap between user requirements and current condition is that the requirements during construction process cannot be accurately and dynamically described, modeled and managed. The traditional construction methods are still main stream and comprehensive data-driven spatio-temporal modeling is rarely utilized, even though the data-driven analysis of real time and dynamic progress is increasingly critical in mega projects and the construction management of smart sustainable city, and the stages of AEC industry are typical spatial and temporal processes. In addition, the space surrounding and far away from construction sites is not fully involved in the construction management. For instance, supplying and delivery processes during feasibility study, design and demolition stages require spatial analysis from large spatial scales, but the quantitative analysis of spatial and temporal processes is seldom involved in the BIM-based decision making of AEC industry. Therefore, this paper aims to summarize applications of BIM-GIS integration and propose the potentials of its future development in AEC industry from a spatio-temporal statistical perspective. (Yongze Song, 2017)

Using building information modeling (BIM) in conjunction with emerging technologies for the management of infrastructure can help achieve more reliable, sustainable, and safer performance of the network while decreasing maintenance costs and risks, and at the same time generating considerable revenue for all stakeholders (Biancardo, 2020).

1.6. Delimitations and limitations

This paper mainly focused on to develop BIM integrated with GIS technology to monitor progressive road construction schedule in a segmented pattern of the project. On this process, the data are gathered from the satellite source and it is only used for the research paper used only, because the accuracy of satellite data is too far for the construction requirement. This means the data used for this thesis work are not recommended to use for another project work.

In addition to this, the design data doesn't include the structural works (Culvert, bridge, and so on) and other miscellaneous works for the project. It includes only surveying activities, earthwork and road layer formation.

The readers for this paper need to understand, the research paper would be expected as the base for other researchers to work on an advancement of BIM technology for high way projects for monitoring every activity during every life time of the construction processes. In addition, it will be helpful for any linear construction projects (canals, rail ways, sewerage lines, electric lines and so on) as a pivot for progressive advancement.

This paper also doesn't address the detail design part; rather it provides means of information exchange along every chainage considering a geo-spatial aspect.

During in this research journey almost impossible to get a well-organized data in order to focus more on the modeling in a better way, rather I started from the designing part. And the other thing, I couldn't get enough materials especially literatures on the road construction specifically addressing in scheduling and cost analysis part. It wastes much more time and it was a big challenge.

CHAPTER II: LITERATURE REVIEW

2.1. General

Construction management plays an important role in any construction to maximize a project to achieve a pre-planned goal by controlling time, budget and quality.

Construction planning methods used in highway projects are broadly categorized into bar charts, network-based, and linear scheduling methods. The simplest tool of construction planning is bar chart. However, apart from representing the construction activities on a time scale, bar charts don't provide much help with respect to scale, bar charts don't provide much help with respect to location breakdown, continuous resource utilization, and cost optimization. Along with bar charts, network-based methods like Critical Path Method (CPM) are commonly used methods in the planning of highway construction projects. However, network-based methods too have limitations when applied to repetitive projects: (1) continuous crew engagement is not ensured, (2) multiple crew strategies are difficult to implement, (3) there is no information about work location, progress direction, and task production rates at any point of time during project execution, and (4) the network becomes relatively large and complicated when applied to a repetitive project. (Sharma, 2018)

2.2. Google Earth Pro

Google Earth (Google Inc., Mountain View, CA), released in 2005, is a satellite imagery-based mapping service that has gained widespread use in the field of accident reconstruction. The software creates a virtual globe by combining several different file formats and imaging methods including aerial photography, satellite imagery, and geographic information system (GIS) technology. Google Earth Pro is a feature-rich version of the Google Earth software and includes advanced measurement tools as well as other features for commercial use of the program. (Shawn Harrington, 2017)

Google Earth Pro is sometimes the only way to accurately depict a collision site's condition at the time of the accident being studied. In addition, using Google Earth Pro to take case-specific measurements of the subject intersection can be more cost efficient than conventional methods and can limit unnecessary travel (Shawn Harrington, 2017)

Google Earth file format is Keyhole Markup Language (KML) which is a file format for modeling and storing geographic features such as points, lines, images, polygons, and models for display in Google Earth, Google maps or other applications. It can use KML to share places and information with other users of these applications. For its reference system, KML uses 3D geographic coordinates; longitude, latitude and altitude, in that order, the longitude, latitude components are as defined by the World Geodetic System of 1984 (WGS84). The vertical component (altitude) is measured from the WGS84 EGM96 Geoid vertical datum. (Dr. Nagi Zomrawi Mohammed, 2013)

2.3. Global Mapper

Global Mapper is an affordable and easy-to-use GIS Data processing application that offers access to an unparalleled variety of spatial datasets and provides just the right level of GIS functionality to satisfy both experienced GIS professionals and mapping novices. Equally well suited as a standalone spatial data management tool and as an integral component of an enterprise-wide GIS, Global Mapper is a must-have for anyone who deals with maps or spatial data: Unmatched spatial data format support, Low cost and easy-to-use, just the right, level of GIS functionality and Unmatched and complimentary support. (Global mapper, n.d.)

Global Mapper is more than just a utility; it has built in functionality for distance and area calculations, raster blending, feathering, spectral analysis, elevation querying, line of sight calculations, cut-and-fill volume calculations, as well as advanced capabilities like image rectification, contour generation from surface data, view shed analysis, watershed delineation, terrain layer comparison, and triangulation and gridding of 3D point data. (Global mapper, n.d.)

2.4. Geographic Information System (GIS)

A host of professionals have been in the process of developing automated tool for efficient storage, analysis and presentation of geographic data. These efforts have apparently been the results of demands by users for the data and information of spatial nature. This rapidly evolving technology has come to be known as GIS. (Girma, 2017)

GIS is a decision-support system, which has all the features of an information system. The major difference between GIS and other information systems is that the GIS data are geo-referenced. The location information or spatial information and all the other attributes that are related to this location are important components of GIS. Such information is important to the further spatial and temporal analysis (Xin Liu, 2017)

Esri provides many applications that are help to integrate GIS and AEC-design-oriented workflows. One of these apps is Esri Classic Story Maps. Esri Story Maps let you combine authoritative maps with narrative text, embedded web apps and tools, images, and multimedia content to tell a story. In this story, Esri UK has combined these elements to provide a holistic presentation of how the ArcGIS system aids in the integration GIS and BIM throughout an AEC project. (Transform AEC Projects with GIS and BIM, 2022) Personally this training MOOC is a very advanced and shows latest version of Esri technology advancement to integrate GIS with the BIM technology in the sector. But, it doesn't focus the construction of highway techniques to contribute more beyond depending on other software products.

2.5. Building Information Modeling (BIM)

Building Information Modeling can solve the traditional design problems which make the all highway construction phases from inception till operation more efficient and east to be managed. Although there is a great deal of advantages of adopting BIM in road construction and design that have been proved theoretically and practically, application of BIM is still comparatively slow in developing countries such as Malaysia due to its high investment in time and cost in the early stage of construction and lack of awareness about the software. (Yung, 2020)

Building Information Modeling (BIM) is a disruptive methodology in building and civil engineering infrastructure management, covering all stages of the structure's life cycle. (Juan F. Dols, 2021)

2.5.1. Building Information Modeling for Civil Engineering

Initially, the BIM model was created in the AECO industry (architecture, engineering, construction, and operations sectors) to be applied in the building sector, but rapidly has expanded to other areas of construction, such as civil—bridges, tunnels, airports, ports and mines, and transportation—roads and highways, railways and mass transit infrastructures (Jua21; Juan F. Dols, 2021)

Three-dimensional (3D) modeling methods have been applied in government-procured infrastructure projects for many years. However, building information modeling (BIM) goes beyond the production of 3D models generally in its philosophy and applications, not entirely limited to the visualization of a facility. It encompasses the proper creation and use of digitized time-related and cost related information throughout the entire project, as well as in maintaining the lifecycle of its deliverables. This is vital for infrastructure projects in general to handle the highly complex and diverse nature of project requirements, particularly for managing the expenses incurred during major road/highway construction. (Chong, 2016)

In recent years, BIM has proved to be a valid tool to support projects in the architecture and construction industry. Most BIM software packages available on the commercial market are mainly used for buildings and their components. The typical procedures for the generation of as-designed BIM require the assembly of predefined components already subdivided into families, such as walls, columns, floors, roofs, windows, doors, ceilings, and ramps. Different object libraries are available on the web. Alternatively, the user can generate tailored parametric objects for a specific application. Nowadays, the creation of a BIM can be carried out with several software packages (Luigi Barazzetti, 2020)

The use of BIM in either road or railway infrastructure projects for design, construction, and maintenance would serve to create, manage, and maintain all critical information pertaining to an asset such as geospatial information, graphic representation of the transportation networks, resources required in the project, etc. The proper utilization of BIM data will help to achieve a generally cost-effective design solution and improve efficiency in communication among project stakeholders. (Chong, 2016)

2.6. Integration of BIM and GIS

The integration of building information modeling (BIM) and geographic information system/science (GIS) is a strong support for smart sustainable city due to its capabilities in data integration, quantitative analysis, application of technologies and urban management. BIM-GIS integration on construction management is a new and fast developing trend in recent ten years, from research to industrial practice. BIM has advantages on rich geometric and semantic information through the building life cycle, while GIS is a broad field covering geo-visualization-based decision making and geospatial modeling. (Yongze Song, 2017)

Building information modeling (BIM) and geographic information systems (GIS) are powerful technologies used in transforming construction project process information to 3D visualizations. As infrastructures have become bigger and more complex, there is an increased need for the BIM application to the areas of construction project management and engineering; however, conventional methods continue to be used in the initial stages of road construction. (T. Park, 2014)

The integrated use of BIM and GIS, specifically considering the spatiotemporal characteristics, was reviewed. The result of this study was the potential use of BIM+GIS to provide more accurate and dynamic data for decision making and analysis throughout the lifecycle of AEC projects. (Vineela Thellakula, 2021)

The integration system of BIM and GIS enables the effective management of information in various stages of a project's life cycle, namely planning, design, construction, operation, and maintenance. The information at any spatial and temporal scale can be available in such system for different applications. Effective management of heterogeneous information from different sources can also provide essential supports for decision-making. (Xin Liu, 2017)

BIM can be categorized into three levels: data level, process level and application level. However, a sufficient and detailed illustration of previous works on these three levels was missing. (Xin Liu, 2017)

BIM and GIS technologies have been widely used for various construction applications and their successes have proven that integration of BIM and GIS has great potential to improve existing practices for road infrastructure management. (T. Park, 2014)BIM and GIS as recent technologies can realize the huge benefits of infrastructure through its lifecycle. BIM has the ability to improve efficiency and effectiveness through providing a different process of collaboration and a new working approach to transform current Architecture, Engineering, Construction industry structure and practice (Sahar Kurwi)

2.7. Visualization with 3D

The level of detail of the information in a building model depends on the functions it will be used for (Eastman et al., 2011). The BIM and GIS could be used for visualization with 3D models. The 3D model could be used for visualizing the construction in work preparations, collision controls and in the core views between the different disciplines (Eastman et al., 2011, Hardin, 2009). The accuracy is proven to be greater when collision controls are done in one file compared to collision controls in 2D, which have driven the development towards a greater use of 3D models (Hardin, 2009). The 3D model could help all parties understand the details and get a similar picture of the design (Eastman et al.,

2011) which reduces the risk for misunderstandings and clashes (Shamloo and Mobaraki, 2011). The 3D model helps all parties to get a holistic view of the project and makes it easier to visualize drawings and to understand what has to be done in the work preparations (Shamloo and Mobaraki, 2011).

2.8. 4D scheduling and animations

BIM and GIS could be used in construction analysis and planning with 4D animation models and schedule control (Eastman, 2011). In 4D the projects construction schedule is connected to the 3D model (Shamloo and Mobaraki, 2011). 4D scheduling could visualize the construction plan with 4D animations of the site being built according to the schedule. The 4D animation could thus help the contractor to see if the planned work is realistic. 4D animations work as a communication tool to understand the scope, detect potential problems early and visualize the planned construction with completion dates to all actors. Hardin (2009) state that “In a schedule animation, you can show the earthwork excavation, site demolition, pile riving, piers, excavation, forming, site utilities, crane erection, truck loading areas, staging and lay down areas, reinforcement and rebar concrete foundation pour, structural steel erection, and so on” (Hardin, 2009, p. 97). It could also be used in site logistics and coordination of work (Hardin, 2009, Eastman et al., 2011). However, 4D CAD is expensive and requires both knowledge and experience of how to link a schedule to a 3D model (Eastman, 2011). It is also demanding for people working with it for the first time (Shamloo and Mobaraki, 2011). If the scheduling with 4D is done properly the benefit in cost and time would most likely exceed the implementation cost (Eastman, 2011).

2.9. Quantity takeoff with 5D

A building model provides a good appraisal of the quantities but it does not replace estimations since the estimation in the model is uncertain and also since it is not legally valid. Estimators could use quantity takeoffs for visualization, detecting special conditions and compare prices from subcontractors and suppliers. A building model with a high level of detail could reduce bid costs and uncertainties. Furthermore, it is important to use BIM software in an early design phase so that building parts are defined early, to be able to extract quantities and to create cost estimates later on (Eastman, 2011). There are three ways that BIM could be used in quantity takeoffs; exporting quantities to estimation software, link the BIM tools to the estimation tool and to use a quantity takeoff tool. In the first option the estimator could extract quantities and objects from the BIM model and use the information in estimation software as MS Excel (Eastman, 2011, Smith and Tardif, 2009). In the second option the BIM tools are directly connected to the estimation tool allowing the estimator to associate objects with detailed information as assemblies of building parts, labor, material, recipes or an external cost database. If the information is connected to the BIM components it could also be used to create a 4D model. In the third alternative the program for quantity takeoff is directly linked to a library of estimations of building parts, labor and material, which is connected and imported in the cost estimate. Quantity takeoff with BIM could reduce errors and improve accuracy of the estimates. BIM should however only be used as a helping tool in cost estimations. The complete estimation has to be done by a cost estimator since there is always remaining information that has to be added to the estimations from the library (Eastman, 2011).

2.10. BIM at site

BIM could be used on site when the contractor is trying to detect errors on site. The model could be used when doing field-verifications to see if the executed construction matches the model. The contractor could also use laser scanning measurements when checking that the poured concrete is in the right place. The data could then be connected to the BIM system and to GPS tools with exact coordination of the building model which could be used to verify locations on site (Eastman et al., 2011).

2.11. Web Mapping

Web mapping has a relatively short but fast-paced history, with an impressive evolution related to both the dynamics of science and technology, and the increased interests of domain experts and global citizens in consuming new kinds of maps created by web mapping services. (Bert Veenendaal, 2017)

Web mapping is the process of designing, implementing, generating and delivering maps on the World Wide Web to share and update information securely using authentication of the user in collection of users filled forms that someone to access to database.

Technically, the ability of the WWW at this time was to create a Web page (a Hypertext Markup Language or HTML file) in which an image file is embedded. The interaction between the user and the map was implemented by a computer code (a Common Gateway Interface or CGI script), which ran on the Web server. Each time the user clicked on one of the links on the page, the user's Web browser sent a request to the server. The request encoded in it the coordinates of the area that the user was interested in and other options such as the layers that were to be displayed. Once the server received the request, it would execute the CGI script, which would produce the HTML page and the associated image file that presented the new map, and then transfer these files over the Internet to the user's computer. Once the files were received, the user's browser would render them and show them on the computer's screen. (Muki Haklay, 2008)

Methods currently available for monitoring the progress of construction projects include manual recording, RFID tags or QR codes, satellite imagery, photogrammetry, Light Detection and Ranging (LiDAR), Global Navigation Satellite System (GNSS), Building Information Modeling (BIM), and Geographic Information System (GIS)

2.12. Linear Referencing

In some markets, it has been a more common practice to locate things using a Linear Reference System (LRS) instead (Scarponcini, 1999). The term linear referencing emerged from engineering applications where it was preferable to locate a point along a linear feature (often roads) by referencing that location to some other well-defined location, rather than using classical geographic coordinate systems. (Kevin M. Curtin, 2007)

Linear referencing can be used by many organizations, industries, and institutions that work with linear features, such as road-management organizations, transit organizations, oil and gas exploration industries, and water-resources managers, to name only a few. The common element among these industries is their use of linear features and the need to reference a position or measure along those features. (Kevin M. Curtin, 2007) LRM is a process for determining a previously unknown location based on (1) a defined path along the underlying transportation network, (2) a distance along that path measured from a known datum location, and (3) optionally an offset from the path. (Kevin M. Curtin, 2007)

2.13. Geodatabase Creation

Geodatabase is a bag or container in a system, which is used for storing spatial and non-spatial (attribute) data and also the relationships that exist between them. A vector data format in a geodatabase, features and their associated attribute data can be interlinked each other to work together as an integrated system through rules, relationships, and topological associations. In other words, it allows you to model the real world whether as simply or complexly as your needs dictate.

The creation, modification, and storage of spatial data are issues of prime importance in geospatial work, as are concerns about data integrity and data sharing. (Allen, 2020)

Spatial data are organized in structures or models, for their easier management, processing and analysis in order to obtain the information. Thus, it was necessary to integrate all the information related to a commune in a digital collection of data, which can be spatial located in the territory and which should be easy accessed and in real time with computer. This performance can be achieved through geodatabase structures operated with geographic informational systems. (HAIDU, 2011)

2.14. Empirical Review

During this study, more than thirty materials (Books, literatures and websites) are reviewed and also used for the citation. Out of this five of them that had raise the most critical issue are selected which meets the goal of BIM technology that is specially focused on roads construction.

Vilventhan R.R. (2021), in his “Integrating road information modeling (RIM) and geographic information system (GIS) for effective utility relocations in infrastructure projects” tried to develop integrated road information modeling (RIM) and geographic information system (GIS) models to assist early identification of utilities and effective coordination during utility relocation in infrastructure projects. And also, select two ongoing infrastructure projects with significant utility relocation delays as case studies and integrated RIM-GIS models are developed to assist utility relocation. To verify the applications of developed RIM-GIS models, a focus group discussion was conducted with 10 field experts from the considered case studies. In addition to this paper had done on the rail projects it also didn’t show procedural structural layer construction progress.

The aim of the paper “Road Pavement Information Modeling through Maintenance Scenario Evaluation” which was written by Oreto in 2021 is to develop an efficient BIM tool that can assist road pavement maintenance operations through data management arising from laboratory testing on bituminous materials. This means this paper is mainly focused on data management system to facilitate the information which is used for maintenance activity. Even also the methodology used for modeling a 3D model was based on integrating three of the applications which is called ‘InfraWorks’, ‘Civil 3D’ and

‘Revit’ that is also time taking tasks to migrate one to the other and also in addition to this need to install these three softwares in each party computer to communicate each other.

And the other paper which was undertaken by Girma in 2017 is also mainly focused on discussion of the integration between project management software (Primavera) and GIS application software. But, when I visualize the integration and the main knowledge-based technology advancement was not clearly discussed. Rather, it should be between the science of BIM and GIS technology. In my research paper the project management software was used as a data source tool whereas this paper was used as a main body of the research case. And, it also additionally is not a main issue on the science of BIM technology.

On other research paper main focus was on how progressively increasing the importance of visual programming language (VPL). This was also difficult to implement recently in Ethiopia due to the distance between the technology currently applying in the industry in the country and the BIM technology advancement in the world. It is too far; rather it is better to try to adopt the technology step by step starting from not far scale, since the BIM technology needs the contribution of variety of field specialists.

Almost all papers have not tried to work on construction monitoring system especially for the road sector with special consideration with the help of GIS concept. Respect with those papers, my topic is tries to focus mainly on how share schedule of the road construction project progressively with others in geospatial aspect.

2.15. Conceptual Framework

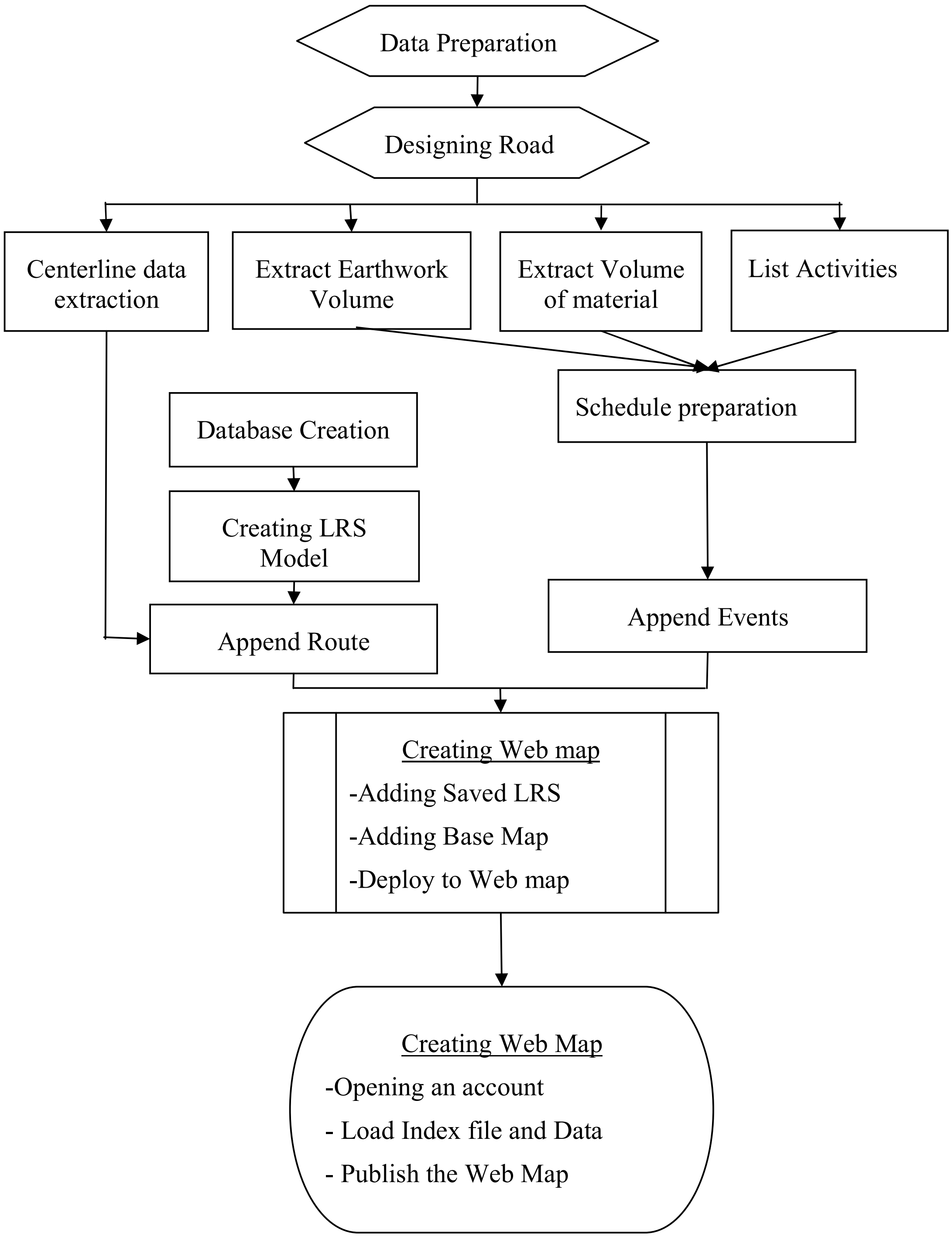


Figure 2.7 Conceptual Framework

CHAPTER III: MATERIALS AND METHODS

3.1. Study Area and Description

a. Location

The study area location is found in the central part of Ethiopia and the project is also geographically located around 8.660 latitude and 39.330 longitude and its terrain is to be considered as between flat and rolling.

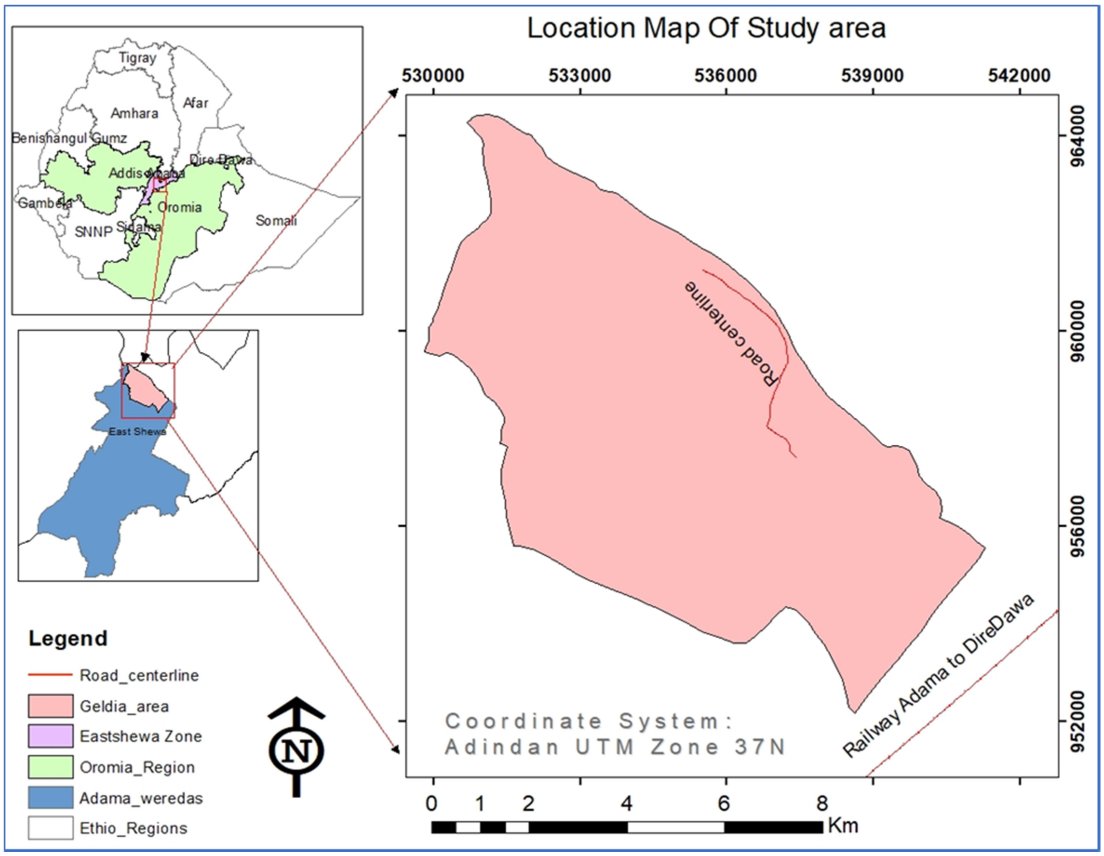


Figure 3.1.i Location map show Geldia village located in Ethiopia Oromia Region.

The origin of the road has starting from a small village Geldia which is found in Oromia region, east Shoa Zone and connects scattered settled farmers who delivered several agricultural products that will be transported to different neighboring towns like Welenchiti, Adama and so on.

The project had been planned to be constructed by the URRAP funded by World Bank through Ethiopian government in 2004E.C. but not well designed and constructed as much as needed due to many reasons.

Figure 3.1.ii Geldia LVR Unpaved Proposal

b. Climate

Since the project location is a few kilometers away in the north direction from Adama town, the climatic condition is considered to be the same. So, based on this fact, I used the data of Adama town directly.

The temperature ranges in an average from 32^0C to 14^0C and also the rainfall is varying from 245 mm in the rainy season up to 0 mm in the dry season.

3.2. Data source

When I had prepared the proposal for this paper, I was planned to do a model using 2D road template drawings and well-prepared cost estimation and project schedule digital documents from other road sector organizations, then I could do my research work not in a much-challenged way. But not, due to the data I got from three governmental institutions was not well organized and compatible one with the other.

That's why I decide to produce the necessary documents by myself in a suitable and standard way. The primary data source was satellite data from google Earth imagery and ASTER GDBMv2 digital elevation model using Global Mapper which had given me

Easing, Northing and Elevation (X, Y, Z) data. Then, I converted to a CSV format using Microsoft Excel.

Using the Excel data, I prepared all 2D road templates using a standard Ethiopian Road authority standard manual for low volume roads and an Autodesk Civil 3D software which is suitable to design complete road design that can give us all the necessary data which can be used for any highway construction projects.

3.3. Materials

In this thesis work, I have used different softwares in each stages of the study: Designing, planning and construction processes. But, considering that my main objective was to show the construction progress under time and cost effect. So as to reach to the main construction process information, I had to go through those process designing and planning works. Under this process also I had used the following softwares listed on the Table Below.

Table 3-3 Material to be Used

No	Item	Version	Purpose
1	Google Earth Pro	7.3.4.8642	-Extract KML file
2	Global Mapper 23	23.00.0000	-Converting KML file to text file format using ASTER GDEMv2 Worldwide Elevation data
3	Microsoft Excel	2016	-Converting and adjusting raw data to csv file format -Computing Cost Break Down and means of integrating different type of date with Arc GIS Pro platform
4	Autodesk Civil 3D	2023	-Designing 2D road templates and preparing road material volume reports
5	Arc GIS desktop	10.7.1	- To model and analyze the LRS
6	QGIS desktop	3.28.3	To design and publish the Web map

3.4. Method of Data Collection

Since the objective of this paper is to show the model is whether it is functional or not, the accuracy of data source and data quality was not an important issue. Because of the data what I got, collected using total station had not have enough corridor space to design with a regular standard. Instead, I prefer to extract KML file from the Google Earth Pro and converted to text file using Global Mapper, and also to use a Bench Marks from a collected data using Total station which is to be used as a georeferencing points. In any application software that is used in this paper, adjusting a coordinate system was a big deal, in order to exchange data between them. Since in different coordinate system it is impossible to get the right location of a feature and also it will be placed distortedly. The following workflow below shows the way.

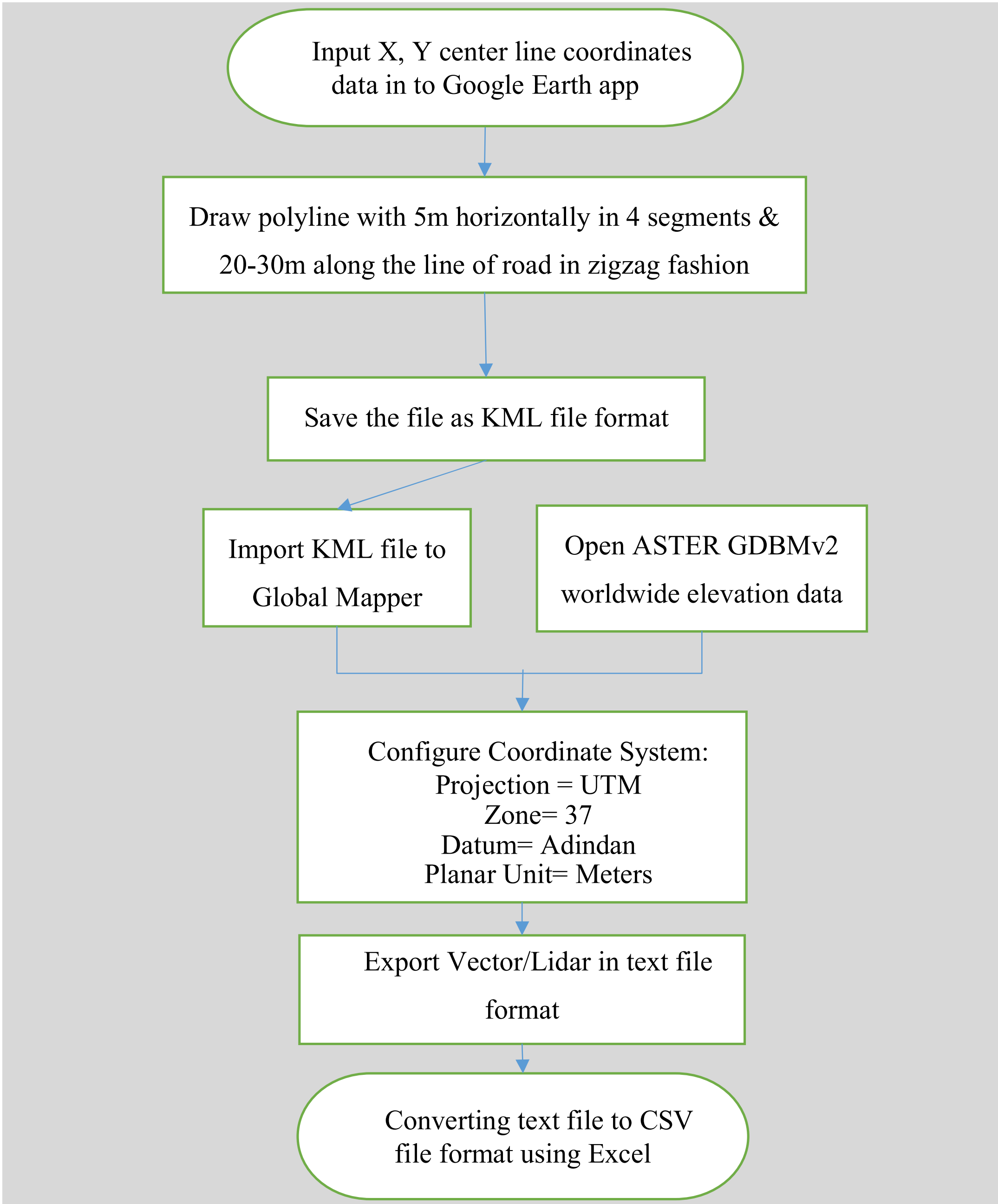


Figure 3.4-i Satellite Data Extraction Procedures

After the CSV data production had been completed, the production of 2D design drawing and quantity of the road material had been successfully completed using Autodesk Civil 3D application software according to ERA rural road design standard manual which was published 2013. The procedural workflow shown below as follows.

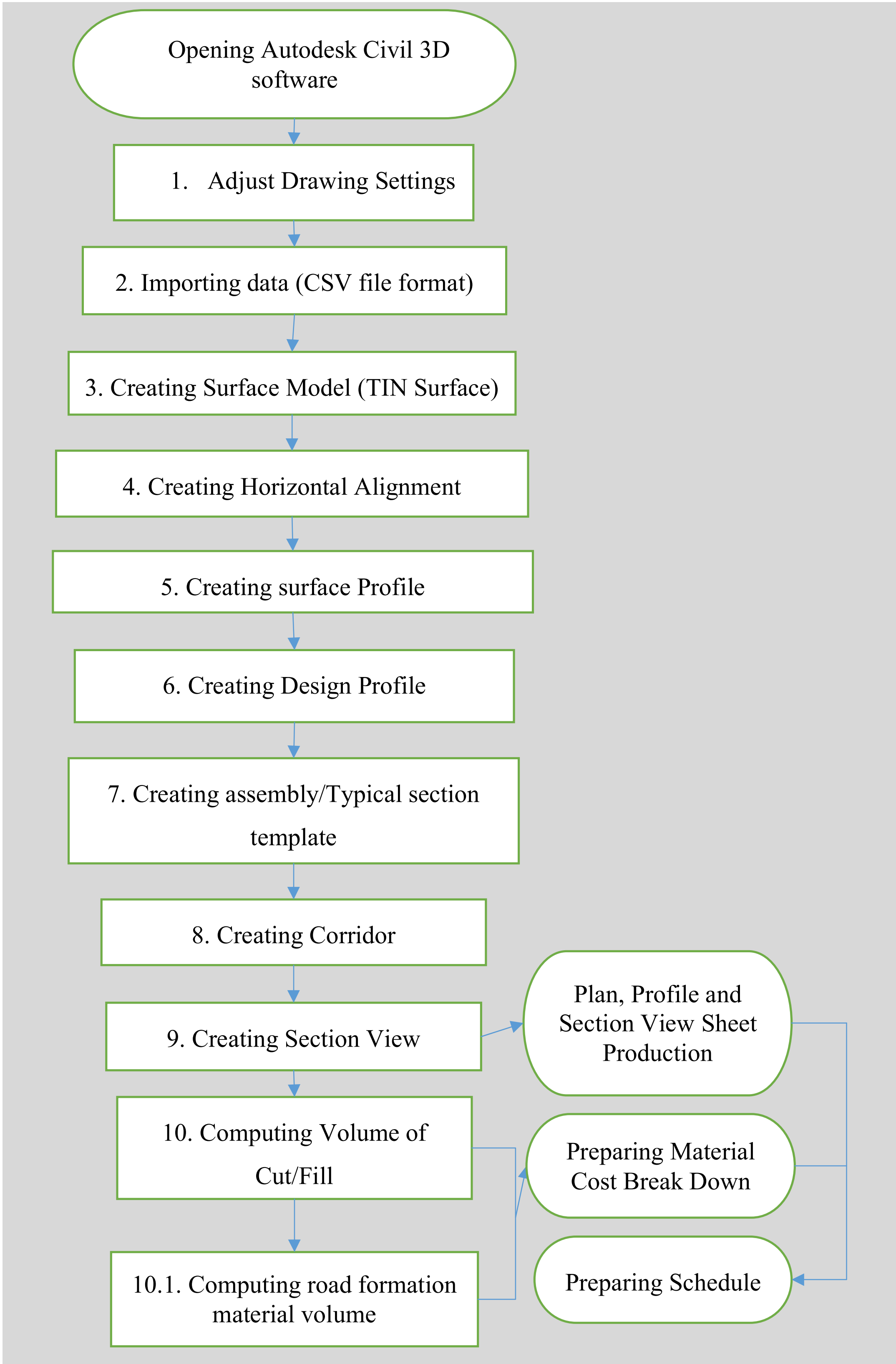


Figure 3.4-ii Designing Road and Data production Procedures

3.5. Method of Data Analysis

The section of the thesis aimed to show the benefit of web GIS in road construction, where information can be analyzed and managers can take the decisions on the basis of available information. Therefore, the key objective is to manage the information from different sources at center level using advanced methods and technologies which perform spatial analysis for enhanced administration and management.

Along with the representation of the route data on a map, the progress is quantified as well.

Eq. 1: Percentage completion along each segment = Work completed along the specific segment / Total work planned along the same segment *100

Similarly, the overall percentage of work done along the route is calculated using the equation 2.

Eq. 2: Project level percentage completion of work = Work completed along all the route/ Total work planned along all the routes*100

The calculation enables the user to understand the level of work completed at the project level and identify the pace of execution.
The Web-based GIS monitoring tool, provides information to enable the project managers or monitoring team to make several kinds of decisions.

3.5.1. General Approach

Over all activities are categorized under the following four stages:

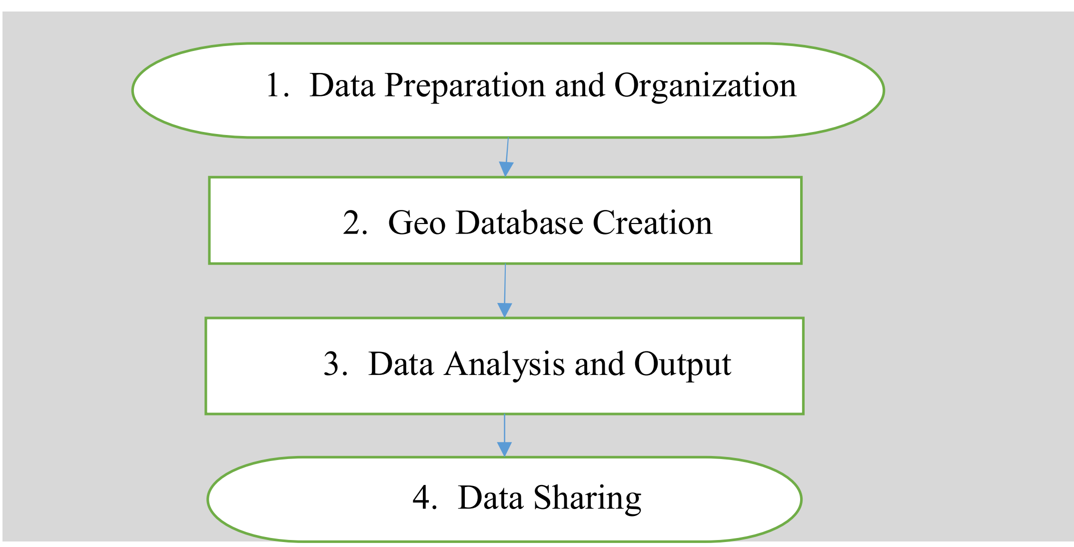


Figure 3.5.1 Workflow for Data approach

i. Data preparation and organization

In this phase the necessary data was organized from the output of the road design software (AutoCAD Civil 3d) and Schedule information from MS Project scheduling software. From AutoCAD Civil 3D, the centerline of the road and profile data had been exported and joining them to make the X, Y, and Z of centerline excel data in the CSV file format, which would use to create the route in LRS. In addition, other design information like volume of cut and fill of earth work and volume of road formation layer (wearing course, base, and base course) had been extracted from the design of Autodesk Civil 3D and it was converted to excel file format so that to make it ready to be used as event information.

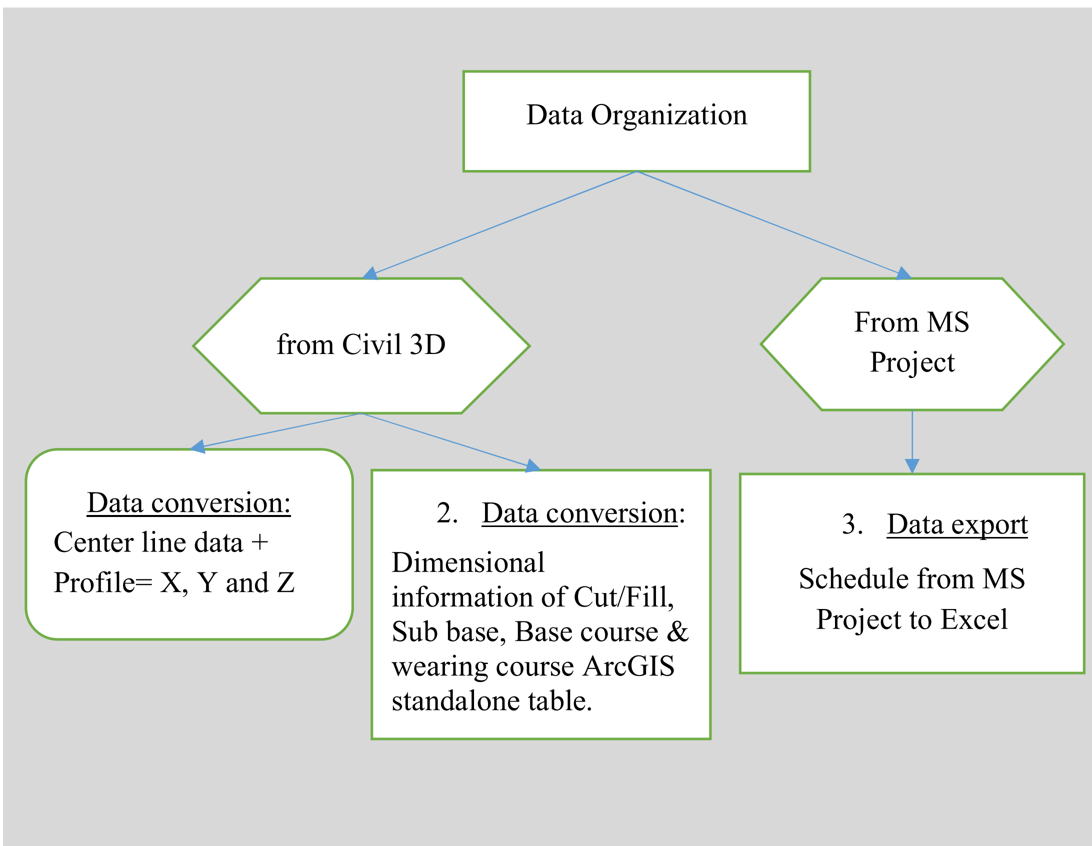


Figure 3.5.1-i Data Preparation and organization

ii. Data storage and management/ Geodatabase Creation

At its most basic level, an ArcGIS geodatabase is a collection of geographic datasets of various types held in a common file system folder, a Microsoft Access database, or a multiuser relational DBMS (such as Oracle, Microsoft SQL Server, PostgreSQL, Informix, or IBM DB2). Geodatabases come in different sizes, have different numbers of users and can scale from small (single-user databases built on files) up to larger (multi-user databases workgroup like department, and enterprise geodatabases accessed by many users).

For efficient data storage and management of vector data, raster data and tables a geodatabase can be created. In my case the advantage of using a geodatabase was for consistent usage of the coordinate system, for improved versatility and usability, and for easy data migration.

There are two different types of geodatabase, which are Personal geodatabase and file geodatabase. From which personal geodatabase are more appropriate for my way, because Original data format for ArcGIS geodatabases stored and managed in Microsoft Access data files so that it can be used and process in other application.

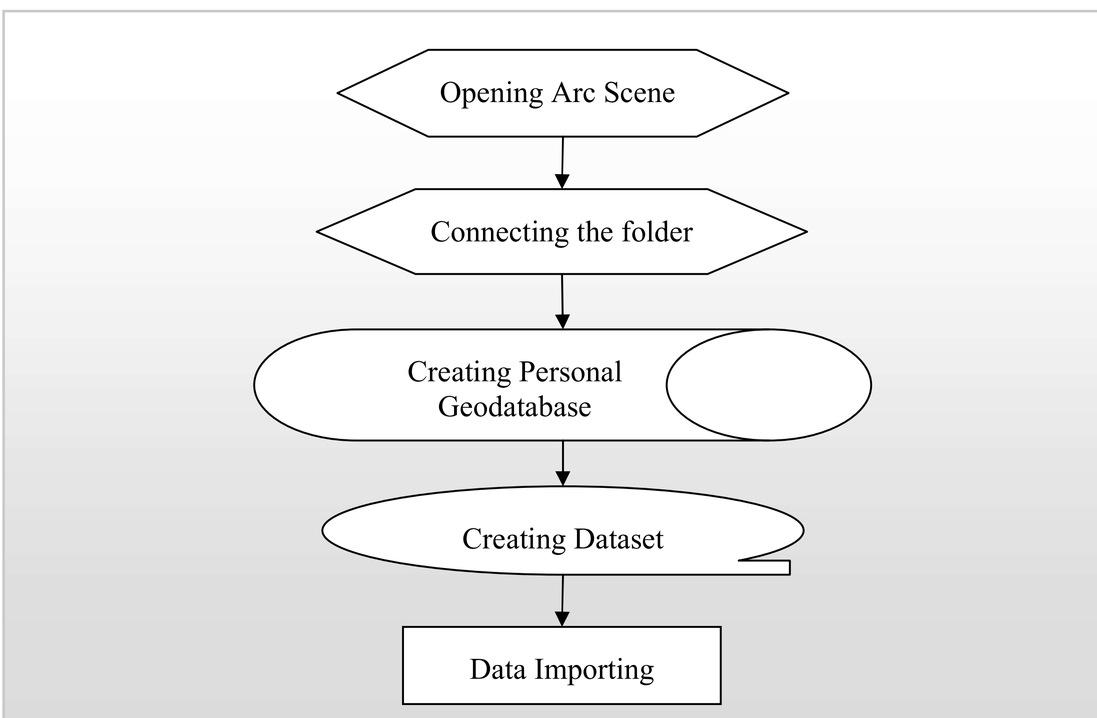


Figure 3.5.1-ii Creating Geodatabase

During creating dataset, I configured the projected local coordinate system and also set tolerance in the default setting.

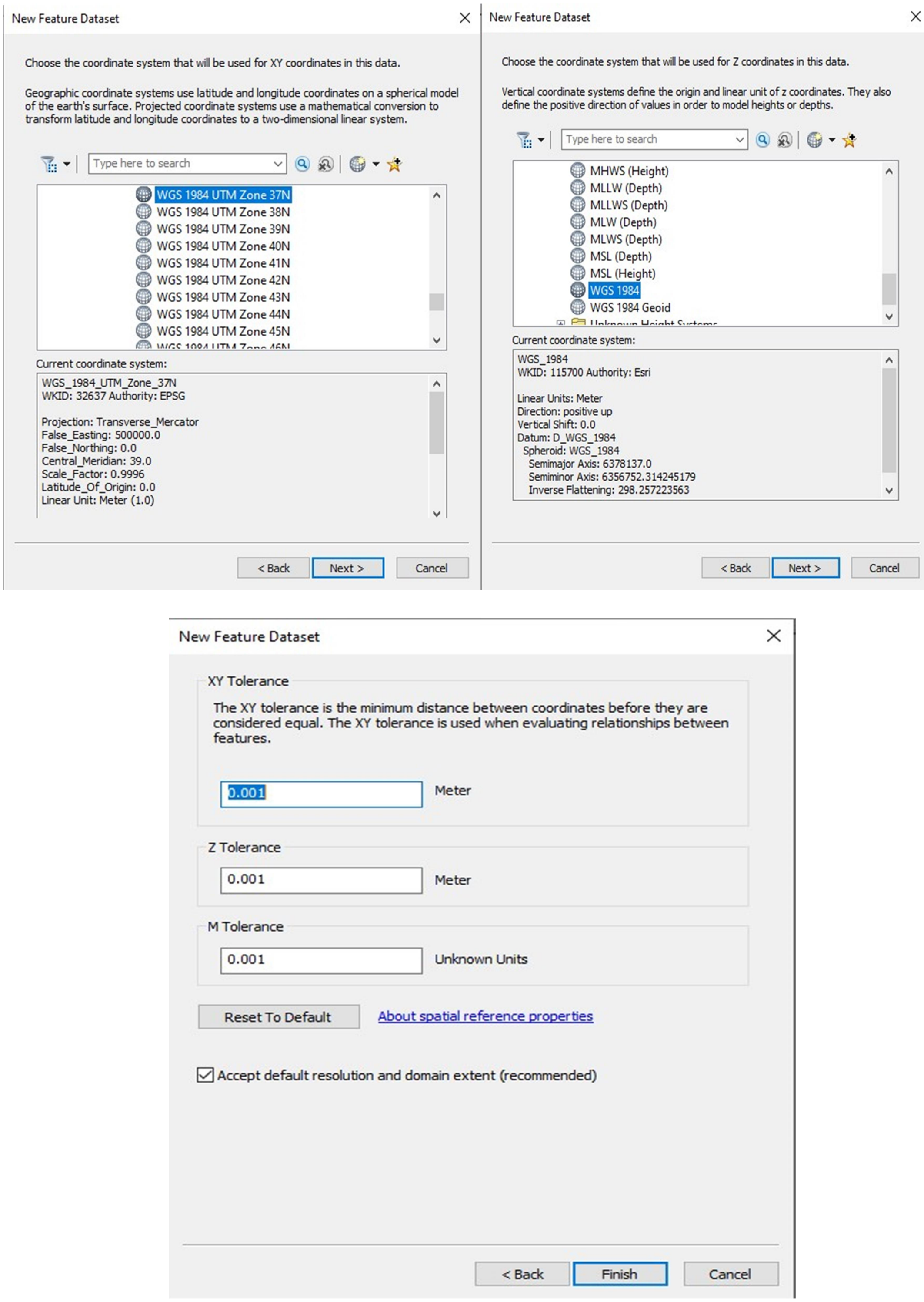


Figure 3.5.1-ii Configuring Dataset

iii. Creating LRS Model

After I had been created the data storage, I created the LRS model in the created dataset in the geodatabase following the procedure shown below.

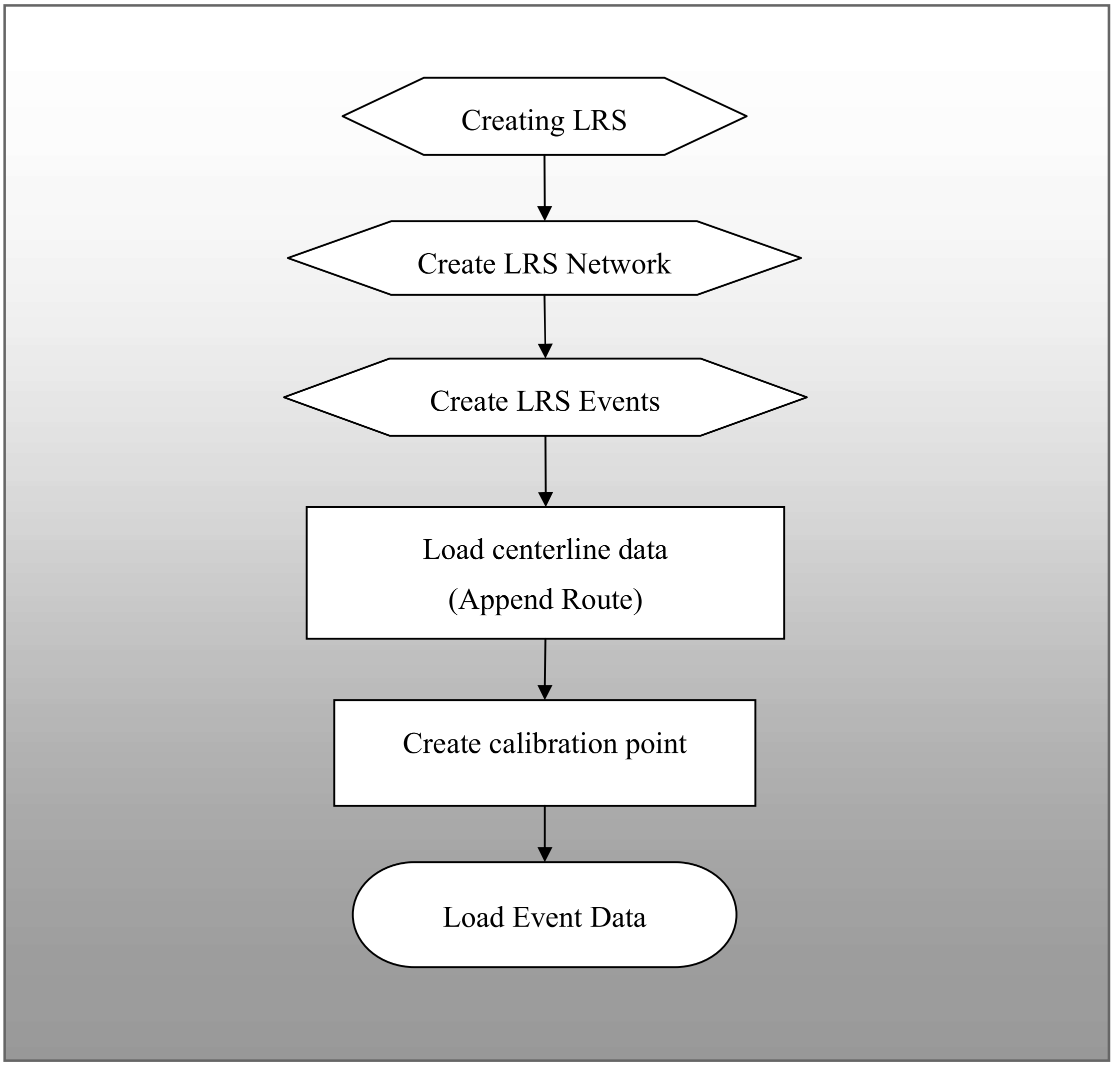


Figure 3.5.1-iii Creating LRS

In this phase a 2D map of the route was prepared by importing the coordinates of the centerline of route in ArcGIS Desktop and the 3D map was prepared by extruding the route with cut/fill depth, subbase, basecourse and surfacing height as extrusion parameter. By integrating 3D information with Schedule and status information of the activities, 4D information of the Road was visualized.

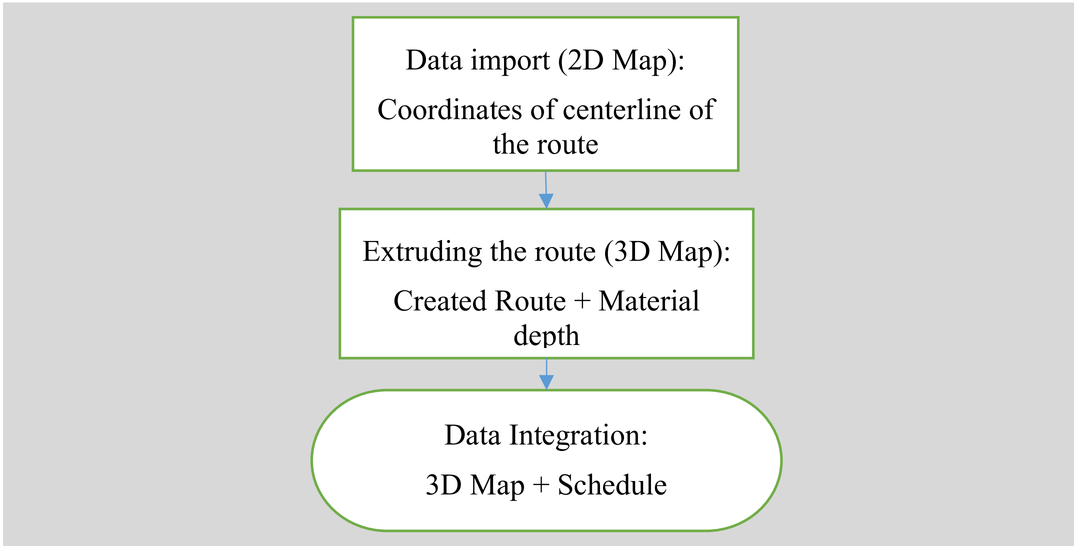
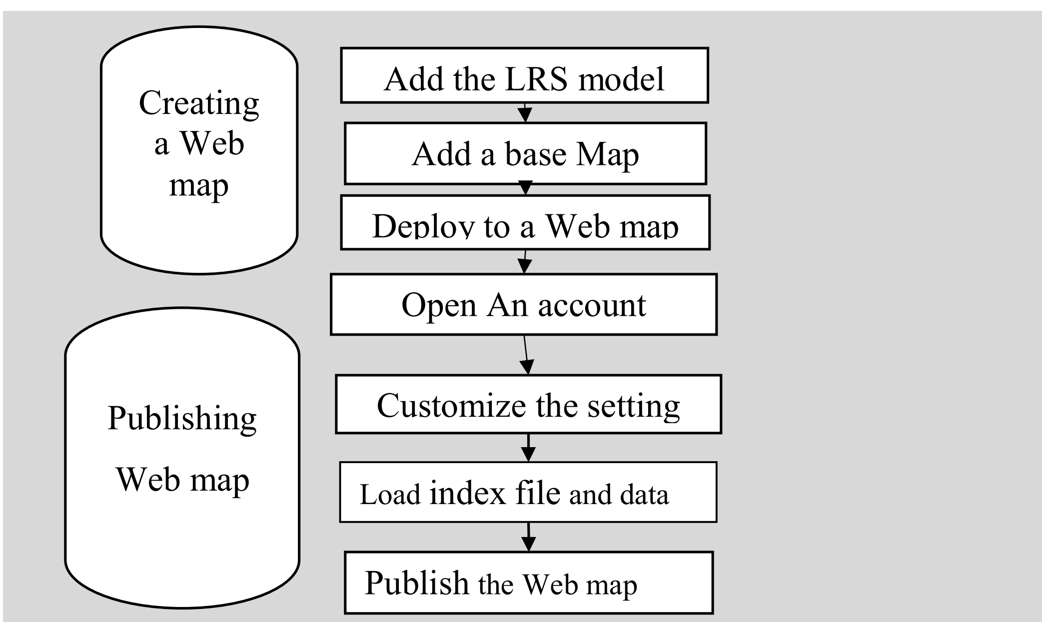


Figure 3.5.1-iv Data Analysis and Output Generation

v. Data sharing and dissemination

In this phase web mapping application was developed with open source tools and plug-in and the necessary information of the road like the centerline of the route, the status of each activity, the schedule information was uploaded to the web mapping application and here the application is tested with local server/local host and shows the possibility how to share to the intended users and decision makers/project managers via internet.



CHAPTER IV: **RESULT AND DISCUSSION**

4.1. Conversion Road Center Line to Route

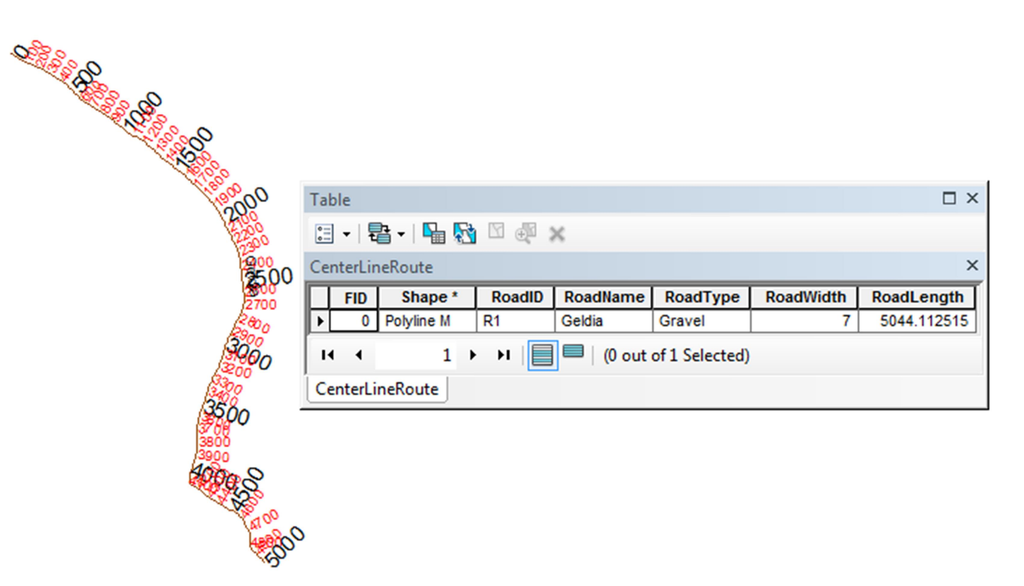
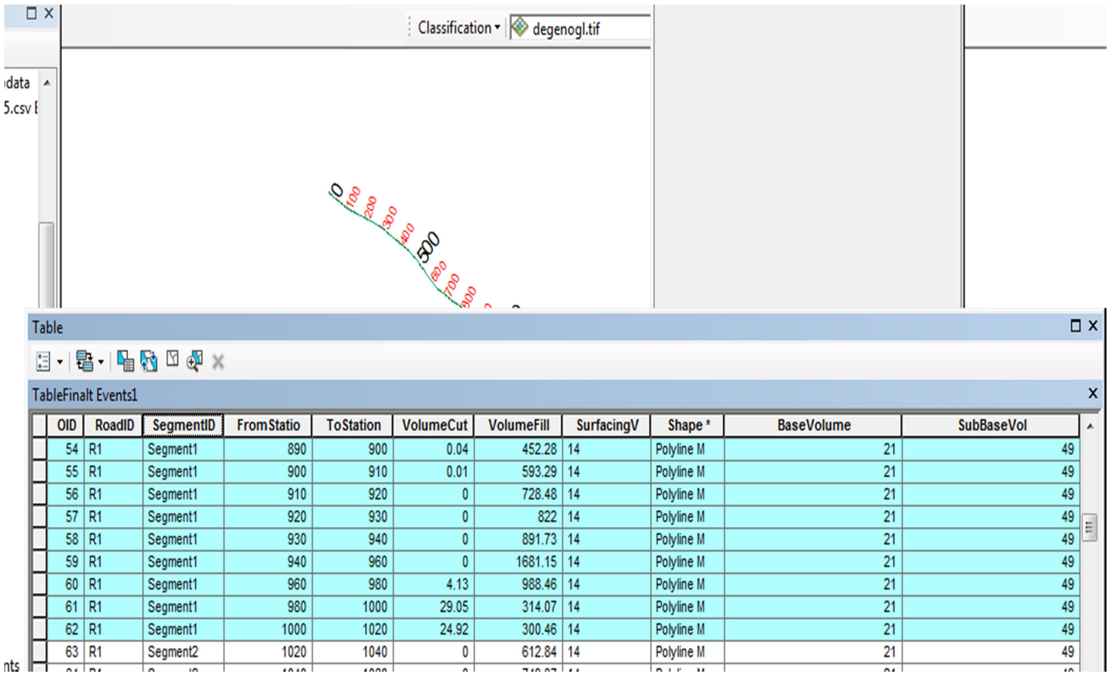


Figure 4.1 Converted Route

Figure 4.1 shows that; the road centerline was converted to a route. The shape field of the attribute table was converted to polyline which means at every location on the route, there is a measure field. In additions the route can be labeled with the Hatch label property of the route layer like stationing. One of the advantages of using a GIS is that you can analyze and share both the spatial/geometry and attribute information in one environment. In the above figure some of the attribute information was entered manually like the RoadName and RoadType. However, the road length was calculated from the geometry. The main advantage of creating a route is that, it enables multiple events of a road can be overlaid and visualized together.

4.2. Segmented route information visualization and manipulation



OID	RoadID	SegmentID	FromStatio	ToStation	VolumeCut	VolumeFill	SurfacingV	Shape *	BaseVolume	SubBaseVol
54	R1	Segment1	890	900	0.04	452.28	14	Polyline M	21	49
55	R1	Segment1	900	910	0.01	593.29	14	Polyline M	21	49
56	R1	Segment1	910	920	0	728.48	14	Polyline M	21	49
57	R1	Segment1	920	930	0	822	14	Polyline M	21	49
58	R1	Segment1	930	940	0	891.73	14	Polyline M	21	49
59	R1	Segment1	940	960	0	1681.15	14	Polyline M	21	49
60	R1	Segment1	960	980	4.13	988.46	14	Polyline M	21	49
61	R1	Segment1	980	1000	29.05	314.07	14	Polyline M	21	49
62	R1	Segment1	1000	1020	24.92	300.46	14	Polyline M	21	49
63	R1	Segment2	1020	1040	0	612.84	14	Polyline M	21	49

Figure 4.2 Information Visualization and Manipulation

Figure 4.2 shows how a road segment information is stored in the attribute table of a GIS like the volume of cut, volume of fill, Sub base volume, base course volume and surfacing volume for each station. In every segment, there are a no of stations and we can get any information with in its chainage. The advantage is, every segmented part of the route is based on the project mile stones but also every chainage is from the design reports. Here the advantage of using GIS is to select specific segment or station and visualize the result graphically and in tabular forms. Even it is possible to summarize the information with segments like summation of volume of cut or fill of chainage in a specific segment, average volume of cut or fill, minimum and maximum cut or fill volume of chainage with in a specific segment, And also, the overall summary of the rout information.

4.3. Information Summarization

Table

SummerizedSegment

OID	SegmentID	Count_SegmentID	Sum_VolumeCut	Sum_VolumeFill	Sum_BaseVolume	Sum_SubBaseVol
0	Segment1	63	8199.42	25736.35	1323	3087
1	Segment2	74	5870.75	53688.85	1554	3626
2	Segment3	61	11601.64	63347.28	1281	2989
3	Segment4	71	21177.83	36673.27	1491	3479
4	Segment5	74	7278.01	52467.32	1554	3626

Figure 4.3-i Information Summary

In figure 4.3.a the summarized road information based on segment had shown. This enables to see the overall summations of cut, fill, Subbase, basecourse and surfacing volumes of each segment. This kind of summarized information is mostly needed for scheduling labor and machinery. This information also facilitates project cost estimation process.

In addition to this the GIS application could make be able us to visualize the segmented information in the other way (using bar graph)

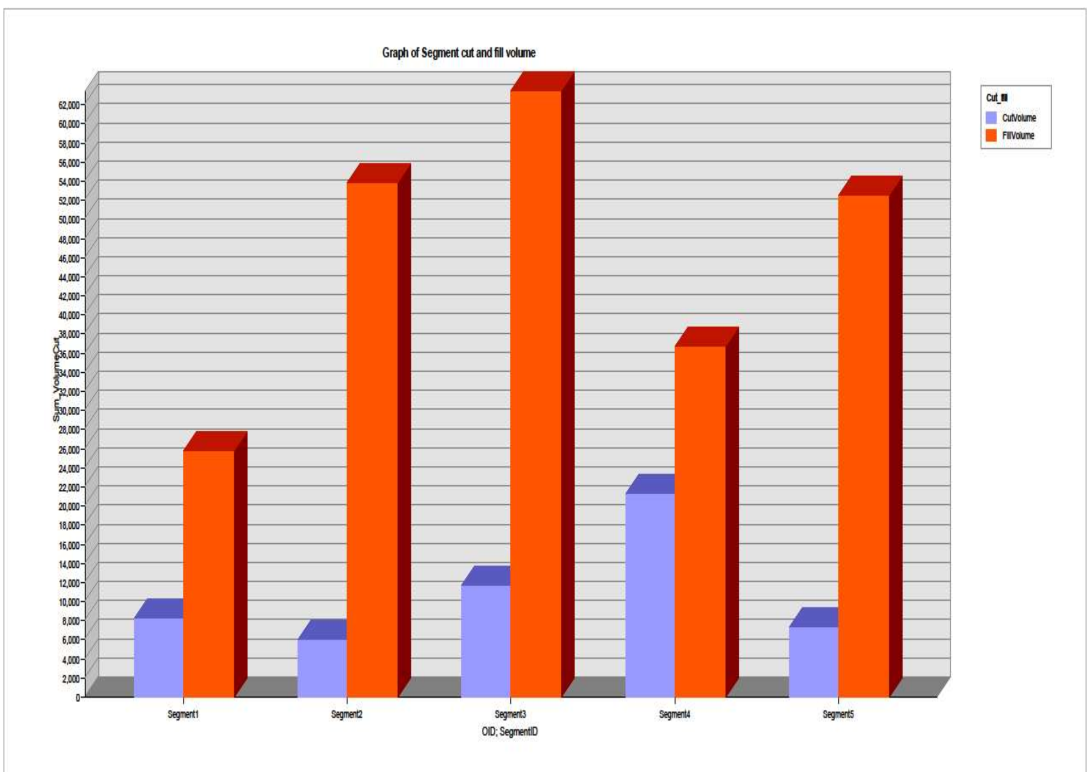
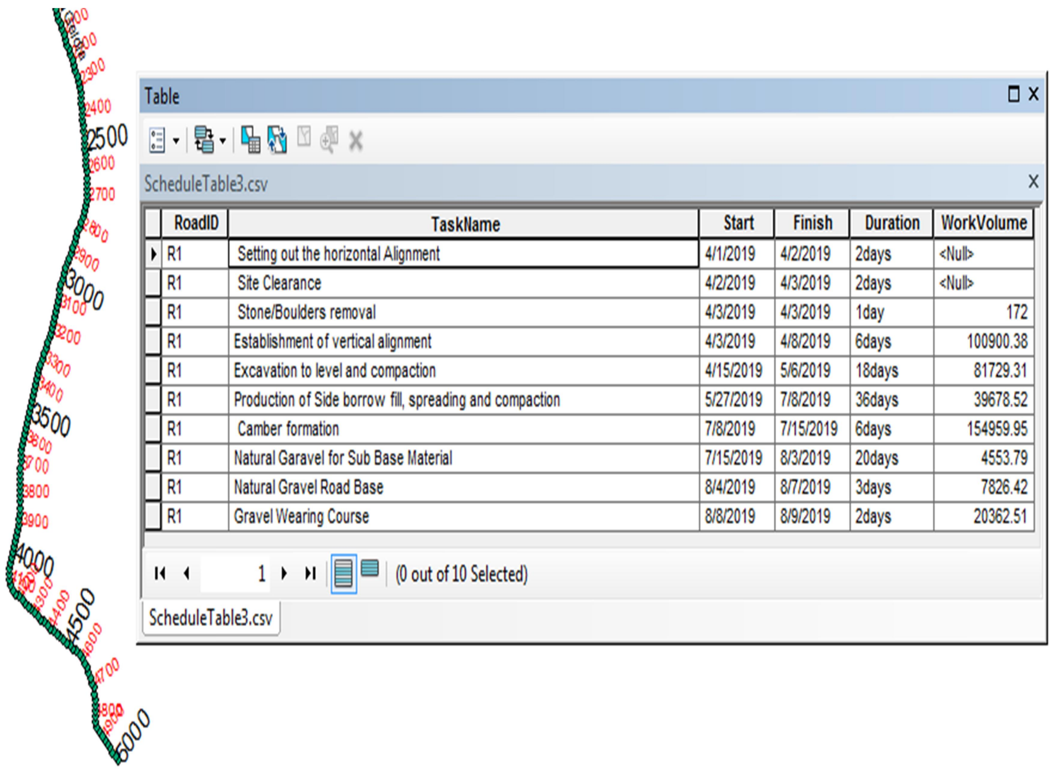


Figure 4.3-ii Graph of Segments per Volume of Cut and/or Fill

In figure 4.3.b the blue shows the cut volumes and the red shows the fill volume for each segment. In segment three relatively high volume of fill was examined. Using this information, any person who can access this information may ask why this much of fill has occur and the engineer also can give a professional answer for the reason why it was happened. This kind of graphs is important for examining the proportion of cut and fill volume. Even it gives information for rechecking and redesigning the road before beginning the construction.

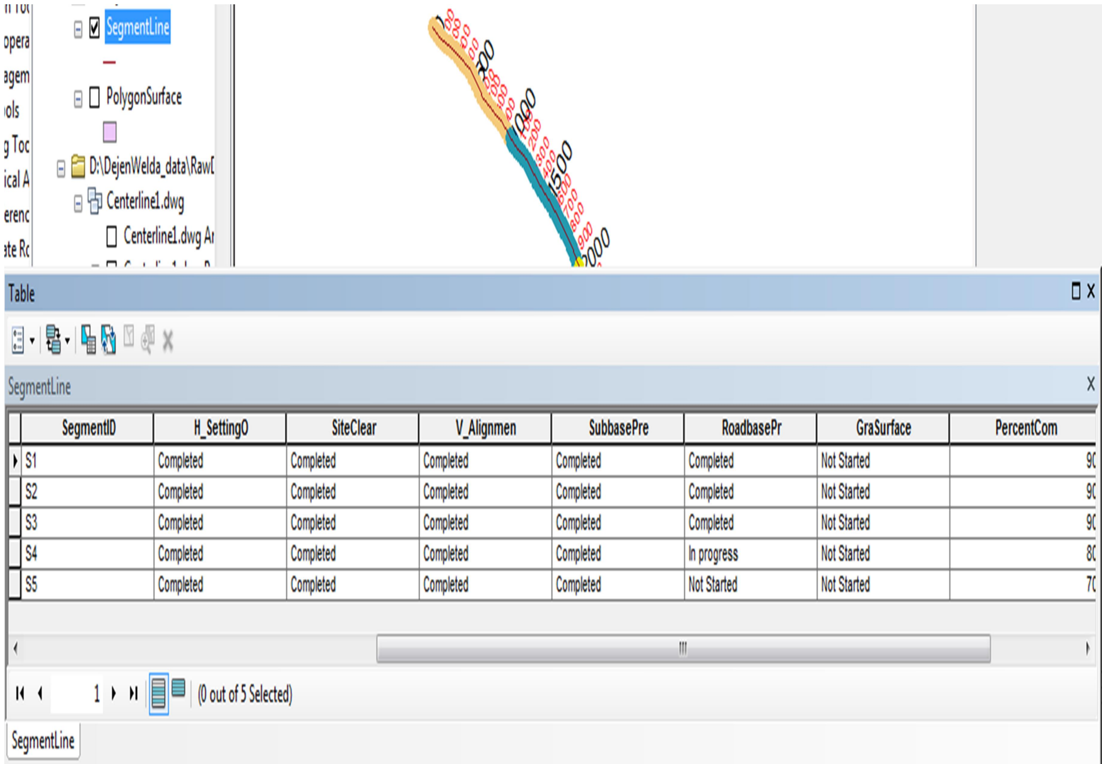


RoadID	TaskName	Start	Finish	Duration	WorkVolume
R1	Setting out the horizontal Alignment	4/1/2019	4/2/2019	2days	<Null>
R1	Site Clearance	4/2/2019	4/3/2019	2days	<Null>
R1	Stone/Boulders removal	4/3/2019	4/3/2019	1day	172
R1	Establishment of vertical alignment	4/3/2019	4/8/2019	6days	100900.38
R1	Excavation to level and compaction	4/15/2019	5/6/2019	18days	81729.31
R1	Production of Side borrow fill, spreading and compaction	5/27/2019	7/8/2019	36days	39678.52
R1	Camber formation	7/8/2019	7/15/2019	6days	154959.95
R1	Natural Garavel for Sub Base Material	7/15/2019	8/3/2019	20days	4553.79
R1	Natural Gravel Road Base	8/4/2019	8/7/2019	3days	7826.42
R1	Gravel Wearing Course	8/8/2019	8/9/2019	2days	20362.51

Figure 4.3-iii Integrated Work Schedule

Figure 4.3.c shows, How the schedule information was formatted and linked to the route with RouteID. And for each activity the start and finished date and work volume is shown. First the schedule information from the MS Project software was exported to excel and then the excel table was formatted and converted to the ArcGIS stand-alone table. After that, the table was joined to the route with the Route ID field.

In this schedule, the figures in it can be changed manually based on amount of work on the site in their unit of measurement and also be shared other belonging parties through online access. When the site work taken place, amount of specific activity will be changed and can be recorded manually.



SegmentID	H_SettingO	SiteClear	V_Alignmen	SubbasePre	RoadbasePr	GraSurface	PercentCom
S1	Completed	Completed	Completed	Completed	Completed	Not Started	9(
S2	Completed	Completed	Completed	Completed	Completed	Not Started	9(
S3	Completed	Completed	Completed	Completed	Completed	Not Started	9(
S4	Completed	Completed	Completed	Completed	In progress	Not Started	8(
S5	Completed	Completed	Completed	Completed	Not Started	Not Started	7(

Figure 4.3-iv Construction Status Report

Figure 4.3.d shows, how the GIS is used for reporting the construction progress status with in a pre-estimated period of construction in each segment and for each activity graphically according to the data encoded by the data encoder. For example, In the above figure activities like setting out, site clearance, vertical alignment, Subbase preparations activities were finished for all segment. Likewise, for base course preparation segment one, two and three were finished and segment four were in progress and segment five still not yet started. For gravel surface activity all the segments are not started. In addition, percentage of all activities are calculated and reported in the attribute table of the GIS. It is also possible to store and visualize the status information of the activities with station based.

4.4. Customized Web Mapping

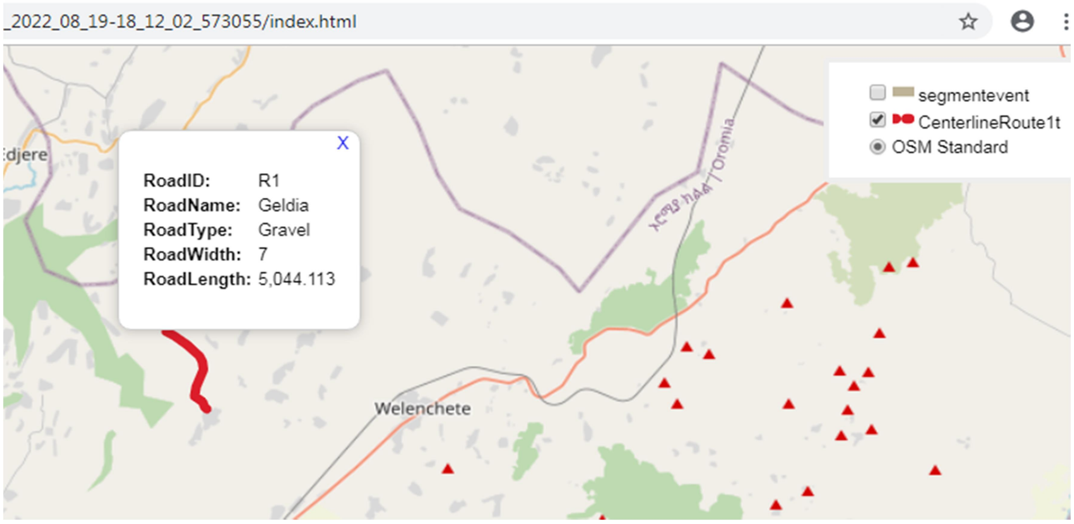


Figure 4.4-i Customized Web Map

Figure 4.4.a shows the Customized web mapping applications displayed general information's about the road centerline information like the routeID, RoadName, RoadType, RoadWidth and RoadLentgh. The Background open street map gives better visualization of the area and shows the surrounding roads and towns.

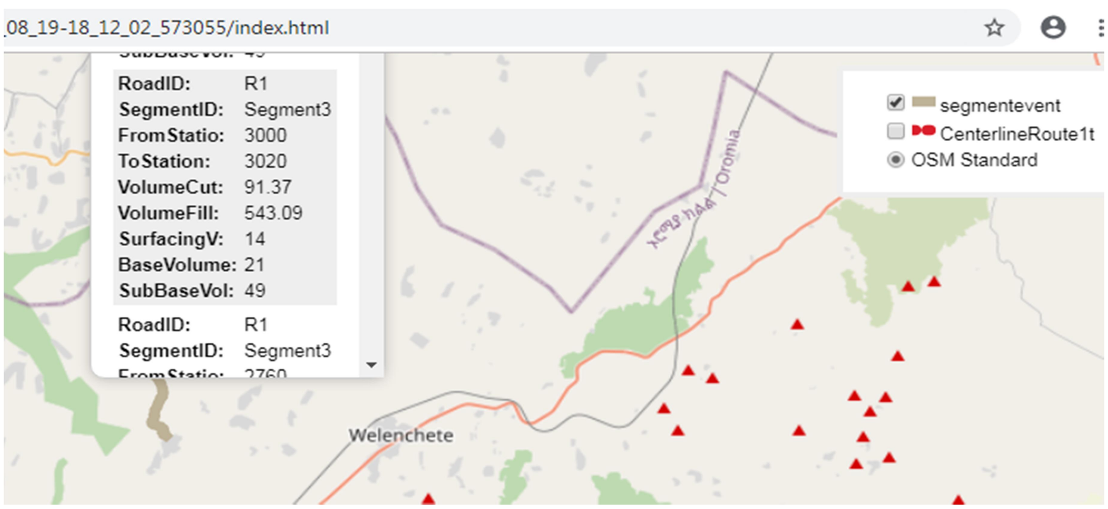


Figure 4.4-ii Displaying General information

Figure 4.4.b Shows the capability of the web mapping application displaying the road information with station ranges like the SegmentID, VolumeCut, VolumeFill, Subbase, basecourse and surfacing volume. The construction progress, current state of fill information can also be reported with similar fashion.

Segmented Information

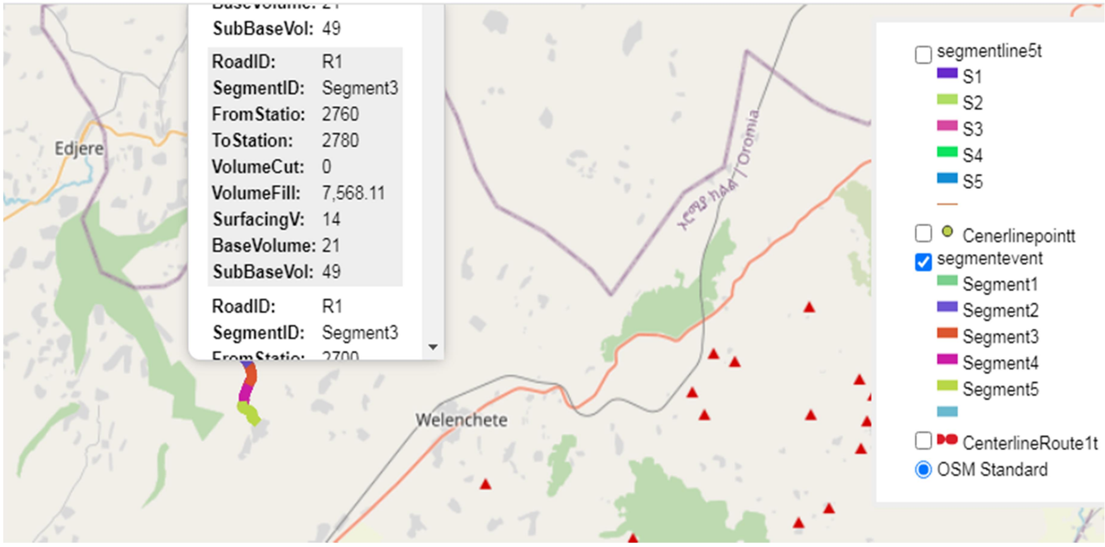


Figure 4.4-iii Customized Map to show Segmented Information

Here the web mapping application was customized to show the contents of the layers with different colors and add some functionally like pan zoom in zoom out and distance measure. One of the advantages of this web mapping application is that to simply measure the distance from the query site to the route station.

Figure 4.4-iv Visualizing Status report

Figure 4.4.d shows the capability of a web mapping application to show each segment and the status of each activity with different colors. The status information and percent completed was reported segment based or station based.

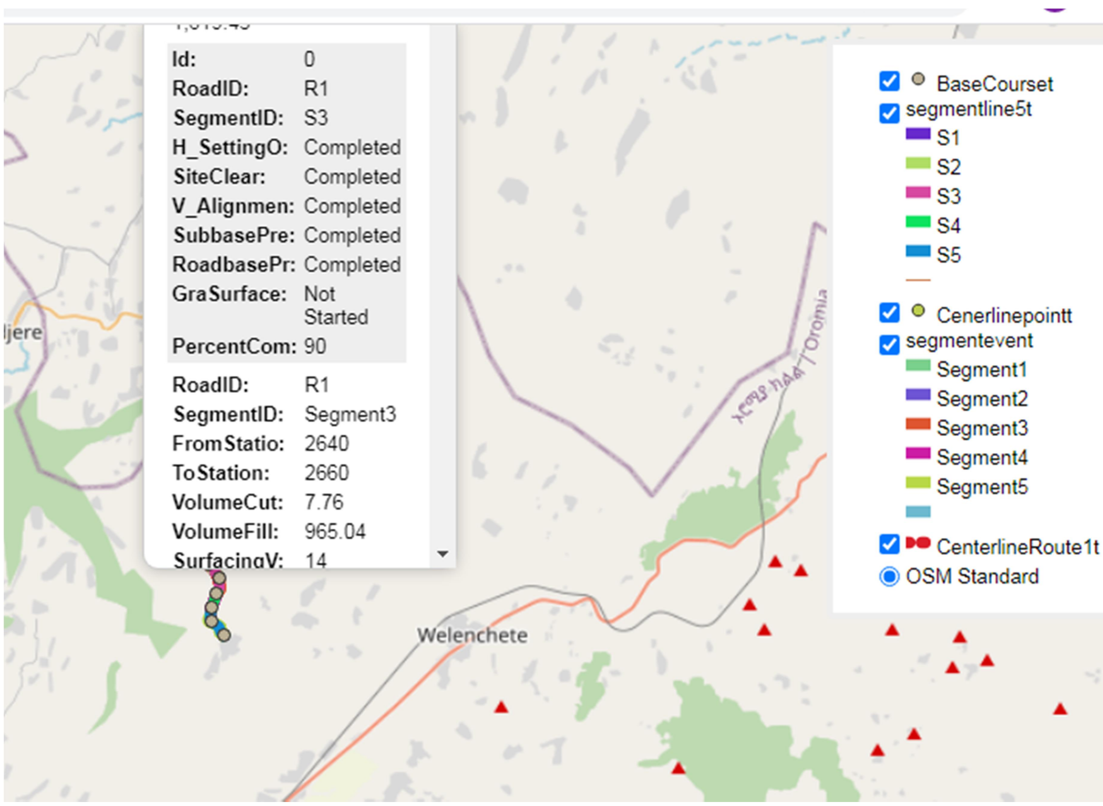
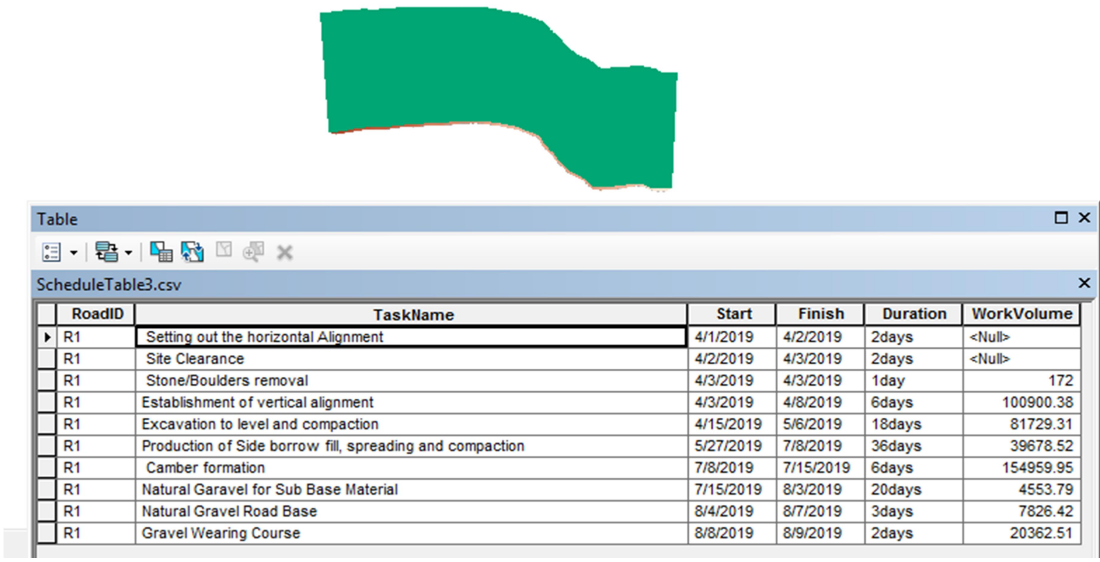


Figure 4.4-iiv Interacting with Map

The above Web maps in figure 4.4.e are interactive. The term interactive implies that the viewer can interact with the map. This can mean selecting different map data layers or features to view, zooming into a particular part of the map that you are interested in, inspecting feature properties, editing existing content, or submitting new content, and so on.it also shows a combination of information about the construction progress like the status of each activity and the volume of work executed or planned.

4.5. Integrated Work Schedule



RoadID	TaskName	Start	Finish	Duration	WorkVolume
R1	Setting out the horizontal Alignment	4/1/2019	4/2/2019	2days	<Null>
R1	Site Clearance	4/2/2019	4/3/2019	2days	<Null>
R1	Stone/Boulders removal	4/3/2019	4/3/2019	1day	172
R1	Establishment of vertical alignment	4/3/2019	4/8/2019	6days	100900.38
R1	Excavation to level and compaction	4/15/2019	5/6/2019	18days	81729.31
R1	Production of Side borrow fill, spreading and compaction	5/27/2019	7/8/2019	36days	39678.52
R1	Camber formation	7/8/2019	7/15/2019	6days	154959.95
R1	Natural Garavel for Sub Base Material	7/15/2019	8/3/2019	20days	4553.79
R1	Natural Gravel Road Base	8/4/2019	8/7/2019	3days	7826.42
R1	Gravel Wearing Course	8/8/2019	8/9/2019	2days	20362.51

Figure 4.5 Work Schedule

4.6. 3D Visualization

Figure 4.6 Visualizing Tree-Dimensional View

Figure 4.6 shows the BIM and GIS are used for visualization with 3D models. The 3D model could help all parties understand the details and get a similar picture of the design which reduces the risk for misunderstandings and clashes the 3D model also helps all parties to get a holistic view of the project and makes it easier to visualize drawings and to understand what has to be done in the work preparations. By integrating the 3D model with the schedule information 4D models established for construction analysis and planning. 4D model could visualize the construction plan with 4D animations of the site being built according to the schedule.

Conclusion

Undeniably, due to the technological advancement from paper-based design to CAD, the remarkable technology leap has taken the AEC industry to a computer-based age. Now, the BIM and GIS integration brings subversive change for the entire industry. In this new era, the design is not merely about drawings, but it is used for scheduling, quantity takeoff, progress monitoring and so on. The application of BIM and GIS can spread throughout the project life cycle: project initiation and/or planning, design, build and operation phases and even rebuilding or dismantling. BIM and GIS are improving the AEC industry to a high-tech and high-productivity industry.

Since proper progress monitoring of projects would aid effective utilization and distribution of project resources, it is essential for large construction projects like road construction. So, this study focused on the integrated use of BIM and GIS for 4D modeling in road construction project and the potential technology of BIM and GIS tools was used to modernize the construction management task. In addition, a WEBGIS tool was customized to cooperate, communication and decision making.

The key finding of this study is that by integrating existing technologies like BIM, Web-based interface and GIS, progress of road projects in particular, can be monitored in a systematic and cost-effective manner. This information system can assist project managers, project owner and construction engineers' team in making the required decisions regarding resource allocation, cost analysis, schedule analysis, and scope management. Consolidated project data of the road segments can be maintained at a single web interface using the tool. The data related to each road segment can be accessed using a filter indicating the segment they belong to. Monitoring at the project level and the segment level would, thus, be facilitated.

Recommendations

In the future, more research is needed to completely automate the process and to increase the web tool's efficiency for progress monitoring of road projects. In addition, the integration of data collected from the site and data from management teams at the office, such as reports for resource planning and allocation, would enable the transformation of this information system into a decision support system.

After seeing the outcomes of this study, it would be beneficial to conduct further study about the use of BIM and GIS especially in road sector. Because the AEC industry is still at a stage transferring into the 3D world, a lot more research would be required to promote the development of new techniques. Overall, the cost of the BIM and GIS and its supporting technologies can be expensive at the start. However, the powerful uses of BIM and GIS increase profits, lower costs, and shorten scheduling time. This nature determines that BIM will be the trend of the AEC industry.

Thanks to the advanced technology, various software is developed to extend the BIM and GIS application. But not all of them are suitable for any kind of projects. So, the new technologies still need time for researchers to test.

In this study the type of project was limited. Therefore, a direction for future work on this subject is to develop more studies on various uses of BIM and GIS in road projects. In addition, more research about the connection and compatibility of BIM and GIS tools will also be required.

Lastly, I recommend the researchers to do more on adding a 3D scene to visualize the real construction environment and also to extend the dimension by applying attributes to interlink the information like cost analysis, facility management and other information which are used to make the road construction progress monitoring starting from planning up to operational process better.

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Appendices

Appendix 1: Centerline coordinates with OGL and Design Elevation

PVI	Station	Easting	Northing	OGL	Design Elevation
0	0+000.00	537401.135	957418.444	1,583.82	
1	0+020.00	537387.082	957432.675	1,583.93	1,583.65
2	0+040.00	537373.029	957446.906	1,583.27	1,583.60
3	0+060.00	537358.976	957461.137	1,582.28	1,583.55
4	0+080.00	537344.924	957475.368	1,582.33	1,583.54
5	0+100.00	537330.871	957489.599	1,582.71	1,583.69
6	0+120.00	537316.818	957503.830	1,583.24	1,584.02
7	0+140.00	537302.766	957518.061	1,583.89	1,584.52
8	0+160.00	537288.930	957532.490	1,584.24	1,585.20
9	0+180.00	537280.744	957550.536	1,584.79	1,586.05
10	0+200.00	537279.756	957570.485	1,585.77	1,587.08
11	0+220.00	537279.395	957590.482	1,586.50	1,588.28
12	0+240.00	537279.034	957610.479	1,587.49	1,589.64
13	0+260.00	537278.673	957630.475	1,588.87	1,591.03
14	0+280.00	537277.845	957650.448	1,590.47	1,592.42
15	0+300.00	537273.534	957669.943	1,592.22	1,593.81
16	0+320.00	537265.367	957688.161	1,593.78	1,595.20
17	0+340.00	537255.439	957705.524	1,595.21	1,596.58
18	0+360.00	537245.512	957722.886	1,597.01	1,597.97
19	0+380.00	537235.584	957740.248	1,599.09	1,599.36
20	0+400.00	537224.549	957756.912	1,601.11	1,600.75
21	0+420.00	537211.521	957772.070	1,602.92	1,602.14
22	0+440.00	537196.703	957785.483	1,604.42	1,603.53
23	0+460.00	537180.327	957796.942	1,605.83	1,603.53
24	0+480.00	537163.091	957807.087	1,607.27	1,603.53
25	0+500.00	537145.844	957817.212	1,608.57	1,603.53
26	0+520.00	537128.596	957827.337	1,609.45	1,603.53
27	0+540.00	537111.348	957837.462	1,611.28	1,603.53
28	0+560.00	537094.101	957847.588	1,613.15	1,603.53
29	0+580.00	537076.853	957857.713	1,614.12	1,603.53
30	0+600.00	537059.605	957867.838	1,614.68	1,603.53
31	0+620.00	537042.358	957877.963	1,614.94	1,603.53
32	0+640.00	537025.110	957888.088	1,615.07	1,603.53
33	0+660.00	537007.960	957898.374	1,615.09	1,603.53
34	0+680.00	536991.383	957909.563	1,614.87	1,603.53
35	0+700.00	536974.864	957920.837	1,614.58	1,603.53
36	0+720.00	536958.344	957932.111	1,614.96	1,603.53
37	0+740.00	536941.825	957943.385	1,615.76	1,603.53

38	0+760.00	536925.305	957954.659	1,617.12	1,603.53
39	0+780.00	536908.785	957965.933	1,618.72	1,603.53
40	0+800.00	536892.266	957977.207	1,619.68	1,603.53
41	0+820.00	536875.746	957988.481	1,619.69	1,603.53
42	0+840.00	536859.227	957999.755	1,619.96	1,603.53
43	0+860.00	536843.239	958011.725	1,620.80	1,603.53
44	0+880.00	536830.975	958027.431	1,622.26	1,603.53
45	0+900.00	536823.823	958046.031	1,623.73	1,603.53
46	0+920.00	536822.406	958065.908	1,624.87	1,603.53
47	0+940.00	536826.741	958085.370	1,625.60	1,603.53
48	0+960.00	536832.942	958104.385	1,625.09	1,603.53
49	0+980.00	536839.143	958123.399	1,623.33	1,603.53
50	1+000.00	536845.343	958142.414	1,622.54	1,603.53
51	1+020.00	536851.544	958161.429	1,622.68	1,603.53
52	1+040.00	536857.744	958180.443	1,622.77	1,603.53
53	1+060.00	536863.935	958199.461	1,622.33	1,603.53
54	1+080.00	536869.518	958218.663	1,621.42	1,603.53
55	1+100.00	536874.125	958238.124	1,619.95	1,603.53
56	1+120.00	536877.742	958257.791	1,619.57	1,603.53
57	1+140.00	536880.363	958277.617	1,620.31	1,603.53
58	1+160.00	536881.979	958297.549	1,621.24	1,603.53
59	1+180.00	536882.605	958317.538	1,622.25	1,603.53
60	1+200.00	536882.898	958337.536	1,621.23	1,603.53
61	1+220.00	536883.192	958357.533	1,619.51	1,603.53
62	1+240.00	536883.485	958377.531	1,618.60	1,603.53
63	1+260.00	536883.778	958397.529	1,617.99	1,603.53
64	1+280.00	536884.072	958417.527	1,617.23	1,603.53
65	1+300.00	536884.365	958437.525	1,616.69	1,603.53
66	1+320.00	536885.031	958457.512	1,616.94	1,603.53
67	1+340.00	536886.804	958477.430	1,617.66	1,603.53
68	1+360.00	536889.697	958497.217	1,619.28	1,603.53
69	1+380.00	536893.702	958516.809	1,620.62	1,603.53
70	1+400.00	536898.805	958536.144	1,621.47	1,603.53
71	1+420.00	536904.992	958555.161	1,621.94	1,603.53
72	1+440.00	536912.182	958573.822	1,622.07	1,603.53
73	1+460.00	536919.402	958592.473	1,622.02	1,603.53
74	1+480.00	536926.309	958611.242	1,621.29	1,603.53
75	1+500.00	536932.900	958630.125	1,620.20	1,603.53
76	1+520.00	536939.174	958649.115	1,618.07	1,603.53
77	1+540.00	536945.142	958668.204	1,616.25	1,603.53
78	1+560.00	536951.025	958687.319	1,615.51	1,603.53
79	1+580.00	536956.907	958706.434	1,615.15	1,603.53
80	1+600.00	536962.790	958725.550	1,615.56	1,603.53
81	1+620.00	536968.674	958744.664	1,616.84	1,603.53
82	1+640.00	536975.388	958763.498	1,619.13	1,603.53

83	1+660.00	536983.615	958781.721	1,620.43	1,603.53
84	1+680.00	536992.572	958799.603	1,619.76	1,603.53
85	1+700.00	537001.530	958817.485	1,619.25	1,603.53
86	1+720.00	537010.487	958835.367	1,618.71	1,603.53
87	1+740.00	537019.444	958853.249	1,618.30	1,603.53
88	1+760.00	537028.402	958871.131	1,619.01	1,603.53
89	1+780.00	537037.359	958889.013	1,619.81	1,603.53
90	1+800.00	537046.316	958906.895	1,621.34	1,603.53
91	1+820.00	537054.526	958925.127	1,622.33	1,603.53
92	1+840.00	537061.222	958943.967	1,621.14	1,603.53
93	1+860.00	537066.710	958963.198	1,619.74	1,603.53
94	1+880.00	537072.110	958982.455	1,618.99	1,603.53
95	1+900.00	537077.511	959001.712	1,618.76	1,603.53
96	1+920.00	537082.912	959020.969	1,619.30	1,603.53
97	1+940.00	537088.313	959040.226	1,619.95	1,603.53
98	1+960.00	537093.744	959059.475	1,620.40	1,603.53
99	1+980.00	537100.227	959078.389	1,620.42	1,603.53
100	2+000.00	537108.232	959096.711	1,619.82	1,603.53
101	2+020.00	537117.194	959114.590	1,618.88	1,603.53
102	2+040.00	537126.175	959132.461	1,617.70	1,603.53
103	2+060.00	537135.155	959150.331	1,616.53	1,603.53
104	2+080.00	537144.136	959168.201	1,616.21	1,603.53
105	2+100.00	537153.117	959186.071	1,616.57	1,603.53
106	2+120.00	537162.098	959203.942	1,617.01	1,603.53
107	2+140.00	537171.078	959221.812	1,617.17	1,603.53
108	2+160.00	537180.059	959239.682	1,616.74	1,603.53
109	2+180.00	537189.040	959257.552	1,616.00	1,603.53
110	2+200.00	537198.021	959275.423	1,614.98	1,603.53
111	2+220.00	537207.001	959293.293	1,613.66	1,603.53
112	2+240.00	537215.931	959311.188	1,613.35	1,603.53
113	2+260.00	537223.780	959329.578	1,614.13	1,603.53
114	2+280.00	537230.102	959348.547	1,614.15	1,603.53
115	2+300.00	537234.857	959367.967	1,613.34	1,603.53
116	2+320.00	537238.012	959387.711	1,612.47	1,603.53
117	2+340.00	537239.547	959407.647	1,611.45	1,603.53
118	2+360.00	537239.451	959427.641	1,611.76	1,603.53
119	2+380.00	537237.742	959447.563	1,612.84	1,603.53
120	2+400.00	537235.439	959467.430	1,613.92	1,603.53
121	2+420.00	537233.136	959487.297	1,614.54	1,603.53
122	2+440.00	537230.833	959507.164	1,614.20	1,603.53
123	2+460.00	537228.530	959527.031	1,613.56	1,603.53
124	2+480.00	537226.228	959546.898	1,612.63	1,603.53
125	2+500.00	537223.925	959566.765	1,611.53	1,603.53
126	2+520.00	537221.622	959586.632	1,610.66	1,603.53
127	2+540.00	537219.319	959606.499	1,610.00	1,603.53

128	2+560.00	537217.016	959626.366	1,609.78	1,603.53
129	2+580.00	537214.713	959646.233	1,609.99	1,603.53
130	2+600.00	537212.410	959666.100	1,610.12	1,603.53
131	2+620.00	537210.108	959685.967	1,610.30	1,603.53
132	2+640.00	537207.805	959705.834	1,610.07	1,603.53
133	2+660.00	537205.502	959725.701	1,610.38	1,603.53
134	2+680.00	537202.597	959745.483	1,610.88	1,603.53
135	2+700.00	537198.103	959764.966	1,611.77	1,603.53
136	2+720.00	537192.036	959784.018	1,612.89	1,603.53
137	2+740.00	537184.435	959802.512	1,614.05	1,603.53
138	2+760.00	537175.679	959820.492	1,615.60	1,603.53
139	2+780.00	537166.844	959838.435	1,616.29	1,603.53
140	2+800.00	537158.009	959856.378	1,616.33	1,603.53
141	2+820.00	537149.174	959874.320	1,615.38	1,603.53
142	2+840.00	537140.339	959892.263	1,613.53	1,603.53
143	2+860.00	537131.504	959910.206	1,612.23	1,603.53
144	2+880.00	537122.668	959928.149	1,610.96	1,603.53
145	2+900.00	537113.833	959946.091	1,610.60	1,603.53
146	2+920.00	537104.998	959964.034	1,611.72	1,603.53
147	2+940.00	537096.163	959981.977	1,613.19	1,603.53
148	2+960.00	537087.328	959999.919	1,614.50	1,603.53
149	2+980.00	537078.493	960017.862	1,615.48	1,603.53
150	3+000.00	537069.658	960035.805	1,617.41	1,603.53
151	3+020.00	537060.819	960053.746	1,619.08	1,603.53
152	3+040.00	537051.169	960071.257	1,620.11	1,603.53
153	3+060.00	537040.123	960087.923	1,620.99	1,603.53
154	3+080.00	537027.898	960103.750	1,622.29	1,603.53
155	3+100.00	537015.496	960119.440	1,623.62	1,603.53
156	3+120.00	537003.094	960135.131	1,624.36	1,603.53
157	3+140.00	536990.692	960150.821	1,625.19	1,603.53
158	3+160.00	536978.290	960166.511	1,626.67	1,603.53
159	3+180.00	536965.723	960182.069	1,628.10	1,603.53
160	3+200.00	536952.507	960197.078	1,630.10	1,603.53
161	3+220.00	536938.633	960211.481	1,631.90	1,603.53
162	3+240.00	536924.151	960225.273	1,632.47	1,603.53
163	3+260.00	536909.500	960238.887	1,632.23	1,603.53
164	3+280.00	536894.848	960252.501	1,632.24	1,603.53
165	3+300.00	536880.197	960266.115	1,632.55	1,603.53
166	3+320.00	536865.546	960279.729	1,633.08	1,603.53
167	3+340.00	536850.894	960293.343	1,634.03	1,603.53
168	3+360.00	536836.243	960306.957	1,635.17	1,603.53
169	3+380.00	536821.592	960320.571	1,635.83	1,603.53
170	3+400.00	536806.941	960334.185	1,635.76	1,603.53
171	3+420.00	536792.289	960347.798	1,635.33	1,603.53
172	3+440.00	536777.609	960361.381	1,635.86	1,603.53

173	3+460.00	536762.430	960374.401	1,636.75	1,603.53
174	3+480.00	536746.615	960386.640	1,637.08	1,603.53
175	3+500.00	536730.206	960398.070	1,637.23	1,603.53
176	3+520.00	536713.663	960409.310	1,637.42	1,603.53
177	3+540.00	536697.347	960420.876	1,637.26	1,603.53
178	3+560.00	536681.263	960432.763	1,636.72	1,603.53
179	3+580.00	536665.418	960444.966	1,637.15	1,603.53
180	3+600.00	536649.818	960457.481	1,638.64	1,603.53
181	3+620.00	536634.469	960470.302	1,640.04	1,603.53
182	3+640.00	536619.376	960483.425	1,642.02	1,603.53
183	3+660.00	536604.493	960496.784	1,644.37	1,603.53
184	3+680.00	536589.626	960510.163	1,645.85	1,603.53
185	3+700.00	536574.760	960523.542	1,645.83	1,603.53
186	3+720.00	536559.893	960536.920	1,645.73	1,603.53
187	3+740.00	536545.027	960550.299	1,646.06	1,603.53
188	3+760.00	536530.160	960563.677	1,646.34	1,603.53
189	3+780.00	536515.294	960577.056	1,646.12	1,603.53
190	3+800.00	536500.015	960589.954	1,645.46	1,603.53
191	3+820.00	536483.742	960601.572	1,645.55	1,603.53
192	3+840.00	536466.695	960612.028	1,646.19	1,603.53
193	3+860.00	536449.555	960622.334	1,647.07	1,603.53
194	3+880.00	536432.415	960632.640	1,648.32	1,603.53
195	3+900.00	536415.274	960642.946	1,649.93	1,603.53
196	3+920.00	536398.134	960653.252	1,651.72	1,603.53
197	3+940.00	536380.994	960663.559	1,653.24	1,603.53
198	3+960.00	536363.854	960673.865	1,654.58	1,603.53
199	3+980.00	536346.966	960684.575	1,656.30	1,603.53
200	4+000.00	536330.561	960696.013	1,658.37	1,603.53
201	4+020.00	536314.672	960708.157	1,659.78	1,603.53
202	4+040.00	536299.329	960720.984	1,661.21	1,603.53
203	4+060.00	536284.561	960734.469	1,662.43	1,603.53
204	4+080.00	536269.970	960748.146	1,663.31	1,603.53
205	4+100.00	536254.979	960761.384	1,663.69	1,603.53
206	4+120.00	536239.598	960774.167	1,663.71	1,603.53
207	4+140.00	536223.840	960786.482	1,664.07	1,603.53
208	4+160.00	536207.721	960798.320	1,664.59	1,603.53
209	4+180.00	536191.253	960809.668	1,665.03	1,603.53
210	4+200.00	536174.452	960820.517	1,664.56	1,603.53
211	4+220.00	536157.335	960830.860	1,664.24	1,603.53
212	4+240.00	536140.092	960840.993	1,665.10	1,603.53
213	4+260.00	536122.849	960851.126	1,666.38	1,603.53
214	4+280.00	536105.606	960861.259	1,667.04	1,603.53
215	4+300.00	536088.363	960871.392	1,668.24	1,603.53
216	4+320.00	536071.120	960881.524	1,670.59	1,603.53
217	4+340.00	536053.876	960891.657	1,670.99	1,603.53

218	4+360.00	536036.633	960901.790	1,671.00	1,603.53
219	4+380.00	536019.793	960912.561	1,670.48	1,603.53
220	4+400.00	536004.319	960925.213	1,669.68	1,603.53
221	4+420.00	535990.288	960939.459	1,669.61	1,603.53
222	4+440.00	535976.528	960953.973	1,669.57	1,603.53
223	4+460.00	535962.767	960968.487	1,670.04	1,603.53
224	4+480.00	535949.007	960983.001	1,670.60	1,603.53
225	4+500.00	535935.247	960997.515	1,671.21	1,603.53
226	4+520.00	535921.486	961012.029	1,671.58	1,603.53
227	4+540.00	535907.616	961026.435	1,673.08	1,603.53
228	4+560.00	535892.794	961039.855	1,674.84	1,603.53
229	4+580.00	535876.927	961052.021	1,676.31	1,603.53
230	4+600.00	535860.256	961063.069	1,675.51	1,603.53
231	4+620.00	535843.498	961073.984	1,674.57	1,603.53
232	4+640.00	535826.739	961084.900	1,673.62	1,603.53
233	4+660.00	535809.980	961095.815	1,672.91	1,603.53
234	4+680.00	535793.222	961106.731	1,672.73	1,603.53
235	4+700.00	535776.463	961117.646	1,672.70	1,603.53
236	4+720.00	535759.704	961128.561	1,673.19	1,603.53
237	4+740.00	535742.770	961139.197	1,674.25	1,603.53
238	4+760.00	535725.078	961148.511	1,675.24	1,603.53
239	4+780.00	535706.706	961156.406	1,676.28	1,603.53
240	4+800.00	535688.162	961163.897	1,677.63	1,603.53
241	4+820.00	535669.618	961171.388	1,678.89	1,603.53
242	4+840.00	535651.074	961178.880	1,680.46	1,603.53
243	4+860.00	535632.530	961186.371	1,682.62	1,603.53
244	4+880.00	535613.986	961193.862	1,684.45	1,603.53
245	4+900.00	535595.442	961201.353	1,685.40	1,603.53
246	4+920.00	535576.900	961208.851	1,686.05	1,603.53
247	4+940.00	535558.744	961217.226	1,686.57	1,603.53
248	4+960.00	535541.332	961227.053	1,687.12	1,603.53
249	4+980.00	535524.731	961238.201	1,687.98	1,603.53
250	5+000.00	535508.341	961249.663	1,688.73	1,603.53
251	5+020.00	535491.952	961261.126	1,689.57	1,603.53
252	5+040.00	535475.563	961272.588	1,690.58	1,603.53
253	5+045.02	535471.450	961275.465	1,690.83	

Appendix 2: Earth Work Volume Report

Project: Geldia to 5+054.019 LVR

Alignment: Alignment - for Geldia Centre Line

Sample Line Group: SL Collection - for Geldia

Start Sta: 0+000.000

End Sta: 5+045.019

Client:

Contractor:

Consultant/Supervisor:

Station	Cut Area (m2)	Cut Volume (m3)	Reu. Vol. (m3)	Fill Area (m2)	Fill Vol. (m3)	Cum. Cut Vol. (m3)	Cum. Reusable Vol. (m3)	Cum. Fill Vol. (m3)	Cum. Net Vol. (m3)
0+000.000	20.86	0	0	0	0	0	0	0	0
0+020.000	29.63	504.9	504.9	0	0	504.9	504.9	0	504.9
0+040.000	15.87	455.04	455.04	0	0	959.94	959.94	0	959.94
0+060.000	2.34	182.11	182.11	7.41	74.07	1142.04	1142.04	74.07	1067.97
0+080.000	1.84	41.8	41.8	6.92	143.26	1183.84	1183.84	217.34	966.5
0+100.000	5.23	70.76	70.76	3.58	104.99	1254.59	1254.59	322.33	932.26
0+120.000	9.41	146.48	146.48	3.06	66.39	1401.07	1401.07	388.72	1012.35
0+140.000	13.17	225.86	225.86	7.37	104.33	1626.93	1626.93	493.05	1133.88
0+160.000	7.12	192.75	192.75	11.46	197.23	1819.68	1819.68	690.27	1129.4
0+170.000	4.49	45.37	45.37	12.68	141.24	1865.05	1865.05	831.52	1033.54
0+180.000	3.04	28.82	28.82	11.41	136.36	1893.88	1893.88	967.88	926
0+200.000	0.35	30.88	30.88	11.57	236.09	1924.76	1924.76	1203.97	720.78
0+220.000	0.19	5.41	5.41	18.61	301.89	1930.17	1930.17	1505.86	424.3
0+240.000	0.25	4.42	4.42	27.6	462.15	1934.58	1934.58	1968.01	-33.43
0+260.000	0.26	5.15	5.15	27.98	555.82	1939.74	1939.74	2523.84	-584.1
0+280.000	0.06	3.1	3.1	24.93	536.19	1942.84	1942.84	3060.03	-1117.19
0+290.000	0.11	0.75	0.75	21.39	237.24	1943.59	1943.59	3297.27	-1353.68
0+300.000	0.29	1.77	1.77	15.04	185.62	1945.36	1945.36	3482.89	-1537.52
0+310.000	0.69	4.39	4.39	9.91	126.37	1949.75	1949.75	3609.26	-1659.51
0+320.000	0.78	6.64	6.64	10.7	104.11	1956.39	1956.39	3713.37	-1756.98

0+340.000	1.81	25.95	25.95	11.03	217.24	1982.34	1982.34	3930.61	-1948.27
0+360.000	2.5	43.16	43.16	4.84	158.68	2025.5	2025.5	4089.29	-2063.8
0+380.000	14.19	166.92	166.92	0	48.41	2192.42	2192.42	4137.71	-1945.29
0+390.000	23.29	189.01	189.01	0	0	2381.43	2381.43	4137.71	-1756.28
0+400.000	28.02	258.04	258.04	0	0	2639.47	2639.47	4137.71	-1498.23
0+410.000	31.67	298.6	298.6	0	0	2938.07	2938.07	4137.71	-1199.63
0+420.000	34.88	331.85	331.85	0	0	3269.92	3269.92	4137.71	-867.79
0+430.000	38.6	366.09	366.09	0	0	3636.01	3636.01	4137.71	-501.69
0+440.000	42.62	405.45	405.45	0	0	4041.46	4041.46	4137.71	-96.24
0+450.000	44.59	437.54	437.54	0	0	4479.01	4479.01	4137.71	341.3
0+460.000	44.93	451.31	451.31	0	0	4930.31	4930.31	4137.71	792.61
0+480.000	46.36	912.91	912.91	0	0	5843.22	5843.22	4137.71	1705.52
0+500.000	45.64	919.99	919.99	0	0	6763.21	6763.21	4137.71	2625.5
0+520.000	47.78	934.21	934.21	0	0	7697.42	7697.42	4137.71	3559.71
0+540.000	44.7	924.74	924.74	0	0	8622.16	8622.16	4137.71	4484.45
0+560.000	56.89	1015.91	1015.91	0	0	9638.07	9638.07	4137.71	5500.37
0+580.000	53.58	1104.76	1104.76	0	0	10742.84	10742.84	4137.71	6605.13
0+600.000	44.79	983.72	983.72	0	0	11726.55	11726.55	4137.71	7588.85
0+620.000	33.26	780.5	780.5	0	0	12507.05	12507.05	4137.71	8369.35
0+640.000	22	552.58	552.58	0.52	5.2	13059.63	13059.63	4142.9	8916.73
0+660.000	18.82	401.62	401.62	6.5	71.53	13461.25	13461.25	4214.44	9246.81
0+680.000	4.83	232.76	232.76	21.97	287.95	13694.01	13694.01	4502.38	9191.63
0+700.000	0	48.28	48.28	35.8	577.69	13742.3	13742.3	5080.07	8662.23
0+720.000	0	0	0	42.85	786.49	13742.3	13742.3	5866.56	7875.73
0+740.000	0	0.06	0.06	35.78	786.33	13742.35	13742.35	6652.89	7089.46
0+760.000	2.85	28.55	28.55	17.68	534.63	13770.91	13770.91	7187.52	6583.39
0+780.000	15.02	178.74	178.74	1.58	192.58	13949.64	13949.64	7380.09	6569.55
0+800.000	18.13	331.52	331.52	0.57	21.45	14281.16	14281.16	7401.54	6879.62
0+820.000	6.8	249.31	249.31	4.14	47.05	14530.47	14530.47	7448.6	7081.87
0+840.000	5.58	123.79	123.79	8.47	126.1	14654.25	14654.25	7574.7	7079.55
0+850.000	9.14	73.59	73.59	8.14	83.1	14727.84	14727.84	7657.79	7070.05
0+860.000	10.98	85.37	85.37	5.2	72.39	14813.22	14813.22	7730.19	7083.03
0+870.000	15.05	112.4	112.4	1.22	35.39	14925.62	14925.62	7765.57	7160.04

0+880.000	26.99	192.39	192.39	0	7.05	15118.01	15118.01	7772.63	7345.38
0+890.000	39.68	317.74	317.74	0	0	15435.74	15435.74	7772.63	7663.12
0+900.000	53.49	452.25	452.25	0	0	15887.99	15887.99	7772.63	8115.37
0+910.000	67.18	592.99	592.99	0	0	16480.99	16480.99	7772.63	8708.36
0+920.000	69.48	687.17	687.17	0	0	17168.16	17168.16	7772.63	9395.53
0+930.000	67.31	691.17	691.17	0	0	17859.32	17859.32	7772.63	10086.69
0+940.000	71.98	695.85	695.85	0	0	18555.17	18555.17	7772.63	10782.55
0+960.000	67.37	1393.58	1393.58	0	0	19948.75	19948.75	7772.63	12176.12
0+980.000	23.61	909.86	909.86	0	0	20858.61	20858.61	7772.63	13085.99
1+000.000	7.73	313.46	313.46	0.08	0.78	21172.07	21172.07	7773.41	13398.66
1+020.000	22.22	299.54	299.54	0	0.78	21471.61	21471.61	7774.19	13697.42
1+040.000	38.54	607.63	607.63	0	0	22079.24	22079.24	7774.19	14305.05
1+060.000	35.83	743.73	743.73	0	0	22822.97	22822.97	7774.19	15048.78
1+070.000	29.46	327.18	327.18	0	0	23150.15	23150.15	7774.19	15375.96
1+080.000	17.09	232.86	232.86	0	0	23383.01	23383.01	7774.19	15608.82
1+090.000	5.79	113.82	113.82	2.92	14.67	23496.83	23496.83	7788.86	15707.97
1+100.000	1.69	36.7	36.7	16.51	97.93	23533.53	23533.53	7886.79	15646.74
1+110.000	0.86	12.39	12.39	24.82	208.53	23545.92	23545.92	8095.32	15450.6
1+120.000	2.92	18.37	18.37	19.95	226.17	23564.29	23564.29	8321.49	15242.8
1+130.000	6.79	47.24	47.24	11.29	158.25	23611.53	23611.53	8479.74	15131.78
1+140.000	15.87	110.44	110.44	2.13	68.24	23721.97	23721.97	8547.98	15173.99
1+150.000	24.06	196.58	196.58	0	10.9	23918.55	23918.55	8558.88	15359.67
1+160.000	40.18	319.2	319.2	0	0	24237.75	24237.75	8558.88	15678.87
1+170.000	57.93	489.13	489.13	0	0	24726.88	24726.88	8558.88	16167.99
1+180.000	77.32	676.21	676.21	0	0	25403.09	25403.09	8558.88	16844.21
1+200.000	57.57	1348.84	1348.84	0	0	26751.93	26751.93	8558.88	18193.04
1+220.000	21.97	795.32	795.32	0.34	3.41	27547.25	27547.25	8562.29	18984.95
1+240.000	11.17	331.37	331.37	5.91	62.55	27878.62	27878.62	8624.85	19253.77
1+260.000	12.29	234.66	234.66	10.72	166.34	28113.28	28113.28	8791.19	19322.09
1+280.000	5.8	180.91	180.91	18.88	296.05	28294.19	28294.19	9087.24	19206.96
1+300.000	3.1	88.97	88.97	22.24	411.21	28383.16	28383.16	9498.45	18884.71
1+310.000	4.65	39.48	39.48	17.06	194.07	28422.65	28422.65	9692.52	18730.13
1+320.000	8.83	69.39	69.39	8.38	124.59	28492.04	28492.04	9817.1	18674.93

1+330.000	15.56	125.34	125.34	2.27	52.02	28617.37	28617.37	9869.13	18748.25
1+340.000	34.69	256.51	256.51	0	11.04	28873.88	28873.88	9880.17	18993.72
1+350.000	48.54	420.13	420.13	0	0	29294.01	29294.01	9880.17	19413.85
1+360.000	76.17	624.43	624.43	0	0	29918.45	29918.45	9880.17	20038.28
1+370.000	105.5	907.11	907.11	0	0	30825.56	30825.56	9880.17	20945.39
1+380.000	127.93	1163.19	1163.19	0	0	31988.75	31988.75	9880.17	22108.58
1+390.000	125.13	1263.57	1263.57	0	0	33252.32	33252.32	9880.17	23372.16
1+400.000	137.64	1315.73	1315.73	0	0	34568.05	34568.05	9880.17	24687.88
1+410.000	148.79	1434.09	1434.09	0	0	36002.14	36002.14	9880.17	26121.98
1+420.000	154.99	1520.89	1520.89	0	0	37523.03	37523.03	9880.17	27642.86
1+430.000	158.98	1571.78	1571.78	0	0	39094.81	39094.81	9880.17	29214.65
1+440.000	162.08	1605.3	1605.3	0	0	40700.12	40700.12	9880.17	30819.95
1+450.000	163.98	1630.31	1630.31	0	0	42330.43	42330.43	9880.17	32450.27
1+460.000	161.62	1628.02	1628.02	0	0	43958.45	43958.45	9880.17	34078.29
1+470.000	153.26	1574.38	1574.38	0	0	45532.83	45532.83	9880.17	35652.67
1+480.000	142.35	1478.02	1478.02	0	0	47010.85	47010.85	9880.17	37130.69
1+490.000	129.26	1358.05	1358.05	0	0	48368.9	48368.9	9880.17	38488.73
1+500.000	111.05	1201.57	1201.57	0	0	49570.47	49570.47	9880.17	39690.31
1+510.000	94.51	1027.82	1027.82	0	0	50598.29	50598.29	9880.17	40718.12
1+520.000	59.03	767.71	767.71	0	0	51366	51366	9880.17	41485.84
1+530.000	28.65	438.39	438.39	0	0	51804.4	51804.4	9880.17	41924.23
1+540.000	22.06	253.51	253.51	8.27	41.36	52057.91	52057.91	9921.52	42136.38
1+560.000	7.11	291.7	291.7	23.89	321.61	52349.61	52349.61	10243.14	42106.47
1+580.000	2.25	93.6	93.6	36.21	601	52443.21	52443.21	10844.13	41599.08
1+600.000	2.22	44.65	44.65	30.03	662.43	52487.86	52487.86	11506.57	40981.3
1+620.000	12.7	149.21	149.21	12.79	428.25	52637.08	52637.08	11934.82	40702.25
1+630.000	26.27	199.91	199.91	0	61.53	52836.98	52836.98	11996.35	40840.63
1+640.000	50.27	386.69	386.69	0	0	53223.67	53223.67	11996.35	41227.32
1+650.000	72.25	614.56	614.56	0	0	53838.23	53838.23	11996.35	41841.88
1+660.000	80.17	761.57	761.57	0	0	54599.8	54599.8	11996.35	42603.45
1+680.000	59.51	1396.76	1396.76	0	0	55996.56	55996.56	11996.35	44000.21
1+700.000	47.53	1070.35	1070.35	0	0	57066.92	57066.92	11996.35	45070.56
1+720.000	23.84	713.7	713.7	0	0	57780.61	57780.61	11996.35	45784.26

1+740.000	14.25	380.93	380.93	0.83	8.34	58161.55	58161.55	12004.69	46156.86
1+760.000	23.57	378.18	378.18	0	8.34	58539.73	58539.73	12013.04	46526.7
1+780.000	33.72	572.83	572.83	0	0	59112.57	59112.57	12013.04	47099.53
1+800.000	69.83	1035.44	1035.44	0	0	60148	60148	12013.04	48134.97
1+810.000	84.12	766.14	766.14	0	0	60914.14	60914.14	12013.04	48901.11
1+820.000	88.12	854.85	854.85	0	0	61768.99	61768.99	12013.04	49755.96
1+830.000	71.63	792.25	792.25	0	0	62561.24	62561.24	12013.04	50548.2
1+840.000	56.87	639.27	639.27	0	0	63200.51	63200.51	12013.04	51187.48
1+860.000	13.45	702.71	702.71	0	0	63903.23	63903.23	12013.04	51890.19
1+880.000	1.36	148.09	148.09	7.6	76.03	64051.32	64051.32	12089.07	51962.25
1+900.000	0.79	21.52	21.52	12.43	200.31	64072.84	64072.84	12289.38	51783.46
1+920.000	6.6	73.89	73.89	0.27	126.96	64146.74	64146.74	12416.34	51730.4
1+940.000	28.19	347.88	347.88	0	2.68	64494.62	64494.62	12419.02	52075.6
1+960.000	51.07	792.58	792.58	0	0	65287.2	65287.2	12419.02	52868.19
1+970.000	62.13	569.32	569.32	0	0	65856.52	65856.52	12419.02	53437.51
1+980.000	67.36	653.02	653.02	0	0	66509.54	66509.54	12419.02	54090.53
1+990.000	66.5	676.65	676.65	0	0	67186.19	67186.19	12419.02	54767.18
2+000.000	59.67	638.92	638.92	0	0	67825.11	67825.11	12419.02	55406.1
2+020.000	37.23	969.02	969.02	0	0	68794.13	68794.13	12419.02	56375.12
2+040.000	11.19	484.21	484.21	2.69	26.88	69278.34	69278.34	12445.9	56832.45
2+060.000	3.25	144.37	144.37	23.39	260.83	69422.71	69422.71	12706.72	56715.99
2+080.000	3.71	69.56	69.56	26.13	495.2	69492.27	69492.27	13201.92	56290.35
2+100.000	7.62	113.25	113.25	9.68	358.01	69605.52	69605.52	13559.93	56045.58
2+120.000	20.29	279.03	279.03	0.72	103.99	69884.55	69884.55	13663.92	56220.63
2+140.000	34.94	552.26	552.26	0	7.23	70436.81	70436.81	13671.16	56765.65
2+160.000	33.99	689.3	689.3	0	0	71126.11	71126.11	13671.16	57454.95
2+180.000	20.9	548.93	548.93	0	0	71675.04	71675.04	13671.16	58003.88
2+200.000	3.32	242.27	242.27	7.79	77.86	71917.31	71917.31	13749.01	58168.29
2+220.000	0	33.23	33.23	32.77	405.53	71950.54	71950.54	14154.54	57796
2+240.000	0	0	0	33.5	663.39	71950.54	71950.54	14817.93	57132.6
2+250.000	0	0	0	18.94	262.74	71950.54	71950.54	15080.68	56869.86
2+260.000	2.11	10.67	10.67	5.22	120.82	71961.2	71961.2	15201.5	56759.7
2+270.000	4.97	35.74	35.74	0.57	28.9	71996.94	71996.94	15230.4	56766.54

2+280.000	5.48	52.98	52.98	1.21	8.85	72049.92	72049.92	15239.25	56810.67
2+290.000	3.32	44.79	44.79	3.01	20.92	72094.71	72094.71	15260.17	56834.54
2+300.000	0.55	19.64	19.64	11.32	71.85	72114.35	72114.35	15332.02	56782.32
2+310.000	0	2.77	2.77	20.68	161.59	72117.12	72117.12	15493.61	56623.51
2+320.000	0	0.01	0.01	32.89	271.8	72117.13	72117.13	15765.41	56351.72
2+330.000	0	0	0	46.64	404.65	72117.13	72117.13	16170.06	55947.06
2+340.000	0	0	0	58.81	537.2	72117.13	72117.13	16707.26	55409.86
2+350.000	0	0	0	56.49	588.07	72117.13	72117.13	17295.34	54821.79
2+360.000	0.03	0.17	0.17	34.37	463.97	72117.29	72117.29	17759.3	54357.99
2+370.000	1.72	8.43	8.43	14.67	250.57	72125.72	72125.72	18009.87	54115.85
2+380.000	8.19	48.55	48.55	0.58	77.45	72174.27	72174.27	18087.32	54086.95
2+400.000	44.23	524.15	524.15	0	5.75	72698.42	72698.42	18093.07	54605.35
2+420.000	81.09	1253.2	1253.2	0	0	73951.62	73951.62	18093.07	55858.55
2+440.000	80.75	1618.44	1618.44	0	0	75570.06	75570.06	18093.07	57476.99
2+460.000	68.31	1490.6	1490.6	0	0	77060.66	77060.66	18093.07	58967.59
2+480.000	46.2	1145.04	1145.04	0	0	78205.7	78205.7	18093.07	60112.63
2+500.000	19.85	660.42	660.42	0	0	78866.12	78866.12	18093.07	60773.05
2+520.000	5.24	250.85	250.85	1.77	17.65	79116.97	79116.97	18110.72	61006.25
2+540.000	1.3	65.39	65.39	7.46	92.28	79182.36	79182.36	18203	60979.36
2+560.000	2.07	33.69	33.69	6.4	138.6	79216.05	79216.05	18341.6	60874.45
2+580.000	7.84	99.06	99.06	0.06	64.53	79315.1	79315.1	18406.13	60908.97
2+600.000	24.3	321.34	321.34	0	0.55	79636.44	79636.44	18406.68	61229.76
2+620.000	36.62	609.13	609.13	0	0	80245.57	80245.57	18406.68	61838.89
2+640.000	39.26	758.78	758.78	0	0	81004.35	81004.35	18406.68	62597.66
2+660.000	57.24	965.04	965.04	0	0	81969.39	81969.39	18406.68	63562.71
2+670.000	70.6	637.52	637.52	0	0	82606.91	82606.91	18406.68	64200.23
2+680.000	88.09	790.38	790.38	0	0	83397.29	83397.29	18406.68	64990.61
2+690.000	111.63	995.51	995.51	0	0	84392.8	84392.8	18406.68	65986.12
2+700.000	137.87	1245	1245	0	0	85637.8	85637.8	18406.68	67231.12
2+710.000	172.55	1551.71	1551.71	0	0	87189.51	87189.51	18406.68	68782.83
2+720.000	208.24	1907.97	1907.97	0	0	89097.48	89097.48	18406.68	70690.79
2+730.000	242.39	2263.11	2263.11	0	0	91360.58	91360.58	18406.68	72953.9
2+740.000	282.31	2639.34	2639.34	0	0	93999.93	93999.93	18406.68	75593.24

2+760.000	261.94	5434.3	5434.3	0	0	99434.23	99434.23	18406.68	81027.54
2+780.000	278.61	5405.54	5405.54	0	0	104839.8	104839.8	18406.68	86433.08
2+800.000	262.33	5409.38	5409.38	0	0	110249.2	110249.2	18406.68	91842.46
2+820.000	207.26	4695.9	4695.9	0	0	114945.1	114945.1	18406.68	96538.37
2+840.000	129.06	3363.25	3363.25	0	0	118308.3	118308.3	18406.68	99901.62
2+860.000	77.12	2061.76	2061.76	0	0	120370.1	120370.1	18406.68	101963.4
2+880.000	4.89	820.08	820.08	6.84	68.43	121190.1	121190.1	18475.11	102715
2+900.000	0.33	52.2	52.2	50.12	569.59	121242.3	121242.3	19044.71	102197.6
2+920.000	2.07	24	24	66.45	1165.7	121266.4	121266.4	20210.41	101055.9
2+940.000	6.09	81.65	81.65	51.33	1177.82	121348	121348	21388.23	99959.77
2+960.000	9.84	159.3	159.3	41.05	923.81	121507.3	121507.3	22312.03	99195.27
2+980.000	9.78	196.22	196.22	32.2	732.56	121703.5	121703.5	23044.59	98658.93
3+000.000	15.14	249.21	249.21	9	412.06	121952.7	121952.7	23456.65	98496.08
3+020.000	25.31	404.49	404.49	0	90.02	122357.2	122357.2	23546.67	98810.55
3+030.000	25.97	249.31	249.31	0	0	122606.5	122606.5	23546.67	99059.86
3+040.000	23.42	241.08	241.08	0	0	122847.6	122847.6	23546.67	99300.94
3+050.000	20.11	212.39	212.39	0	0	123060	123060	23546.67	99513.32
3+060.000	17.68	183.99	183.99	0	0	123244	123244	23546.67	99697.31
3+070.000	20.6	186.81	186.81	0	0	123430.8	123430.8	23546.67	99884.12
3+080.000	23.8	221.98	221.98	0	0	123652.8	123652.8	23546.67	100106.1
3+100.000	31.77	555.72	555.72	0	0	124208.5	124208.5	23546.67	100661.8
3+120.000	22.78	545.48	545.48	0	0	124754	124754	23546.67	101207.3
3+140.000	16.95	397.26	397.26	1.43	14.34	125151.2	125151.2	23561.01	101590.2
3+160.000	25.63	425.76	425.76	0	14.34	125577	125577	23575.35	102001.6
3+170.000	30.7	281.63	281.63	0	0	125858.6	125858.6	23575.35	102283.3
3+180.000	35.6	329.69	329.69	0	0	126188.3	126188.3	23575.35	102613
3+190.000	47.36	412.83	412.83	0	0	126601.2	126601.2	23575.35	103025.8
3+200.000	54.18	506.39	506.39	0	0	127107.5	127107.5	23575.35	103532.2
3+210.000	64.94	595.25	595.25	0	0	127702.8	127702.8	23575.35	104127.4
3+220.000	72.82	688.54	688.54	0	0	128391.3	128391.3	23575.35	104816
3+230.000	73.13	729.76	729.76	0	0	129121.1	129121.1	23575.35	105545.7
3+240.000	62.88	680.04	680.04	0	0	129801.1	129801.1	23575.35	106225.8
3+260.000	33.26	961.43	961.43	0	0	130762.6	130762.6	23575.35	107187.2

3+280.000	10.3	435.59	435.59	0	0	131198.2	131198.2	23575.35	107622.8
3+300.000	2.66	129.54	129.54	5.03	50.34	131327.7	131327.7	23625.69	107702
3+320.000	1.63	42.88	42.88	7.44	124.71	131370.6	131370.6	23750.4	107620.2
3+340.000	5.73	73.59	73.59	1.39	88.26	131444.2	131444.2	23838.67	107605.5
3+360.000	20.63	263.58	263.58	0	13.9	131707.8	131707.8	23852.56	107855.2
3+380.000	28.16	487.89	487.89	0	0	132195.6	132195.6	23852.56	108343.1
3+400.000	19.65	478.07	478.07	0	0	132673.7	132673.7	23852.56	108821.2
3+420.000	7.69	273.34	273.34	2.86	28.63	132947.1	132947.1	23881.19	109065.9
3+440.000	9.56	172.47	172.47	0.76	36.2	133119.5	133119.5	23917.39	109202.1
3+450.000	16.08	127.25	127.25	0	3.81	133246.8	133246.8	23921.2	109325.6
3+460.000	24.24	200.2	200.2	0	0	133447	133447	23921.2	109525.8
3+470.000	28.91	263.82	263.82	0	0	133710.8	133710.8	23921.2	109789.6
3+480.000	25.47	270.61	270.61	0	0	133981.4	133981.4	23921.2	110060.2
3+490.000	24.16	248.11	248.11	0	0	134229.5	134229.5	23921.2	110308.3
3+500.000	21.61	229.68	229.68	0	0	134459.2	134459.2	23921.2	110538
3+510.000	19.11	203.62	203.62	0	0	134662.8	134662.8	23921.2	110741.6
3+520.000	14.88	169.97	169.97	0	0	134832.8	134832.8	23921.2	110911.6
3+530.000	9.52	122.04	122.04	0.74	3.68	134954.8	134954.8	23924.88	111030
3+540.000	5.54	75.31	75.31	4.28	25.06	135030.2	135030.2	23949.94	111080.2
3+550.000	2.73	41.35	41.35	13.79	90.36	135071.5	135071.5	24040.3	111031.2
3+560.000	1.38	20.56	20.56	23.66	187.26	135092.1	135092.1	24227.56	110864.5
3+570.000	0.58	9.78	9.78	23.56	236.11	135101.8	135101.8	24463.67	110638.2
3+580.000	0.46	5.17	5.17	20.96	222.61	135107	135107	24686.27	110420.7
3+590.000	2.91	16.85	16.85	7.82	143.87	135123.9	135123.9	24830.14	110293.7
3+600.000	10.24	65.77	65.77	0	39.09	135189.6	135189.6	24869.23	110320.4
3+610.000	24.18	172.13	172.13	0	0	135361.8	135361.8	24869.23	110492.5
3+620.000	41.8	329.92	329.92	0	0	135691.7	135691.7	24869.23	110822.5
3+630.000	67.82	548.09	548.09	0	0	136239.8	136239.8	24869.23	111370.6
3+640.000	98.93	833.72	833.72	0	0	137073.5	137073.5	24869.23	112204.3
3+660.000	171.54	2704.65	2704.65	0	0	139778.2	139778.2	24869.23	114908.9
3+680.000	211.19	3827.31	3827.31	0	0	143605.5	143605.5	24869.23	118736.2
3+700.000	185.04	3962.28	3962.28	0	0	147567.8	147567.8	24869.23	122698.5
3+720.000	140.45	3254.82	3254.82	0	0	150822.6	150822.6	24869.23	125953.3

3+740.000	105.06	2455.08	2455.08	0	0	153277.7	153277.7	24869.23	128408.4
3+760.000	72.76	1778.26	1778.26	0	0	155055.9	155055.9	24869.23	130186.7
3+780.000	26.22	989.8	989.8	0	0	156045.7	156045.7	24869.23	131176.5
3+790.000	6.2	165.3	165.3	6.55	32	156211	156211	24901.23	131309.8
3+800.000	0.31	33.87	33.87	28.48	170.96	156244.9	156244.9	25072.19	131172.7
3+810.000	0	1.6	1.6	46.18	366.69	156246.5	156246.5	25438.89	130807.6
3+820.000	0	0	0	59.85	523.55	156246.5	156246.5	25962.44	130284
3+840.000	0	0	0	76.48	1358.15	156246.5	156246.5	27320.59	128925.9
3+860.000	0	0	0	82.19	1586.71	156246.5	156246.5	28907.3	127339.2
3+880.000	0	0	0	74.62	1568.09	156246.5	156246.5	30475.39	125771.1
3+900.000	0	0	0	53.47	1280.88	156246.5	156246.5	31756.27	124490.2
3+920.000	0	0	0	29.68	831.49	156246.5	156246.5	32587.76	123658.7
3+940.000	0.43	4.3	4.3	15.67	453.56	156250.8	156250.8	33041.32	123209.4
3+960.000	1.59	20.16	20.16	9.64	253.15	156270.9	156270.9	33294.47	122976.5
3+970.000	3.3	24.82	24.82	4.13	68.4	156295.7	156295.7	33362.87	122932.9
3+980.000	10.08	67.34	67.34	0	20.52	156363.1	156363.1	33383.39	122979.7
3+990.000	23.9	169.84	169.84	0	0	156532.9	156532.9	33383.39	123149.5
4+000.000	39.32	314.68	314.68	0	0	156847.6	156847.6	33383.39	123464.2
4+010.000	46.81	427.81	427.81	0	0	157275.4	157275.4	33383.39	123892
4+020.000	53.76	499.12	499.12	0	0	157774.5	157774.5	33383.39	124391.1
4+030.000	60.2	565.62	565.62	0	0	158340.2	158340.2	33383.39	124956.8
4+040.000	66.85	630.96	630.96	0	0	158971.1	158971.1	33383.39	125587.7
4+050.000	72.05	690.55	690.55	0	0	159661.7	159661.7	33383.39	126278.3
4+060.000	77.97	746.78	746.78	0	0	160408.4	160408.4	33383.39	127025.1
4+070.000	80.49	792.27	792.27	0	0	161200.7	161200.7	33383.39	127817.3
4+080.000	78.2	793.45	793.45	0	0	161994.2	161994.2	33383.39	128610.8
4+090.000	71.22	747.11	747.11	0	0	162741.3	162741.3	33383.39	129357.9
4+100.000	59.25	652.38	652.38	0	0	163393.6	163393.6	33383.39	130010.3
4+110.000	47.43	533.4	533.4	0	0	163927.1	163927.1	33383.39	130543.7
4+120.000	35.59	415.06	415.06	0	0	164342.1	164342.1	33383.39	130958.7
4+130.000	29.55	325.7	325.7	0	0	164667.8	164667.8	33383.39	131284.4
4+140.000	25.68	276.14	276.14	0	0	164944	164944	33383.39	131560.6
4+150.000	23.47	245.72	245.72	0	0	165189.7	165189.7	33383.39	131806.3

4+160.000	22.5	229.82	229.82	0	0	165419.5	165419.5	33383.39	132036.1
4+170.000	22.54	225.19	225.19	0	0	165644.7	165644.7	33383.39	132261.3
4+180.000	19.94	212.42	212.42	0	0	165857.1	165857.1	33383.39	132473.7
4+190.000	8.07	140.08	140.08	0.72	3.58	165997.2	165997.2	33386.98	132610.2
4+200.000	3.18	56.25	56.25	9.48	50.96	166053.4	166053.4	33437.94	132615.5
4+210.000	1.62	23.98	23.98	21.18	153.3	166077.4	166077.4	33591.24	132486.2
4+220.000	0.9	12.58	12.58	29.27	252.25	166090	166090	33843.49	132246.5
4+240.000	0.44	13.38	13.38	14.17	434.37	166103.4	166103.4	34277.86	131825.5
4+260.000	17.65	180.86	180.86	0	141.72	166284.2	166284.2	34419.58	131864.6
4+280.000	29.38	470.22	470.22	0	0	166754.4	166754.4	34419.58	132334.9
4+300.000	52.48	818.52	818.52	0	0	167573	167573	34419.58	133153.4
4+320.000	89.29	1417.66	1417.66	0	0	168990.6	168990.6	34419.58	134571
4+340.000	94.89	1841.76	1841.76	0	0	170832.4	170832.4	34419.58	136412.8
4+360.000	88.02	1829.06	1829.06	0	0	172661.5	172661.5	34419.58	138241.9
4+370.000	79.05	834.8	834.8	0	0	173496.3	173496.3	34419.58	139076.7
4+380.000	68.31	735.4	735.4	0	0	174231.7	174231.7	34419.58	139812.1
4+390.000	62.4	654.8	654.8	0	0	174886.5	174886.5	34419.58	140466.9
4+400.000	45.24	540.76	540.76	0	0	175427.2	175427.2	34419.58	141007.6
4+410.000	39.07	422.47	422.47	0	0	175849.7	175849.7	34419.58	141430.1
4+420.000	36.34	377.07	377.07	0	0	176226.8	176226.8	34419.58	141807.2
4+440.000	30.59	669.3	669.3	0	0	176896.1	176896.1	34419.58	142476.5
4+460.000	29.85	604.33	604.33	0	0	177500.4	177500.4	34419.58	143080.8
4+480.000	38.65	684.96	684.96	0	0	178185.3	178185.3	34419.58	143765.8
4+500.000	46.15	847.98	847.98	0	0	179033.3	179033.3	34419.58	144613.7
4+520.000	50.44	965.87	965.87	0	0	179999.2	179999.2	34419.58	145579.6
4+540.000	90.93	1408.5	1408.5	0	0	181407.7	181407.7	34419.58	146988.1
4+550.000	113.84	1011.54	1011.54	0	0	182419.2	182419.2	34419.58	147999.6
4+560.000	135.95	1232.81	1232.81	0	0	183652	183652	34419.58	149232.5
4+570.000	155.72	1439.94	1439.94	0	0	185092	185092	34419.58	150672.4
4+580.000	132.5	1432.7	1432.7	0	0	186524.7	186524.7	34419.58	152105.1
4+600.000	107.46	2402.06	2402.06	0	0	188926.7	188926.7	34419.58	154507.2
4+620.000	83.93	1913.96	1913.96	0	0	190840.7	190840.7	34419.58	156421.1
4+640.000	43.35	1272.85	1272.85	0	0	192113.5	192113.5	34419.58	157694

4+660.000	14.39	577.39	577.39	2.79	27.87	192690.9	192690.9	34447.45	158243.5
4+680.000	9.69	240.8	240.8	17.46	202.45	192931.7	192931.7	34649.9	158281.8
4+700.000	2.22	119.1	119.1	38.9	563.57	193050.8	193050.8	35213.47	157837.4
4+720.000	0	22.18	22.18	50.26	891.62	193073	193073	36105.09	156967.9
4+730.000	0	0	0	52.91	515.85	193073	193073	36620.94	156452.1
4+740.000	0	0	0	47.86	493.61	193073	193073	37114.55	155958.5
4+750.000	0	0	0	43.59	449.45	193073	193073	37564	155509
4+760.000	0	0	0	41.68	422.8	193073	193073	37986.79	155086.2
4+770.000	0	0	0	40.41	410.7	193073	193073	38397.49	154675.5
4+780.000	0	0	0	34.2	373.61	193073	193073	38771.1	154301.9
4+800.000	0	0	0	19.24	534.38	193073	193073	39305.48	153767.5
4+820.000	1.21	12.14	12.14	8.84	280.78	193085.1	193085.1	39586.26	153498.9
4+840.000	8.65	98.67	98.67	0.19	90.32	193183.8	193183.8	39676.58	153507.2
4+860.000	48.88	575.3	575.3	0	1.95	193759.1	193759.1	39678.52	154080.6
4+880.000	81.7	1305.79	1305.79	0	0	195064.9	195064.9	39678.52	155386.4
4+900.000	64.9	1466.02	1466.02	0	0	196530.9	196530.9	39678.52	156852.4
4+920.000	57.37	1222.68	1222.68	0	0	197753.6	197753.6	39678.52	158075.1
4+930.000	54.5	557.64	557.64	0	0	198311.3	198311.3	39678.52	158632.7
4+940.000	46.26	501.09	501.09	0	0	198812.3	198812.3	39678.52	159133.8
4+950.000	39.24	424.08	424.08	0	0	199236.4	199236.4	39678.52	159557.9
4+960.000	36.54	375.06	375.06	0	0	199611.5	199611.5	39678.52	159933
4+970.000	35.18	354.61	354.61	0	0	199966.1	199966.1	39678.52	160287.6
4+980.000	35.28	352.32	352.32	0	0	200318.4	200318.4	39678.52	160639.9
5+000.000	31.29	665.72	665.72	0	0	200984.1	200984.1	39678.52	161305.6
5+020.000	29.13	604.19	604.19	0	0	201588.3	201588.3	39678.52	161909.8
5+040.000	32.52	616.45	616.45	0	0	202204.8	202204.8	39678.52	162526.3
5+045.019	21.45	135.42	135.42	0	0	202340.2	202340.2	39678.52	162661.7

Appendix 3: Work Schedule

WBS	Task Mode	Task Name	Progress	Start	Finish	Duration	Length	Volume of Work	Unit
2000	**Scheduled**	**SETTING OUT & SITE CLEARANCE**		**01/04/2019**	**05/04/19**	**5**			
	Auto								
2100	**Scheduled**	**Setting out the horizontal Alignment**		**01/04/2019**	**02/04/19**	**2**			
	Auto								
21.01	**Scheduled**	Setting out the horizontal Alignment		01/04/2019	02/04/19	2	5045.019	5045.02	KM
	Auto								
2200	**Scheduled**	**Site Clearance**		02/04/2019	03/04/19	2	5045.019	100900.38	M^2
	Auto								
22.04	**Scheduled**	**Stone/Boulders removal**		03/04/2019	03/04/19	1	3211.400	172.00	M^3
	Auto								
	Scheduled	Project Execution Report (1)		04/04/2019	04/04/19	0			
	Auto								
3000	**Scheduled**	**EARTH WORKS**		**03/04/2019**	**19/06/19**	**78**			
	Auto								
3100	**Scheduled**	**Establishment of vertical alignment**		**03/04/2019**	**26/04/19**	**24**			
	Auto								
31.01	**Scheduled**	Establishment of vertical alignment		03/04/2019	08/04/19	6	5045.019	100900.38	M^2
	Auto								
31.02	**Scheduled**	Excavation to level and compaction		15/04/2019	06/05/19	18	5045.019	81729.31	M^3
	Auto								
31.03	**Scheduled**	**Construction of Embankment**		**07/05/2019**	**29/06/19**	**54**			

	Auto								
I	Scheduled	Side borrow		07/05/2019	24/05/19	18			
	Auto								
a	Scheduled	Production of Side borrow fill, spreading and compaction		27/05/2019	08/07/19	36	5045.019	39678.52	M^3
	Auto								
3200	Scheduled	**CONSTRUCTION OF THE ROAD FORMATION**		**08/07/2019**	**01/02/20**	**27**			
	Auto								
32.01	Scheduled	**Spreading and Compaction for Camber formation**		**08/07/2019**	**15/07/19**	**6**			
	Auto								
a	Scheduled	Spreading and thrown to the centre of the road and Compaction for Camber formation		08/07/2019	15/07/19	6	5045.019	154959.95	M^3
	Auto								
32.02	Scheduled	**Road layer formation material production, loading, transporting and unloading on the calculated road distance interval considering that road way, shoulders and fore slope consumption**		**05/07/2019**	**25/07/19**	**21**			
	Auto								
c	Scheduled	Natural Gravel for Sub Base Material		05/07/2019	13/07/19	9	5045.019	4553.79	M^3
	Auto								
b	Scheduled	Natural Gravel Road Base		14/07/2019	20/07/19	7	5045.019	7826.42	M^3
	Auto								
a	Scheduled	Gravel Wearing Course		21/07/2019	25/07/19	5	5045.019	20362.51	M^3

	Auto								
32.03	**Scheduled**	**Road layer formation material spreading and compaction evenly for road way, shoulders and fore slope of side ditch.**		**15/07/2019**	**13/08/19**	**25**			
	Auto								
c	**Scheduled**	Natural Gravel for Sub Base Material		15/07/2019	03/08/19	20	5045.019	4553.79	M^3
	Auto								
b	**Scheduled**	Natural Gravel Road Base		04/08/2019	07/08/19	3	5045.019	7826.42	M^3
	Auto								
a	**Scheduled**	Gravel Wearing Course		08/08/2019	09/08/19	2	5045.019	20362.51	M^3
	Auto								
	Scheduled	Project Execution Report (2)		10/08/2019	10/08/19	0			
	Auto								