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MASTER PROGRAM

UAV AND BIM TECHNOLOGY PERFORMANCE IN INFRASTRUCTURE PROJECTS

MASTER'S THESIS

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THESIS STATEMENT

I declare that the master's thesis on "UAV and BIM Technology Performance in Infrastructure Projects", which I prepared under the supervision of Asst. Prof. Dr. Servet Yaprak, according to the thesis writing guide of Tokat Gaziosmanpaşa University Graduate Education Institute, is an original study in accordance with scientific ethical values and rules, and that I will accept all kinds of legal sanctions if the opposite is determined.

13/09/2022

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ABSTRACT

UAV AND BIM TECHNOLOGY PERFORMANCE IN INFRASTRUCTURE PROJECTS

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A safe and reliable transportation system helps people and goods get where they need to go and connect. This will boost the economy and improve people's life. This thesis focuses on the practical section of the UAV and BIM technology performance in infrastructure projects, in which the UAV can obtain accurate 3D topographic data in rugged terrain and hard-to-reach regions. UAV output data can easily integrate with BIM software to build, design, and manage. This study is about an application study to evaluate the performance of both UAV and BIM-InfraWorks software by comparing terrestrial measurement and CAD design in existing highway design projects.

Most of the previous UAV and BIM application examples only cover buildings. There are not many studies that provide information about the use of UAVs and BIM in infrastructure projects. Therefore, this research aims to:

1. To what extent are UAV and BIM tools suitable for manipulating all aspects of infrastructure projects such as data collection, design and management?

2. How does the combination of UAV and BIM work, which have become promising tools for obtaining accurate data compared to terrestrial surveying and traditional CAD design in road projects?

The purpose of combining Building Information Modeling (BIM) and Unmanned Aerial Vehicles (UAV) Systems is to obtain precise topography and make it easy to see and explore the ground in real-time. The study results showed that the combined UAV-BIM system produced a large amount of data that could be analyzed. In addition, in a highway project, the design of the road was carried out using BIM technology and the amount of excavation, which is one of the important cost items, was tried to be optimized.

KEYWORDS: UAV, Oblique Camera, BIM, Highway Design, Vertical Optimization, and Autodesk InfraWorks.

ÖZET

ALT YAPI PROJELERİNDE İHA VE BİM TEKNOLOJİ PERFORMANSI

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Yüksek Lisans, Harita Mühendisliği Anabilim Dalı
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Güvenli ve güvenilir bir ulaşım sistemi, insanların ve mal hareketleri ve bağlantı kurmaları gereken yere ulaşmalarına yardımcı olur. Bu ekonomiyi canlandıracak ve insanların yaşamlarını iyileştirecektir. Bu tez, İHA'nın engebeli arazilerde ve ulaşılması zor bölgelerde doğru 3B topografik veriler elde edebildiği altyapı projelerinde İHA ve BIM teknolojisi performansının pratik bölümüne odaklanmaktadır. Oluşturmak, tasarlamak ve yönetmek için BIM yazılımıyla kolayca entegre olabilir. Bu çalışma, mevcut karayolu tasarım projelerinde yersel ölçüm ve geleneksel CAD tasarımının karşılaştırılmasıyla hem UAV hem de BIM-InfraWorks yazılımının performansını ele almaya yönelik pratik çalışmalara ayrılmıştır.

Daha önceki İHA ve BIM uygulama örneklerinin çoğu sadece binaları kapsamaktadır. Altyapı projelerinde İHA'ların ve BIM'in kullanılması hakkında bilgi veren çalışmalar çok fazla değildir. Bu nedenle, bu araştırma şunları amaçlamaktadır:

1. UAV ve BIM araçları, veri toplama, tasarım ve yönetim gibi altyapı projelerinin tüm yönlerini manipüle etmek için ne ölçüde uygundur?

2. Karayolu projelerinde yersel ölçüm ve geleneksel CAD tasarımına kıyasla doğru veri elde etmek için umut verici araçlar haline gelen İHA ve BIM kombinasyonu nasıl çalışmaktadır?

Bina Bilgi Modelleme (BIM) ve İnsansız Hava Araçları (IHA) Sistemlerini birleştirmenin amacı, gerçek topografyayı elde etmek ve zemini gerçek zamanlı olarak görmeyi ve keşfetmeyi kolaylaştırmaktır. Çalışma sonuçları, birleşik İHA-BIM sisteminin analiz edilebilecek büyük miktarda veri üretildiğini göstermiştir. Ayrıca bir karayolu projesinde BIM teknolojisi kullanarak yolun tasarımı gerçekleştirilmiş ve önemli maliyet kalemlerinden biri olan hafriyat miktarları optimize edilmeye çalışılmıştır.

Anahtar Kelimeler: İHA, Oblik Kamera, BIM, Otoyol Tasarımı, Dikey Optimizasyon ve Autodesk InfraWorks.

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Abbreviations	Description
AASHTO	American Association of Highway and Transportation Official
AEC	Architecture, Engineering, and Construction
AECO	Architecture, Engineering, Construction, and Operation
AGL	Above Ground Level
BIM	Building Information Modeling
CAD	Computer-Aided Design
CAGR	Compound Annual Growth Rate
CDE	Common Data Environment
DEM	Digital Elevation Model
DPW	Digital Photogrammetry Workstation
DSM	Digital Surface Modeling
DTM	Digital Terrain Modeling
FGDC	Federal Geographic Data Committee
GCP	Ground Control Point
GIS	Geographic Information System
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSD	Ground Sample Distance
ICAA	Iraq Civil Aviation Authority
IMU	Initial Measurement Unit
ISO	International Organization for Standardization
LIDAR	Light Detection and Ranging
LOD	Level of Detail
NSDI	National Spatial Data Infrastructure
PVI	Point of Vertical Intersection

RFI	Request For Information
RGB	Red, Green, Blue
RMSE	Root-Mean-Squared Error
RPAS	Remotely Piloted Aircraft Systems
RS	Remote Sensing
RTK	Real-Time Kinematic
SLAM	Simultaneous Localization And Mapping
SUAV	Small Unmanned Aerial Vehicle
SUV	Sport Utility Vehicle
TIN	Triangular Irregular Networks
TLS	Terrestrial Laser Scanning
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UGS	Unmanned Ground Systems
UK	United Kingdom
US	United States
USD	United States Dollar
VTOL	Vertical Take-Off and Landing

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1. INTRODUCTION

1.1. Introduction

Infrastructure systems are one of the most significant cornerstone components in every region's construction and development programs. Road infrastructure construction and maintenance are essential for most countries' economies. For road administrations, this involves improving the efficiency of road construction and management, reducing the danger of project cost overruns, and increasing transparency in the use of public monies (Šimenić, 2021). Infrastructure management's traditional techniques of doing business, particularly in the road sector, are unable to tackle the increasingly important difficulties that face the industry today.

An infrastructure development project's execution is a multi-step operation, not a one-time occurrence (Vacanas, Themistocleous, Agapiou, & Hadjimitsis, 2015). Architecture, Engineering, and Construction are evolving due to new techniques and technology (Abbondati, Biancardo, Palazzo, Capaldo, & Viscione, 2020). This includes Building Information Modeling (BIM), artificial intelligence, robots, 3D printing, additive manufacturing, the Internet of Things, autonomous cars, UAVs, augmented and virtual reality, and other related technologies and processes (Šimenić, 2021). Unlike conventional project management methods, including new technologies such as Building Information Modeling (BIM), Unmanned Aerial Systems (UAS), and real-time cloud-based data modeling and analysis allows for real-time project control, monitoring, and inspection (Moeini, Oudjehane, Baker, & Hawkins, 2017). However, BIM implementations in transportation infrastructure lags many years behind that in building development. The majority of published BIM principles and standards are concerned with architecture, specifically with vertical structures (Šimenić, 2021).

Infrastructure projects are increasingly utilizing BIM. According to the Smart Market Report (The Business Value of BIM for Infrastructure, 2012) by McGraw-Hill Construction, over half of the infrastructure organizations in the United States employed BIM technology and procedures on certain sections of their projects. Highway and infrastructure project stakeholders are turning to cutting-edge technology like Building Information Modeling (BIM) to help them save time and money while maintaining the quality of their projects and the environment (Shaaban, Nadeem, & Economics, 2015). Before final design and plan documentation, designers and civil engineers require access to technologies that allow the modeling of alternative design scenarios. This allows for easy evaluation of project timelines and design options, allowing for the most efficient and cost-effective design approach with negligible impact on communities. BIM enables engineers to more easily forecast the performance of projects before they are built, respond to design changes more quickly, optimize designs through analysis, simulation, and visualization, and generate higher-quality construction documentation (Strafaci, 2008).

Design and management are essential for successful infrastructure construction projects as the topographic data acquisition techniques. New technologies allow the direct collection of spatial data about the physical features, which may be integrated into design processes. Unmanned Aerial Vehicles (UAVs), proven to be a competitive topographic data gathering tool intended to function without a human pilot onboard, are good examples of such developing technology (Koeva, Muneza, Gevaert, Gerke, & Nex, 2018). In today's world, Unmanned Aerial Vehicles (UAVs) are rapidly employed in civil and scientific research in various fields.

Technologies including 3D scanning, virtual reality, BIM, unmanned aerial and ground systems (UAS and UGS), autonomous machinery and equipment, and innovative building materials have matured in terms of technology and commercial maturity, enabling major changes in the construction business (Moeini et al., 2017). It would be easier to gather and organize information using BIM and drones. Then there would be less conflict and more production (Efosa, 2019).

UAV methods are highly beneficial for capturing data from vast regions and high terrain that would take considerably longer to collect without the use of remote sensing. Photogrammetry is a practical remote sensing method for mapping and modeling, especially in places where people cannot safely reach or access it (Kottenstette, 2005). In addition, photogrammetry delivers an all-in-one solution by collecting topographic data and images in one operation. Real-world data is replacing geometric representations in a design context. UAV output maps assist design teams in increasing accuracy and accommodating physical-world circumstances by customizing a design to match precisely with real-world settings. UAVs give a level of accuracy that, when combined with proper flight height and the appropriate overlapping rates, just cannot be achieved with more traditional observation techniques (Yaprak, Yildirim, Susam, Inyurt, & Oguz, 2018).

A mix of vertical and oblique UAV pictures is recommended as the best approach for recording steep terrain (Kozmus Trajkovski, Grigillo, & Petrovič, 2020). The UAV collected topography data, then incorporated it into the BIM model and rendered it to create the topographic maps. Small Unmanned Aerial Vehicles have made significant advances in the commercial field and the military occupation. Advanced photogrammetry technology has reduced the cost of aerial mapping and improved the quality of results. The imagery taken by UAVs has been manipulated to produce various digital models through photogrammetric processing.

These tools are changing how infrastructure projects are done, from data collecting along a highway alignment corridor to entire site inspection, especially in hazardous locations where acquiring reliable data can be difficult and in project design optimization. This high-level automated procedure from design to management will lower the project's total cost by minimizing the number of requests for information (RFI) and modification orders.

1.2. Thesis Organization

This thesis is structured as follows. Following this introduction, Chapter 2 will provide a general overview of UAV and BIM systems and a review of the application of UAV and BIM in infrastructure projects. Chapter 3 will present a proposed method of topographical data acquisition, a highway corridor study, and an overview and workflow of the aerial survey. Following that, the information gathered from the UAV and the processing data will be used to create a base map of topographic data for designing highways using BIM technology. Finally, the optimization of vertical highway alignment and a 3D-based detection methodology will be proposed. Chapter 4 will present a sample result from the BIM study design and a detailed quality summary. Chapter 4 will also include a report on the essential findings and limitations of the first proposed approach. The conclusion, lessons learned, and future research are discussed in Chapter 5.

2. BACKGROUND AND LITERATURE REVIEW

This section provides a brief review of some available methods in the literature. This chapter will include background information on UAVs and BIM, the evolution and the state-of-the-art use of UAVs and BIM in the field of topographic data acquisition, and the design of infrastructure projects from different communities. In addition, this chapter submits information on the role of UAVs and BIM in highway projects and related techniques for build, design, and management.

2.1. UAV Overview

For the sake of this research, Unmanned Aerial Vehicle systems (UAVs) and drones shall be referred to as UAV(s) and drones, respectively, because "UAV" and "drone" are the most often used words in both literature and practice, respectively. Unmanned Aerial Systems (UAS), Unmanned Aerial Vehicles (UAV), Remotely Piloted Aircraft Systems (RPAS), and drones are all terms used to describe UAS. A UAS is made up of four parts: 1) an aircraft with no pilot on board, 2) a remote pilot station, 3) a command and control link, and 4) a payload specific to the application/operation, which frequently includes specialized cameras or other sensors that capture data for immediate analysis (Commerce). The American Society has defined the term UAV photogrammetry for Photogrammetry and Remote Sensing "as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena" (Wolf, Dewitt, & Wilkinson, 2014). Meanwhile, during the 1980s and 1990s, the advancement of computer technology had a significant impact on the growth of remote sensing systems. Thus, during the last thirty years, photogrammetry has progressed from analog to analytical to digital (Balenović et al., 2011) (Figure 1). During this development, analog aerial photographs and analog or analytical stereo instruments were replaced by digital aerial images and digital photogrammetric workstations (Magnusson, 2007).

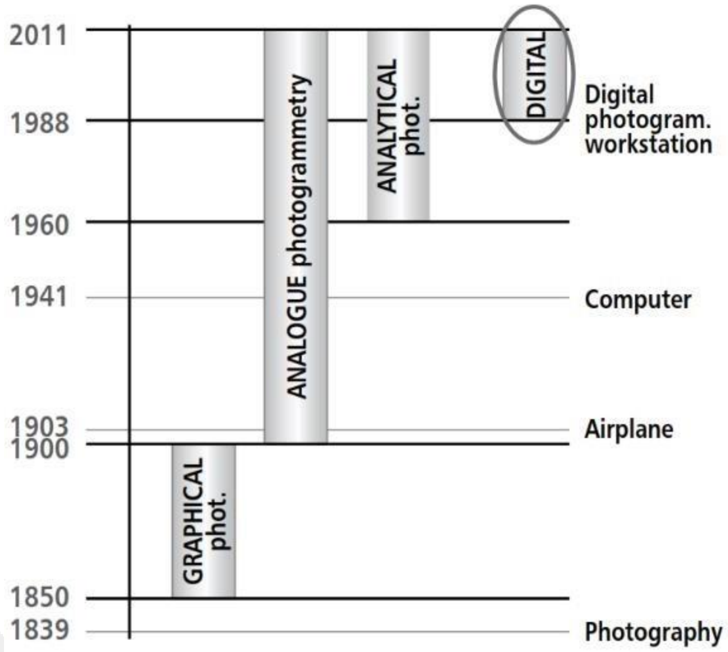


Figure 1**.** Phases of photogrammetry development, as a result of technological innovation (T, 2005)

Military research and development have historically dominated the development of Unmanned Aerial Vehicles (UAVs) ((Nex & Remondino, 2014)). Unmanned Aerial Vehicles (UAVs) have been utilized in unmanned inspection, surveillance, reconnaissance, and geographical survey for the military, with remote sensing technologies being used in the process ((Remondino, Barazzetti, Nex, Scaioni, & Sarazzi, 2012)). In the recent decade, low-cost Small Unmanned Aerial Vehicles (SUAVs) have made considerable breakthroughs in commercial and military sectors, with the retail industry seeing the most significant gains. The use of cutting-edge photogrammetry technology, for example, has decreased the cost of aerial mapping while simultaneously improving the quality of the data. When GNSS became more accurate and cheap, it became possible to keep a UAV system's position in a global reference system almost anywhere around the world and in real-time (Siebert & Teizer, 2014). They are fitted with precision sensors, such as inertial motion units (IMUs) and gyroscopes, that allow them to recognize the aircraft's alignment and location. The use of a microcomputer allows for autonomous navigation without the need for a large amount of human intervention on the part of the pilot (Vacanas et al., 2015).

The image captured by Unmanned Aerial Vehicles (UAVs) has been manipulated to create multiple digital models using photogrammetric processing, applied in various commercial industries such as surveying, inspection, and archeology. UAVs have made big improvements in their equipment. They can now get high-resolution images from many different angles in a cost-effective and efficient way. When someone uses Metric Photogrammetry and Structure for Motion, which is the science of figuring out object characteristics from rectified stereophotographs, they can get information from the images. Photogrammetry can help you figure out things like distances, angles, areas, volumes, elevations, object sizes, and object shapes in images that are all overlaid on top of each other (Adams, Friedland, & Levitan, 2010).

Recently, the global drone industry has been booming. As Unmanned Aerial Vehicle (UAV) technology becomes more advanced, more approachable, and more affordable, troves of recreational and commercial drone pilots are entering the drone industry, and the usage of Unmanned Aerial Vehicles (UAVs) has become popular in numerous applications and industries. They are now freely available to anybody. As a result, safety concerns were raised, and restrictions were enacted to restrict the use of Unmanned Aerial Vehicles (UAVs) by civilians, for the most part. Many civil aviation authorities from various countries put in place rules and regulations to limit the frequency of accidents in both the air and on the ground, and the results have been positive. Most of these authorities offer certification examinations to UAV operators to help them enhance their technical and situational skills. Currently, no country has agreed on a universal set of unified drone rules. Many governments have embraced the use of drones, particularly for recreational purposes, as something that does not require extensive regulation and should merely be watched for safety reasons. Other nations have extremely tight laws and regulations prohibiting the use of drones, regardless of their intended use; for example, drones are banned in Iraq, according to the Iraq Civil Aviation Authority (ICAA), which oversees the country's national aviation authority. ICAA duties state that if you attempt to enter Iraq with a drone, it will be confiscated at the border checkpoint. Thus, pilots must ensure that they follow all applicable protocols before taking to the skies. The following are the international standard guidelines for the use of Unmanned Aerial Vehicles (UAVs):

- It's only allowed to fly if an operator and an observer can see it from where they are standing (s).
- UAVs are not allowed to fly in restricted airspaces like airports or military airspace.
- UAVs are not allowed to fly above a specific altitude (different for every country).

In 2020, the global commercial drone industry was estimated to be worth USD 13.44 billion. From 2021 to 2028, it is predicted to rise at a compound annual growth rate (CAGR) of 57.5 percent (Figure 2 and Figure 3). In terms of volume, demand in 2020 was estimated to be 689.4 thousand units (Grand View Research, 2021).

Drones are employed for various purposes, including filming and emergency response. Furthermore, due to their ability to survey lands, offer constant and exact project notifications, increase safety, and prevent harmful accidents on construction sites, these devices are in high demand in the real estate and construction sectors. Over the last few years, the number of business use cases for drones has increased dramatically. For example, drone manufacturers and software solution providers are continually inventing, testing, and upgrading solutions for diverse markets.

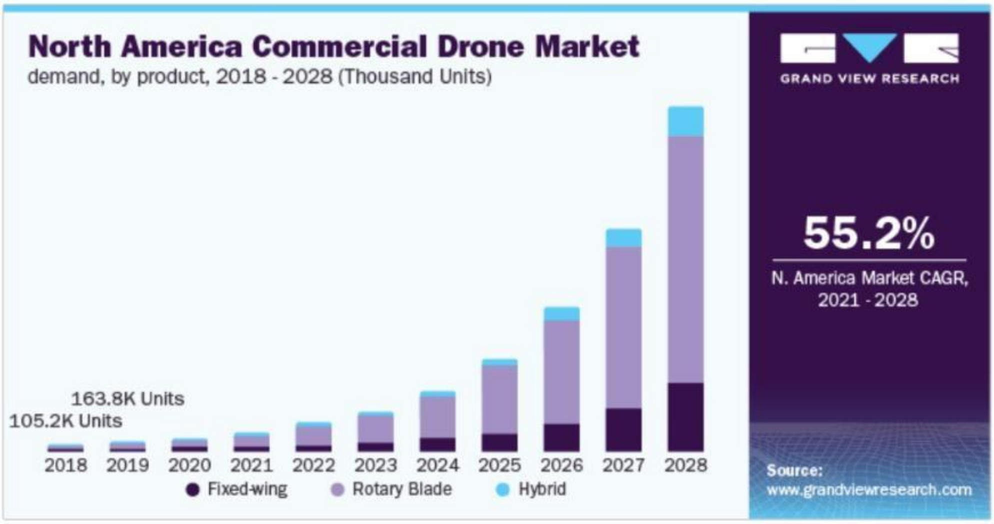


Figure 2. 2018-2028 North America Commercial Drone Market (Grand View Research, 2021)

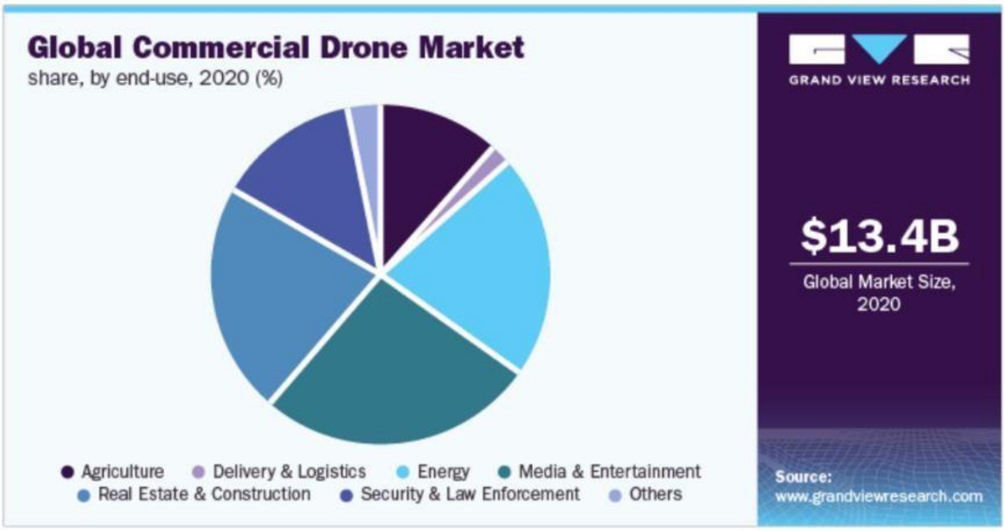


Figure 3. Global Commercial Drone Market 2020 (Grand View Research, 2021)

Drone sales are predicted to surge by 180 percent, from 2.5 million in 2016 to 7 million in 2020. As a result, newer and more diverse variants are continually reaching the market, making it tough to keep up with various models. Because there is presently no formal categorization or explicit rules for different types of drones, things can get even more muddled. The following (Figure 4) are the four most common types of drones: fixed-wing, single-rotor, multirotor, and fixed-wing hybrid VTOL drones (Grand View Research, 2021). These drones are categorized according to their payload, ranging from small ones weighing only a few hundred grams to large ones weighing several hundred kilograms and operating precisely like a real plane. Drones are commonly employed in dangerous and inaccessible areas to map out elevated infrastructure with broken power lines, unstable roofs, and search and rescue operations (Kozmus Trajkovski et al., 2020).

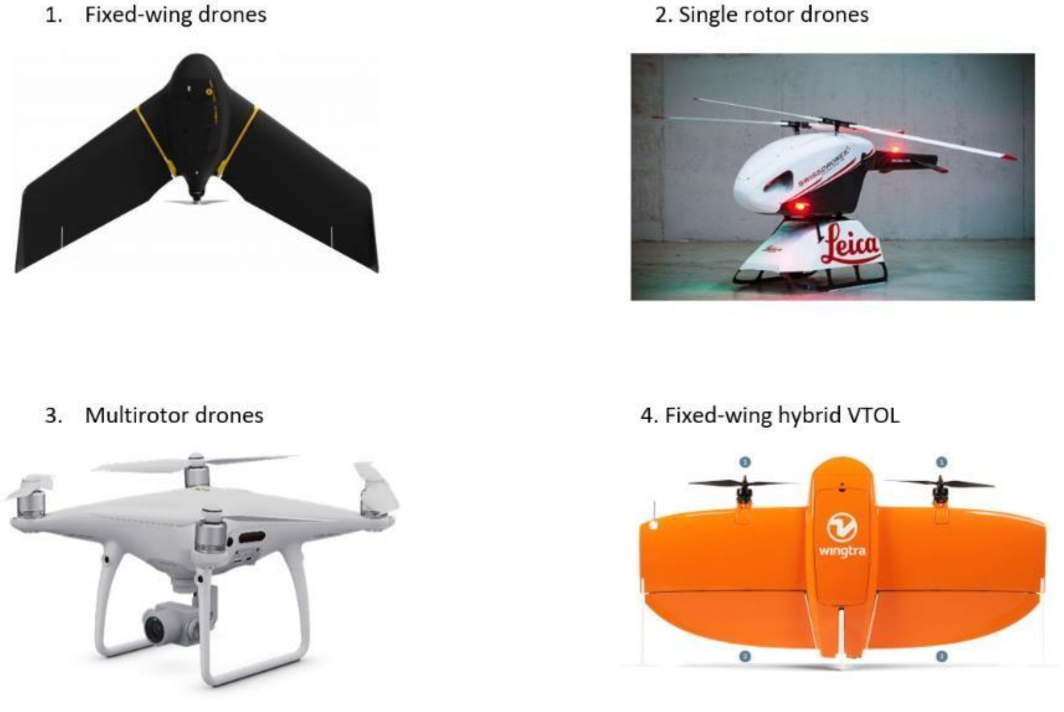


Figure 4. Types of drones (1. AgEagle Aerial Systems Inc, 2. Leica Geosystems AG, **3.** Dji, 4. Wingtra AG.)

2.2. The role of UAV in land surveying

Land surveying is becoming an increasingly complex and challenging profession as the world's population continues to rise and land becomes scarcer. Land surveying is the process of taking measurements of a specific piece of land before a construction project starts. For construction crews to start digging, they have to plan out what they will do.

Surveyors use these measurements and data to figure out the features and boundaries of a piece of land. A land survey is almost always the first step in improving a piece of land. Surveys provide important information that helps people make smart decisions about everything from planning a construction site to designing and maintaining infrastructure and more. On-site progress data gathering is often handled by the contractor's engineers, who manually update the project schedule and supplement it with images, the site diary, minutes of progress meetings, and other communications as needed. Many math and high-tech surveying tools are used to make maps and measurements of the land. Land surveyors have long used a wide range of traditional methods and tools, including manned flights, satellite data, total robotic stations, GNSS receivers, 3D scanners, handheld tablets, digital levels, underground locators, GIS, and surveying software, to map territories for many years. Many projects needed faster turnaround times and more detailed modeling of the site’s topography to get done on time. In general, this type of data collection takes a long time and costs money (Barry & Coakley, 2013).

Traditional Geographic Information Systems (GIS) methods used in conjunction with BIM technology for construction projects are primarily based on the utilization of satellite information. There are several drawbacks to this. Images taken from satellites have a lower resolution, and they may contain observation gaps caused by atmospheric phenomena such as cloud cover. They may also have limited coverage over a specific region due to the satellite's orbit around the Earth (Adams et al., 2010).

It is impossible to obtain elevations of high precision more significant than a few centimeters. Targeted remote sensing through conventional manned aerial platforms, on the other hand, can become extremely difficult to employ due to the high cost of the equipment or inaccessible due to logistical and human constraints (Ezequiel et al., 2014). One piece of equipment used is a drone for this (UAV). Drones give us a better picture of existing ground and what is going on at the site. With a drone, topographic surveys can be done the same way they would be done with traditional methods. The relevance of a UAV's capacity to record geographic data with equal accuracies to RTK GNSS, as well as the richness of detail exposed only by 10mm GSD aerial photography, is truly revolutionary (Barry & Coakley, 2013). However, several studies have examined the implementation of UAVs will become more common in the civil engineering applications (Lee, 2019; Siebert & Teizer, 2014; Svensson & Andersson, 2018; Tkáč & Mésároš, 2019). The appearance of UAS, which, based on their qualities, may replace existing traditional technology (Barry & Coakley, 2013), signaled a substantial shift in the topographical survey, particularly in humongous regions, steep terrain, 3D models, and more details of the existing ground situation. Under suboptimal conditions, UAV photogrammetry can reach an accuracy of up to 1:200 scales according to NSDI & FGDC mapping accuracy standards. Most digital cameras record the panchromatic, red, blue, green, and infrared components of the electromagnetic spectrum concurrently during a single aerial survey. It is possible to obtain six elements of pictures (X, Y, Z, omega, phi, kappa) immediately after UAV takeoff using GNSS (Global Positioning System) and IMU (Inertial Measurement Unit). The photos are then fed directly into Digital Photogrammetry Workstations (DPWs) for processing. As a result, a whole phase of the typical fieldwork procedure was eliminated, saving time, effort, and money (Balenović et al., 2011). The use of digital photogrammetry, which has been talked about before, has made it one of the most important ways to get spatial data in many different fields of geodesy, geography, geology, etc. (Balenović et al., 2011)

Another advantage of digital photogrammetry is that the whole photogrammetric measurement and photo interpretation are stored digitally (permanently). While the short time required for data capture is a significant advantage, the most considerable advantage of UAVs is their low acquisition cost when compared to both LiDAR and TLS (Rusnák, Sládek, Buša, & Greif, 2016). This enables easy management at any point in time, unlike field measurement control and future reprocessing of the data (e.g., testing of a future automated system for tree species classification, crown delineation, and so on) (Balenović et al., 2011). The advancement of the small Unmanned Aerial Vehicle (UAV) over the last five years has resulted in their widespread use in a variety of scientific disciplines, providing a cost-effective and time-efficient method of topographic mapping. UAVs can carry a variety of sensor types but are most frequently equipped with digital cameras. Camera images produce high-resolution orthophotos of study areas and three-dimensional surface models (meshes) with resolutions and accuracy of several centimeters. As a result, photogrammetry is being used to replace traditional aerial survey methods such as manned vehicles with Unmanned Aerial Vehicles (UAVs) equipped with RGB, multispectral, and Light Detection and Ranging (LIDAR).

2.3. The role of UAVs in infrastructure projects

The fundamental drawback of traditional land surveying procedures is that they take far too long to complete when it comes to highway construction projects. Surveyors may be required to travel vast distances in order to collect all of the data necessary to support the design of a project's infrastructure. During the period in which this data collection takes place, the remainder of the project will be forced to shut down to await the return of the surveyors, resulting in a waste of time and money. Furthermore, topographical maps were used to help plan highway routes as they were being built. These maps were often given very tiny things. Accurate topographical and feature information is critical for effective road alignment planning (Albattah & GIS, 2016).

During the highway right-of-way surveying process, you need to quickly gather detailed information about the proposed route so that the project can move forward. This can be done with the help of modern land surveying technology, like Unmanned Aerial Vehicles (UAVs). Photogrammetry is an excellent way to map and model things that people can't reach or get to. It's especially useful in places where people can't safely go or get to them (Kottenstette, 2005). Because aerial mapping drones aren't manned, they can help make road surveying safer. Unmanned Aerial Systems (UASs) have swiftly invaded architecture, engineering, construction, and operations (AECO) techniques in recent years, and forecasts show that their application in these sectors will continue to rise in the near future (Gheisari, Bastos Costa, & Irizarry, 2022).

Traditionally, surveyors have to go overland, often through rough terrain that is hard to reach. The chances of a surveyor getting hurt at work went up dramatically just by being in this kind of environment. On the other hand, UAVs make it possible for surveyors to do all their work from a central office ("Aerial Data Collection," 2015). Fortunately, there are new highway surveying tools that make it easier to build roads through rough terrain and hard-to-reach areas. This means that projects can now be finished on time.

In Turkey, the SenseFly company is one case study example of how drones can be used to map corridors instead of traditional instruments. As part of a proposed high-speed rail route connecting the Turkish capital of Ankara with the city of Izmir, Turkish State Railways was required to conduct a comprehensive land survey. Artu Harita awarded the Turkish government's first Unmanned Aerial Vehicle survey contract, used a senseFly eBee to map a vast 140-kilometer-long rail corridor. The high quality and speed with which its data products were delivered impressed its client, and it surpassed its traditional surveying competitors (SenseFly, 2017). Capturing topographic data using a drone is up to five times faster and requires fewer people than traditional approaches (Wingtra). Unmanned Aerial Vehicles could be used to speed up highway development projects that cover a lot of ground. This is one of the research goals.

In addition to providing cost-effective, timely, and workflow-optimized results, UAV mapping can produce a variety of other valuable outputs, such as:

1. Orthographic images in high quality
2. TIN, mesh, or 3D point cloud
3. Road, structural, slope, and other feature break lines
4. Digital Surface Model (DSM) or Digital Terrain Model (DTM)
5. A point cloud that has been classified
6. Elevation contours and DEM
7. Water flow modeling
8. As-built comparison to design models
9. Customized outputs to meet your individual requirements

2.4. BIM overview

Infrastructure management's traditional techniques of doing business, particularly in the road sector, are unable to tackle the increasingly essential difficulties that face the industry today (Šimenić, 2021). Designers worldwide use the AutoCAD design program, which is based in San Rafael, California, to model everything from office furniture to structures to aircraft components. It also happens to be one of the world's largest manufacturers of Building Information Modeling (BIM) software, which designers, engineers, and architects use to model the physical objects they aim to construct digitally and then transfer those models to computer-based models. Building Information Modeling (BIM) is a potential breakthrough in the architecture, engineering, and construction (AEC) industry (Chuck Eastman, 2011). BIM technology creates one or more accurate virtual models of a building digitally.

In 1992, Van Nederveen and Tolman used the term BIM for the first time in the journal Automation in Building. However, in the 1960s, Engelbart wrote a report called "Augmenting Human Intellect: A Conceptual Framework.” This report looked into the origins of parametric modeling and non-geometric information (1962). In that report, he talked about how designers could make an unusual, computer-aided construction model. In the early days of BIM, object-oriented systems and parametric modeling linked to CAD software were commonplace (Efosa, 2019). Before BIM was used in construction, the development of 3D modeling was very important. According to (Chuck Eastman, 2011), 3D modeling became more and more important in research in the 1960s, which led to software that could make simple three-dimensional structures. In recent years, Building Information Modelling has become a meaningful way to improve productivity when constructing buildings. There is still a long way to go before BIM is used more in making other types of infrastructure. However, the use of BIM for infrastructure is growing quickly because owners and engineering service providers see the value of 3D modeling and intelligent objects (Šimenić, 2021). In addition, digital technologies and processes are changing how projects are made, delivered, and managed. This includes Building Information Modeling (BIM), artificial intelligence, robots, 3D printing, additive manufacturing, the Internet of Things, autonomous cars, UAVs, augmented and virtual reality, and other related technologies and processes (Šimenić, 2021). By utilizing BIM technology, it is possible to create a single virtual model of a project, allowing all parties involved in the design process of the project (owners, architects, engineers, contractors, subcontractors, and suppliers) to collaborate more accurately and efficiently than with traditional processes (Azhar & engineering, 2011). For example, according to (Manning & Messner, 2008), rapid 3D visualization is one of the many advantages of utilizing BIM, while others include increased information available to support project development decisions, fast and accurate updates of standard change during conceptual development, decreased labor hours needed to establish reliable space programs, improved communication across the entire team, and increased trust in compliant outcomes. Besides 2-D construction paperwork, deliverables include the model itself and all of the valuable information it includes, which may be used for various tasks such as quantity takeoff, construction sequencing, as-built comparisons, and even operations & maintenance (Strafaci, 2008).

Traditional ways of doing business in infrastructure management are inadequate to meet the greater challenges of today, especially in the road sector. Because inefficiency is no longer allowed in today's economy, all infrastructure-related businesses, including road authorities, must increase productivity, processes, and transparency to effectively plan, build, maintain, and manage road infrastructure to produce value for their customers.

Design, analysis, and documentation are separate processes in traditional drafting-centric ways. This looks at what-if scenarios that are inefficient and costly (Strafaci, 2008). A sound system must be used to meet these goals (Šimenić, 2021):

- The design, construction, and maintenance process should be more transparent and follow the same steps.
- Fewer mistakes and fewer change orders.
- Productivity has gone up.
- Improved coordination between stakeholders
- Money-savings.

The development of object parametric modeling laid the groundwork for all of the BIM software that is used today. In 2000, a company called Charles River made the *Revit* design tool. This software was similar to other programs that let architects and designers design buildings in 3D. The goal was to let them do this. On the other hand, Revit was very different from other software at the time. In 3D modeling, Revit fully embraced the idea of parametric modeling based on the values of objects. There were a lot of different properties, features, and other things that the software could use to make a model. All BIM software is based on this vital addition to CAD because it is important.

Because there are so many different definitions of BIM out there, the whole purpose comes from the United States National Building Information Model Standard Project Committee, which says: “A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle, defined as existing from earliest conception to demolition. A basic premise of BIM is a collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder”. It is essential to know that BIM is not a single product or technology. Instead, it is a group of software applications that help with project coordination and collaboration. Because BIM is also used to make design and construction documents for a road or other type of infrastructure before it's built, this is another way to use it to make these documents.

The United Kingdom BIM maturity model categorizes BIM into three levels of maturity (Figure 5. BIM Maturity Levels (United-BIM). Each level supports the requirements for BIM management and modeling. For example, the British government's target for 2016 was to achieve BIM level 2 (United-BIM).

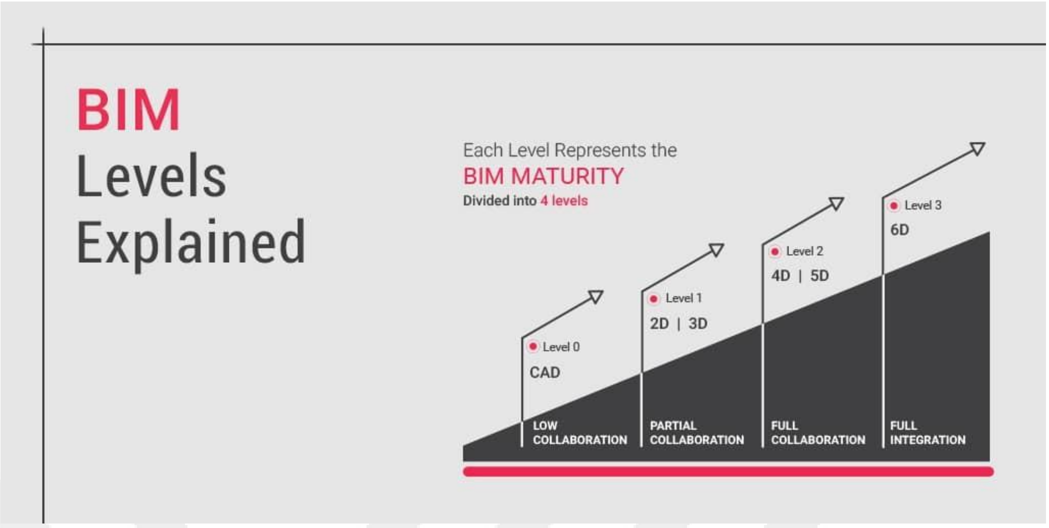


Figure 5. BIM Maturity Levels (United-BIM)

Early on, the UK government recognized that BIM levels encourage collaborative cooperation in the AEC industry. The progressive and identifiable milestones are classified into several categories according to the level of collaboration that these milestones promise (United-BIM). There are currently four maturity levels of Building Information Modeling (Figure 6). They deal with degrees of cooperation between disciplines and the ability to exchange information digitally. BIM levels define the Level of Detail (LOD) at which a BIM model will be developed. These levels, which range from 0 through 3 and beyond, are as follows:

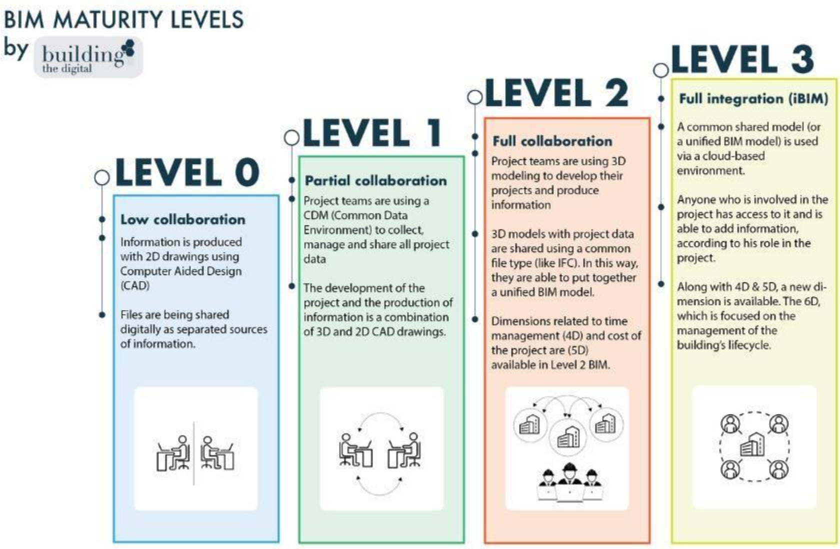


Figure 6. BIM Levels (source: www.buildingthedigital.com)

Level 0 BIM:

Level 0, in its most basic form means that there is no collaboration. Only 2D CAD drafting is used, mainly for Production Information. It can be done with paper or electronic prints or a mix of both. In fact, most of the industry is already a long way ahead of this now (NBS, 2017).

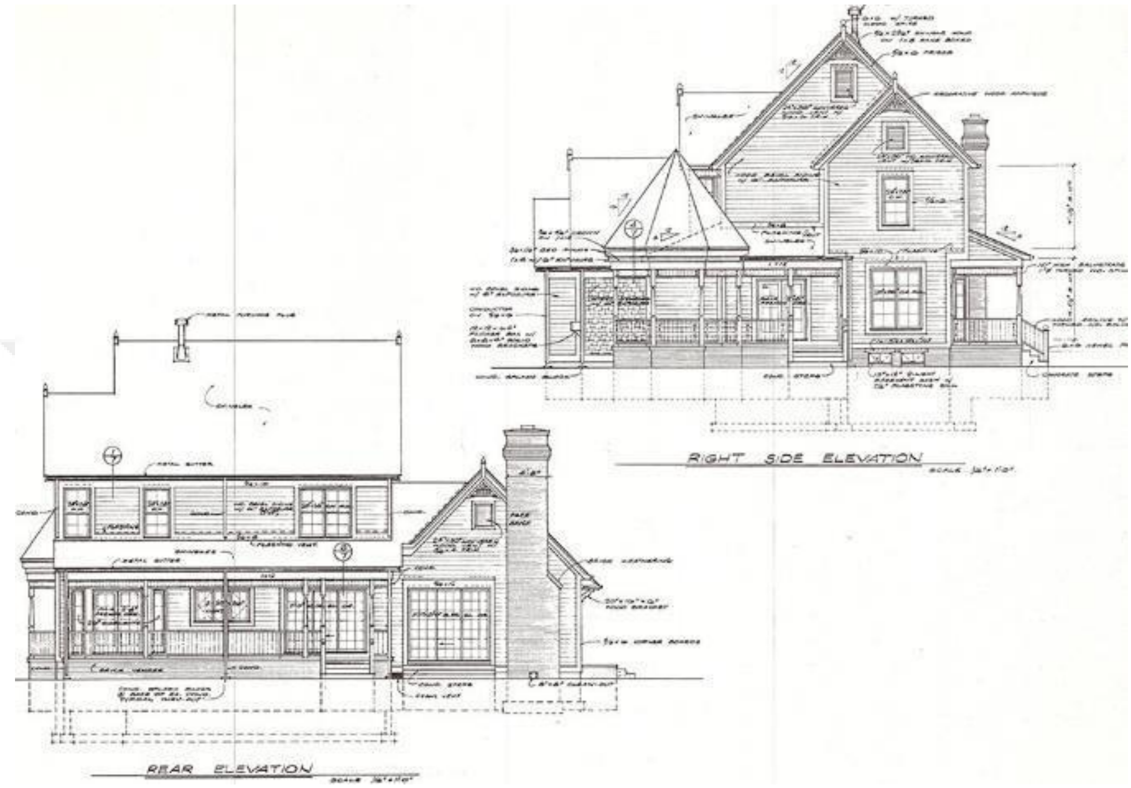


Figure 7. BIM Level 0 (United-BIM)

Level 1 BIM:

BIM level 1 creates collaboration management techniques and sets standards for standardized CAD and 3D modeling approaches. The BIM Level 1 documentation methods for quality control, information exchange, document naming, and CAD drawing designation — the core of the common data environment – are based on British Standards 1192 (Šimenić, 2021).

Level 2 BIM:

It uses attribute data to build an information model that incorporates geometric aspects in three dimensions. Each piece of information about a project or asset is stored electronically and in three-dimensional coordinates. BIM level 2 is used throughout the entire project, focused on information transfer and exchange (Šimenić, 2021).

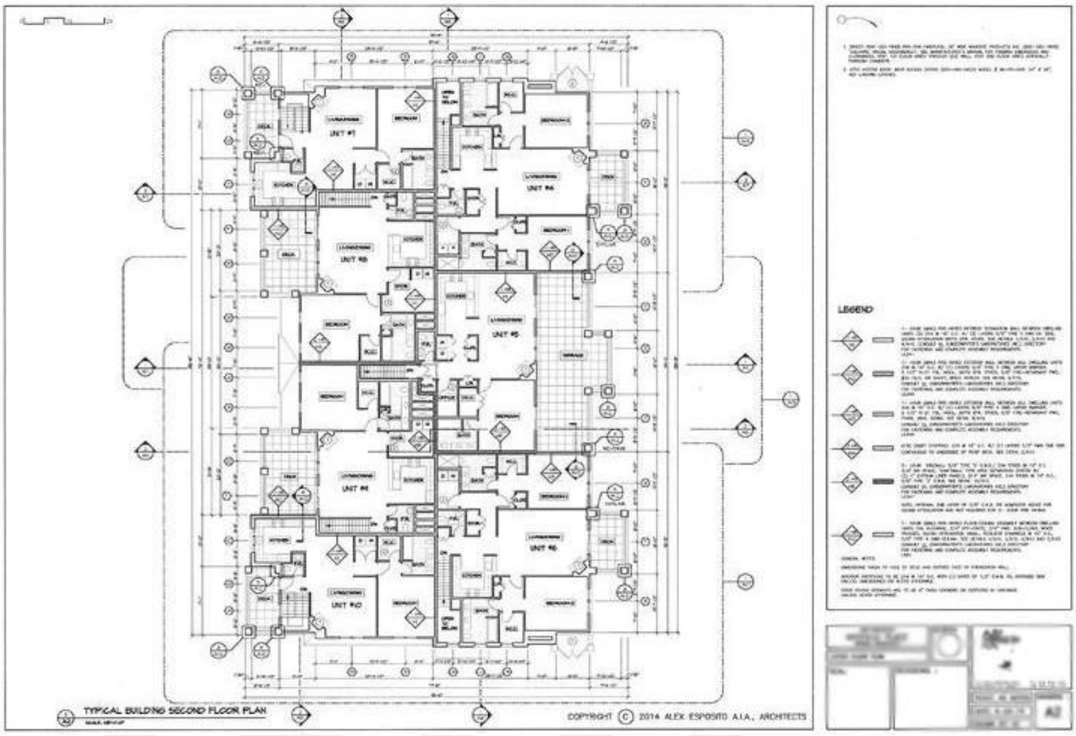


Figure 8**.** BIM Level 1 (United-BIM)

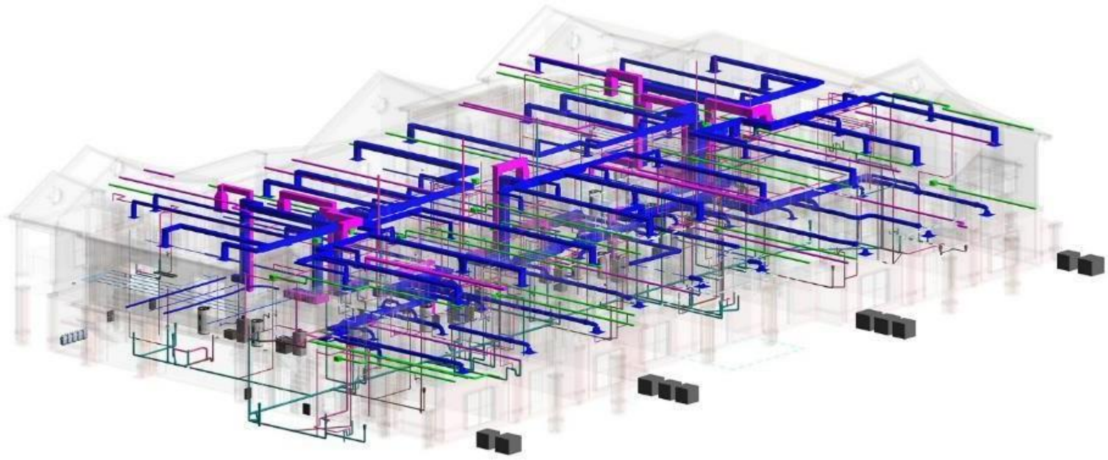


Figure 9. BIM Level 2 (United-BIM)

Level 3 BIM:

BIM level 3 envisions a fully integrated approach to asset and project management. The information will be accessible to individuals who require it in a way that enables diverse stakeholders to reuse it for a variety of reasons. BIM level 3 allows the integration of additional digital developments, such as asset management systems and smart cities. Though this level is gaining momentum, many organizations in the United Kingdom are still considering transferring from Level 2 to Level 3 (United-BIM).

Figure 10. BIM Level 3 (United-BIM)

The Digital Built Britain strategy lays the groundwork for Level 3 and beyond adoption, aligning with the government's construction strategies such as the Business and Professional Services Strategy 2022, the Smart Cities Strategy 2023, the Information Economy Strategy 2024, and the Industrial Strategy – Construction 2025 (United-BIM).

BIM dimensions govern how the virtual 3D model will be built throughout the lifecycle of the building. The team can more correctly calculate the building's time frame, cost, and performance based on the information stored in the BIM model.

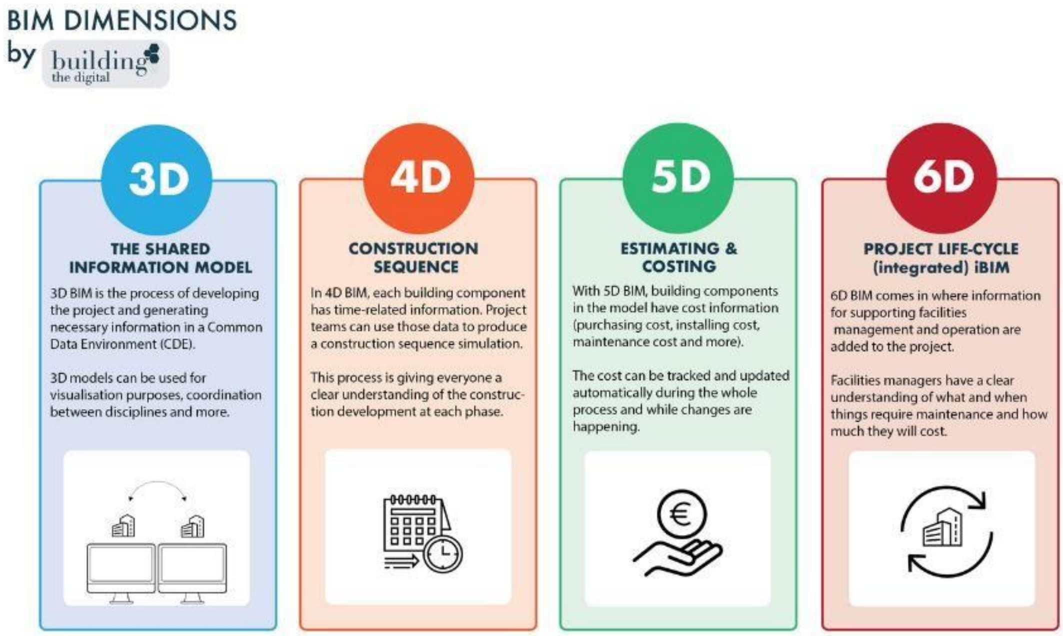


Figure 11. BIM Dimensions (source: www.buildingthedigital.com)

2.5. The role of BIM technology in infrastructure projects

BIM (Building Information Modeling) has transformed the Architectural Engineering Construction (AEC) industry by demonstrating benefits throughout the entire life cycle process. Design tools have evolved from 2D CAD to 3D modeling to object-oriented modeling with BIM, which has transformed the AEC industry. This technical advancement has also resulted in the introduction of numerous different BIM tools and technologies that are tailored to certain AEC jobs and activities ranging from design to building and maintenance (ProtaBIM, 2017). The widespread lack of understanding and knowledge of the primary BIM functions and critical competencies, despite the fact that it is strategically necessary to employ and take full advantage of BIM tools, is a major concern.

Multiple studies have indicated that inefficient usage of BIM technologies is still prevalent and that the infrastructure CAD business continues to rely on CAD tools to design infrastructure (Šimenić, 2021). As a result, it is critical to link BIM tools and technology to essential jobs and activities across the infrastructure life cycle process. It is the purpose of this section to provide an overview of the most often used technologies for integrating BIM in infrastructure projects.

BIM has primarily been used in the construction industry rather than on large-scale infrastructure projects like highways (Castañeda, Sánchez, Herrera, Pellicer, & Porras, 2021). BIM is commonly used in architecture or in what may be described as "vertical structures" in general. As the name implies, Building Information Modelling (BIM) was embraced in the design of buildings considerably earlier than road infrastructure and has been codified with an array of well-defined standards, methods, libraries, and software (Analytics, 2017). On the other hand, the use of BIM technology in horizontal constructions began more recently. When compared to the use of BIM in building projects, the use of BIM in infrastructure projects is progressively gaining momentum (Shaaban et al., 2015). However, BIM principles can be applied to roads and motorways even if civil engineering projects have some characteristics. A questionnaire survey among transportation experts and contractors in the Arabian Gulf area gathered practitioners' views on BIM and assessed the industry's preparedness for BIM adoption. BIM is currently used in transportation and infrastructure projects (Shaaban et al., 2015). 3D models can better depict these items than 2D CAD drawings for new motorways, tunnels, bridges, and so forth (Šimenić, 2021). Currently, over 60% of bridge, road, and highway projects use BIM for various aspects of the project (Shaaban et al., 2015). BIM is used on approximately half of all infrastructure projects in the United States, according to architectural, engineering, and construction (AEC) firms (Shaaban et al., 2015).

Although the creation of applications and tools for road infrastructure is more recent than BIM for building architecture, a useful collection of tools is already available today. Different software tools are used to achieve a specific goal at different points in the project. These include analysis, drawing, visualization, clash and error detection, scheduling, and so on. To make BIM work for infrastructure projects, Autodesk company released Civil 3D 2006 software in 2005. This software used parametric modeling to make a road model. This differs from the Land Development Desktop, which only used the CAD platform. The first versions didn't have very good BIM abilities, but over time, they became more important and significant and were used more. The idea of making a 3D corridor model of a road was later used by other big software companies, like Bentley, with its Open Road application. Thus, an intelligent 3-D model of the roadway is produced, in which parts of the design are dynamically linked to one another — not only points and surfaces and alignments but a rich set of information and the properties associated with it (Strafaci, 2008). The use of BIM usually leads to the need to use many different applications that can communicate with each other in a simple way. The architecture, engineering, and construction (AEC) industry are dominated by two major software vendors in an international market setting: Autodesk and Bentley. Both provide complete solutions for the use of BIM in civil engineering projects. Autodesk's solution is the Architecture, Engineering & Construction collection. Civil 3D software is the primary application in civil engineering and construction documentation (Autodesk). It is built on the well-known CAD software AutoCAD. The application provides parametric modeling by generating a Corridor Road Model and a highly detailed method for showing and marking all projected objects using display styles. In the conceptual design phase, the InfraWorks software application is responsible for planning and designing the analysis. Unlike Civil 3D, which is a CAD application, InfraWorks was originally intended to be a BIM application. InfraWorks can be utilized successfully to generate alternative and variant solutions, as well as 3D visualizations. The collection includes Navisworks Manage, a significant and frequently used software package for conducting project reviews and doing 4D and 5D BIM studies. When it comes to project collaboration, other solutions are available in addition to the Autodesk collection (Autodesk). When it comes to project collaboration, there are additional solutions available outside of the Autodesk library. The Autodesk Vault application is designed for internal design team interactions, whereas the BIM 360 CDE platform is meant for broader collaboration among all project participants and stakeholders.

When the project is done, the digital model is sent to the contractor. Designers and contractors can get more information from each other more quickly, thanks to the BIM model. There is a lot more information in this way, and the way it's organized is better than standard CAD project documentation written down and put in a book. The more detailed components are, the easier it is to figure out how much it will cost to buy, build, and install them. This leads to the Virtual Construction Model. It also doesn't happen because direct import and export of data (e.g., a designed subgrade surface can be loaded directly into a GNSS-guided machine control) eliminate the chance of misreading or misinterpreting the data (Šimenić, 2021). Better designs, increased efficiency, and productivity are the most immediate benefits of BIM for road and highway design. The time it takes to evaluate more options, execute design changes, and produce construction documentation is significantly reduced because design and construction documentation are dynamically linked (Strafaci, 2008). During the construction process, the design team and contractors can communicate better, which makes it easier for them to make changes and updates, which is often necessary for motorway projects for several reasons. In the end, the term "BIM" has become a lot more common in the engineering field.

2.6. Use of integration of UAV and BIM technologies in infrastructure projects

A BIM process for road and highway design begins with the compilation of coordinated, reliable design information about the project, the first step in implementing the process (Strafaci, 2008). Designers have several tools at their disposal before starting a project to record the current conditions and better understand the environment. With the use of drones, it is possible to add vegetation and trees, as well as houses, water regions, existing roads (with services and bridges), and even the topographic terrain. Digitalization, such as 3D scanning and virtual reality, as well as Building Information Modeling (BIM), Unmanned Aerial and Ground Systems (UAS and UGS), autonomous machinery and equipment, and advanced building materials, have advanced technologically and market maturity, allowing for fundamental changes to boost construction sector productivity and efficiency (Moeini et al., 2017). With the help of BIM and drones, it would be easier to get the information needed for a construction project's planning and to keep it organized. This would help avoid disputes and increase productivity in work (Efosa, 2019).

BIM-based solutions can support vast volumes of existing data and include tools for altering and importing raster data, geographic information system (GIS) data, and reality capture data into the project area. There are numerous techniques for reality capture data collecting; the most commonly utilized are Unmanned Aerial Vehicles (UAVs) and static and mobile LiDAR systems. These characteristics are especially evident in modern BIM tools, which are primarily meant for conceptual projects, are built on newer platforms than CAD applications, and were originally designed to allow work in a 3D environment with vast volumes of data (Šimenić, 2021).

Once the environment has been built, topographic studies of the terrain's height or slope can be performed. When the input data is readily available or relevant, the UAV approach can deliver accurate existing ground data. When correctly studied using available technologies, the BIM model can be used to demonstrate the best location for the project site or the best route (Šimenić, 2021). Modern BIM tools include mapping applications and websites that enable users to explore topography in a variety of ways, for as, by showing a project on the Google Earth platform. The combined BIM-UAS system is a collection of "large amounts of data" that can be used for analysis. The goal of combining Building Information Modeling and unmanned aerial systems is to make it easier to see and analyze the ground in real-time and then design, analysis, and optimize highways projects with BIM technology. Using UAVs and BIM technology together could make it easy to see how the project progresses in 3D. This would be very helpful to the highway designer involved in the project. Technological and practical issues need to be investigated during this development.

3. DATA AND METHOD

3.1. Research Objectives

According to a previous study, BIM (Building Information Modeling) and UAV (Unmanned Aerial Vehicle) are the future technologies to address data collecting, design, low productivity, and project delivery delays in the infrastructure business. There are new highway surveying tools that make it easier to build roads through rough terrain and hard-to-reach areas. This means that projects can now be finished on time, safely, and with less effort than compared with terrestrial surveying. Unmanned Aerial Vehicles could speed up highway development projects that cover a lot of ground. This is one of the research goals. In addition, digital technologies and processes are changing how projects are made, delivered, and managed. This comprises BIM, artificial intelligence, robotics, 3D printing, additive manufacturing, the Internet of Things, self-driving cars, Unmanned Aerial Vehicles (UAVs), augmented and virtual reality, and other related technologies and processes (Šimenić, 2021).

Despite extensive research, combined UAV and BIM technology have not yet found a significant practical application in optimizing vertical roadway design and comparing it to traditional design methods. However, there was no practical and comparative example with traditional works of getting the benefits of UAS and BIM in highway design projects. Among the numerous causes, the primary ones were the expensive cost of aerial images and equipment (i.e., UAS, GNSS, Total station, etc.), the demanding office work that necessitates the use of digital photogrammetric and BIM methodologies, and inadequate knowledge or training is another barrier to the successful adoption of BIM software.

To close this gap, the study aims to demonstrate the extent to which UAV and BIM tools are suitable for manipulating all aspects of infrastructure projects such as data collection, design, and management, by exploring the potential of the BIM - UAV solution.

This will demonstrate that the UAV can obtain accurate 3D topographic data. It can easily integrate with BIM software to build, design, and manage infrastructure projects. This study examines the use of two different technologies, UAV and BIM, in the planning, design, and management of highway projects. In addition to describing these technologies, the paper compares them, showing the outcomes of combining them. Photogrammetry, for example, is less expensive and gives the user more control over the finished model. At the same time, typical CAD software cannot register highway project optimizations such as earthwork optimization. BIM is better for these optimizations and designs and for producing higher-quality models.

The combined BIM-UAS system generates a large amount of data that can be analyzed. The goal of combining Building Information Modeling and unmanned aerial systems is to acquire precise topography and make it easier to see and explore the ground in real-time, and then use BIM technology to design highways and optimize earthworks quantities. Consequently, with BIM and UAV, efficient data collection and effective management of a construction project planning would be essential aspects of data collection, design, error prediction, and optimization in construction productivity.

3.2. Study Area and Available Data

The study was performed on a highway area of around 10 kilometers long in the SORAN city district of IRAQ (Figure 12) and located on the easterly facing slope of HINDREEN mountain near the existing road of SORAN - CHOMAN (Figure 13).

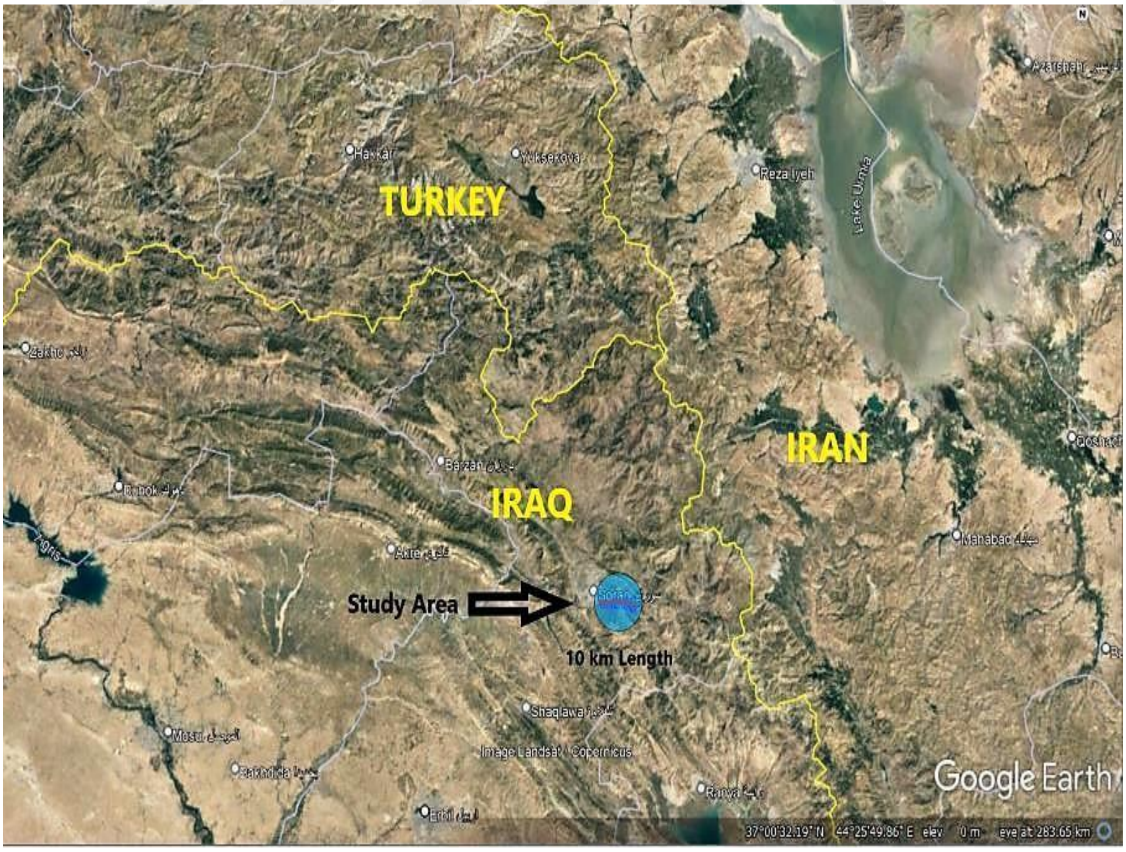


Figure 12. Overview of project location

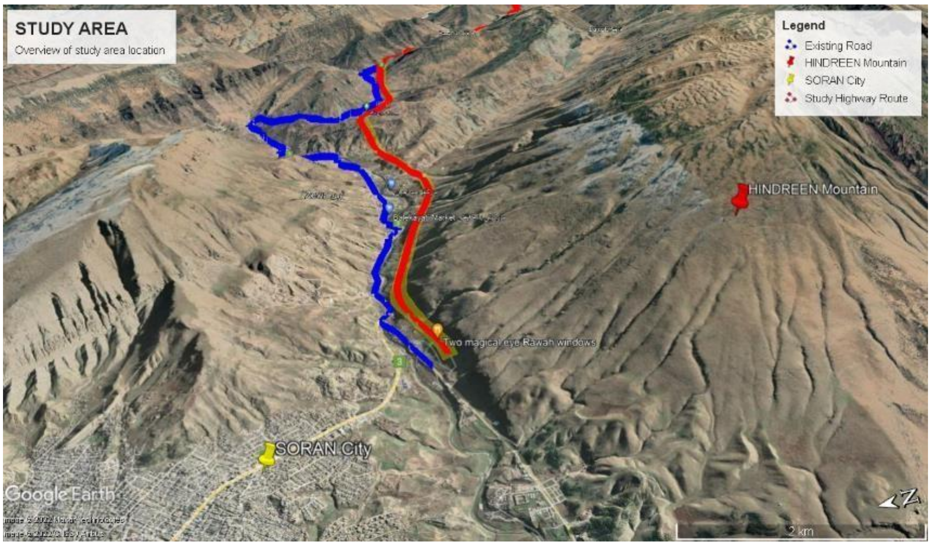


Figure 13. Location of the highway project

The Directorate of Road and Bridge\Erbil did a survey and did the project. The Government gave all the needed information, like topographical data and maps, longitudinal profiles, cross sections, etc. The documents of the project were received as shown in (Table 1) below:

Table 1. The documents of the study area project

Item	Description
Control Station Points	Approximately every 500 meters along the route
Technical Topographic Report	Includes: 1. Establishment of reference points network 2. Data collection method 3. Supplementary surveying 4. Mapping 5. Quality assurance procedure 6. Problem occurred during the work performance
Topographic Map	dwg format
Road Design Plan and Profile	dwg format
Cross Sections	dwg format
Bill of Quantity	Includes: 1. Bridges 2. Culvert and Chanal 3. Tunnel 4. Interchange 5. Roadway 6. Wall

The project was surveyed with a mobile Terrestrial Laser Scanning (TLS Riegl z420i) on the ground (Figure **14**), and due to the mobile scanning cannot reach some steep and wadi area, the third party surveyed using GNSS Leica system 520 and Total Station Leica 06 instruments. Digital level Leica DiNi 12 used for establishing elevation to reference control points.

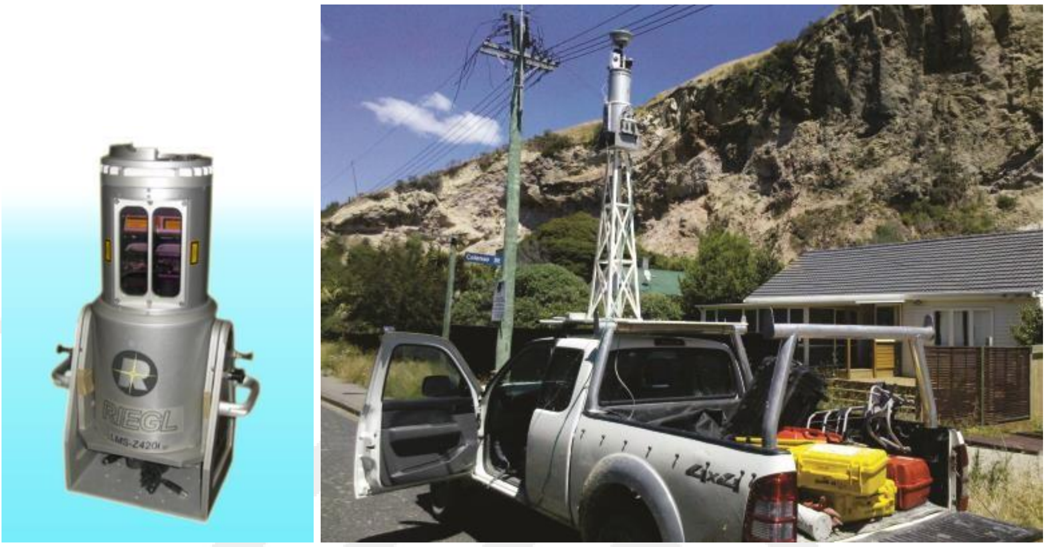


Figure 14. Riegl z420i terrestrial laser scanner

CAD software was used to design the highways project. All of the data and results of the design were given to the client by them. The project was surveyed and developed since 2012 and hasn't been starting of construction yet.

3.3. Technology and data acquisition

The traditional ways of doing business in infrastructure management, especially in the road sector, can't deal with the growing problems that the industry is facing right now (Šimenić, 2021). In contrast to traditional project management methods, modern technologies such as Unmanned Aerial Systems (UAS), Building Information Modeling (BIM), and real-time cloud-based data modeling and analysis provide real-time project control, monitoring, and inspection. To make topographical maps, there are a lot of different methods that can be used, like UAV photogrammetry, satellite photogrammetry, and terrestrial surveying with a total station or GNSS techniques (Jalloh, Ahmad, Mat Amin, & Sasaki, 2017).

The whole technological context of the study is presented in (Figure 15). In the first part, the data acquisition of existing topography and photogrammetry processing for the generation of topographical maps. The second part, analysis the topo terrain and geometric design of highways and optimization.

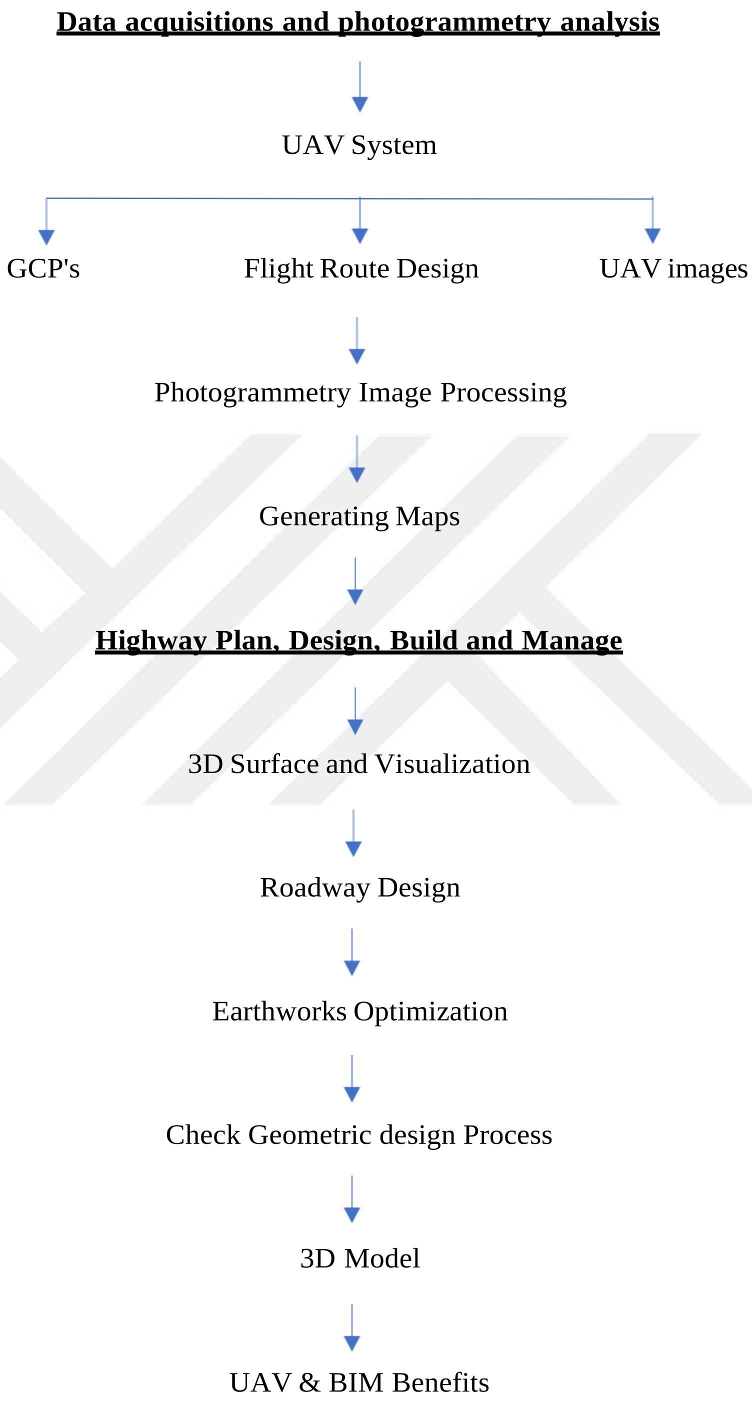


Figure 15. The entire workflow of the study

3.3.1. Data Acquisitions

Concerning the inventory, evaluation, and monitoring of study areas utilizing UAVs, there is a crucial issue that requires additional research. This study area is situated facing the HINDREEN mountainside. Consequently, it is essential to establish a procedure for conducting a UAV campaign for the photogrammetric mapping of steep terrain and its environs. According to (Tong et al., 2015) and (Kozmus Trajkovski et al., 2020) suggested oblique camera method for merging UAV-based photogrammetry and TLS for the 3D mapping, monitoring, and accurate 3D modeling of open-pit mine regions and side slopes. It is suggested that the best way to record steep terrain is with a mix of vertical and sideways UAV pictures. The intention was to use the oblique camera for the entire area route.

As a result, to increase the accuracy of the topographic data to be obtained, oblique cameras with five lenses, four of which are tilted 45 degrees, one to the right and left, the others to the front and back, with the central lens vertically positioned at least one angle were used. (Fig. 18). This was also done so that topographic data could be more easily interpreted.

The survey field team assigned to the project consisted of two teams of three (team chiefs and 2 Topo Surveyors) who were sent to the site for site exploration and retrieval of boundary evidence. The crew searched for evidence of boundaries using a variety of methods, including hand-held GIS maps, pocket GNSS navigators, and aerial photo overlays. Evidence found and potential rape were as outlined in the preliminary study drawings. The survey team set ground control point targets throughout the project area.

Team One: Created ground target checkpoints for photogrammetry processing and checkpoints.

Team Two: Mission flight and aerial images acquisition (Figure 16).

Figure 16. Survey Field Teams

For acquisition of topographical data used UAV/Drone technology. The Foxtech NAGA Quadcopter (Figure 17) drone used in the topographic mapping is a four-rotor flying platform. It is stabilized by inertial measurement units (IMU), including gyroscopes, acceleration sensors, altimeter, and compass. This unit is attached to a GNSS unit. Flight endurance with 30000 mAh lithium- batteries lasts up to 50 minutes (NAGA drone). A NAGA drone compact Foxtech 3DM V4 oblique camera (Figure 18), five lenses 3D modeling oblique camera, was used for image acquisition, and ISO sensitivity, zoom, and aperture were set at fixed values with exposure time less than 1/800 s.

Figure 17**.** Foxtech NAGA Quadcopter Drone

Figure 18**.** Foxtech 3DM V4 oblique camera

When planning a flight for an Unmanned Aerial Vehicle (UAV), the most important things to think about are the area of interest, the flight altitude above ground level (AGL), the flight speed, the forward and side overlap of successive images, and the digital camera's sensor size, pixel resolution, and focal length (Kozmus Trajkovski et al., 2020). The main parts of the system are aerial and ground techniques (Figure 19). The remote sensing sensor suite, the automatic control system, and the UAV platform are the parts that make up the aerial systems. The main jobs of the aerial systems are to send the planned flight paths to the controller and keep an eye on the UAV while it is in the air. The parts on the ground include a system for planning routes, a ground control system (GCS), and a system for receiving data. The main jobs of the ground components are to plan and design the flight paths, get real-time information about the UAV's flight attitude, and control the UAV's flight. A wireless transmission channel is also used to send flight data between the aerial systems and the ground station, up to 3 km, so that the UAV flight routes can be tracked, the flight plan can be changed, or the UAV can automatically switch to manual flight in case of an emergency or landing.

Figure 19**.** The system consists of two main components: aerial and ground techniques

The flight campaign was conducted on 12th July 2021, when the land was not densely covered by vegetation. A total of 152 Ground Control Points (GCPs) were irregularly placed on the slope and flat surface every 50-150 meters along the 10km route (Figure 21) and were targeted by GNSS i50 CHC (Figure 22) with RTK corrections (GNSS, GLONASS, Beduo, and Galileo). The GCPs' horizontal and vertical accuracy was 10–20 mm.

Figure 20. GCPs irregularly placed on the slope and flat surface.

Figure 21. Distribution of Ground Control Points

Figure 22. GNSS CHCNAV i50

The positioning strategy of the ground control points was determined according to a minimum corridor width of 125 meters and a flight plan of 9.5 kilometers. Ground control points have been set up and marked. The coordinates of the points established every 50-150 meters were accurately measured using a base rover GNSS in RTK mode (Fig. 23).

These target marks (Figure 23) were used for photogrammetry processing and quality control to check and validate photogrammetry outputs.

Figure 23**.** GCPs Establishing

flight mission was designed using QGround Control software (Figure 24). Minimum overlap between images was set to 70 percent longitudinal and 60 percent lateral. In order to minimize the high slopes and GSD loss caused by the terrain topography, each flight was made separately parallel to the terrain slope direction. Color photographs obtained during aerial survey are in RGB type. The minimum corridor width is 125 meters, and its length is 10 kilometers. The highest possible ground sampling distance of 2 cm GSD was applied to the field. The total number of photographs obtained is 11,228. The geolocation accuracy of UAV photos depends on the camera orientation, the configuration of the GCPs (sensitivity, density and distribution), the image quality, the terrain cover, and the topographical complexity of the scene (Vericat, Brasington, Wheaton)., Cowie and Applications, 2009).

Figure 24**.** Flight mission plan by QGround Control software

3.3.2. Data Processing

The Agisoft Metashape program was used to process a total of 11,764 UAV photos with separated the images into three chunks (Figure 25). The first chunk is about three kilometers long, the second about 2.5 kilometers, and the third about four kilometers long.

The Metashape method aligns the images and generates tie points at the start. The Structure from Motion algorithm (SfM) is used in this software to recreate the actual surface from many large numbers of overlapping pictures. The software finds matching features on each image and calculates image orientation, exterior orientation parameters, and building model geometry via iterative bundle block adjustment. The GCPs are input into aero triangulation, which allows for more exact exterior orientation parameter calculation and better spatial georeferencing accuracy (Figure 26). Based on the presence of GCPs in the project region, image orthorectification and geo registration are related to aerial triangulation (Xiang & Tian, 2011).

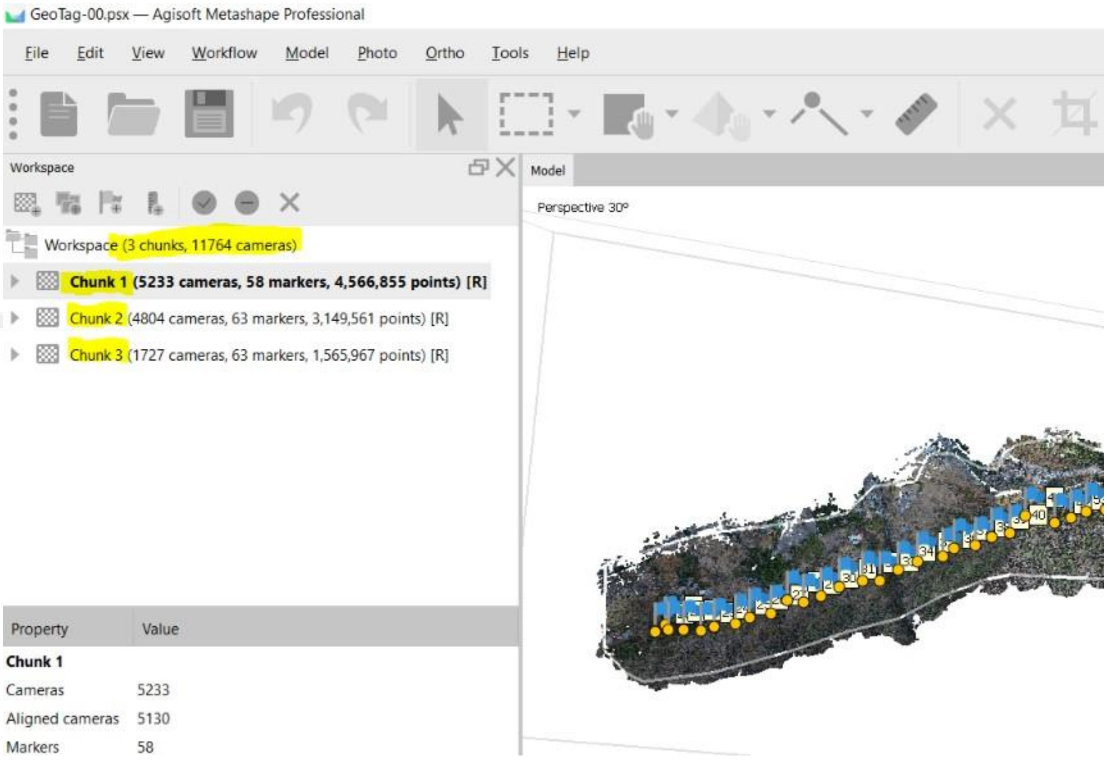


Figure 25. Metashpe images processing Chunk groups

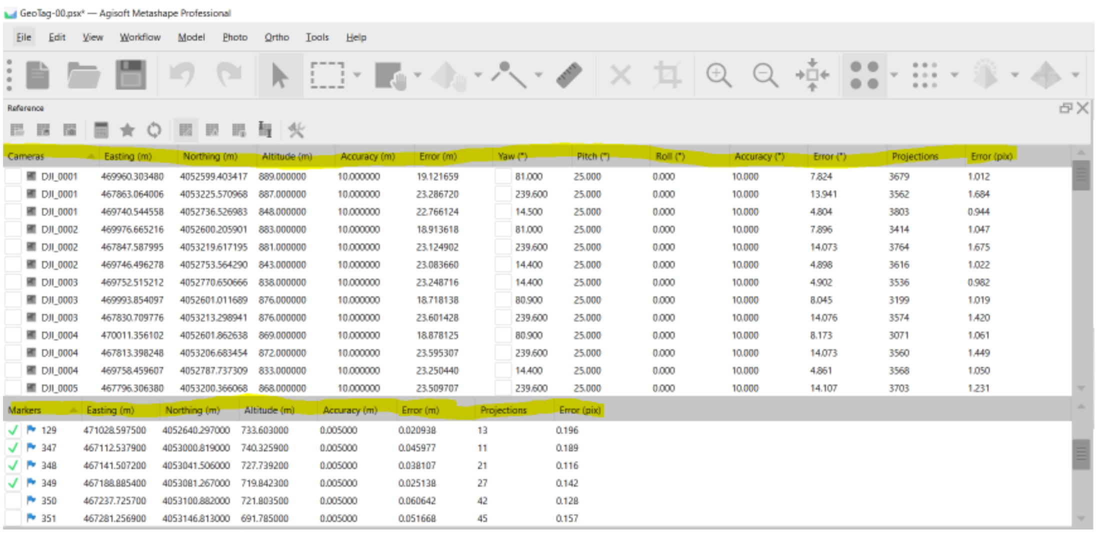


Figure 26. The exterior orientation parameter estimations

The Digital Surface Model (DSM) is created in the final stage by creating the model texture and exporting a 3D model and orthoimage mosaic. Photogrammetry only creates a surface envelope and is unable to capture land covered with low vegetation. As a result, LiDAR point cloud data that can penetrate the low vegetative canopy is used for this function.

Vertical accuracy and the effect of vegetation on vertical disparities between the UAV-derived elevation model and the actual terrain surface were evaluated by comparing control points targeted by GNSS (152 points) and designated as a ground control points (ground point cloud data). The dense point cloud, which included both point cloud and ground point cloud data (Figure **27**), was exported as raster elevation models with pixel resolutions of 10 cm.

Figure 27. Generating all Points Clouds (a). Generating Ground Points Clouds (b)

The Digital Terrain Model was named after the elevation model created from ground point cloud data (DTM) (Figure 28).

The Root Mean Square Error was determined using the equation (RMSE)

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(z_i - z_j)^2}$$

Where:

n – the number of evaluated points,

zi – the coordinate of the issue on the DSM/DTM,

zj – the coordinate of the reference surface (GNSS measured in the field).

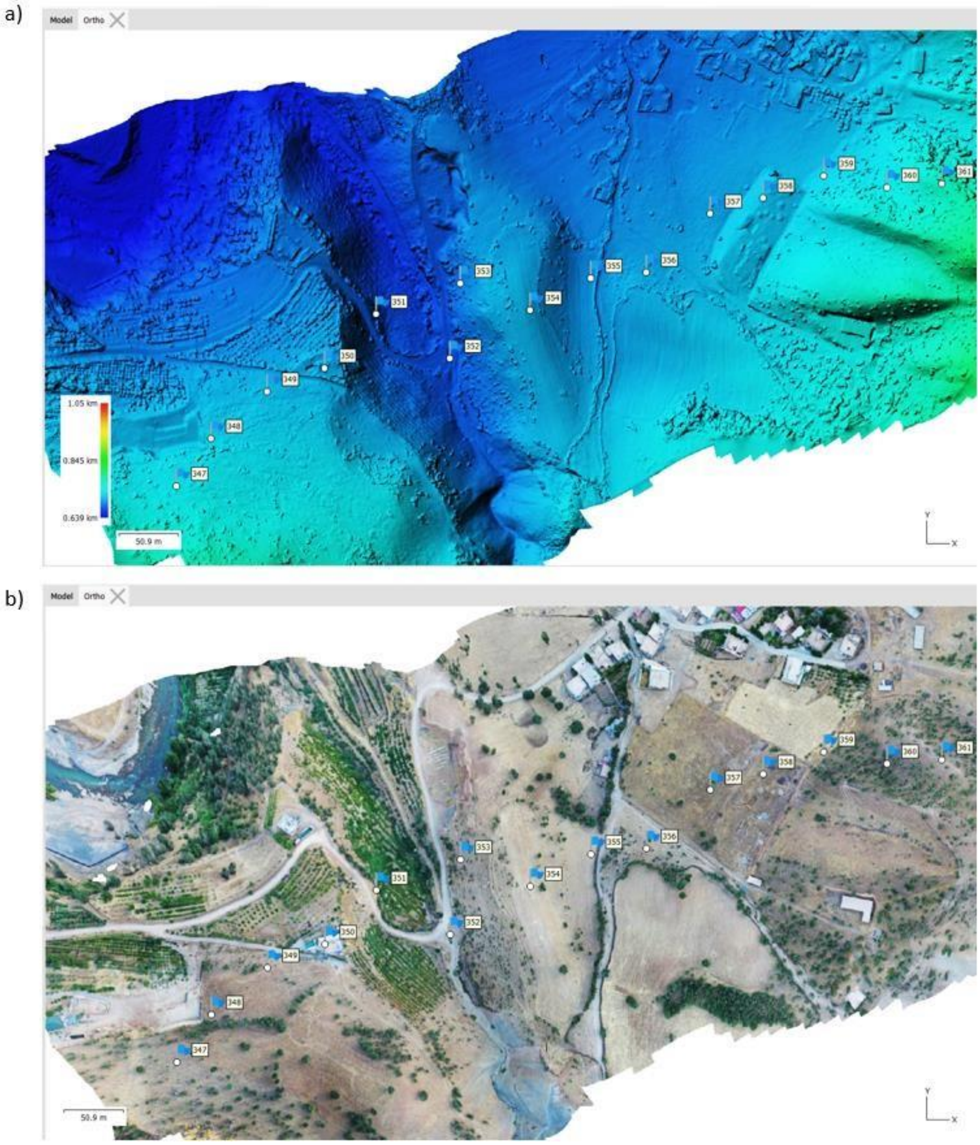


Figure 28. Generating Raster of Digital Terrain Model (a), Generating orthoimage Mosaic (b).

3.4. Plan, Build, Design, and Manage

It is important to have a transportation system that is safe and works well so that people and goods can get where they need to go and connect with each other. This will help the economy grow and improve people's quality of life. A key part of that transportation system is the highway and road system. From start to finish, the four important stages of road infrastructure are planning, design, building, and management (Markus Oeser, 2021). Unlike conventional project management methods, including new technologies such as Building Information Modeling (BIM), Unmanned Aerial Systems (UAS), and real-time cloud-based data modeling and analysis allows for real-time project control, monitoring, and inspection (Moeini et al., 2017).

A Building Information Model (BIM) is a shared source of information about a building that can be used to make good decisions throughout its life cycle, which is defined as the time between when it is first thought of and when it is torn down. BIM is based on the idea that different stakeholders work together at different points in a building's life cycle to add, remove, update, or change information in the BIM to support and reflect their roles (Abbondati et al., 2020; Azhar & engineering, 2011; Manning & Messner, 2008; Shaaban et al., 2015; Strafaci, 2008).

It's important to know that Building Information Modeling (BIM) is not a single product or technology. Instead, it's a group of software programs that make it easier to coordinate and work together on projects (Šimenić, 2021). BIM is also a way to build a road, bridge, tunnel, or another type of infrastructure virtually before it is built. This is how design and construction documentation are made (Autodesk). The architecture, engineering, and construction (AEC) business are dominated by two major software vendors – Autodesk and Bentley – on a global scale. Both companies provide complete BIM solutions for civil engineering projects.

The solution from Autodesk is the Architecture, Engineering, and Construction Collection. Civil 3D and InfraWorks are the main applications for civil engineering and construction documentation. The Civil 3D is based on AutoCAD, a well-known CAD program. The application supports parametric modeling by making what is called a "Corridor Road Model." It also has a very detailed system for showing all projected elements through display styles and marking them. On the other hand, during the conceptual design phase, the InfraWorks application is used to plan and design the analysis. InfraWorks was first made as a BIM application, which is different from Civil 3D, which works in a CAD environment. It can process and analyze a much bigger set of data in a natural 3D environment because it runs on a more modern platform and makes better use of the hardware resources it has (like a graphics card). InfraWorks can be used to create 3D visualizations as well as different and alternative solutions. Thanks to the Autodesk company, these applications are offered to students for free for a year.

3.4.1. Site modeling and analyzing a 3D real-world environment

Before starting a project, the designer can use a number of tools to get a better idea of the environment and terrain as it is now. There are tools that can be used to make the environment look more real, such as adding plants and trees, houses, water areas, roads, services, bridges, and so on.

InfraWorks BIM-based applications can work with a lot of existing data, and the digital elevation model (DEM) created by UAV techniques can be imported directly into InfraWorks. In (Figure 29) imported the topographic acquisition DEM format data generated by photogrammetry techniques.

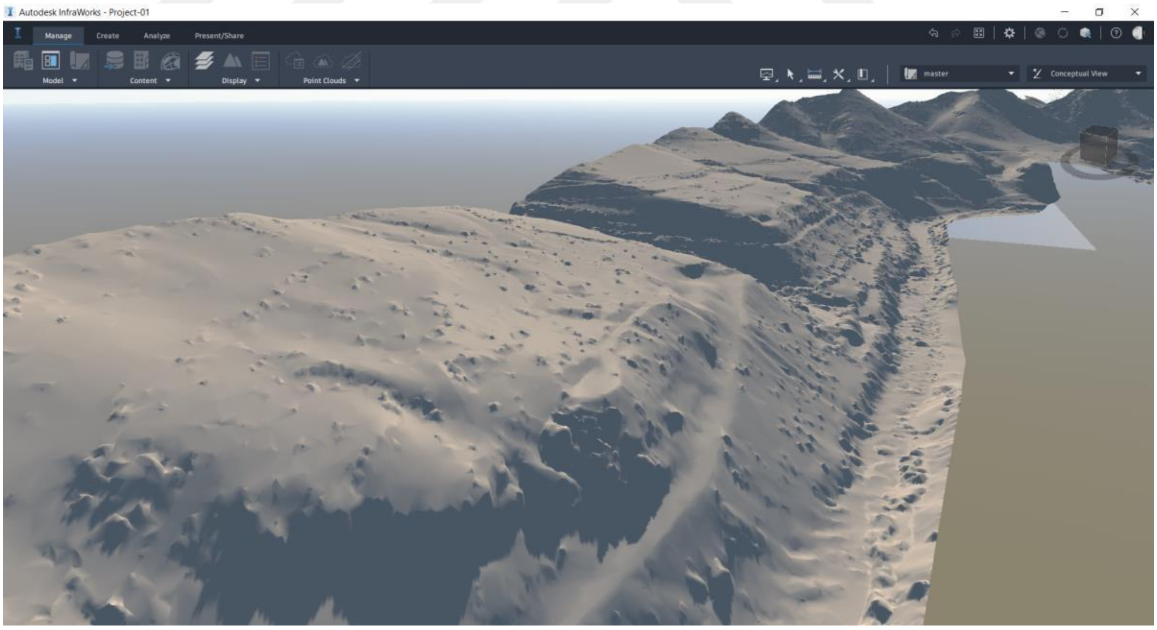


Figure 29**.** Import Digital Elevation Model into InfraWorks software

Infraworks software can compare several sources of data (2D CAD drawings, GIS data, 3D terrain models) to proposed project boundaries to get a better understanding of how the project will affect existing parcels and easements. InfraWorks also can add different dwg, 3d models, and more.

And have tools for manipulating and importing raster data, geographic information system (GIS) data, and reality capture data into the project space (Figure 30). Once the environment is set up, topographic analyses of the terrain's height or slope can be done, with reality capture technology with Unmanned Aerial Vehicles (UAV). InfraWorks has improved this deliverable so that it now gives a very accurate 3-D image that is used for design and makes communication easier.

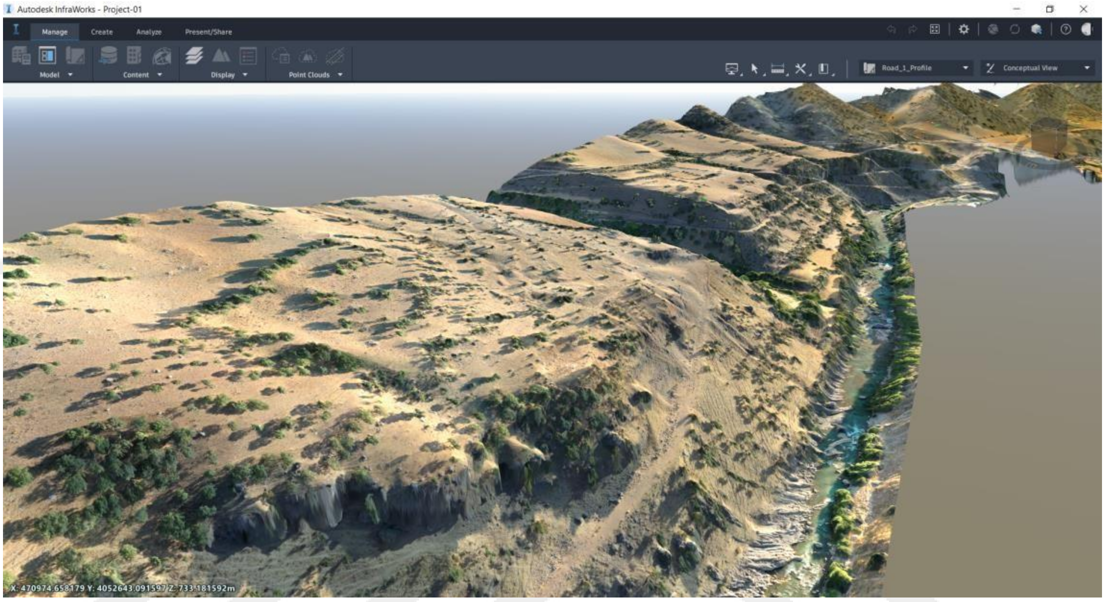


Figure 30**.** Import Raster GIS data into InfraWorks software

These features are especially common in the newer BIM tools, which are mostly used for conceptual projects, are built on newer platforms than CAD programs, and were originally designed to help people work in a 3D environment with a lot of data.

3.4.2. Design and Earthwork Optimization

After generating current ground conditions in InfraWorks by importing raster orthoimages and digital elevation models, start integrating highway alignments suggested into InfraWorks (Figure 31). InfraWorks builds roads that meet the standards for engineered roads by having horizontal curves, spirals, vertical curves, and other features. And access to a lot of tools that let you look at and change these geometric properties that are used in engineering. Some of these tools are special gizmos points, extra asset cards, extra panels, and others.

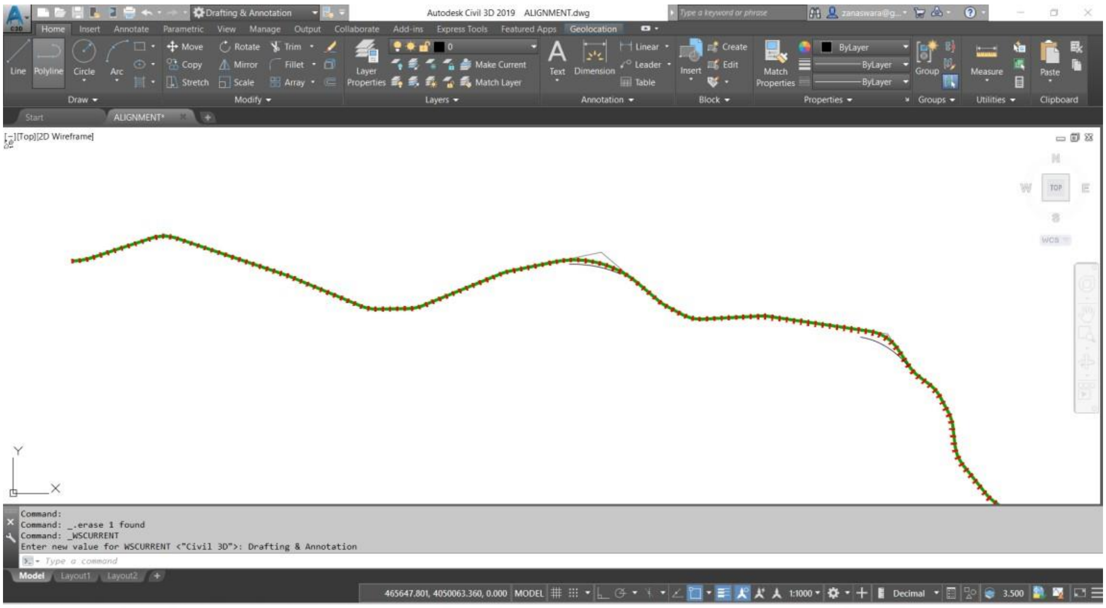


Figure 31. Proposed Highway alignment of The Government

In (Figure 32) along with a road asset card that displays design speed, design standards, and other data, you can view special gizmos points that show the geometry of a horizontal engineering curve. Compared to the sketches produced by the fundamental CAD tools, this technology allows for the design of significantly more complex roads (Chappell, 2015).

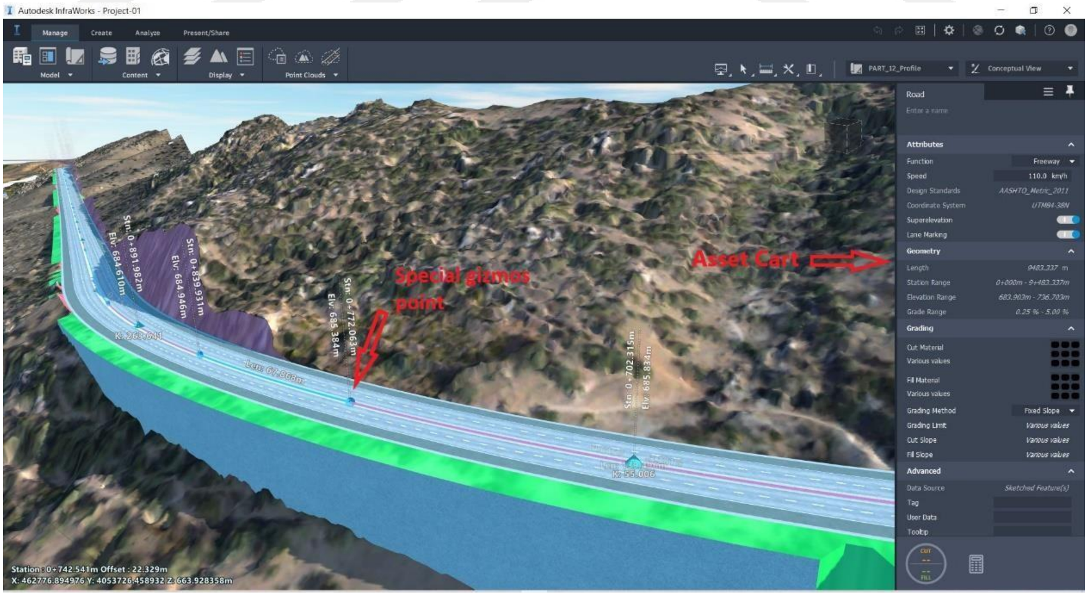


Figure 32. An engineered curve and its associated asset card

The software includes the AASHTO standard for road and highway design. Choose from numerous classifications when designing a road (Figure 33). A design speed is assigned based on the roadway classification selected, which then automatically produces horizontal and vertical geometry for the route. In other words, the software automatically designs the roadway as you click places on the screen.

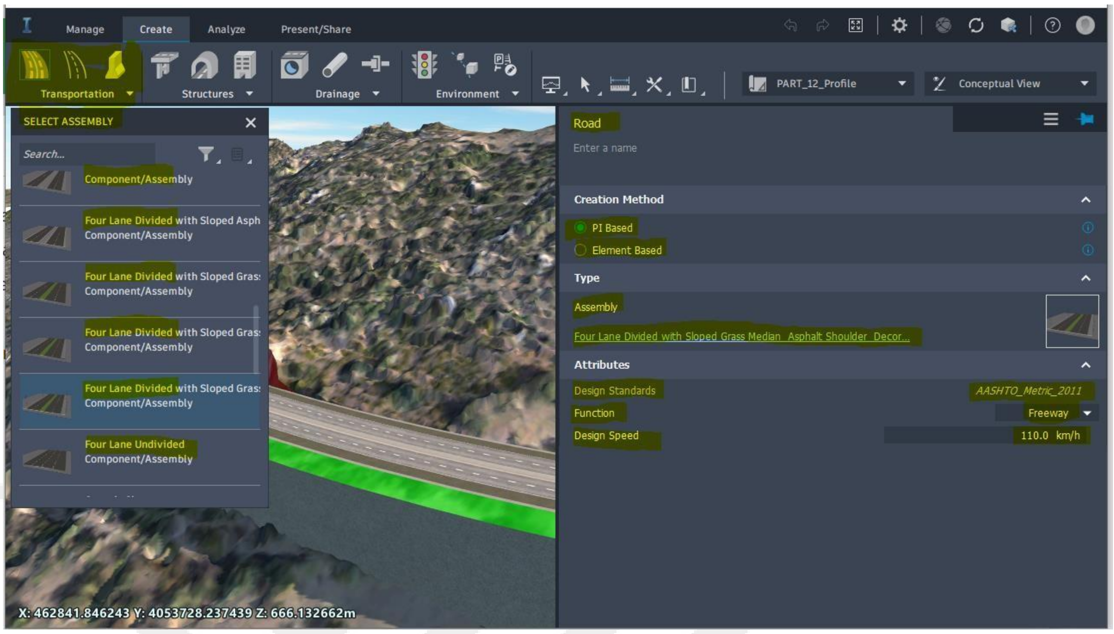


Figure 33. The road classification options

This software allows for the direct creation of a 3D highway road and profile. When making a road, a profile view is one of the most important tools. The Roadway Design for InfraWorks application has a panel called Profile View (Figure 34). In the profile view, you can see the design and use a full set of tools to change the design.

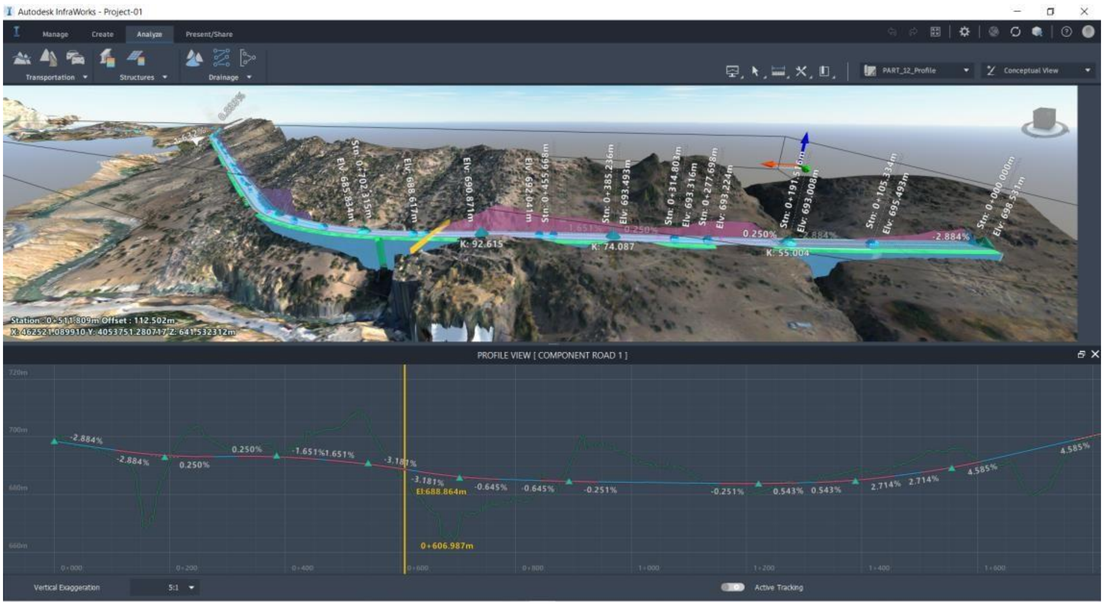


Figure 34. The Profile View panel

Analysis of Sight Distance Visibility is one of the most important things that go into making a road, we can do a sight distance analysis for a road, which looks at the shape of the road and any parts of the model that might get in the way. In the form of colored bands, tooltips, and sight pins, the analysis gives useful visual and written feedback. (Figure 35) is an analysis of the sight distance that shows an accident zone and an area where the sight fails.

Figure 35. A sight distance analysis

Studies on how to best align a highway are typically broken up into two parts: first, the horizontal alignment of the roadway is figured out, and then, the vertical alignment is altered by modifying the design controls (Wolshon, 2001).

Because excavation is such an expensive component of construction, one of the first concerns that will be asked about the design is going to concern the amount of material that will need to be cut and filled. Earthwork is another important component of performing road design, and it is one that has a significant impact on the cost. The InfraWorks application offers a strong optimization tool that will assess and modify the road profile of the roadway in order to reduce the costs connected with earthmoving. The computations are carried out in the cloud because of the significant amount of computational power that is necessary to carry out optimization. When the optimization process is finished, a new profile is sent out. The design is then uploaded to the cloud services provided by InfraWorks, where it is analyzed and updated. This new profile comes with a report that not only details the resulting geometry but also provides an in-depth analysis of the earthwork and associated costs. The panel for configuring optimization is shown in (Figure 36) and can be found under the Profile Optimization section.

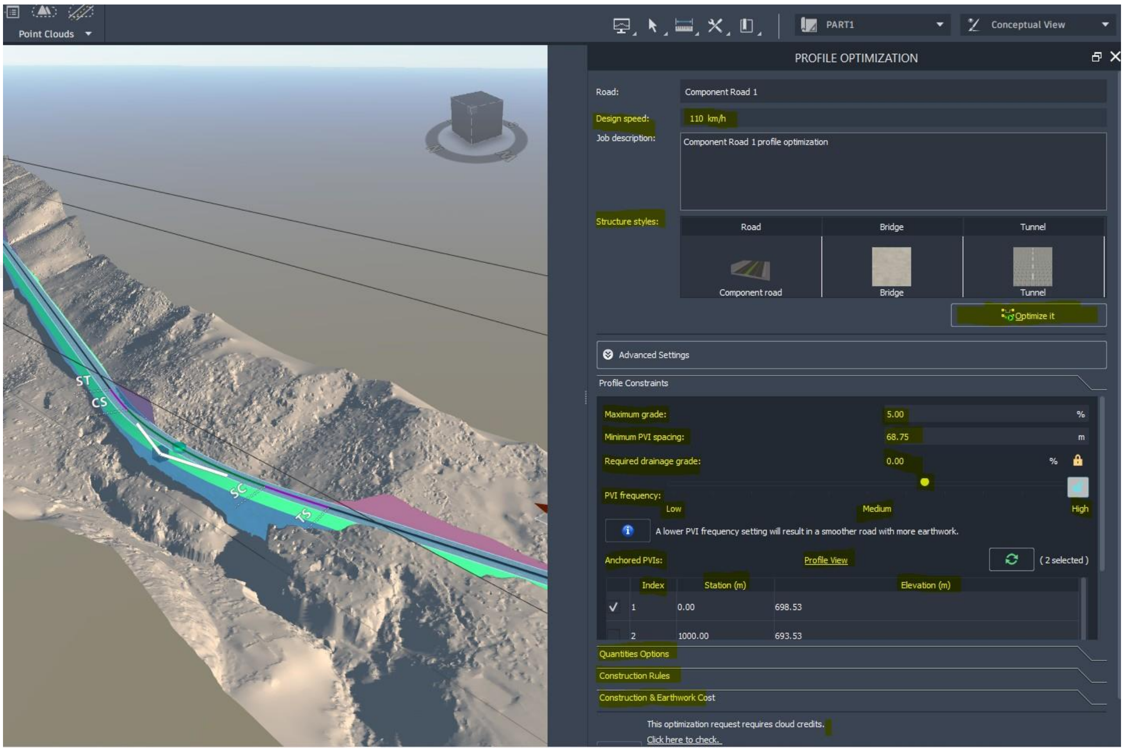


Figure 36**.** A profile optimization

Used vertical optimization tools were utilized, with the goal of reducing the amount of earthwork cut and fill. Employed all the necessary design criteria, such as the design speed, maximum grade, and minimum grade for drainage, etc. With InfraWorks software, it is possible to envision and optimize designs using real-world data to generate high-quality models.

The highway route offered (Figure 31) was included after proving the current reality of the natural land using photogrammetry data. According to AASHTO specifications for roads and scope of work requirements, InfraWorks BIM techniques were used to submit vertical profile optimization jobs, each using a different combination of parameters (Figure 37), such as:

- ✓ Design speed,
- ✓ Maximum grade,

- ✓ Minimum grade for drainage,
- ✓ How to grade roadside cut slopes and fill slopes (cross-slopes).
- ✓ When to use roads, bridges, and tunnels
- ✓ PVI frequency and minimum PVI spacing
- ✓ PVIs that must remain at a fixed station and elevation
- ✓ Placement and capacity of borrow and waste pits

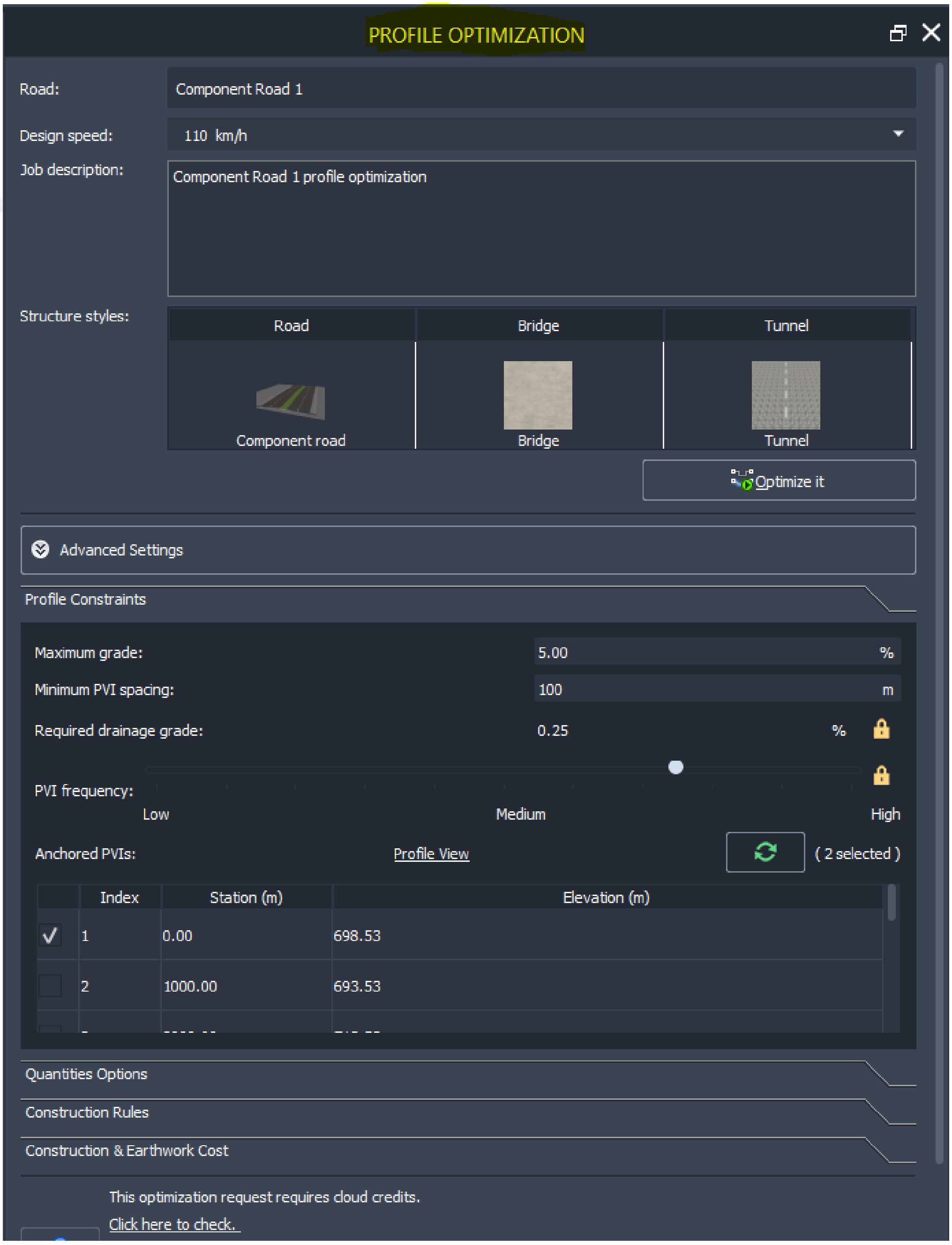


Figure 37. Vertical optimization parameters

We need to utilize the same standard of geometric design criteria and section template for all key conventional highway design projects in order to begin a profile optimization and identify the outcomes of BIM and traditional methods of highway design. The AASHTO standard guidelines that were employed in the design of the traditional CAD approach are presented in (Table 2).

Table 2. Geometric Design Criteria for Horizontal and Vertical Alignment

Geometric Design Criteria for Horizontal and Vertical Highway Alignment		
Horizontal Curvature	Design Speed	110 k\hr
	Minimum Radius	560 m
	Maximum Rate of Superelevation	6%
	Minimum Grade	0.50%
	Maximum Grade	5%
Vertical Curvature	Design Speed	110 k\hr
	Minimum K value of Stopping Sight Distance	74
	Minimum K value of Passing Sight Distance	146
	Minimum K value of Hesdlight Sight Distance	55

The cloud is used to perform InfraWorks Optimization operations, which then return existing ground profiles that run parallel to the proposed centerline of the road. The procedure can determine where the profile intersects with other roads and then generates those junctions. An algorithm is used to identify water crossings and determine how much it would cost to build bridges. The Work Monitor panel will appear when the data has been successfully sent for optimization, and the just submitted job should be shown with a state of In Progress, as denoted by the double blue arrows (Figure 38).

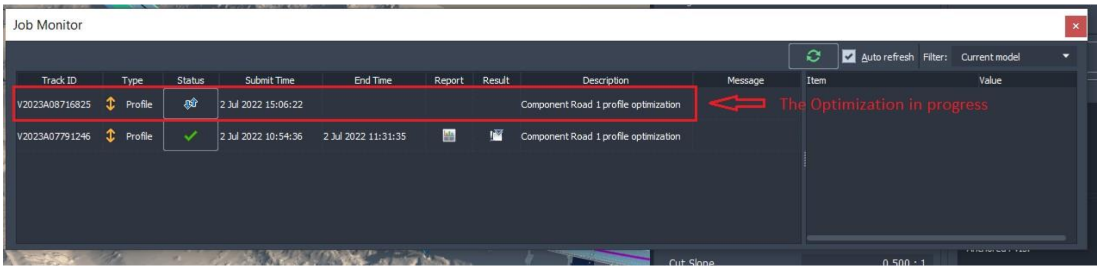


Figure 38. The Job Monitor panel shows the status optimization progress.

When the optimization is complete, you will get an email notification from Autodesk that the optimization results are ready for download (Figure 39).

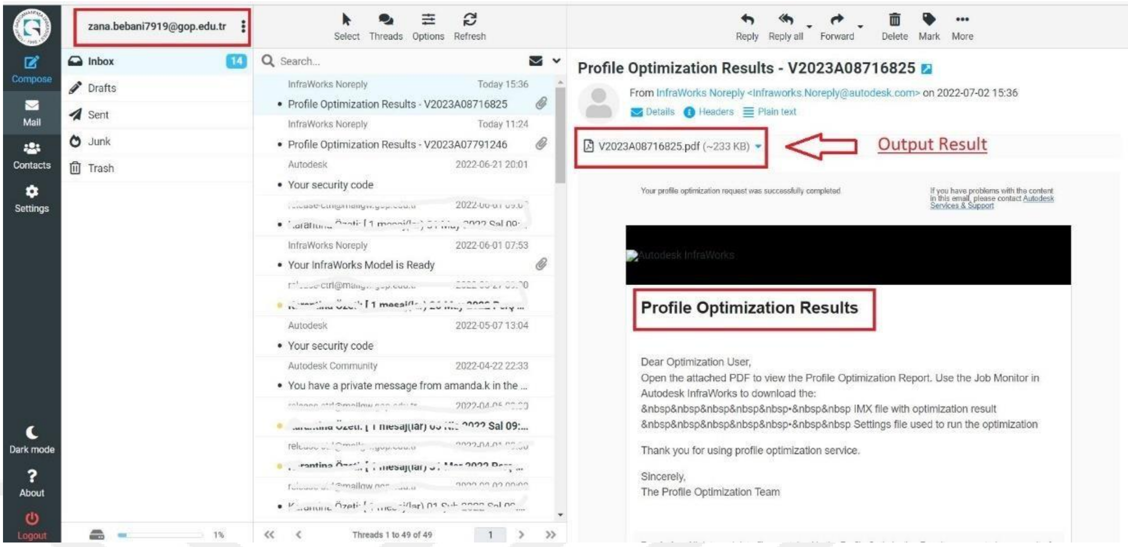


Figure 39**.** Get an email notification from Autodesk that the optimization is ready for download.

And a green checkmark will appear in the Status column in the Job Monitor panel in InfraWorks. In addition, once the optimization has been completed, icons will appear in the Report and Result columns (Figure 40).

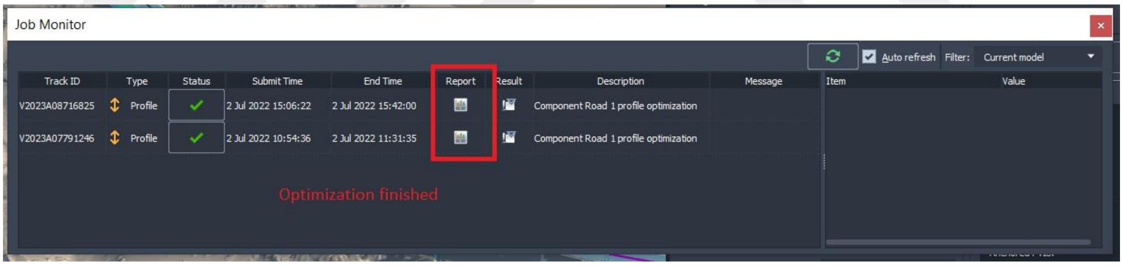


Figure 40**.** Job Monitor status indicator the report and result completed.

If you click the button in the Report column, a PDF containing information about the optimization, including the revised profile design, cost of construction, earthworks data, and cross-section views, will download and open (Figure 41). The newly proposed design has the capability of importing the optimized road into the model as a proposal. After doing so, the various proposals may be compared to one another to see which one offers the most beneficial answer for the project.

1. Profile Information

Total project cost:	$18,421,203	Number of PVI's:	40
Linear unit:	meter	Maximum grade:	5.00 %
Design speed:	110	Required drainage grade:	0.00 %
Length:	5,764.76	Minimum PVI spacing:	68.75

2. Construction Information

Total construction cost:[1]	$12,634,178	Use bridges:	Yes
Number of bridges:	2	Use tunnels:	No
Number of tunnels:	0	Sample line distance:	10.00
Number of retainings:	0		

[1] The construction costs are computed at every sample line, using a selected assembly or style, and a sample line distance for the length of a construction subsection. Individual cost computations for the different assemblies are explained below. The total construction cost is the sum of the individual subsection costs.

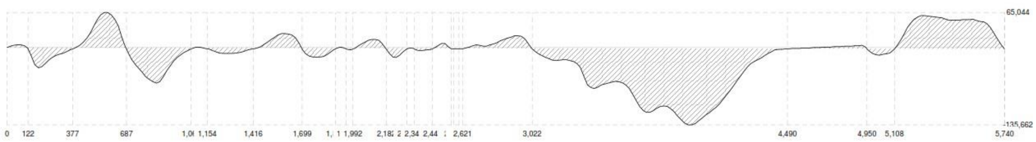
3. Earthwork Information

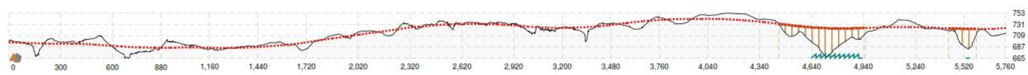
Total earthwork cost:	$5,787,025	Max section length:	300.00
Num earthwork sections:	20	Num waste pits:	1
Num earthwork sub-sections:	288	Num borrow pits:	1
Num. stratum:	1	Swath width:	24.45

3.1. Earthwork for Strata Layer 1.

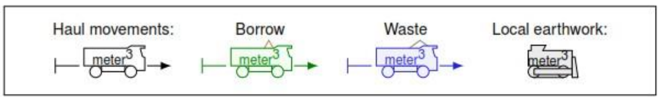
Cum. cut:	636,673.23	Excavation cost:	$3.06
Cum. fill:	636,673.22	Load cost:	$1.87
Net volume:	0.02	Haul cost (per km):	$2.40
Volume unit:	cubic meter	Embankment cost:	$4.41
Layer name:		Waste cost:	$.98
Reusability factor:	1.00	Borrow cost:	$2.75

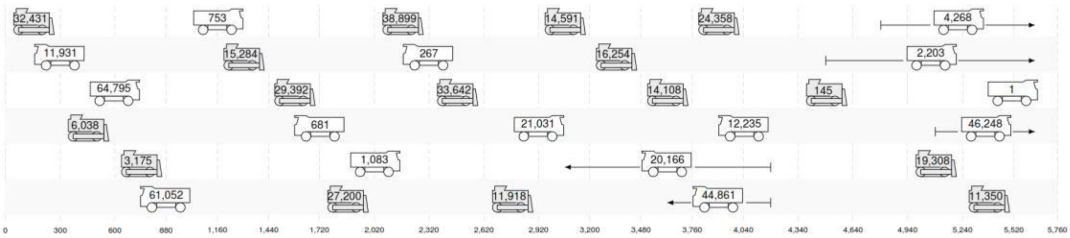
3.1.1. *Mass diagram for strata layer 1.*

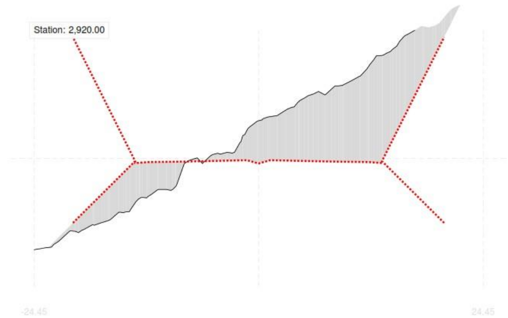




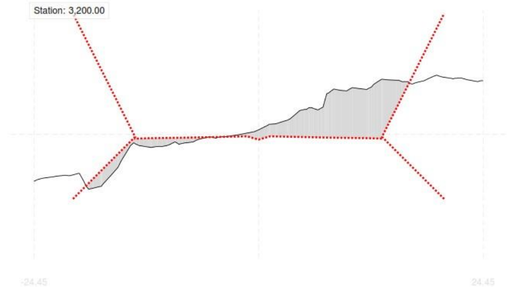
3.1.2. *Hauling Scheme for strata layer 1.*







Cut area:	160.55
Fill area:	38.76
Road elevation:	728.90
Surface high:	746.79
Surface low:	718.94
Road cost per linear meter:	$933.53
Road width:	21.40
Datum width:	26.90



Cut area:	60.04
Fill area:	11.27
Road elevation:	724.12
Surface high:	730.56
Surface low:	718.17
Road cost per linear meter:	$933.53
Road width:	21.40
Datum width:	26.90

4. Volume Report

Station:	Cut area: (m^2)	Cut vol: (m^3)	Fill area: (m^2)	Fill vol. (m^3)	Cum. cut: (m^3)	Cum. fill: (m^3)	Cum. net: (m^3)
0.00	158.38	0.00	31.98	0.00	0.00	0.00	0.00
300.00	110.39	32,431.11	8.43	44,362.27	32,431.11	44,362.27	-11,931.17
600.00	29.30	82,764.43	148.79	6,037.80	115,195.54	50,400.07	64,795.47
880.00	84.78	3,175.27	125.25	129,022.60	118,370.81	179,422.67	-61,051.86
1,160.00	13.28	67,273.91	91.06	5,253.35	185,644.73	184,676.03	968.70
1,440.00	73.43	15,283.93	8.96	16,037.21	200,928.65	200,713.23	215.42
1,720.00	0.00	29,391.85	526.02	30,288.47	230,320.50	231,001.70	-681.20
2,020.00	168.92	28,964.77	0.00	27,200.48	259,285.27	258,202.19	1,083.09
2,320.00	195.16	38,899.39	16.02	40,249.75	298,184.66	298,451.94	-267.27
2,620.00	47.10	33,908.66	112.88	33,641.51	332,093.32	332,093.44	-0.12
2,920.00	160.55	32,949.32	38.76	11,918.02	365,042.65	344,011.47	21,031.18
3,200.00	60.04	14,591.47	11.27	55,788.78	379,634.12	399,800.24	-20,166.12
3,480.00	131.45	16,254.32	40.85	57,174.20	395,888.44	456,974.44	-61,086.00
3,760.00	189.37	14,108.13	1.25	58,968.70	409,996.57	515,943.14	-105,946.58
4,040.00	232.24	24,357.98	0.00	36,593.06	434,354.54	552,536.20	-118,181.66
4,340.00	152.39	98,984.40	0.00	0.00	533,338.95	552,536.20	-19,197.26
4,640.00	26.84	21,253.73	2.35	141.50	554,592.68	552,677.71	1,914.97
4,940.00	0.00	4,642.49	0.00	97.72	559,235.17	552,775.43	6,459.74
5,240.00	267.59	65,555.42	0.00	19,307.59	624,790.59	572,083.01	52,707.58
5,520.00	30.59	10,802.63	0.46	11,514.21	635,593.22	583,597.22	51,996.00
5,760.00	0.00	874.41	379.56	53,178.90	636,467.62	636,776.12	-308.50

5. List of PVI's

PVI	Station	Elevation	Curve length
*1	0.00	695.21	0.00
2	161.42	693.68	144.33
3	414.41	692.68	98.37
4	560.86	690.15	123.87
5	702.08	686.29	105.25
6	888.09	684.76	91.49
7	1,002.87	685.72	88.02
8	1,111.90	685.45	97.40
9	1,230.66	684.23	105.89
10	1,383.11	685.60	137.11
11	1,538.40	688.50	97.15
12	1,654.76	692.60	95.39
13	1,906.24	705.17	70.91
14	1,988.51	709.22	69.28
15	2,079.26	713.52	75.36
16	2,294.12	723.93	94.35
17	2,419.62	728.43	100.57
18	2,548.02	731.29	114.62
19	2,675.38	732.16	90.34
20	2,779.80	731.59	89.69

PVI	Station	Elevation	Curve length
21	2,906.50	729.37	92.48
22	3,048.74	725.20	96.84
23	3,165.38	723.84	104.97
24	3,336.29	725.10	149.78
25	3,514.12	731.26	95.50
26	3,620.65	735.85	93.09
27	3,738.20	739.43	95.66
28	3,874.37	741.82	113.68
29	4,052.37	742.22	98.15
30	4,170.68	740.91	96.25
31	4,309.37	737.58	111.53
32	4,521.33	729.28	76.59
33	4,611.96	725.93	79.24
34	4,719.90	723.48	96.85
35	4,827.51	722.94	92.67
36	5,043.07	725.48	183.70
37	5,277.05	725.87	137.29
38	5,443.65	723.07	145.40
39	5,635.64	721.77	115.19
*40	5,764.76	723.60	0.00

Figure 41. The optimization project generates a PDF report that contains information about the centerline profile, the cost of construction and earthwork, the cross sections, and a list of PVI's stations.

As you have seen, the roadway design for the InfraWorks module is an extremely vital tool that can be used to create, visualize, and evaluate various road designs. Despite this, the Autodesk Civil 3D software is the one responsible for the detailed design at this point (Chappell, 2015). To provide precise infrastructure designs and documentation, Autodesk Civil 3D is the best available tool. Users of Autodesk Civil 3D with a locally installed version of InfraWorks can open an InfraWorks model directly in Civil 3D. Using an IMX file that was exported from an InfraWorks model, an Autodesk Civil 3D user can import InfraWorks model data into Autodesk Civil 3D.

In the screenshot shown in (Figure 42), a project for a highway is being displayed in the software Autodesk Civil 3D. This project was optimized and exported by InfraWorks. The analyze tool in InfraWorks makes it possible to export a design created in InfraWorks to Civil 3D, which opens the way for the beginning of the detailed design phase.

After the concept profile has been exported to Civil 3D, the design process in greater detail can begin. The components of road corridors, the type of daylight, and styles, for instance, are all open to dynamic modification and editing within Civil 3D. The cross-section shown in (Figure 43) illustrates the transformation of daylight slopes and slops into Bench type and retaining walls.

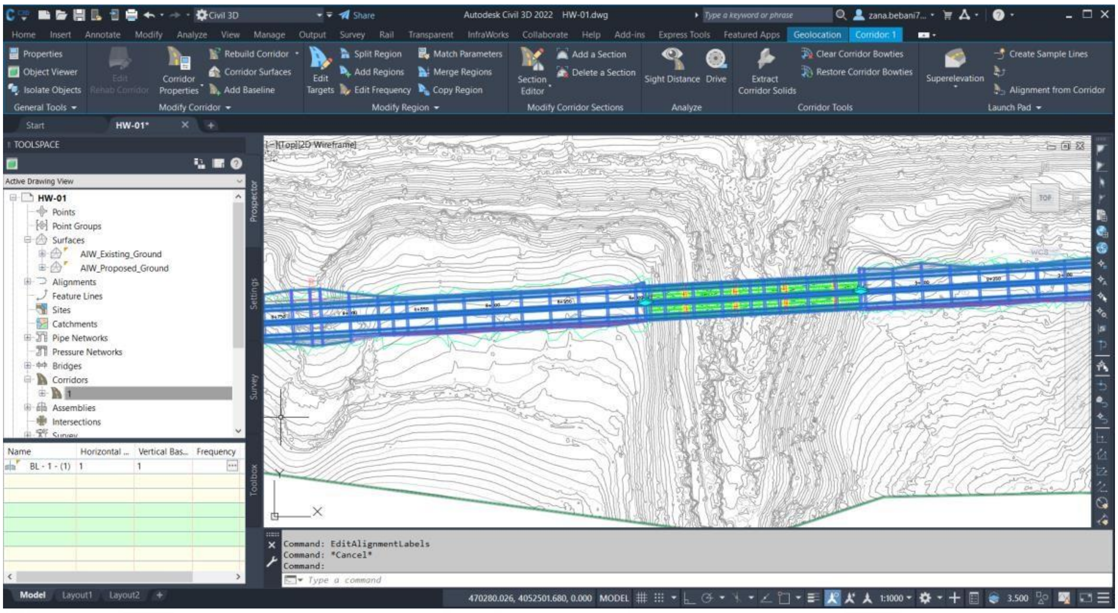


Figure 42. The project exported from InfraWorks to Civil 3D software

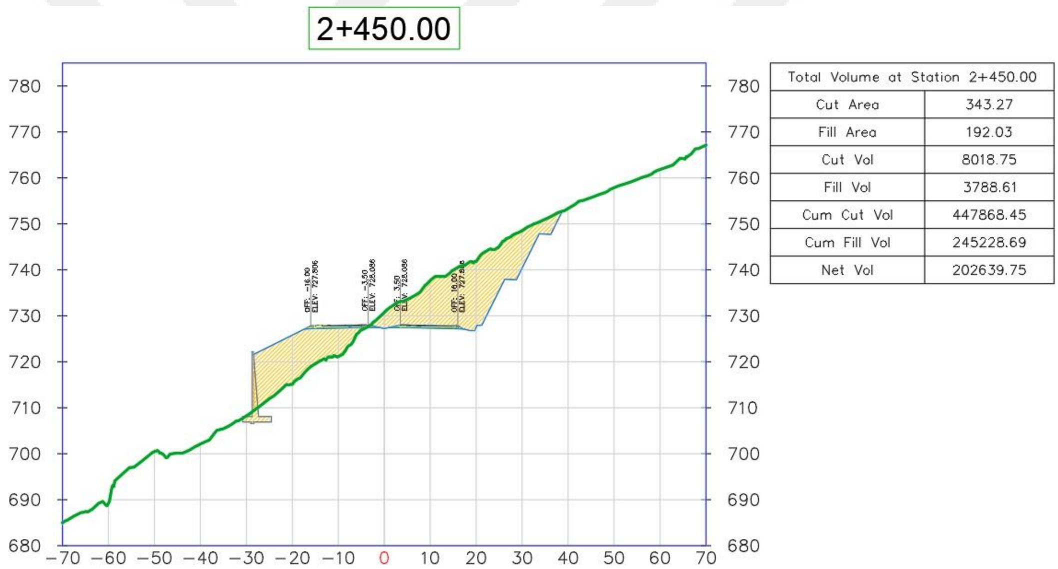


Figure 43. Changing the cross-section daylight to bench type and adding a retaining wall in required sections in Civil 3D software.

It is possible to construct project sheets in Autodesk Civil 3D, which can then be used to communicate data with relevant authorities and contractors. Drafting and document creation, including labeling and outputs that adhere to graphical standards for documentation of profiles and cross sections, are all included in Civil 3D's toolkit, as are the management and processing of survey data, the bidding and construction phases, and the phases of bidding and construction themselves. These tools contain the capability to personalize a template, and they are an automatic output from the design area, complete with the perspective and any details that have been provided.

The feature known as "Plan Production" in Civil 3D is responsible for the automatic configuration and creation of the plan and profile sheets for a road. It is a complicated feature that can automate many different functions within Civil 3D and AutoCAD (Figure 44). Two kilometers of alignment sheets are presented in Appendix 1.

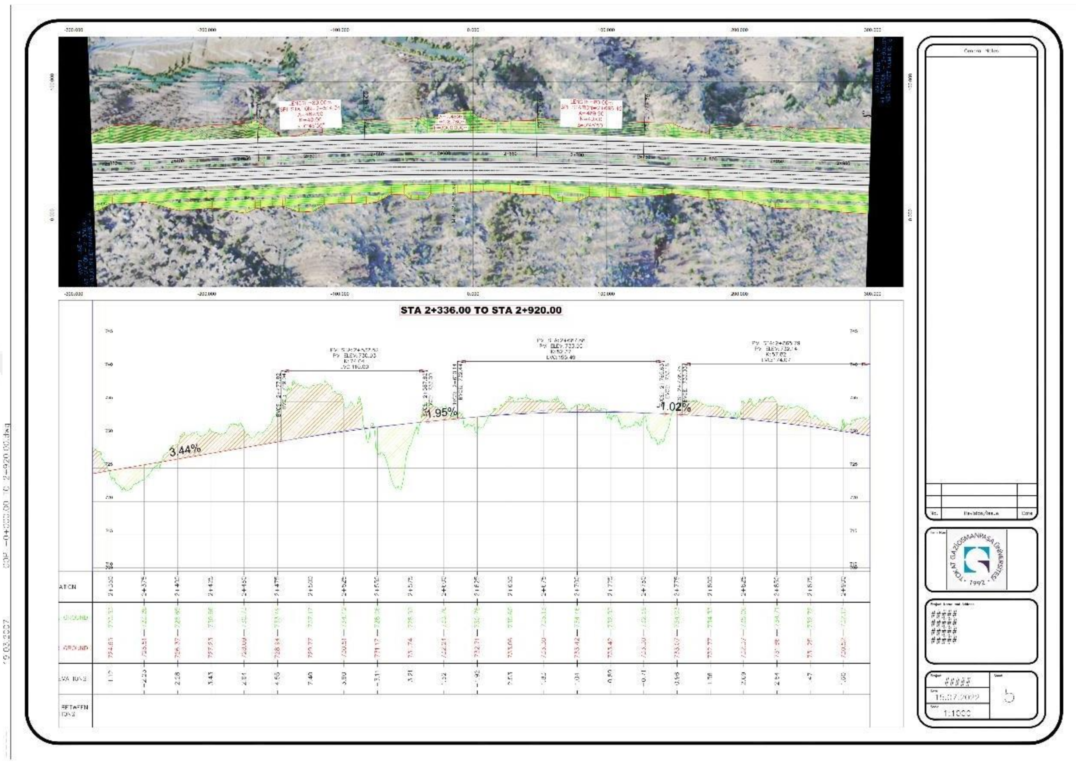


Figure 44. A sheet that has been automatically configured by the Civil 3D

InfraWorks is better for conceptual design work, though it is getting better at more detailed work, and it is significantly ahead of Civil 3D when it comes to flythroughs, orbiting, etc., even with large datasets. Information sharing between the two programs is also getting better, but don't give up on Civil 3D just yet. You'll need to make drawings and other things that you can't do in InfraWorks.

4. RESULTS

The study aims to what extent UAV & BIM tools are appropriate for manipulating all aspects of the infrastructure projects such as data collection, design, and management; by exploring the potential of a BIM - UAV solution. This will demonstrate that the UAV can obtain accurate 3D topographic data. It can easily integrate with BIM software to build, design, and manage infrastructure projects. This study examines the use of two different technologies, UAV and BIM, in the planning, design, and management of highway projects.

4.1. Result of Topographic Survey

Most of the time, the method used to acquire topographical data depends on the object being measured, it is land areas, whether it can be reached, how much vegetation is there, whether there is sludge, etc., and the level of sensitivity that is needed (S. J. T. V. Yaprak, 2020). The topographic model was initially assessed by UAV and subtracting the elevations generated from the oblique camera. The use of GNSS control points formed the basis for the evaluation of the quality of the photogrammetric elevation model. The RMSE for the vertical difference that was calculated for DTM between field GNSS, and photogrammetry processing data was approximately 7 centimeters (Table 3).

Table 3. GCP Check Points RMSE of the quality DTM

Count	X error (cm)	Y error (cm)	Z error (cm)
Check Points RMSE of Chunk 1			
37	15.7	7.7	13.6
Check Points RMSE of Chunk 2			
25	5.5	3.7	4.4
Check Points RMSE of Chunk 3			
35	2.5	2.2	3.1

The Check GCP mean RMSE for the vertical difference of DTM = 7 cm

This good accuracy (7cm) of the photogrammetry elevation data for a highly terrain area is due to several factors, the most important of which firstly is the use of a UAV equipped with an oblique camera (Figure 45) improves the vertical accuracy of topographic elevation models in steep terrain and inaccessible areas.

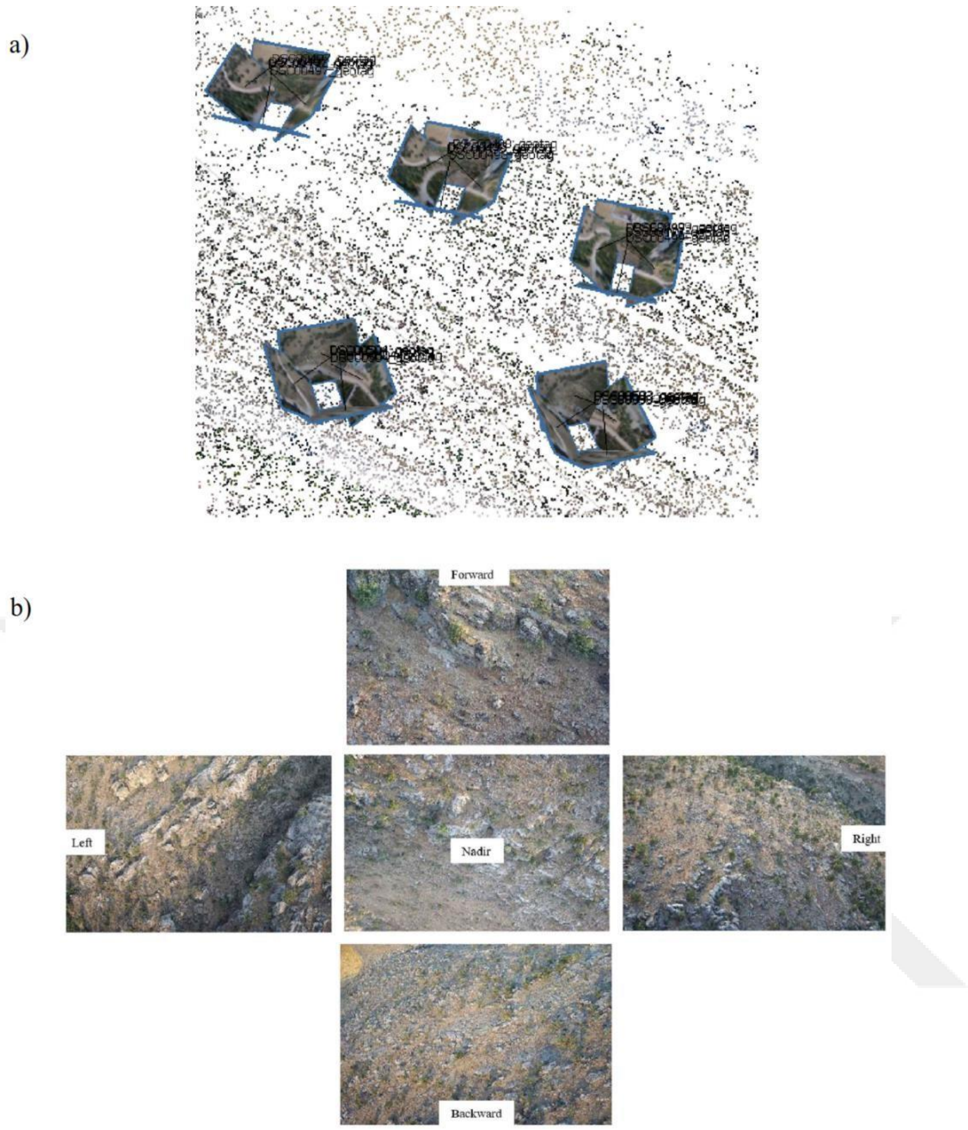


Figure 45. The position and angles of images in Metashape (a), the five images of one camera (b)

Because the images have large-scale changes and not all details are captured in the rugged terrain, a UAV survey of a steep terrain should not contain only vertical images; instead, a combination of vertical and oblique images is the best option (Kozmus Trajkovski et al., 2020). The combination of the two distinct kinds of images requires even more time to be spent processing, but the result is a point cloud that contains a great deal more information and an orthophoto that is accurate.

Secondly is the use of many ground control points in the processing and creation of a topographic map. (Table 4) displays the RMSE of GCP ground control points used for each part of the data processing, where 80 Ground Control Points were used.

It is preferable to cancel the images in which a large proportion of the sky appears because the program is unable to merge and find tie points in those images. This is because a multi-lens camera takes several images simultaneously at the same time (five shots) so that four images are tilted at an angle of 45 degrees. In most of these images, the appearance of the sky is greater than 50 percent. Where I decided not to use a few pictures of photogrammetry processing. In addition, Chunk 1 utilized 75% of the longitudinal and side overlap that was present. In the second and third Chunk2 and Chunk3, this ratio was lowered to 65% for the longitudinal overlap and 60% for the side overlap. The percentage of mistakes that could be found in the table dropped significantly between the second and third Chunks. This indicates that the overlap should be reduced when using a multi-lens camera. And in the case of taking images that show the sky in a proportion greater than fifty percent, it should not be used in producing greater than fifty percent; it should not be used in producing topographic maps.

Table 4. GCP RMSE of the processing data

Ground Control Points RMSE of Chunk 1

Count	X error (cm)	Y error (cm)	Z error (cm)
14	1.2	1.4	1.5

Ground Control Points RMSE of Chunk 2

Count	X error (cm)	Y error (cm)	Z error (cm)
38	1.7	2.8	1.3

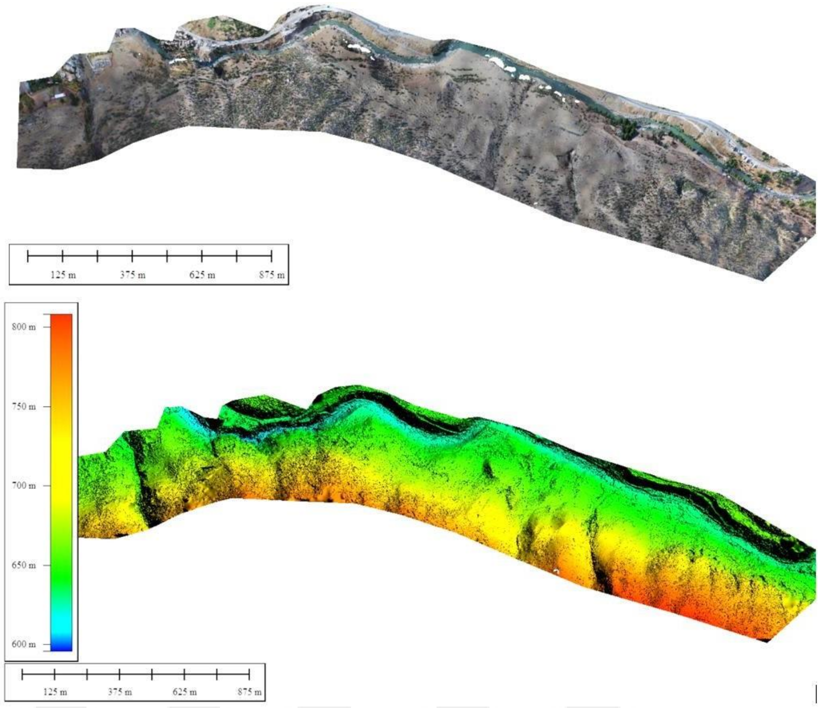
Ground Control Points RMSE of Chunk 3

Count	X error (cm)	Y error (cm)	Z error (cm)
28	1.4	1.2	1.5

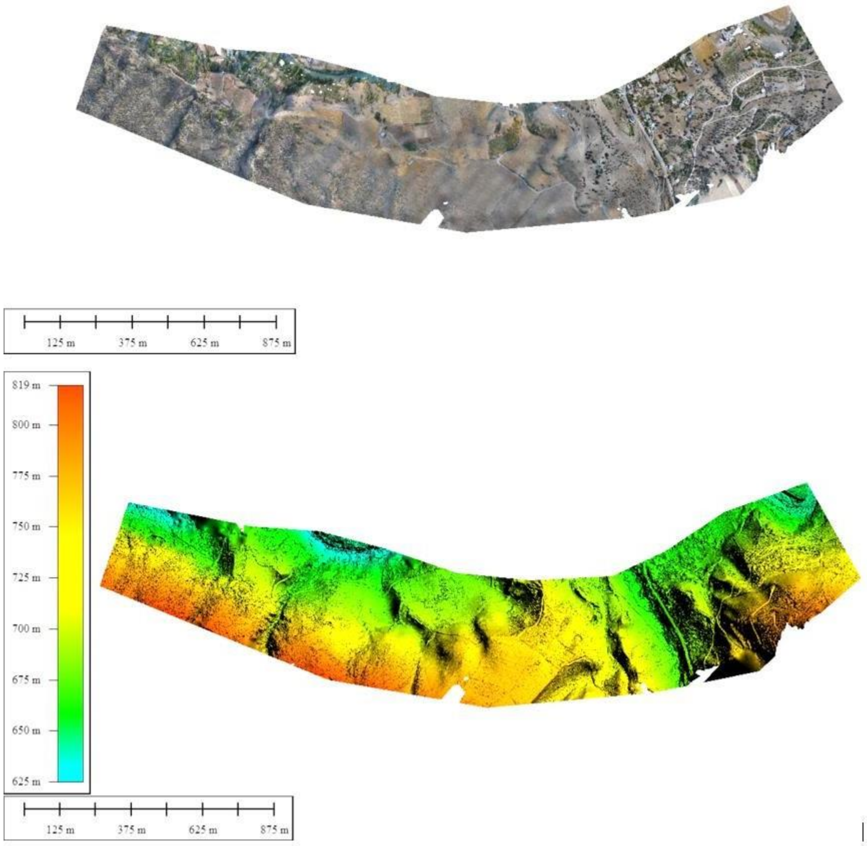
GCPs are essential for the accurate orientation and positioning of aerial photographs within the spatial coordinate system. This is a pre-requisite to produce georeferenced and 3D models of the earth's surface point cloud, DSM, DTM, and orthoimage. Other factors also contribute to this good accuracy of the photogrammetry elevation data like the flying altitude above ground level (AGL), the camera's sensor size and orientation, pixel resolution, focal length, and flight speed.

The last step involves producing the model texture, exporting a 3D model, and assembling an orthoimage mosaic to form the digital terrain model (DTM). (Figure 46) Below is an orthomosaic and the associated digital surface model screen shoot in Global Mapper software.

a)


125 m
375 m
625 m
875 m
800 m
750 m
700 m
650 m
600 m
125 m
375 m
625 m
875 m

b)


125 m
375 m
625 m
875 m
819 m
800 m
775 m
750 m
725 m
700 m
675 m
650 m
625 m
125 m
375 m
625 m
875 m

c)

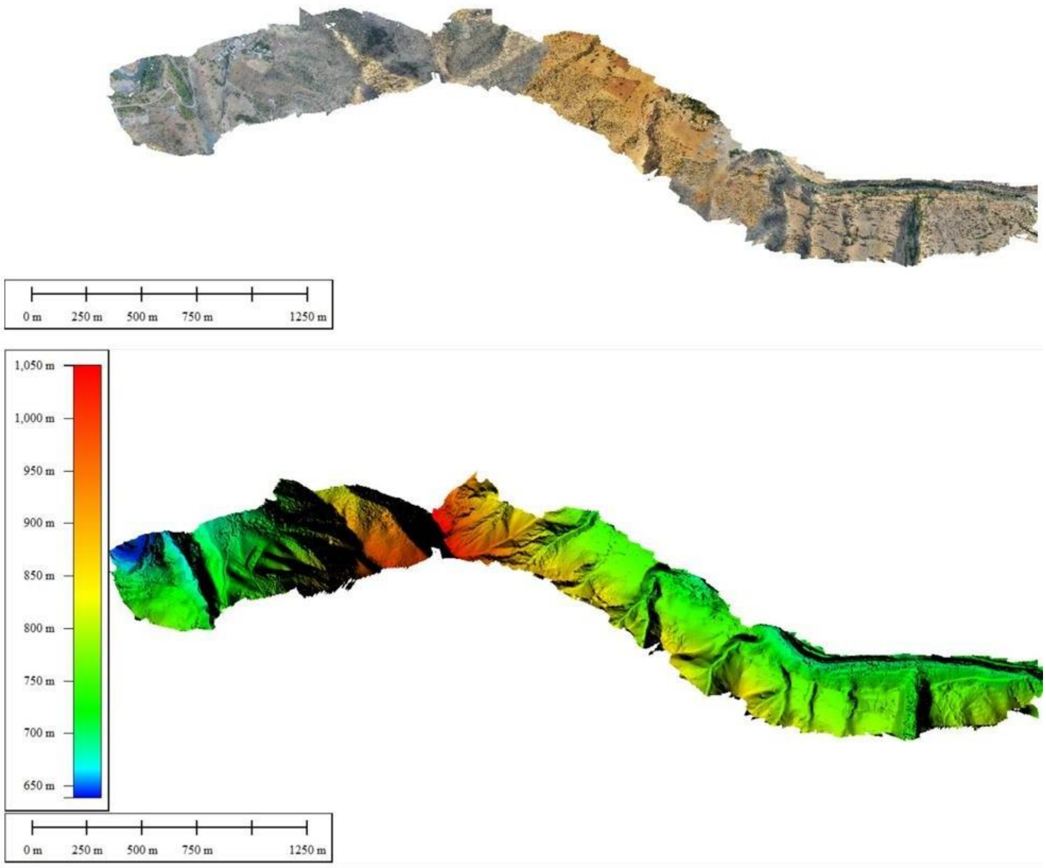


Figure 46. Generation of Orthomosaic and DTM outputs, Part one (a), Part two (b), and Part three (c).

In addition to generating the DTM and the Orthoimage, the UAV mapping techniques have the potential to generate a wide variety of other useful outputs, such as the following:

- Three-dimensional point cloud, TIN, or mesh (File formats: Google earth, 3d Max, Object, etc..).
- Break lines in the road, structural features, slopes, and other features.
- A point cloud that has been classified.
- Customized outputs to meet your specific needs.

On the other hand, the method mentioned in section (3.2. Study Area and Available Data) used terrestrial SUV scanner equipment. Due to the inability of the mobile SUV scanning to reach some steep and wadies areas as well as obstacles in the line of sight preventing access to the site. Therefore, they could not adequately cover some areas because some locations could not conduct the survey or collect all data. A third party utilized GNSS and Total Station instruments to conduct additional surveying for the inaccessible site. As a result, the contractor and survey crew are required to make use of traditional equipment in order to finish the surveys, which results in increased levels of effort, cost, and risk. The finished surveys of all parts and areas are necessary for figuring out how much earthwork needs to be done and designing the necessary infrastructure. Traditional land surveying has three major drawbacks: time, cost, and safety. Survey crews are frequently working on undeveloped or large and high terrain and vegetated land, where they are more likely to fall or be exposed to harsh elements. Furthermore, if a crew is working near a motorway, additional safety precautions must be taken to reduce risk. However, UAV surveys eliminate the need for surveyors to traverse unknown terrain. This helps avoid high-risk situations navigating areas such as rocky and steep terrains. (Kozmus Trajkovski et al., 2020) Further recommended UAV use in areas with steep terrain and a UAV equipped with an oblique camera improves the vertical accuracy of topographic elevation models in steep terrain and inaccessible areas. The steep and muddy terrain, as well as the obstacles in the line of sight, make measuring the terrain's true topography nearly impossible using terrestrial equipment. UAVs give a level of accuracy that, when combined with proper flight height and the appropriate overlapping rates, just cannot be achieved with more traditional observation techniques (Yaprak et al., 2018). Although UAV is limited to the area that is not covered with vegetation in topography, it cannot penetrate the vegetation and generate terrain topography, unlike as airborne LiDAR scanning (Table 5).

Table 5. The comparison between terrestrial and UAV survey

	Terrestrial Survey	**UAV Survey**
Safety	Low safety	High safety
Reachable Site	Limit, the data collection completely depends on the field crew	Unlimited, the data collection does not completely depend on the field crew
Missing Data	In case there are missing data, then need go back to the site and collect missing data.	All the information is contained in the point cloud and orthomosaic image.
Close down	The operation may be needed to close down the highway or any tracks	Operation on site won’t be interrupted

Field Work Limitation	Weather, steep slopes/harsh terrain, and unallowed places	Temperature, vegetation cover, Knowledge/training needed
Output	1) E, N, H list points 2) 3D point cloud (the type of scanner used can capture points only, some modern scanners combined camera to take images and then generate orthoimage)	1) E, N, H list points 2) 3D point cloud 3) Orthoimage 4) Customized outputs to meet your specific needs.
Cost	For unreachable some location with SUV survey, the cost increase more to make supplementary surveying	Reduced the cost of a site survey and workload of specialists in the field
Accuracy	Accurate	It is possible to carry out topographic surveys of the same quality as the highly accurate measurements collected by traditional methods

4.2. Result of BIM Design

Before moving on to the design phase, a topographic survey that includes an accurate 3D representation of the project area is required. The traditional method of collecting data involves employing professional surveyors to take measurements and produce a 2D map view complete with contour lines to indicate changes in elevation. This deliverable has been improved thanks to new remote sensing tools, and it now provides a highly accurate 3D representation that serves as the foundation for the design and makes communication easier.

To ensure that the digital 3D model produced by the BIM software is as accurate as possible, drones essentially serve as data suppliers for the software. They provide the software with information about the conditions of the current site. The UAV mapping techniques that are described in section 4.1 have the potential to generate a wide variety of output data, such as raster DTM/DEM, orthoimage, points cloud/Classified, 3D meshes, and so on. The BIM-based applications that are based on InfraWorks are able to work with a large amount of the data that is produced by UAV techniques, and can compare several sources of data (Figure 47) e.g. 3ds model, fbx model, CityGML, ArcGIS shapefile, and SketchUp model, this data can be imported directly into InfraWorks.

Figure 47. The Data Sources can import into InfraWorks

It may be simple to see how the project develops in 3D using UAVs and BIM technology combined. The project's highway designer would find this to be of great use. During this development, technological and practical issues need to be considered.

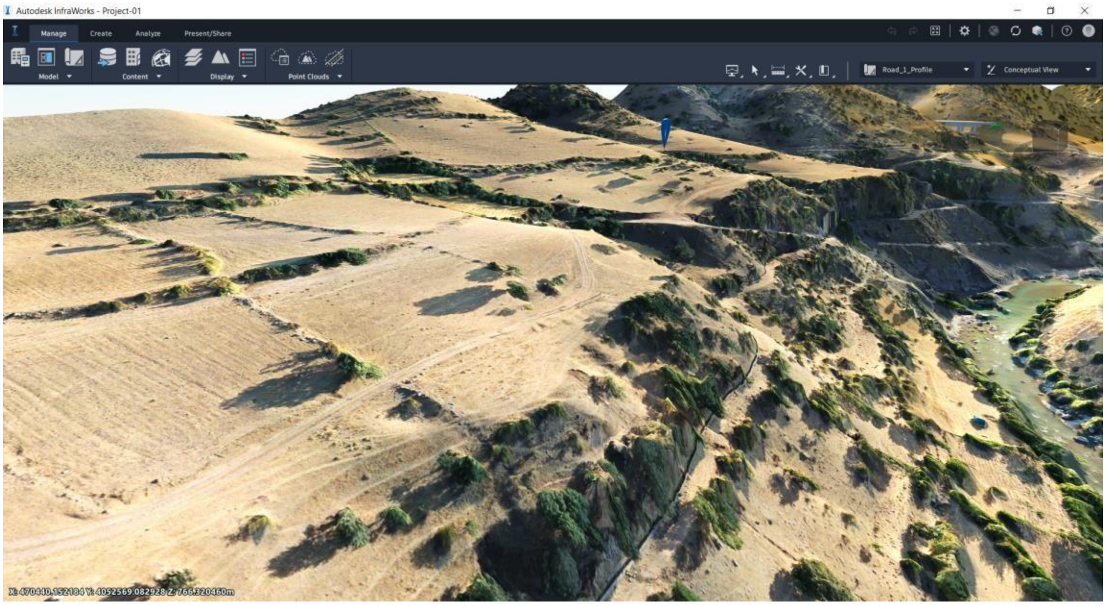


Figure 48. The real 3D environment of UAV data in InfraWorks

Using reality capture technology and Unmanned Aerial Vehicles, topographic analyses of the terrain's height or slope can be performed once the environment is established UAV (Figure 49). Terrain Themes allow you to compare terrain based on Elevation, Aspect, or Slope. This deliverable has been enhanced by InfraWorks so that it now provides a highly accurate 3-D design image and facilitates communication.

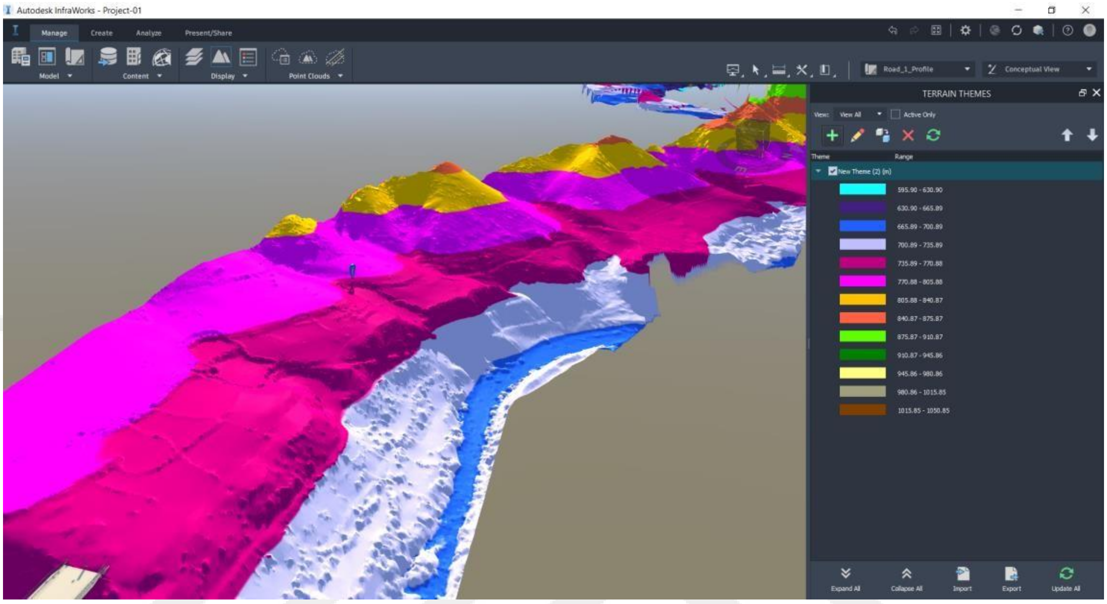


Figure 49. Terrain themes analysis by elevation ranges

It can create rich context models with Autodesk Infraworks that showcase your design in the real world, whether it's built-in or natural surroundings. These models can be used to showcase the design. A better understanding of the context enables you to form decisions on a more solid foundation, which in turn leads to improved project outcomes for both you and your organization. It can easily incorporate GIS data into InfraWorks to collect large amounts of data that give even more accurate information about the area you are modeling in, regardless of whether it is a built-up or natural environment. This gives the ability to model in environments that are more complex than ever before. It will not only provide a better basis for decision-making, but it will also make it easier to communicate the purpose of the project to both internal and external actors if present the project while placing it within the context of the environment and the surrounding area and creation of a 3D highway geometric road and profile.

It is nothing new for professionals in the field of road and highway design to make use of modeling, three-dimensional visualization, and analysis. The difference lies in the fact that design, analysis, and documentation are seen as three separate processes when traditional drafting-centric methodologies are utilized. Because of this, doing an evaluation of "what-if" situations is both inefficient and costly.

The greatest direct advantages of using BIM for the design of roads and highways include improved designs as well as enhanced levels of efficiency and productivity. Because the design and the documentation for the construction of the building are dynamically connected, the amount of time that is required to analyze more options, carry out design revisions, and prepare construction documentation is greatly reduced. For Example, based on a given horizontal alignment and design constraints in the case study, InfraWorks can generate the optimal vertical alignment (Figure 50). The InfraWorks application offers a strong optimization tool that will assess and modify the road profile of the roadway to reduce the costs connected with earthmoving.

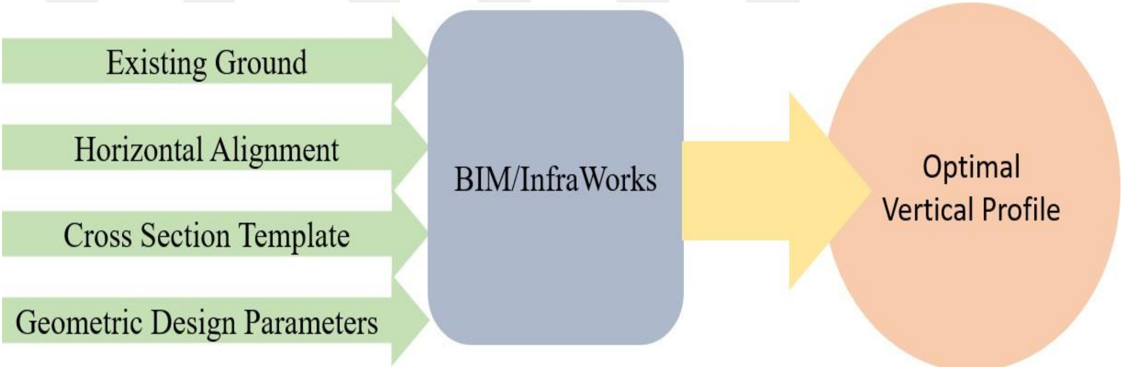


Figure 50. Workflow of InfraWorks Vertical Profile Optimization based on the existing ground surface, horizontal alignment, cross-section definition, and design parameters.

The process that is currently used in the case study (Traditional Method) to determine the vertical alignment relies heavily on trial and error to a significant extent. Adjustments are made iteratively to the alignment while the engineer searches for a solution that meets the design criteria at the lowest possible cost. This cycle of iteration will continue until the designer reaches a point of contentment. This solution is problematic because it is only approximative. As seen in the following illustration, adjustments to the alignment can result in significant earthworks differences.

Table 6. Total Earthwork Volume of BIM optimization every 1 kilometer. In Appendix 2 attached table volume is every 25 meters.

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Volume	Cumulative Cut Volume
0+000	138.91	222.11	0.00	0.00	0.00	0.00
1+005	75.91	323.68	794.74	3337.16	51523.33	168714.77
2+000	13.48	169.61	3350.73	2614.62	178751.39	324310.72
3+000	451.51	71.30	8551.40	2610.18	329409.15	570454.96
4+000	0.00	198.56	0.00	3555.74	561696.02	667168.96
5+000	0.00	0.00	0.00	0.00	563810.37	740949.10
6+000	0.00	0.00	0.00	0.00	607756.73	887019.39
7+000	0.00	0.00	0.00	0.00	607756.73	887019.39
8+000	91.44	304.08	4049.02	5877.40	683052.97	1112859.49
9+000	2.52	63.25	31.49	2285.93	738940.90	1320899.49
9+500	348.08	133.49	6119.05	3334.53	759418.99	1376668.22

Table 7. Earthwork Volumes Comparison of Traditional and BIM Optimization

Earthwork	Traditional	BIM	Reduction
Cut	1937142	1376668	28.90%
Fill	777666	759419	2.30%
TOTAL	**2714808 m^3**	**2136087 m^3**	**21.30%**

By utilizing BIM, we were able to cut down on the amount of highway earthwork cut/fill design by around 21% (Figure 51), based on a given horizontal alignment and various design constraints. The application is used to input and manage all limitations. Curvature, grading, and other limitations are offered to handle drainage, unique fill conditions, and existing utilities. Additionally, the user sets the material transport expenses utilized to determine the best lowest pricing. The manual process of balancing a road through a series of iterative steps requires a significant amount of time. This process is mathematically optimized by InfraWorks, which results in an optimal solution being reached in a matter of minutes, on average. The most straightforward approach to lowering costs associated with earthwork is to use InfraWorks optimal. It solves the difficult three-dimensional problem of minimizing excavation, embankment, and haulage while still meeting design standards and constraints. InfraWorks vertical optimization will calculate the vertical alignment with the lowest possible cost.

Changes in vertical alignment can have a significant impact on earthwork costs. InfraWorks can be utilized for preliminary design in order to rapidly confirm feasibility and cost. During design finalization, it can be used to optimize vertical alignment, run design checks, and calculate construction quantities.

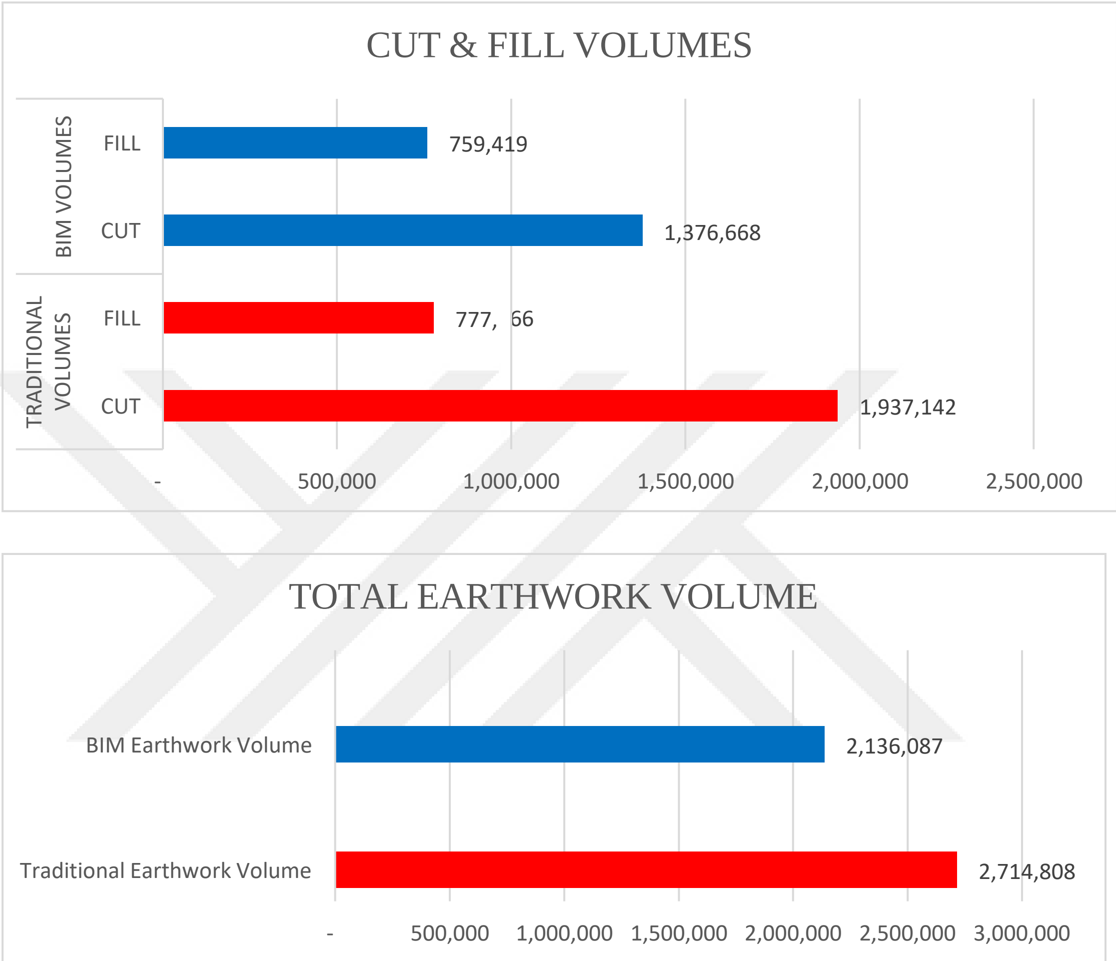


Figure 51. The Comparison of Earthwork between Traditional and BIM method.

In addition to improving efficiencies and productivity, Building Information Modeling (BIM) makes it easier to optimize roadways by including visualization, simulation, and analysis in the design process. When working with InfraWorks 3D processes, visualization is not a separate step but rather one of several outputs from an intelligent model (Figure 52). The designer can work in a conventional 2D workflow, and then quickly and easily convert that information over to a 3D perspective to depict concepts in a manner that is straightforward and easy to comprehend. This kind of integration makes it possible to quickly go back and forth between the two, which makes it easier to fine-tune the design at the same instant that information is received.

Figure 52. 3D perspective visualization in InfraWorks.

When compared to other, more traditional, and frequently used CAD software products, InfraWorks provides a number of additional capabilities as well as advantages. It makes it possible to produce rapid and seamless 3D visualizations of real-world contexts within a shorter amount of time.

BIM makes it possible to produce improved visualization that is useful for each design step. Different parties are better able to comprehend the design concept and specifics when using a 3D project model that is integrated into a genuine environment. Every stakeholder who might be affected by an infrastructure project, including the general public, may be interested in learning more about it. The collection of 3D models contains a representation of the civil and structural design, as well as services, traffic design, noise barriers, drainage, and lighting models. Design authoring tools are used to construct these design models and link them to a database, including data on specifications, schedules, costs, various features, materials, etc.

A 3D model of a highway site or corridor can be used to demonstrate the benefits and disadvantages of a particular location based on a variety of variables, such as multiple environmental consequences - on rivers, noise propagation, nearby structures, woods, historical objects, and so on.

In the traditional method, visualizations had to be created by specialist organizations, which not only resulted in significantly higher costs but also needed significantly more time. Another key issue was that the visualizations were static and not connected to the project model in any way. This problem is solved by workflows that are based on Building Information Modeling (BIM), as the visualization is directly based on the live model.

Because the links between objects are preserved in the model rather than being locked into individual sheets, using model-based tools makes it easier to handle even large changes to the design. This is because the individual sheets are not used. It is simple and quick to reprint drawings of sections, profiles, and other production sheets and layouts, in addition to being easily brought up to date and accurately labeled.

5. CONCLUSION

This thesis study tested the practical application of the performance of UAV and BIM technologies to manage all aspects of the project such as data collection, design, and project management for road projects, as well as comparing the performance and achievements of UAV and BIM system with terrestrial measurement and traditional CAD design.

One of the goals of combining BIM and UAV in the study was to obtain precise topography data and make it easier to see and explore the ground in real time. Thus, in the next stage BIM technology was used to optimize the design of the road and the amount of earthwork (excavation/filling). The study showed that the UAV can collect accurate 3D topography data over rough terrain and hard-to-reach areas faster, safer, and less labor-intensive than terrestrial measurements. The five-camera system used in the project provided 7 cm accuracy in the elevation data, even though the topography was very steep. The use of an inclined camera system and more ground control points was found to improve vertical accuracy of topographic elevation models on steep terrain and inaccessible areas.

UAV mapping in engineering projects has proven to be an advantage as they can generate Orthoimage, 3D point cloud, TIN or mesh in addition to DTM. DEM and ortho images produced with UAV techniques were directly transferred to BIM software.

Infraworks was able to compare various data sources 2D CAD drawings, GIS data and 3D terrain models with proposed project boundaries and gain a better understanding of how the project affects existing terrains and elevations. InfraWorks software made it possible to create 3D highway alignment, profiles and sections. InfraWorks can also generate the optimal vertical alignment based on a particular horizontal alignment and design constraints in the case study. While the conventional method for determining vertical alignment relied heavily on trial/test, the InfraWorks application offered a powerful optimization tool that evaluated and adjusted the road profile, reducing excavation costs. InfraWorks demonstrated that it can also be used for preliminary design to quickly verify feasibility and cost. InfraWorks also offered the ability to import data into Civil 3D by adding a different dwg model and a 3D model and creating detailed design drawings.

The study showed that the use of the BIM system reduced the amount of road excavation cut/fill calculated using the conventional design method by approximately 21%. In addition, BIM has assisted in method development by incorporating visualization, simulation, and analysis into the design process. The combination of UAV and BIM technology made it easy to see in 3D how the project was progressing. As a result, significant gains such as efficient data collection and effective project management, significant reduction in excavation amounts, data collection, design, error estimation and optimization were achieved with BIM and UAV. The system was very helpful to the highway designer. Better designs, increased efficiency and productivity have proven to be one of the most immediate benefits of BIM for road and highway design.

Every new technology doubles the amount of data created. A large amount of data was generated that could be analyzed by the combined BIM-UAV system.

Future research may include the use of new LiDAR or SLAM techniques in areas where photogrammetry imaging techniques cannot remove vegetation, particularly low vegetation, especially in areas covered with vegetation.

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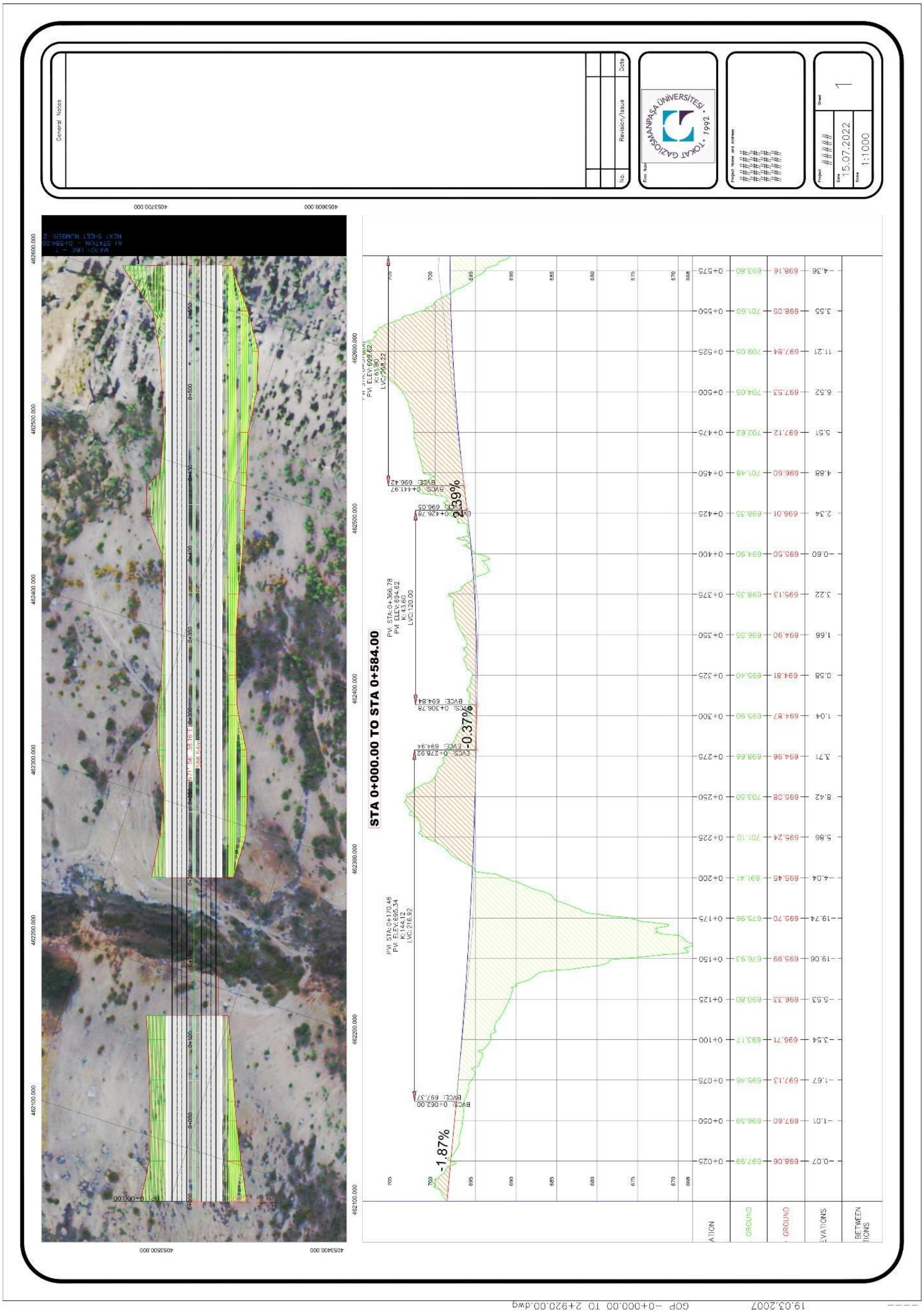
APPENDIX 1 Two Kilometers of Alignment Layout Sheets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General Notes
Revision/Issue
Date
TOKAT GAZİOSMANPAŞA ÜNİVERSİTESİ • 1992 •
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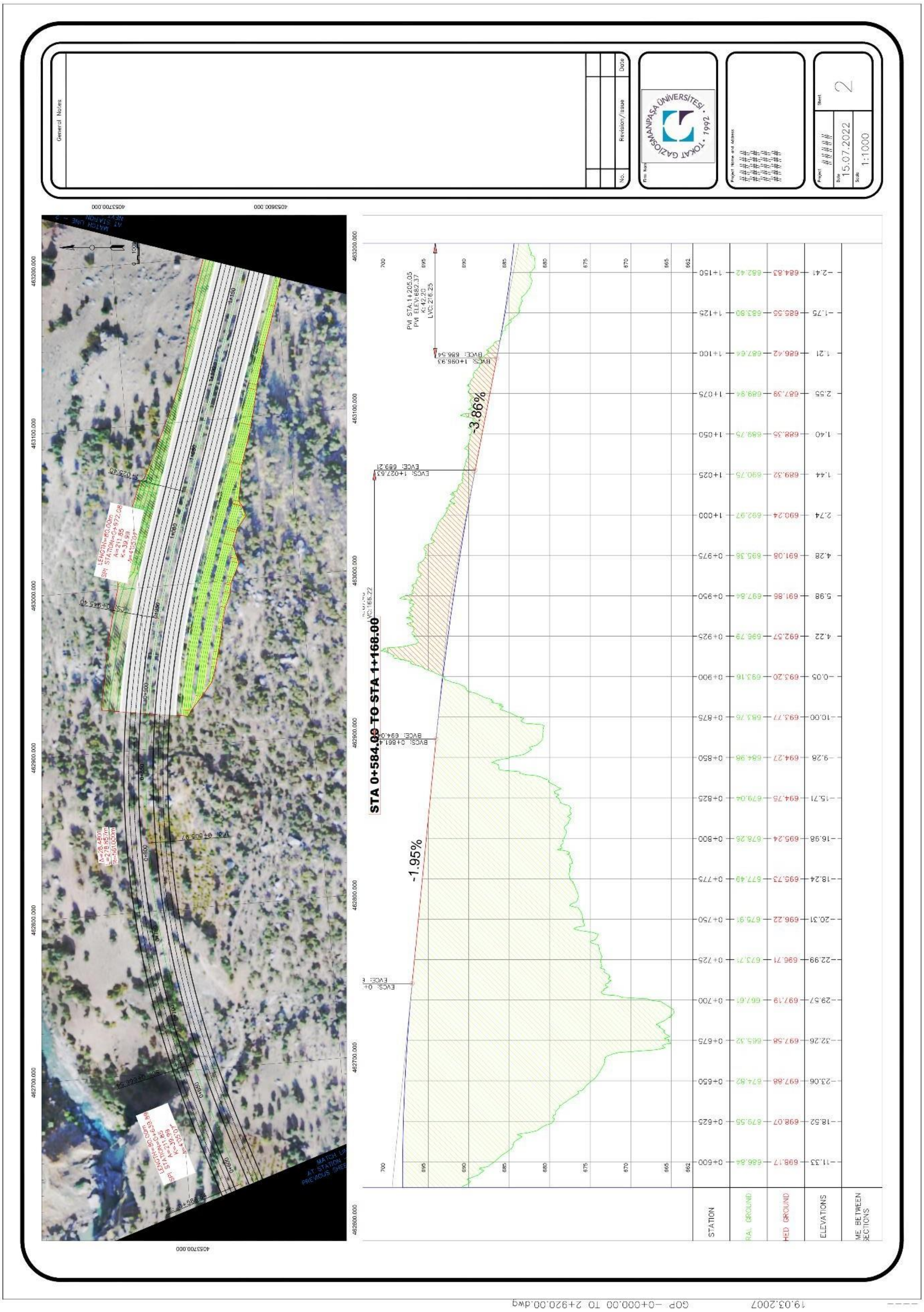
19.03.2007



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General Notes
Revision/Issue
Date
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2
STATION
ELEVATIONS
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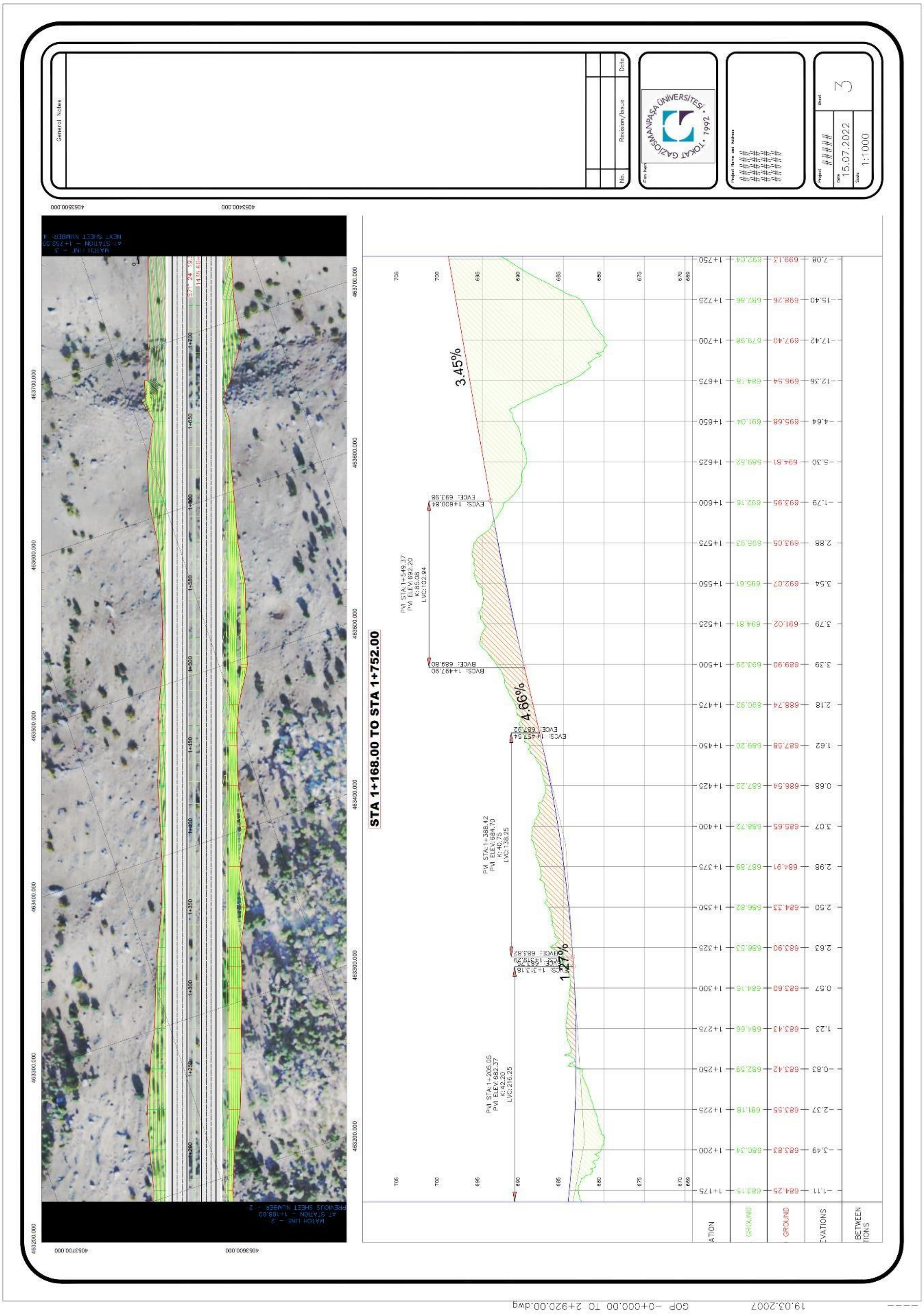
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General Notes
Revision/Issue
Date
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15.07.2022
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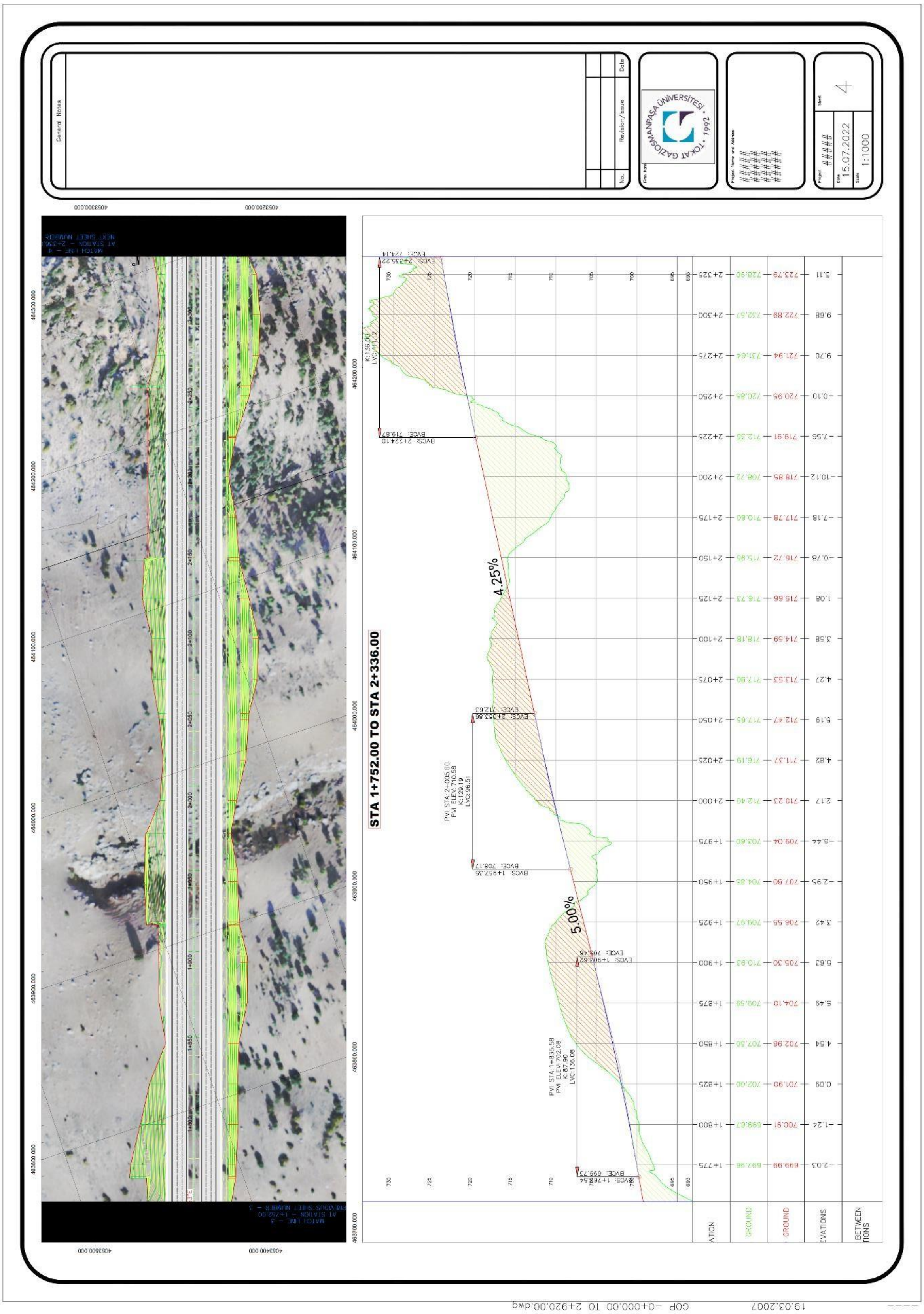
Sheet
3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General Notes
Revision/Issue
Date
No.
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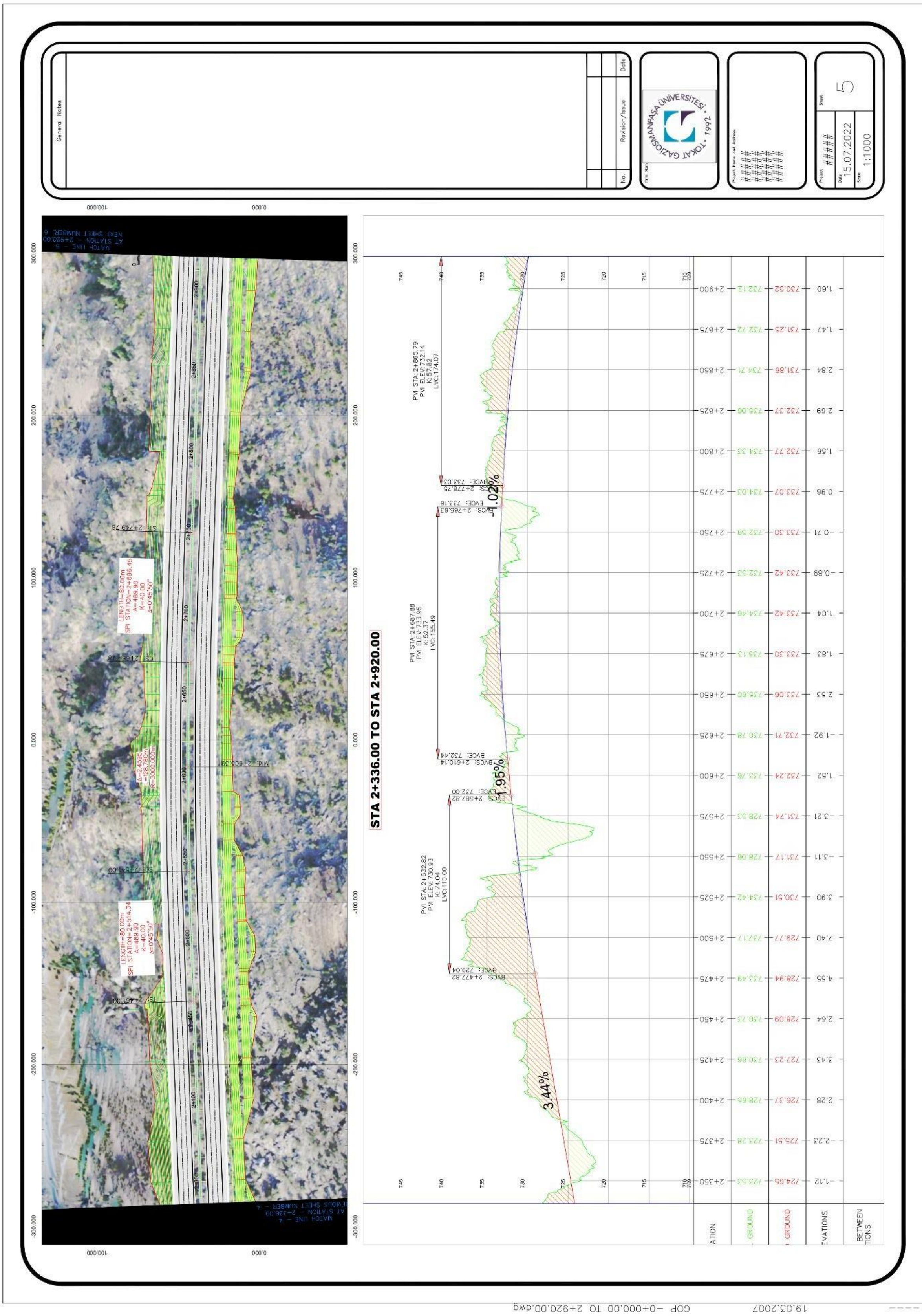
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General Notes
Revision/Issue
Date
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PVI ELEV:730.93
PVI STA:2+687.88
PVI ELEV:733.95
PVI STA:2+865.79
PVI ELEV:732.14
19.03.2007
COP -0+000.00 TO 2+920.00.dwg

<u>APPENDIX 2</u> Total Earthwork Volume of BIM optimization every 25 meters

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+000.00	138.91	222.11	0.00	0.00	0.00	0.00
0+025.00	90.08	183.07	2862.26	5064.74	2862.26	5064.74
0+050.00	96.91	100.48	2337.37	3544.28	5199.63	8609.02
0+075.00	106.57	64.06	2543.52	2056.69	7743.15	10665.72
0+100.00	152.03	27.75	3232.46	1147.66	10975.61	11813.37
0+125.00	0.03	0.00	1900.75	346.90	12876.36	12160.28
0+150.00	0.00	0.00	0.38	0.00	12876.74	12160.28
0+175.00	0.00	0.00	0.00	0.00	12876.74	12160.28
0+200.00	0.00	0.00	0.00	0.00	12876.74	12160.28
0+225.00	5.59	381.35	69.92	4766.85	12946.66	16927.12
0+250.00	0.12	439.67	71.43	10262.72	13018.09	27189.84
0+275.00	13.22	336.89	166.69	9706.97	13184.78	36896.82
0+300.00	42.12	162.84	691.64	6246.60	13876.42	43143.42
0+325.00	19.02	126.40	764.14	3615.44	14640.56	46758.86
0+350.00	6.54	136.41	319.44	3285.12	14960.00	50043.98
0+375.00	0.00	213.91	81.75	4379.01	15041.75	54422.98
0+400.00	92.71	195.66	1158.90	5119.61	16200.65	59542.60
0+425.00	197.32	289.36	3625.36	6062.74	19826.01	65605.34
0+450.00	83.44	317.10	3509.49	7580.70	23335.50	73186.04
0+475.00	8.68	359.54	1151.54	8457.95	24487.04	81643.99
0+500.00	0.04	455.96	108.97	10193.68	24596.01	91837.67
0+525.00	1.07	656.73	13.87	13908.61	24609.89	105746.28
0+550.00	27.17	311.00	353.08	12096.61	24962.97	117842.90
0+575.00	310.59	55.24	4222.08	4577.97	29185.05	122420.86
0+590.00	0.00	0.00	2329.45	414.29	31514.50	122835.15
0+600.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+610.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+620.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+630.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+640.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+650.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+660.00	0.00	0.00	0.00	0.00	31514.50	122835.15

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+670.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+680.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+690.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+700.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+710.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+720.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+730.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+740.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+750.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+760.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+770.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+780.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+790.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+800.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+810.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+820.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+830.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+840.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+850.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+860.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+870.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+880.00	0.00	0.00	0.00	0.00	31514.50	122835.15
0+890.00	340.85	87.25	1754.44	422.79	33268.94	123257.94
0+900.00	247.96	235.87	3036.91	1565.83	36305.85	124823.77
0+910.00	208.37	410.70	2361.21	3136.57	38667.06	127960.34
0+920.00	193.59	524.52	2083.09	4536.30	40750.15	132496.64
0+930.00	178.67	524.17	1930.00	5080.62	42680.15	137577.26
0+940.00	142.04	494.07	1661.87	4932.34	44342.02	142509.61
0+955.00	121.57	422.64	2046.33	6675.08	46388.35	149184.68
0+965.00	101.29	434.69	1114.29	4286.63	47502.64	153471.31
0+975.00	117.51	418.80	1094.01	4267.45	48596.64	157738.76
0+985.00	112.94	382.61	1152.25	4007.06	49748.89	161745.81

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+995.00	83.04	343.75	979.90	3631.79	50728.79	165377.60
1+005.00	75.91	323.68	794.74	3337.16	51523.53	168714.77
1+015.00	76.34	293.49	761.21	3085.85	52284.74	171800.61
1+025.00	75.41	258.84	758.75	2761.64	53043.49	174562.26
1+050.00	53.58	200.19	1612.46	5737.89	54655.96	180300.15
1+075.00	20.57	210.59	926.98	5134.80	55582.94	185434.94
1+100.00	22.24	140.29	535.19	4386.04	56118.13	189820.98
1+125.00	62.09	69.21	1054.15	2618.75	57172.28	192439.73
1+150.00	98.83	67.15	2011.56	1704.53	59183.85	194144.26
1+175.00	62.59	71.34	2017.79	1731.10	61201.63	195875.36
1+200.00	143.48	56.59	2575.80	1599.13	63777.44	197474.49
1+225.00	138.57	124.11	3525.63	2258.80	67303.07	199733.29
1+250.00	90.83	172.42	2867.50	3706.66	70170.57	203439.95
1+275.00	44.85	195.99	1695.93	4605.20	71866.50	208045.15
1+300.00	46.37	180.28	1140.21	4703.48	73006.72	212748.63
1+325.00	28.54	192.23	936.32	4656.37	73943.03	217405.00
1+350.00	13.52	237.87	525.67	5376.14	74468.70	222781.15
1+375.00	6.11	227.65	245.31	5818.98	74714.02	228600.13
1+400.00	11.64	248.86	221.90	5956.39	74935.91	234556.52
1+425.00	29.96	149.98	520.06	4985.48	75455.97	239541.99
1+450.00	22.72	154.91	658.57	3811.17	76114.55	243353.17
1+475.00	22.82	186.67	569.35	4269.79	76683.90	247622.95
1+500.00	4.39	276.11	340.19	5784.73	77024.09	253407.68
1+525.00	0.02	269.07	55.18	6814.77	77079.26	260222.45
1+550.00	9.96	250.25	124.82	6491.46	77204.08	266713.91
1+575.00	13.68	204.50	295.49	5684.33	77499.57	272398.24
1+600.00	118.94	79.57	1657.66	3550.89	79157.23	275949.12
1+625.00	210.10	13.15	4112.90	1158.95	83270.14	277108.07
1+650.00	154.43	10.28	4556.53	292.88	87826.67	277400.95
1+675.00	580.90	0.00	9191.58	128.55	97018.24	277529.50
1+700.00	831.77	0.06	17658.39	0.80	114676.63	277530.30
1+725.00	712.85	0.00	19307.74	0.80	133984.37	277531.10

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
1+750.00	350.81	14.94	13295.71	186.74	147280.07	277717.85
1+775.00	210.51	106.01	7016.44	1511.83	154296.51	279229.67
1+800.00	167.90	156.54	4730.03	3281.82	159026.54	282511.50
1+825.00	89.97	153.58	3223.31	3876.48	162249.86	286387.97
1+850.00	0.00	260.21	1124.63	5172.30	163374.48	291560.28
1+875.00	0.00	348.47	0.02	7608.47	163374.50	299168.75
1+900.00	0.00	357.30	0.00	8822.10	163374.50	307990.84
1+925.00	48.45	225.88	605.59	7289.74	163980.09	315280.59
1+950.00	305.31	123.90	4421.99	4372.26	168402.08	319652.85
1+975.00	254.58	39.56	6998.59	2043.25	175400.67	321696.10
2+000.00	13.48	169.61	3350.73	2614.62	178751.39	324310.72
2+025.00	1.91	306.07	192.38	5945.91	178943.78	330256.63
2+050.00	9.87	355.14	147.18	8265.05	179090.95	338521.68
2+075.00	34.65	386.00	556.40	9264.21	179647.35	347785.90
2+100.00	46.14	362.16	1009.84	9351.94	180657.19	357137.84
2+125.00	110.01	252.29	1951.88	7680.56	182609.07	364818.40
2+150.00	206.31	143.98	3953.96	4953.41	186563.03	369771.81
2+175.00	429.79	56.13	7951.21	2501.37	194514.24	372273.18
2+200.00	586.19	5.83	12699.73	774.46	207213.97	373047.64
2+225.00	457.65	69.34	13048.02	939.66	220261.99	373987.31
2+250.00	194.59	264.48	8152.99	4172.82	228414.98	378160.13
2+275.00	19.95	562.12	2681.69	10332.59	231096.67	388492.72
2+300.00	4.33	633.42	303.43	14944.25	231400.10	403436.97
2+325.00	22.87	423.24	339.97	13208.20	231740.07	416645.17
2+350.00	123.65	170.21	1831.48	7418.11	233571.55	424063.27
2+375.00	147.86	107.22	3393.83	3467.84	236965.38	427531.11
2+400.00	51.24	277.75	2488.79	4812.04	239454.17	432343.15
2+425.00	111.06	298.23	2028.77	7199.75	241482.94	439542.90
2+450.00	192.03	343.27	3788.61	8018.75	245271.55	447561.65
2+465.00	48.73	280.10	1805.67	4675.23	247077.22	452236.89
2+475.00	0.05	350.54	243.90	3153.17	247321.12	455390.06
2+485.00	0.88	473.17	4.67	4118.55	247325.79	459508.61

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
2+495.00	0.12	517.18	4.99	4951.76	247330.78	464460.38
2+505.00	0.09	473.27	1.06	4952.27	247331.84	469412.65
2+515.00	146.16	414.87	731.25	4440.72	248063.09	473853.37
2+525.00	284.51	330.76	2153.32	3728.15	250216.41	477581.52
2+540.00	432.78	315.63	5379.67	4847.95	255596.08	482429.46
2+550.00	576.70	222.09	5047.39	2688.62	260643.47	485118.09
2+560.00	641.43	150.63	6090.64	1863.61	266734.11	486981.70
2+570.00	373.92	153.45	5076.74	1520.41	271810.85	488502.11
2+580.00	112.20	230.44	2430.59	1919.47	274241.43	490421.58
2+590.00	68.35	197.83	902.78	2141.35	275144.21	492562.93
2+600.00	88.36	180.57	783.57	1891.96	275927.78	494454.89
2+610.00	135.59	157.34	1119.75	1689.53	277047.53	496144.42
2+620.00	182.86	122.46	1592.24	1398.98	278639.78	497543.40
2+630.00	108.98	94.76	1459.19	1086.09	280098.97	498629.49
2+640.00	47.88	135.32	784.31	1150.39	280883.27	499779.88
2+650.00	52.23	187.86	500.55	1615.89	281383.83	501395.77
2+660.00	48.84	192.07	505.36	1899.65	281889.19	503295.42
2+670.00	92.75	189.75	707.95	1909.07	282597.14	505204.49
2+680.00	104.94	203.08	988.46	1964.13	283585.60	507168.62
2+690.00	114.95	239.82	1099.49	2214.51	284685.09	509383.13
2+700.00	128.09	226.37	1215.23	2330.96	285900.32	511714.09
2+710.00	133.39	190.65	1307.42	2085.11	287207.74	513799.20
2+720.00	157.51	179.56	1454.49	1851.06	288662.22	515650.26
2+730.00	211.07	142.92	1842.90	1612.42	290505.13	517262.68
2+740.00	311.09	131.04	2610.84	1369.82	293115.96	518632.51
2+750.00	333.33	117.88	3222.14	1244.62	296338.10	519877.13
2+775.00	54.67	108.25	4850.09	2826.65	301188.19	522703.78
2+800.00	46.28	161.18	1261.98	3367.88	302450.17	526071.66
2+825.00	89.99	181.01	1703.40	4277.36	304153.57	530349.02
2+850.00	110.28	273.69	2503.31	5683.76	306656.88	536032.79
2+875.00	61.28	225.51	2144.47	6240.01	308801.35	542272.80
2+900.00	90.15	235.89	1892.87	5767.41	310694.22	548040.22

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
2+925.00	96.90	326.88	2338.05	7034.54	313032.27	555074.76
2+950.00	148.27	278.60	3064.59	7568.52	316096.86	562643.28
2+975.00	232.60	137.52	4760.90	5201.50	320857.75	567844.78
3+000.00	451.51	71.30	8551.40	2610.18	329409.15	570454.96
3+025.00	632.67	130.50	13552.25	2522.47	342961.40	572977.43
3+050.00	482.15	239.48	13935.23	4624.67	356896.63	577602.10
3+075.00	396.53	96.62	10983.45	4201.24	367880.08	581803.34
3+100.00	262.16	214.40	8233.58	3887.83	376113.66	585691.17
3+125.00	306.19	112.00	7104.43	4080.04	383218.08	589771.21
3+150.00	194.15	132.26	6254.26	3053.26	389472.34	592824.48
3+175.00	74.68	23.41	3360.37	1945.87	392832.72	594770.35
3+200.00	41.42	90.84	1451.27	1428.06	394283.99	596198.41
3+225.00	70.07	78.68	1393.57	2118.99	395677.56	598317.40
3+250.00	144.69	24.40	2684.51	1288.59	398362.07	599605.98
3+275.00	0.00	0.00	1808.69	305.05	400170.75	599911.04
3+300.00	0.00	0.00	0.00	0.00	400170.75	599911.04
3+325.00	0.00	0.00	0.00	0.00	400170.75	599911.04
3+350.00	0.00	0.00	0.00	0.00	400170.75	599911.04
3+375.00	0.00	0.00	0.00	0.00	400170.75	599911.04
3+400.00	149.32	126.84	1866.48	1585.54	402037.23	601496.58
3+425.00	54.09	301.08	2542.61	5349.03	404579.84	606845.61
3+450.00	135.91	305.52	2374.97	7582.51	406954.81	614428.12
3+475.00	160.20	298.47	3701.31	7549.93	410656.12	621978.04
3+500.00	95.42	192.89	3195.22	6142.00	413851.34	628120.05
3+525.00	111.22	98.13	2583.02	3637.74	416434.36	631757.79
3+550.00	206.77	27.28	3974.94	1567.67	420409.30	633325.45
3+575.00	330.15	0.00	6711.59	341.02	427120.89	633666.48
3+600.00	556.87	0.00	11087.75	0.00	438208.64	633666.48
3+625.00	781.78	12.81	16733.12	160.18	454941.76	633826.66
3+645.00	727.46	1.79	15092.45	146.03	470034.22	633972.68
3+655.00	680.04	0.00	7037.49	8.94	477071.71	633981.62
3+665.00	590.45	0.04	6352.41	0.21	483424.12	633981.83

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
3+675.00	436.75	5.41	5136.00	27.25	488560.12	634009.08
3+685.00	319.71	16.90	3782.34	111.55	492342.46	634120.64
3+695.00	194.35	55.68	2570.33	362.91	494912.79	634483.55
3+705.00	95.28	110.89	1448.18	832.84	496360.97	635316.39
3+720.00	33.13	208.03	939.45	2447.47	497300.42	637763.87
3+730.00	11.71	294.21	217.84	2576.63	497518.26	640340.49
3+740.00	3.18	343.55	72.22	3270.28	497590.48	643610.77
3+750.00	2.98	360.77	29.86	3609.93	497620.34	647220.70
3+760.00	15.20	336.08	88.21	3575.23	497708.55	650795.93
3+770.00	35.98	281.43	248.12	3170.61	497956.67	653966.55
3+780.00	56.32	218.79	447.55	2567.64	498404.22	656534.19
3+790.00	85.63	168.77	688.90	1989.05	499093.12	658523.24
3+800.00	132.39	135.63	1057.78	1563.41	500150.90	660086.65
3+810.00	222.58	91.41	1716.80	1167.55	501867.69	661254.20
3+820.00	260.20	53.41	2338.13	745.76	504205.82	661999.96
3+830.00	328.83	18.77	2864.27	372.12	507070.09	662372.07
3+840.00	392.41	3.01	3516.43	112.50	510586.52	662484.58
3+850.00	561.00	0.00	4674.53	15.56	515261.05	662500.14
3+860.00	550.21	0.00	5456.47	0.00	520717.51	662500.14
3+870.00	574.21	0.00	5516.42	0.00	526233.94	662500.14
3+880.00	565.11	0.00	5696.62	0.00	531930.55	662500.14
3+890.00	555.22	0.00	5601.64	0.00	537532.19	662500.14
3+900.00	530.74	0.00	5429.78	0.00	542961.97	662500.14
3+910.00	488.89	0.00	5098.11	0.00	548060.08	662500.14
3+920.00	426.02	0.00	4574.54	0.00	552634.63	662500.14
3+930.00	327.60	0.00	3768.10	0.00	556402.73	662500.14
3+940.00	192.83	0.00	2602.13	0.00	559004.86	662500.14
3+950.00	98.69	2.25	1457.58	11.24	560462.44	662511.38
3+975.00	0.00	85.90	1233.59	1101.83	561696.02	663613.21
4+000.00	0.00	198.56	0.00	3555.74	561696.02	667168.96
4+025.00	0.00	188.20	0.00	4834.51	561696.02	672003.47
4+050.00	1.54	114.04	19.22	3777.98	561715.24	675781.45

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
4+075.00	6.89	108.27	105.32	2778.86	561820.56	678560.31
4+100.00	0.00	176.22	86.11	3556.06	561906.67	682116.37
4+125.00	0.00	255.64	0.00	5398.20	561906.67	687514.57
4+150.00	0.00	304.81	0.00	7005.62	561906.67	694520.20
4+175.00	0.00	321.83	0.00	7832.99	561906.67	702353.19
4+200.00	0.00	323.66	0.00	8068.58	561906.67	710421.77
4+225.00	0.00	320.40	0.00	8050.67	561906.67	718472.44
4+250.00	0.00	315.27	0.00	7945.85	561906.67	726418.29
4+275.00	0.00	241.88	0.00	6964.32	561906.67	733382.61
4+300.00	0.00	94.06	0.00	4199.18	561906.67	737581.79
4+310.00	0.00	41.23	0.00	676.44	561906.67	738258.23
4+320.00	9.06	20.74	45.28	309.87	561951.95	738568.10
4+330.00	22.25	11.91	156.53	163.27	562108.48	738731.38
4+340.00	28.22	12.27	252.33	120.90	562360.80	738852.28
4+350.00	24.88	21.80	265.49	170.35	562626.29	739022.63
4+360.00	16.58	24.05	207.30	229.23	562833.59	739251.86
4+370.00	5.74	23.58	111.58	238.12	562945.17	739489.97
4+380.00	0.19	28.06	29.66	258.20	562974.84	739748.17
4+390.00	1.84	28.89	10.39	285.27	562985.22	740033.44
4+400.00	10.37	30.98	62.46	297.08	563047.68	740330.52
4+410.00	19.84	26.26	154.48	282.63	563202.16	740613.15
4+420.00	31.27	21.02	261.01	232.72	563463.17	740845.87
4+430.00	0.00	0.00	159.55	103.23	563622.72	740949.10
4+440.00	0.00	0.00	0.00	0.00	563622.72	740949.10
4+450.00	0.00	0.00	0.00	0.00	563622.72	740949.10
4+460.00	0.00	0.00	0.00	0.00	563622.72	740949.10
4+470.00	0.00	0.00	0.00	0.00	563622.72	740949.10
4+480.00	0.00	0.00	0.00	0.00	563622.72	740949.10
4+490.00	0.00	0.00	0.00	0.00	563622.72	740949.10
4+500.00	0.00	0.00	0.00	0.00	563622.72	740949.10
4+510.00	0.00	0.00	0.00	0.00	563622.72	740949.10
4+525.00	0.90	0.00	6.93	0.00	563629.65	740949.10

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
4+535.00	5.82	0.00	33.61	0.00	563663.26	740949.10
4+545.00	6.15	0.00	59.84	0.00	563723.10	740949.10
4+555.00	4.33	0.00	52.41	0.00	563775.51	740949.10
4+565.00	1.32	0.00	28.26	0.00	563803.76	740949.10
4+575.00	0.00	0.00	6.60	0.00	563810.37	740949.10
4+585.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+600.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+625.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+650.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+675.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+700.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+725.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+750.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+775.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+800.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+825.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+850.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+875.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+900.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+925.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+950.00	0.00	0.00	0.00	0.00	563810.37	740949.10
4+975.00	0.00	0.00	0.00	0.00	563810.37	740949.10
5+000.00	0.00	0.00	0.00	0.00	563810.37	740949.10
5+025.00	0.00	0.00	0.00	0.00	563810.37	740949.10
5+050.00	145.08	43.63	1813.49	545.40	565623.86	741494.50
5+075.00	192.58	57.16	4220.80	1259.90	569844.67	742754.40
5+100.00	43.46	106.90	2950.50	2050.76	572795.17	744805.16
5+125.00	2.17	375.09	570.30	6024.90	573365.46	750830.06
5+150.00	2.69	655.54	60.70	12882.85	573426.16	763712.91
5+175.00	2.02	874.54	58.81	19126.01	573484.97	782838.92
5+200.00	0.00	862.44	25.21	21712.25	573510.18	804551.17
5+225.00	0.00	613.85	0.00	18453.56	573510.18	823004.73

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
5+250.00	4.45	364.64	55.67	12231.16	573565.85	835235.89
5+275.00	27.43	205.89	398.56	7131.66	573964.41	842367.55
5+300.00	42.04	146.39	868.43	4403.48	574832.84	846771.03
5+325.00	52.15	100.10	1177.38	3081.11	576010.22	849852.14
5+350.00	35.62	114.37	1097.11	2680.91	577107.33	852533.04
5+375.00	35.77	96.86	892.37	2640.42	577999.70	855173.46
5+400.00	54.36	74.27	1126.60	2139.10	579126.30	857312.57
5+425.00	77.33	35.14	1646.16	1367.57	580772.46	858680.14
5+450.00	22.87	4.59	1252.51	496.59	582024.97	859176.73
5+475.00	0.00	0.00	285.86	57.38	582310.83	859234.11
5+500.00	0.00	0.00	0.00	0.00	582310.83	859234.11
5+525.00	0.00	0.00	0.00	0.00	582310.83	859234.11
5+550.00	0.00	0.00	0.00	0.00	582310.83	859234.11
5+575.00	0.00	0.00	0.00	0.00	582310.83	859234.11
5+600.00	37.52	25.45	469.04	318.13	582779.86	859552.24
5+625.00	0.00	229.81	469.04	3190.71	583248.90	862742.95
5+650.00	0.00	75.82	0.00	3820.35	583248.90	866563.30
5+660.00	44.27	0.90	221.34	383.60	583470.24	866946.91
5+670.00	157.31	0.00	1007.87	4.50	584478.11	866951.40
5+680.00	249.99	0.00	2036.48	0.00	586514.59	866951.40
5+690.00	280.47	0.00	2652.31	0.00	589166.90	866951.40
5+700.00	286.32	0.00	2833.97	0.00	592000.88	866951.40
5+710.00	260.59	0.00	2734.58	0.00	594735.46	866951.40
5+720.00	225.28	0.00	2429.35	0.00	597164.81	866951.40
5+730.00	190.86	0.00	2080.70	0.00	599245.50	866951.40
5+740.00	158.75	0.00	1768.05	0.00	601013.55	866951.40
5+750.00	126.22	0.00	1442.36	0.00	602455.91	866951.40
5+760.00	100.52	1.67	1149.69	8.06	603605.60	866959.47
5+770.00	89.58	9.39	965.70	53.53	604571.30	867012.99
5+780.00	89.51	11.91	910.83	103.14	605482.13	867116.13
5+790.00	80.33	18.08	864.55	145.27	606346.68	867261.40
5+800.00	56.04	45.21	681.85	316.44	607028.54	867577.85

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
5+810.00	33.84	127.81	449.39	865.11	607477.92	868442.96
5+820.00	10.69	196.42	222.67	1621.15	607700.60	870064.11
5+830.00	0.27	262.72	54.80	2295.72	607755.40	872359.83
5+840.00	0.00	295.46	1.34	2790.92	607756.73	875150.75
5+850.00	0.00	306.02	0.00	3007.39	607756.73	878158.14
5+860.00	0.00	391.77	0.00	3488.93	607756.73	881647.07
5+870.00	0.00	455.13	0.00	4234.50	607756.73	885881.57
5+875.00	0.00	0.00	0.00	1137.83	607756.73	887019.39
5+900.00	0.00	0.00	0.00	0.00	607756.73	887019.39
5+925.00	0.00	0.00	0.00	0.00	607756.73	887019.39
5+950.00	0.00	0.00	0.00	0.00	607756.73	887019.39
5+975.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+000.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+025.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+050.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+075.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+100.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+125.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+150.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+175.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+200.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+225.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+250.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+275.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+300.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+325.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+350.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+375.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+400.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+425.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+450.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+475.00	0.00	0.00	0.00	0.00	607756.73	887019.39

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
6+500.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+525.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+550.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+575.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+600.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+625.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+650.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+675.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+700.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+725.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+750.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+775.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+800.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+825.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+840.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+860.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+880.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+900.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+920.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+940.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+960.00	0.00	0.00	0.00	0.00	607756.73	887019.39
6+980.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+000.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+020.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+040.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+060.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+080.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+100.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+120.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+140.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+160.00	0.00	0.00	0.00	0.00	607756.73	887019.39
7+180.00	0.00	0.00	0.00	0.00	607756.73	887019.39

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
7+200.00	0.00	558.29	0.00	5538.94	607756.73	892558.33
7+220.00	50.29	26.24	515.33	5795.71	608272.06	898354.04
7+240.00	274.42	18.55	3326.75	436.28	611598.82	898790.32
7+260.00	104.21	182.31	3881.97	1951.65	615480.78	900741.98
7+275.00	2.28	279.88	817.60	3389.33	616298.38	904131.31
7+290.00	0.77	387.97	23.34	4935.64	616321.72	909066.95
7+305.00	0.10	512.01	6.50	6749.87	616328.22	915816.82
7+320.00	0.00	615.53	0.73	8456.56	616328.95	924273.38
7+335.00	0.00	705.30	0.00	9906.24	616328.95	934179.62
7+350.00	0.00	785.80	0.00	11183.28	616328.95	945362.90
7+375.00	0.00	1216.33	0.00	25026.64	616328.95	970389.54
7+400.00	14.93	1390.23	186.64	32582.04	616515.59	1002971.59
7+425.00	0.00	692.80	186.64	26037.95	616702.23	1029009.54
7+450.00	92.78	13.24	1159.81	8825.47	617862.03	1037835.01
7+475.00	164.50	22.10	3216.10	441.71	621078.14	1038276.72
7+500.00	104.73	122.27	3365.43	1804.59	624443.57	1040081.31
7+525.00	47.98	252.31	1908.88	4682.26	626352.44	1044763.56
7+550.00	42.08	444.71	1125.74	8712.75	627478.18	1053476.31
7+575.00	33.88	350.66	949.48	9942.01	628427.65	1063418.33
7+600.00	70.58	177.62	1305.72	6603.41	629733.37	1070021.74
7+625.00	175.97	56.35	3081.90	2924.66	632815.27	1072946.39
7+650.00	0.00	0.00	2199.67	704.44	635014.94	1073650.83
7+675.00	0.00	0.00	0.00	0.00	635014.94	1073650.83
7+700.00	0.00	0.00	0.00	0.00	635014.94	1073650.83
7+725.00	0.00	0.00	0.00	0.00	635014.94	1073650.83
7+750.00	0.00	0.00	0.00	0.00	635014.94	1073650.83
7+775.00	0.00	0.00	0.00	0.00	635014.94	1073650.83
7+800.00	61.34	0.00	766.81	0.00	635781.74	1073650.83
7+825.00	103.94	224.26	2066.05	2803.19	637847.79	1076454.02
7+850.00	194.39	324.77	3729.05	6862.76	641576.84	1083316.78
7+875.00	245.67	291.90	5500.71	7708.32	647077.55	1091025.10
7+900.00	287.30	309.51	6662.08	7517.63	653739.64	1098542.73

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
7+925.00	361.51	71.60	8110.03	4763.84	661849.67	1103306.57
7+950.00	389.18	28.17	9383.58	1247.04	671233.25	1104553.61
7+975.00	232.48	166.11	7770.70	2428.48	679003.95	1106982.09
8+000.00	91.44	304.08	4049.02	5877.40	683052.97	1112859.49
8+020.00	35.98	432.98	1274.25	7370.58	684327.22	1120230.07
8+040.00	4.44	548.57	404.25	9815.47	684731.46	1130045.54
8+060.00	1.45	534.28	58.93	10828.49	684790.39	1140874.02
8+080.00	0.18	245.88	16.30	7801.57	684806.69	1148675.59
8+100.00	0.00	0.00	1.81	2458.78	684808.50	1151134.37
8+120.00	0.00	0.00	0.00	0.00	684808.50	1151134.37
8+140.00	0.00	0.00	0.00	0.00	684808.50	1151134.37
8+160.00	0.00	0.00	0.00	0.00	684808.50	1151134.37
8+180.00	0.00	0.00	0.00	0.00	684808.50	1151134.37
8+200.00	0.00	0.00	0.00	0.00	684808.50	1151134.37
8+225.00	37.32	71.72	466.48	896.47	685274.99	1152030.84
8+250.00	0.00	415.66	466.48	6092.28	685741.47	1158123.12
8+275.00	0.00	920.09	0.00	16696.97	685741.47	1174820.09
8+300.00	0.00	952.08	0.00	23402.21	685741.47	1198222.30
8+325.00	0.00	838.83	0.00	22386.43	685741.47	1220608.72
8+350.00	0.20	716.13	2.55	19436.99	685744.02	1240045.71
8+375.00	0.02	698.28	2.79	17680.10	685746.81	1257725.81
8+390.00	1.09	621.66	8.29	9899.52	685755.10	1267625.34
8+405.00	6.05	541.30	53.54	8722.21	685808.63	1276347.55
8+420.00	16.85	400.07	171.78	7060.33	685980.41	1283407.88
8+435.00	50.05	191.65	501.80	4437.95	686482.21	1287845.82
8+450.00	147.26	0.00	1456.09	1459.37	687938.30	1289305.20
8+465.00	452.55	0.00	4439.49	0.00	692377.79	1289305.20
8+480.00	495.77	0.00	7028.19	0.00	699405.98	1289305.20
8+490.00	363.19	0.00	4250.21	0.00	703656.18	1289305.20
8+500.00	180.02	0.00	2691.54	0.00	706347.72	1289305.20
8+510.00	66.79	2.29	1222.37	11.82	707570.09	1289317.02
8+520.00	26.99	29.78	460.88	164.58	708030.98	1289481.60

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
8+530.00	11.76	48.47	189.43	400.90	708220.41	1289882.50
8+540.00	5.89	61.63	86.05	563.10	708306.46	1290445.60
8+550.00	6.32	57.73	59.48	609.64	708365.94	1291055.24
8+560.00	11.54	45.68	87.16	528.45	708453.10	1291583.69
8+570.00	33.21	16.07	219.06	316.41	708672.16	1291900.10
8+580.00	127.09	0.00	791.58	82.63	709463.74	1291982.73
8+590.00	202.12	0.00	1631.24	0.00	711094.98	1291982.73
8+600.00	201.15	0.00	2000.02	0.00	713095.00	1291982.73
8+610.00	108.88	10.34	1532.35	53.32	714627.35	1292036.05
8+620.00	12.22	88.80	594.17	507.35	715221.52	1292543.41
8+630.00	0.00	151.40	59.51	1223.89	715281.03	1293767.30
8+640.00	0.23	188.85	1.12	1726.27	715282.15	1295493.57
8+650.00	0.00	186.56	1.12	1901.05	715283.27	1297394.62
8+660.00	0.16	159.73	0.78	1755.21	715284.05	1299149.83
8+670.00	0.00	134.36	0.78	1493.16	715284.83	1300642.99
8+680.00	0.01	92.60	0.04	1155.44	715284.87	1301798.43
8+690.00	4.79	60.55	23.39	782.46	715308.26	1302580.89
8+700.00	16.66	31.31	107.25	459.30	715415.51	1303040.18
8+710.00	34.73	13.66	256.92	224.86	715672.43	1303265.05
8+720.00	66.01	6.87	503.69	102.67	716176.12	1303367.71
8+730.00	97.11	5.98	815.60	64.27	716991.71	1303431.98
8+740.00	133.24	2.20	1151.73	40.91	718143.44	1303472.89
8+750.00	196.58	0.00	1649.11	11.00	719792.55	1303483.89
8+760.00	366.90	0.00	2817.43	0.00	722609.98	1303483.89
8+775.00	471.50	0.00	6288.05	0.00	728898.03	1303483.89
8+800.00	145.22	0.00	7709.10	0.00	736607.13	1303483.89
8+825.00	12.85	45.96	1975.94	574.51	738583.07	1304058.40
8+850.00	0.92	90.88	172.13	1710.49	738755.20	1305768.89
8+875.00	0.84	106.14	22.03	2462.78	738777.23	1308231.67
8+900.00	2.72	95.32	44.50	2518.33	738821.73	1310750.00
8+925.00	1.67	100.01	54.86	2441.62	738876.59	1313191.62
8+950.00	0.48	107.06	26.86	2588.36	738903.45	1315779.98

Total Earthwork Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
8+975.00	0.00	119.62	5.97	2833.57	738909.42	1318613.56
9+000.00	2.52	63.25	31.49	2285.93	738940.90	1320899.49
9+025.00	0.00	0.00	31.49	790.63	738972.39	1321690.11
9+050.00	0.00	0.00	0.00	0.00	738972.39	1321690.11
9+075.00	0.00	0.00	0.00	0.00	738972.39	1321690.11
9+100.00	0.00	0.00	0.00	0.00	738972.39	1321690.11
9+125.00	0.00	0.00	0.00	0.00	738972.39	1321690.11
9+150.00	0.00	0.00	0.00	0.00	738972.39	1321690.11
9+175.00	16.39	65.48	204.84	818.49	739177.23	1322508.61
9+200.00	52.25	61.66	857.92	1589.21	740035.16	1324097.82
9+225.00	12.48	97.98	809.05	1995.48	740844.21	1326093.30
9+250.00	3.14	107.28	195.19	2565.74	741039.39	1328659.03
9+275.00	0.24	98.89	42.19	2577.04	741081.58	1331236.08
9+300.00	10.82	99.84	138.18	2484.12	741219.76	1333720.20
9+325.00	17.58	116.46	354.98	2703.76	741574.75	1336423.95
9+350.00	9.51	178.04	338.69	3681.18	741913.43	1340105.14
9+375.00	14.79	210.00	303.74	4850.52	742217.17	1344955.66
9+400.00	36.94	252.47	646.56	5780.90	742863.74	1350736.56
9+425.00	12.25	301.59	614.91	6925.69	743478.64	1357662.25
9+450.00	224.25	359.43	2956.33	8262.74	746434.97	1365924.99
9+475.00	324.94	233.26	6864.97	7408.71	753299.94	1373333.70
9+493.18	348.08	133.49	6119.05	3334.53	759418.99	1376668.22

<u>APPENDIX 3</u> Permission Letter of Directorate of Roads and Bridges \ Erbll-Iraq