# Development ofIntegrated BIM-Based Highway Alignment Planning and Optimization Framework

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This is to certify that the thesis entitled

# Developmentof Integrated BIM-BasedHighway Alignment Planning and Optimization Framework

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A thesis submitted in partial fulfillment of the requirement for the degree of

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# ABSTRACT

Efficient transportation infrastructure is vital for economic development and societal progress. Highway alignment optimization is a critical aspect of enhancing transportation networks, as it directly impacts traffic flow, congestion levels and overall road network efficiency. Traditionally, highway alignment selection has relied on conventional methods, such as manual surveys, heuristic decision-making and limited digital tools. However, these practices often face significant challenges, including suboptimal alignments, higher construction costs, environmental degradation and stakeholder conflicts due to limited collaboration and transparency during the planning process.

A significant challenge in highway projects is the occurrence of conflicts among various stakeholders, including engineers, urban planners, environmentalists and local communities. In this regard, the BIM-based system may serve as a platform for transparent communication and informed decision-making, facilitating conflict resolution and stakeholder engagement. Through transparent communication and informed decision-making processes facilitated by the BIM system, conflicts can be resolved efficiently, leading to smoother project execution and stakeholder satisfaction.

This research proposes the optimization of highway alignment usingBuilding Information Modeling (BIM) technology.The study aims to develop a BIM-based system that integrates various data sources, design parameters and analysis tools for highway planning and design. Through this system, the effectiveness of BIM technology in optimizing highway alignment can be evaluated, considering factors such as travel time reduction, congestion alleviation and safety enhancement.

Furthermore, this research evaluates the technical and financial implications of implementing the BIM-based system for alignment optimization compared to conventional practices. By considering safety parameters, environmental factors and cost-effectiveness, the study aims to demonstrate the advantages of utilizing BIM technology in highway alignment optimization.

The results of the case study revealed that the optimized alignment achieved a 30% reduction in congestion and a 20% improvement in travel times compared to

conventional alignments. Additionally, the selected alignment demonstrated superior geometric compliance, cost-efficiency and minimal environmental disruption, achieving a 10.7% reduction in construction costs. These outcomes highlight the significant advantages of using BIM technology for highway alignment optimization, particularly in achieving a balance between technical, economic and environmental objectives.

Overall, this research demonstrates the transformative potential of BIM in transportation infrastructure planning, offering a scalable and sustainable methodology for optimizing highway alignment. The findings from the Dera Ghazi Khan Northern Bypass case study underscore the efficacy of BIM-based approaches in addressing the complexities of modern highway projects and advancing infrastructure development.

# DEDICATION

We humbly dedicate this work to our beloved and supportive parents, whose unwavering love, sacrifices and prayers have been the foundation of our journey. Their selflessness, patience and trust in us have been the driving force behind every milestone we have achieved. This success is a testament to their dedication and belief in our abilities and we are forever grateful for their endless encouragement and faith.

We also extend our heartfelt tribute to our honorable teachers, who have been a source of guidance and inspiration throughout our academic journey. Their wisdom and mentorship have equipped us with the patience, courage and resilience to face the challenges of life and achieve our goals.

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| *ACI* | = | American Concrete Institute |
| *ASTM* | = | American standards of testing and materials |
| *BIM* | = | Building Information Modelling |
| *AASHTO* | = | American Association of State Highway and Transportation Officials |
| *AADT* | = | Average Annual Daily Traffic |
| *CPEC* | = | China-Pakistan Economic Corridor |
| *EIA* | = | Environmental Impact Assessment |
| *ESAL* | = | Equivalent Single Axle Load |
| *GIS* | = | Geographic Information System |
| *GPS* | = | Global Positioning System |
| *LOS* | = | Level of Service |
| *NHA* | = | National Highway Authority |
| *O&D* | = | Origin and Destination |
| *ROW* | = | Right of Way |
| *VOC* | = | Vehicle Operating Cost |
| *RCC* | = | Reinforced Cement Concrete |
| *N-55* | = | Indus Highway |
| *N-70* | = | National Highway 70 |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background and Significance

Highway infrastructure plays a pivotal role in a nation's security, economy and overall well-being. Efficient and reliable mobility of citizens and goods is essential for social and economic development. One critical aspect of highway planning is selecting an optimal alignment. However, this process is often complex and time-consuming, involving comprehensive assessments of various factors such as cost and environmental impact [1].

The traditional approach to highway planning and design often involves the use of 2D drawings and manual processes, which are inherently limited in their ability to capture the complexities of the built environment. These conventional methods often result in suboptimal outcomes, characterized by inefficiencies, cost overruns and environmental degradation. Moreover, the lack of interoperability between different design software further exacerbates these challenges, leading to disjointed workflows and compromised project outcomes[2].

In response to these shortcomings, the integration of Building Information Modeling (BIM) technology has emerged as a transformative force in highway planning and design. BIM facilitates the creation of comprehensive digital models that encompass both the physical and functional characteristics of infrastructure assets[3]. By centralizing project data within a cohesive digital environment, BIM enables stakeholders to collaborate more effectively, make informed decisions and optimize project outcomes across the entire lifecycle of a highway project[4].

## 1.2 Significance of BIM in Highway Planning

Building Information Modeling (BIM) stands as a transformative force in highway planning and design, reshaping traditional methodologies and offering a host of benefits across the project lifecycle. Its significance is profound, touching upon various aspects crucial to the success of transportation infrastructure projects.

One key aspect of BIM lies in its capacity for comprehensive data integration. By amalgamating geometric, spatial, temporal and attribute data into a centralized digital model, BIM provides a holistic view of highway infrastructure. This wealth of information empowers stakeholders to make better-informed decisions, leading to optimized project outcomes.

Moreover, BIM fosters a collaborative environment wherein multidisciplinary project teams, including engineers, architects, urban planners and other stakeholders, can seamlessly work together. Breaking down silos and promoting cross-disciplinary communication, BIM ensures alignment towards common objectives, ultimately enhancing project efficiency and integration.

The visualization and simulation capabilities of BIM are equally significant. Through virtual modeling, stakeholders can explore various design alternatives, assess their impacts and make informed decisions prior to construction. This proactive approach aids in identifying potential issues early on, reducing risks and minimizing costly changes during the construction phase.

Furthermore, BIM facilitates improved coordination and clash detection by overlaying different design elements and identifying potential conflicts. This proactive approach helps prevent errors and inconsistencies, leading to smoother construction processes and fewer delays.

Data-driven decision-making is another critical aspect of BIM. By providing access to real-time data and analytics, BIM empowers stakeholders to make informed decisions throughout the project lifecycle. Analyzing key performance indicators and monitoring project progress in real-time enables stakeholders to identify optimization opportunities and respond promptly to changes or disruptions.

BIM also enhances communication and stakeholder engagement by providing visual representations of the project that are easy to understand and interpret. This fosters transparency and trust among project stakeholders, including government agencies, local communities and the general public[5].

## 1.3 Research Objectives

### 1.3.1 Development of a BIM-Based System for Highway Planning and Design:

Develop and implement a comprehensive Building Information Modeling (BIM) system tailored for highway planning and design, integrating diverse data sources, geometric parameters and analytical tools.

Establish standardized workflows and protocols to streamline data exchange, enhance collaboration among stakeholders and facilitate informed decision-making throughout the project lifecycle.

Leverage BIM's visualization and modeling capabilities to identify optimization opportunities and address complex challenges in transportation infrastructure development.

### 1.3.2 Evaluation of System Effectiveness in Highway Alignment Optimization:

Utilize the developed BIM-based system to evaluate and compare multiple highway alignment alternatives through a systematic and data-driven approach.Analyze key performance metrics such as traffic flow, travel time, road safety and environmental sustainability to assess the effectiveness of the proposed system in optimizing highway alignments.

Conduct simulation and scenario analyses within the BIM platform to quantify the benefits of optimized alignments in enhancing infrastructure quality and socio-economic outcomes.

### 1.3.3 Assessment of Technical and Financial Implicationsof BIM-Based Approaches:

Perform a comprehensive evaluation of the technical feasibility and scalability of the BIM-based system for highway alignment optimization across varying project conditions and complexities.

Identify potential technical challenges and limitations, including data integration, interoperability and model accuracy and propose solutions to overcome them. Conduct a comparative cost-benefit analysis of BIM-based methodologies versus traditional approaches to highway alignment, considering factors such as initial implementation costs, lifecycle maintenance expenses and long-term cost savings.

### 1.3.4 Advancement of Highway Planning Methodologies through BIM Integration

Explore the potential of BIM technology as a transformative tool for modernizing highway planning and design methodologies, advancing the state of the art in transportation infrastructure development.

Provide valuable insights and recommendations for decision-makers, engineers and planners on how to integrate BIM into infrastructure projects to improve efficiency, sustainability and stakeholder collaboration.

By pursuing these research objectives, the study aims to advance state-of-the-art highway planning and design methodologies, demonstrate the practical applicability of BIM technologies in infrastructure projects and provide valuable insights for decision-makers, engineers and other stakeholders involved in the development of the Dera Ghazi Khan Northern Bypass and similar infrastructure initiatives.

## 1.4 Problem Statement

Efficient highway alignment is a critical component of sustainable transportation infrastructure, directly influencing traffic flow, road safety, environmental sustainability and socio-economic development. However, traditional methods of highway alignment planning are often constrained by fragmented data, limited stakeholder collaboration and the lack of integrated tools for evaluating complex, competing considerations. These challenges frequently result in suboptimal alignments that fail to address critical issues such as congestion, safety risks and environmental impacts while falling short of aligning with long-term growth projections and international standards.

Highway alignment selection is inherently a multifaceted problem that must account for a wide array of parameters, including topographical constraints, land use patterns, environmental sensitivities and cultural heritage preservation. The process also requires balancing competing stakeholder interests, such as minimizing land acquisition impacts while ensuring that the alignment supports future urban and industrial development. Furthermore, the alignment design must integrate seamlessly with existing transportation networks, accommodate technological advancements and adhere to safety and operational standards to optimize its functionality and sustainability.

In this context, the absence of a systematic, data-driven and collaborative approach exacerbates the complexities associated with highway alignment selection. Traditional practices rely heavily on isolated analyses and manual decision-making processes, which often fail to capture the interplay between technical, economic and environmental factors. This leads to inefficiencies, increased project costs and significant delays in implementation.

To address these challenges, this research proposes the development and implementation of an integrated Building Information Modeling (BIM)-based approach for highway alignment optimization. BIM offers a comprehensive platform for data integration, visualization and simulation, enabling planners and engineers to evaluate multiple alignment options with greater precision and collaboration. The proposed approach incorporates advanced modeling tools to analyze critical parameters such as traffic flow, geometric design, environmental impacts and cost-effectiveness.

By leveraging BIM technology, this study aims to overcome the limitations of traditional highway alignment practices, providing a more transparent and data-driven framework for decision-making. This approach not only facilitates the optimization of highway alignment but also enhances stakeholder collaboration, ensures compliance with international design standards and promotes sustainable infrastructure development.

The central problem addressed in this research revolves around the design and implementation of a BIM-based system that can evaluate and optimize highway alignment alternatives, with the aim of creating efficient, safe and environmentally sustainable road networks. By addressing this problem, the study seeks to advance highway planning methodologies and provide actionable insights for the development of modern transportation infrastructure.

## 1.5 Significance of the Research

### 1.5.1 Enhanced Efficiency and Traffic Management:

Optimizing highway alignment through BIM technology ensures that road networks are designed to maximize efficiency, leading to reduced travel times, decreased congestion and improved overall traffic flow. This significantly enhances the commuting experience for travelers and facilitates smoother movement of goods and services, benefiting both individuals and businesses.

### 1.5.2 Conflict Resolution and Stakeholder Engagement:

Highway projects often face conflicts among stakeholders with diverse interests and concerns. The BIM-based system serves as a neutral platform, offering data-driven insights and simulations that aid in resolving conflicts. By fostering transparent communication and informed decision-making processes, the system facilitates effective collaboration among engineers, urban planners, environmentalists and local communities.

### 1.5.3 Streamlined Decision-Making Processes:

The proposed system streamlines decision-making processes by providing real-time simulations and visualizations of proposed highway alignments. Stakeholders can interact with the models, gaining a deeper understanding of project implications and providing more precise feedback. This leads to faster project approvals and accelerates project execution timelines.

#### 1.5.4 Prioritization of Safety Parameters:

By considering safety parameters in alignment optimization, the research contributes to the development of road networks that prioritize the well-being of commuters. The optimized alignments aim to reduce accidents and enhance overall safety standards, promoting safer travel experiences for road users.

#### 1.5.5 Cost-Effective Construction and Resource Optimization:

The optimized alignments generated by the BIM-based system result in cost-effective construction practices. By minimizing land use, material wastage and construction complexities, the system optimizes resource utilization, leading to significant cost savings for infrastructure projects. This ensures efficient allocation of budgetary resources and maximizes the impact of infrastructure investments.

Overall, the research on optimizing the alignment of the Dera Ghazi Khan Northern Bypass using BIM technology holds significant implications for improving transportation infrastructure, fostering sustainable development and enhancing the quality of life for communities in the region.

### 1.6 Case Study of Dera Ghazi Khan Northern Bypass

In the rapidly evolving landscape of infrastructure development in Pakistan, the imperative to enhance connectivity, streamline transportation networks and promote economic growth has emerged as a pivotal priority for governmental authorities. Among the myriad projects aimed at addressing these imperatives, the Construction of Dera Ghazi Khan Northern Bypass stands as a testament to the concerted efforts of the Government of Pakistan (GOP) and the National Highway Authority (NHA) to alleviate congestion, enhance regional connectivity and foster socio-economic development in Southern Punjab.

Dera Ghazi Khan, a bustling city at the crossroads of Indus Highway (N-55) and National Highway (N-70), occupies a strategic position as a gateway to four provinces of Pakistan. However, this strategic advantage has been marred by persistent traffic congestion issues, particularly along the arterial route of N-70, which traverses through the heart of the city. Compounded by the presence of stone crushing plants and a prominent cement factory, the congestion not only impedes the smooth flow of traffic but also poses safety hazards and hampers economic activities vital to the region's prosperity.

In response to these challenges, the Government of Pakistan, mindful of the pivotal role of robust infrastructure in fostering economic growth, initiated the Construction of Dera Ghazi

Khan Northern Bypass project. Envisioned as a critical intervention to redirect through traffic away from the urban core, the bypass aims to enhance mobility, reduce congestion and unlock the region's socio-economic potential.

The case study presented herein revolves around the pressing transportation challenges faced by Dera Ghazi Khan (D.G. Khan) city, a pivotal junction situated at the convergence of Indus Highway (N-55) and National Highway (N-70) in Pakistan. This study delves into the intricacies of highway planning and design, focusing on the development of an integrated BIM-based system to address the chronic traffic congestion plaguing the region.

### 1.6.1 Route Alignment of Dera Ghazi Khan Northern Bypass:

The Dera Ghazi Khan Northern Bypass project is a critical infrastructure initiative aimed at alleviating traffic congestion and enhancing regional connectivity in the Dera Ghazi Khan district of Punjab, Pakistan. Situated at the intersection of National Highway N-70 and Indus Highway N-55, Dera Ghazi Khan serves as a vital transportation hub, facilitating the movement of goods and passengers between various regions of Pakistan.

The proposed route alignment of the Dera Ghazi Khan Northern Bypass traverses through diverse terrain, presenting both opportunities and challenges for the project. The alignment planning process involves careful consideration of numerous factors, including topography, land use patterns, existing infrastructure, environmental sensitivities and socio-economic impacts.

One of the primary objectives of the alignment design is to provide a seamless connection between National Highway N-70 and Indus Highway N-55 while bypassing the congested urban center of Dera Ghazi Khan city. This strategic routing not only enhances traffic flow efficiency but also minimizes disruptions to local communities and businesses.

In addition to addressing traffic congestion, the alignment design prioritizes safety, sustainability and resilience. Engineers and planners must navigate through agricultural lands, water channels, built-up areas and intersecting infrastructure such as railways and roads while minimizing environmental impacts and optimizing the overall performance of the roadway.

Key considerations in the alignment design process include:

- **Geometric Standards:** Adherence to established geometric standards ensures optimal alignment geometry, including curvature, gradient and cross-section profiles. These standards are essential for accommodating high-speed traffic while maintaining safety and comfort for road users.

- **Hydrological Challenges:** The project must address hydrological challenges posed by water channels, canals and drainage patterns in the area. Effective drainage design, culvert placement and flood mitigation measures are critical for ensuring the long-term durability and resilience of the roadway.
- **Environmental Impact:** Environmental considerations play a significant role in alignment design, with measures taken to minimize habitat disruption, soil erosion and water pollution. Environmental impact assessments guide decision-making, ensuring compliance with regulatory requirements and sustainability objectives.
- **Community Engagement:** Engaging with local communities and stakeholders is essential for gathering input, addressing concerns and building support for the project. Public consultation processes facilitate transparency, inclusivity and accountability in alignment decision-making.
- Integration with Existing Infrastructure: The alignment design must seamlessly integrate with existing infrastructure, including roads, railways, utilities and urban developments.

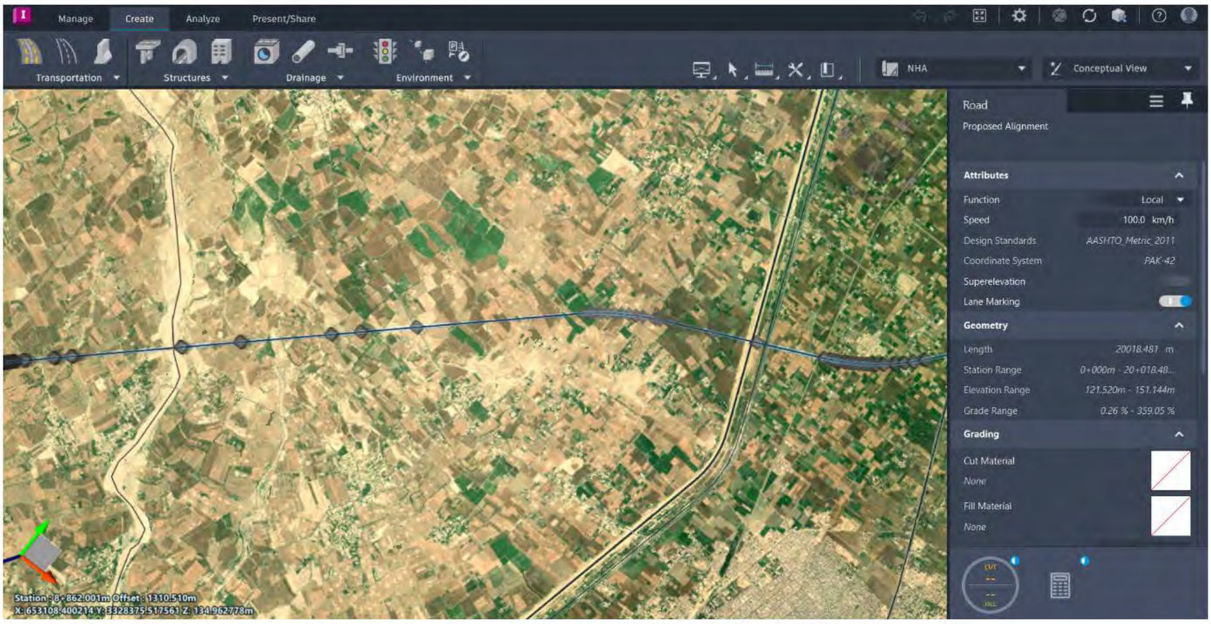
### 1.6.2 Utilizing InfraWorks Software for Alignment Optimization:

InfraWorks software offers advanced capabilities for analyzing and optimizing route alignments in transportation infrastructure projects. By leveraging InfraWorks, it is possible to streamline the alignment design process, evaluate multiple options and assess their impact on various project parameters.

- **Data Integration and Visualization:** InfraWorks enables the integration of geospatial data, including topographic surveys, satellite imagery and cadastral information, allowing users to visualize the project area in a comprehensive 3D environment. This facilitates better understanding of the terrain, existing infrastructure and potential constraints for route alignment.
- **Alignment Alternatives:** InfraWorks empowers users to generate multiple alignment alternatives quickly and efficiently. By adjusting parameters such as alignment geometry, curvature and vertical profiles, engineers can explore different routing options and evaluate their suitability based on project objectives and constraints.
- **Geospatial Analysis**: InfraWorks provides powerful geospatial analysis tools for assessing alignment options in relation to terrain characteristics, land use patterns,

environmental features and socio-economic factors. This analytical capability enables informed decision-making and optimization of alignment designs.

- **Visualization and Simulation:** InfraWorks facilitates the creation of visualizations and simulations to communicate alignment proposals effectively to stakeholders and decision-makers. By generating realistic renderings, animations and interactive models, project teams can solicit feedback, assess visual impacts and enhance public engagement.
- **Optimization and Iteration:** InfraWorks supports iterative refinement of alignment designs through rapid prototyping and scenario testing. Engineers can iteratively adjust alignment parameters, evaluate design alternatives and optimize alignment configurations to achieve desired project outcomes, such as minimizing construction costs, reducing environmental impact, or improving traffic flow efficiency.




By leveraging the advanced capabilities of InfraWorks software, the alignment optimization process for the Dera Ghazi Khan Northern Bypass project can be significantly enhanced, leading to the selection of an optimized alignment that maximizes project benefits while

Figure 1: Interface of InfraWorks Software

addressing various constraints and considerations.

# CHAPTER 2

# LITERATURE REVIEW

The integration of Building Information Modeling (BIM) technology in the field of civil engineering has marked a transformative shift in the way infrastructure projects are conceptualized, designed and executed. The application of BIM in highway planning and design processes has gained significant attention due to its potential to enhance efficiency, accuracy and collaboration.

## 2.1 Role of BIM in Construction Industry

Building Information Modeling (BIM) has emerged as a transformative technology in the Construction industry, revolutionizing the way projects are planned, designed, constructed and managed. The research conducted by Azhar et al. (2012) in the Australasian Journal of Construction Economics and Building delves into the concept of BIM, its applications, benefits, risks and future prospects. From a technological standpoint, BIM is defined as a project simulation comprising 3D models of project components interconnected with relevant information related to planning, design, construction and operation. Unlike traditional 3D CAD models, BIM incorporates intelligent contextual semantics, defining building elements and systems to facilitate a more comprehensive understanding of the project. The parametric nature of BIM allows for dynamic adjustments, ensuring that modifications in one element automatically update related components, thereby reducing errors and enhancing documentation quality [6].

One of the key advantages of BIM lies in its ability to foster collaboration and integration among project stakeholders. By providing a centralized platform for sharing information and coordinating activities, BIM promotes a more cohesive project delivery process. Integrated Project Delivery (IPD) is a concept supported by BIM, emphasizing collaborative efforts to optimize efficiency and minimize waste throughout the project lifecycle [7].

Real-world examples demonstrate the tangible benefits of BIM implementation. In a case study involving a higher education facility project at Savannah State University, BIM technology-facilitated collaboration between the general contractor, architect and owner during the schematic design phase. By creating virtual models of different design options and conducting cost estimates using BIM, the owner was able to make an informed decision that resulted in significant cost savings and expedited decision-making processes [8].

## 2.2 BIM in Remote Construction Projects

Building Information Modelling (BIM) is instrumental in overcoming challenges faced in remote construction projects. By facilitating improved communication, precise resource monitoring and accurate modelling, BIM addresses issues such as procurement management, scheduling accuracy and stakeholder collaboration. The adoption of BIM, supported by an action research approach, emphasizes experiential learning and collaboration, impacting various facets of project management. Overall, BIM implementation in remote construction projects enhances collaboration, efficiency and quality, reshaping the landscape of the construction industry [9].

Through its ability to streamline processes, enhance communication and foster shared understanding among stakeholders, BIM serves as a transformative tool in remote construction settings. By leveraging BIM's capabilities for accurate modeling, resource management and stakeholder engagement, construction projects can achieve increased productivity, efficiency and quality outcomes. The research underscores the significance of BIM adoption in remote contexts, highlighting its potential to revolutionize project management practices and drive innovation in the construction industry [10].

Building Information Modelling (BIM) has revolutionized the construction industry by providing a digital platform for stakeholders to collaborate effectively and optimize design decisions in infrastructure projects. Research indicates that BIM enhances efficiency, reduces errors and leads to cost savings by enabling visualization of projects in a virtual environment, thereby streamlining the construction process. Despite its benefits, challenges such as interoperability issues and high implementation costs exist, underscoring the need for continued research and development to maximize the potential of BIM in infrastructure projects [11].

The growing body of literature on BIM application in infrastructure projects highlights its significant impact on project outcomes and stakeholder collaboration. While barriers to adoption persist, ongoing efforts aim to address these challenges and further advance the utilization of BIM in the construction sector, emphasizing the importance of active publication of research results to showcase advancements in BIM integration [12].

## 2.3 BIM Integration with Emerging Technologies

The literature review by Jorge Jerez Cepa and team explores the integration of Building Information Modeling (BIM) with emerging technologies in the construction industry, particularly focusing on Smart Construction (SC) and Facility Management (FM) phases. By analyzing over 200 references, the study emphasizes the importance of Information and Communication Technologies (ICTs) such as Geographic Information System (GIS), Internet of Things (IoT) and Big Data in enhancing the efficacy of BIM in infrastructure projects. The systematic categorization of articles based on infrastructure types and ICTs provides valuable insights into the trends and advancements in the joint utilization of BIM and ICTs, highlighting the potential for improved project lifecycle management [13].

Through a comprehensive analysis of the interconnectedness of keywords and concepts using VOS viewer, the study underscores the significance of BIM, Construction Industry, Lifecycle and IoT in driving innovation and efficiency in construction projects[14]. The visualization of bibliometric networks showcases the relationships between key terms, offering a holistic view of the evolving landscape of BIM implementation in operation maintenance and transport infrastructure.

Overall, the review provides a roadmap for future research endeavors aimed at leveraging the synergies between BIM and emerging technologies to enhance project outcomes and promote sustainable practices in the construction industry [15].

### 2.4 Enhancing Highway Projects through BIM Adoption

Building Information Modelling (BIM) Integration and Benefits In the construction industry, BIM has revolutionized project planning, design, construction and maintenance, offering standardized processes. BIM's application in highway projects provides advantages like improved visualization, clash detection and decision-making during design. However, the limited adoption of BIM in Malaysia's highway industry is hindered by challenges such as high software costs and insufficient government promotion [16].

Overcoming Barriers for Consultants and Driving Efficiency Consultants in the highway sector can leverage BIM to streamline design processes, enhance collaboration and optimize project efficiency. Addressing challenges like limited awareness and expertise is essential to fully harness BIM's potential in Malaysian highway projects. By embracing BIM and overcoming adoption barriers, consultants can drive innovation, elevate industry standards and enhance project outcomes in highway construction [16].

### 2.5 Integration of BIM in Road Infrastructure Design:

Building Information Modeling (BIM) has revolutionized the Architecture, Engineering and Construction (AEC) industry by enabling the creation of detailed 3D models for road infrastructures through parametric modeling and industry standards like Industry Foundation Classes (IFC). The integration of BIM with procedural modeling tools enhances the design process, allowing for spatial and parametric representation of roadways, thereby improving efficiency and accuracy in infrastructure projects. Studies emphasize the importance of interoperability in BIM for seamless data exchange among stakeholders, highlighting BIM's role as a management tool for smart cities and sustainable urban development [17].

### 2.5.1 Advancements and Challenges in BIM Applications:

Professionals' perceptions towards using BIM in highway and infrastructure projects reveal both benefits and challenges, underscoring the need for continuous innovation and skill development in the transportation sector. The development of specialized tools, such as Autodesk Revit Add-ins for parametric modeling, showcases the evolving landscape of BIM applications in infrastructure design. By leveraging BIM's capabilities and integrating it with emerging technologies like Geographic Information Systems (GIS) and Internet of Things (IoT), stakeholders can drive advancements in smart infrastructure solutions for modern cities, paving the way for more efficient and sustainable road infrastructure projects [17].

## 2.6 Integration of BIM and GIS in Infrastructure Management

The integration of Building Information Modeling (BIM) and Geographic Information Systems (GIS) has revolutionized infrastructure management by providing a comprehensive digital representation of assets. This approach, known as Infrastructures & Structures Information Modeling (ISIM), enables stakeholders to visualize projects in their geospatial context, optimize design decisions and enhance asset performance analysis. By combining the engineering detail of BIM with the geographical data capabilities of GIS, a more effective solution for infrastructure asset management is achieved. ISIM facilitates proactive decision-making throughout the asset lifecycle, from design and construction to operation and maintenance, leading to improved collaboration, reduced costs and enhanced project outcomes. Studies have shown the potential of ISIM in optimizing maintenance practices, streamlining asset performance and supporting sustainable infrastructure development [18].

## 2.7 BIM in Road Safety and Asset Management

Building Information Modeling (BIM) is revolutionizing road safety evaluations and asset management in transportation infrastructure. Through the use of digital models, BIM enables stakeholders to conduct thorough safety assessments, identify potential hazards and make informed decisions to enhance safety standards. Moreover, BIM technology streamlines asset management practices by facilitating efficient maintenance processes, real-time monitoring of asset conditions and optimized resource allocation for infrastructure upkeep. Recent studies, such as those presented at conferences like the AIIT 3rd International Conference on Transport Infrastructure and Systems (TIS ROMA 2022), underscore the reliability and adaptability of BIM methodologies in improving safety and optimizing asset performance. The integration of BIM in road safety and asset management signifies a promising future for sustainable infrastructure development and operational efficiency in the transportation sector [3].

## 2.8 Integration of BIM Technology in Road Engineering Management

The integration of Building Information Modeling (BIM) technology in road engineering management presents a promising solution to enhance efficiency and effectiveness in construction projects, particularly in highway traffic systems. In China, where industrial informatization is advancing, BIM technology offers the potential to address challenges such as high road maintenance costs and inadequate road design. By digitally modeling construction processes, detecting errors and improving management efficiency, engineers can gain better control over project outcomes. However, the current state of BIM technology in China is still in a newly emerging stage, with limited comprehensive promotion and practical application scenarios, highlighting the need for further development and standardization efforts [19].

### 2.8.1 Challenges and Recommendations for BIM Adoption

Despite the benefits of BIM technology in road engineering, challenges exist in terms of standardization, software development and educational initiatives. To promote the popularization of BIM technology in road engineering, suggestions include the development of BIM standards for global integration, the enhancement of local software based on BIM technology and coordination between schools and industry practitioners to promote BIM education and application. While the road to widespread adoption may have obstacles, the continued advancement and integration of BIM technology are crucial for modernizing and optimizing transportation infrastructure, ultimately leading to improved project efficiency, cost-effectiveness and construction quality [20].

## 2.9 Impact of BIM in Construction Projects

Building Information Modelling (BIM) has revolutionized design processes in the construction industry by enabling multidisciplinary teams to collaborate effectively in a shared digital environment. BIM facilitates improved coordination, clash detection and visualization of complex infrastructural projects, leading to more efficient design outcomes. The role of BIM in enhancing communication and decision-making among project stakeholders highlights its potential to streamline design processes and improve project efficiency [20].

### 2.9.1 Enhancing Project Management with BIM

Effective project management is essential for the successful implementation of BIM in construction projects. BIM can streamline project workflows, enhance data management and improve project coordination. However, challenges related to data exchange formats and interoperability may impact the effectiveness of BIM in project management. Establishing common communication protocols and standards is crucial for maximizing the benefits of BIM in project management processes [21].

### 2.9.2 Maximizing Productivity Benefits with BIM

One of the primary objectives of implementing BIM in construction projects is to enhance productivity and efficiency. Identifying and quantifying the productivity benefits generated by BIM in transport infrastructure construction projects is crucial. By conducting case studies and interviews, practical insights can be gained to improve collaboration, reduce rework and enhance decision-making processes. Understanding the factors that influence productivity gains is essential for maximizing the value of BIM in construction projects and achieving better project outcomes [21].

## 2.10 BIM in Transportation Infrastructure

Building Information Modeling (BIM) is increasingly recognized as a valuable tool for enhancing the design, planning and maintenance of transportation infrastructure projects. The literature highlights challenges in integrating specific infrastructure components, like guardrails and retaining walls, into BIM models due to limitations in default BIM-based tools[22]. Researchers emphasize the importance of utilizing BIM tools such as Autodesk Civil 3D, Subassembly Composer and Revit to streamline processes and improve project outcomes in roadways, railways, airports, harbors, bridges and tunnels [23].

Case studies, like the reorganization of internal road systems at the Harbor of Naples, illustrate practical challenges and solutions in applying BIM processes to infrastructure projects. The iterative use of BIM-based tools within the same software suite is crucial for effective collaboration and data exchange among project stakeholders.

Overall, the literature underscores the transformative potential of BIM in revolutionizing the transportation infrastructure sector by improving project coordination, reducing errors and enhancing decision-making processes through interdisciplinary collaboration between academia and industry [24].

# CHAPTER 3

## RESEARCH METHODOLOGY

The **Research Methodology** chapter outlines the systematic approach adopted for this study, detailing each step from data collection and model creation to the analysis and optimization of highway alignment options. Using a BIM-based approach with InfraWorks software, this study evaluates multiple alignment alternatives to select the most efficient route. This methodology provides a structured framework to ensure accurate, data-driven decision-making in optimizing highway planning and design.

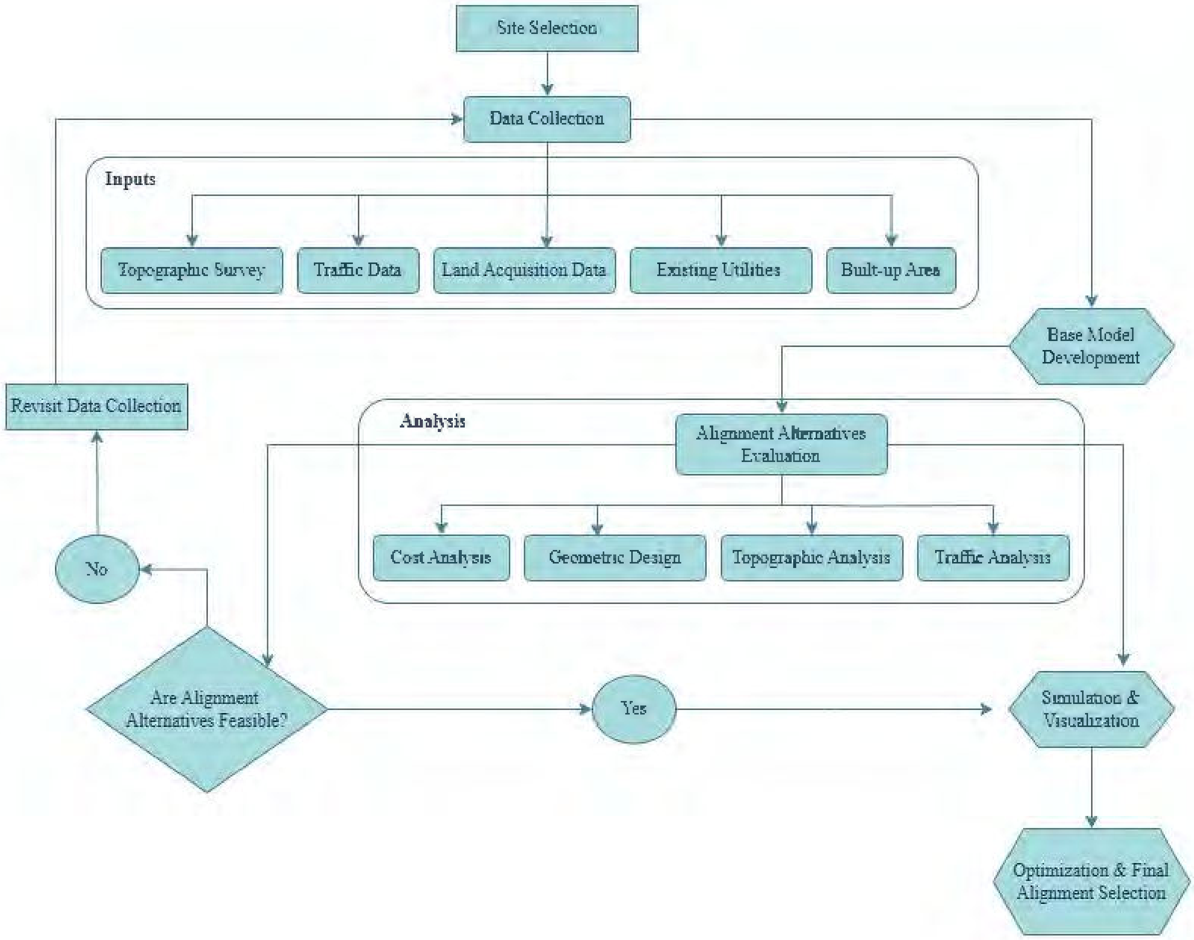



Figure 2: Flow Diagram of Research Methodology

The flowchart given in Figure 2 provides an overview of the structured methodology employed in this research. Starting with site selection, the process includes comprehensive data collection on key parameters like topography, traffic, land acquisition and existing utilities. Using InfraWorks software, a base model was developed, allowing the creation of multiple alignment alternatives. Each alignment was evaluated through detailed analyses—including cost, geometric design and traffic considerations. Simulation and visualization were then utilized to assess the alignments, leading to the selection of an optimized alignment that meets project goals for efficiency, safety and cost-effectiveness. This systematic approach ensures a thorough, data-driven decision-making process in highway planning and design[25].

### 3.1 Site Selection

The first step in this research is selecting a highway project site that presents a diverse set of challenges typical in highway planning and design. The chosen site will reflect varying topographical conditions, urban development levels and traffic patterns. The objective is to ensure that the selected site provides a comprehensive case study for the development and testing of a BIM-based highway planning and design system.

### 3.2 Data Collection

Data collection is critical to developing an accurate representation of the project area. The primary types of data collected include:

- **Topographic Data:** Survey data, including contour levels, elevation points and land features, was obtained through techniques such as GPS and Total Station surveying. This data enables the creation of a detailed digital terrain model (DTM).
- **Traffic Data:** Traffic surveys were conducted to capture traffic volume, vehicle classifications and peak hours. This data helps simulate traffic flow within the model and evaluate the impact of each alignment on traffic congestion and flow.
- **Land Acquisition Data:** Information on existing built-up areas, green spaces, agricultural land and industrial zones within the project area was collected through satellite imagery and field surveys. This includes identifying parcels of land that need to be acquired, assessing the impact of land acquisition on the project's cost and considering socio-economic implications.
- **Environmental Data:** Data related to water bodies, ecologically sensitive zones and protected areas was gathered to ensure minimal environmental impact.
- **Utilities and Infrastructure Data:** Details about existing utilities, including water lines, power grids and sewer systems, were obtained from relevant authorities. Areas with dense urban development will be documented to ensure that alignment planning

minimizes disruptions to these regions. Special attention will be given to avoiding or mitigating impacts on residential, commercial and industrial zones.

## 3.3 Base Model Creation using InfraWorks

Creating a comprehensive base model is a crucial step in the planning and design process for highway projects. InfraWorks software offers a powerful platform for integrating various data sources and generating detailed 3D models of the project area. This section outlines the process of base model creation using InfraWorks, including the importation of topographic data, integration of existing utilities and built-up areas and incorporation of traffic data.

### 3.3.1 Importing Topographic Data:

InfraWorks allows for the importation of topographic data obtained from surveying techniques such as GPS and Total Station. The collected data, including elevation points and contour lines, is imported into the software to create a detailed terrain model of the project area. This terrain model provides a realistic representation of the landscape and serves as the foundation for the highway design.

### 3.3.2 Integration of Existing Utilities and Built-Up Areas:

Once the topographic data is imported, InfraWorks enables the integration of existing utilities and built-up areas into the base model. Information on utilities such as water lines, gas lines and electricity lines is obtained from relevant authorities and incorporated into the model. This information is accurately represented in the 3D model, allowing to assess the impact of proposed highway alignments on existing infrastructure.

Similarly, data on built-up areas, including buildings, roads and other structures, is collected through field surveys and satellite imagery. InfraWorks facilitates the visualization of built-up areas within the model, providing valuable context for the highway design process. By integrating existing utilities and built-up areas, planners can identify potential conflicts and minimize disruptions during construction[26].

### 3.3.3 Traffic Data Integration:

Traffic data plays a critical role in highway planning and design and InfraWorks allows for the incorporation of traffic data into the base model. Vehicle counts and classifications obtained from traffic surveys are imported into the software and used to simulate traffic flow within the model. This simulation helps to assess the impact of different design options on traffic patterns and identify areas of congestion or safety concerns.

By incorporating traffic data into the base model, informeddecisions could be made about highway alignments, intersections and other design elements.This data-driven approachensures that the proposed highway design meets the needs of both current and future trafficdemand, ultimately improving the efficiency and safety of the transportation network. Traffic flow models are developed to observe congestion points and travel times, helping in the selection of alignment alternatives based on their impact on traffic efficiency.

## 3.4 Model Review and Validation

The review and validation process is essential in ensuring that the base model accurately represents the real-world conditions of the project area and serves as a reliable foundation for further analysis and decision-making. The model review and validation process involved several steps to confirm the accuracy of integrated data, alignment with design standards and usability for project stakeholders. InfraWorks provided multiple tools and capabilities to facilitate a thorough review, enabling adjustments as needed to enhance the model's precision and functionality.

### 3.4.1 Model Verification

The first step in the validation process was model verification, ensuring that all data inputs accurately reflected actual site conditions. This involved checking the spatial accuracy, attribute details and connectivity between various data components in the model.

- Cross-Check with Ground Survey Data: Each element in the digital model, including topographic data, utility placements and built-up area representations, was cross-checked against ground survey data and satellite imagery. This comparison ensured that the Digital Terrain Model (DTM) matched the terrain accurately, with no deviations in elevation or contour lines that could affect alignment analysis.
- Utility and Structure Placement Validation: All utilities, such as water lines, sewer systems and power lines, were reviewed for correct spatial placement. Validation was performed by comparing the locations within the model to utility maps provided by local agencies. The location, size and attribute details of structures in built-up areas, such as buildings, roads and other significant landmarks, were confirmed to match real-world dimensions and layouts[27].

### 3.4.2 Alignment with Design Standards

Ensuring the model met required design standards was a critical component of validation. This stage included:

#### 3.4.2.1 Geometric Standards Compliance:

The terrain, slope and curvature of the proposed alignment were reviewed to confirm compliance with geometric design standards, including maximum grade, horizontal curvature and sight distance requirements.

InfraWorks provided real-time feedback on road alignment and geometric specifications, allowing for adjustments if elements deviated from established standards, ensuring that the model was ready for accurate scenario testing.

#### 3.4.2.2 Safety Features Review:

Sightlines, road width and shoulder specifications were validated against safety standards. These elements were checked to ensure that the proposed design options could support safe, high-speed travel, avoiding sharp bends and sudden gradient changes that could affect vehicle maneuverability.

### 3.4.3 BIM Simulation Analysis and Calibration

BIM simulation analysis and calibration are essential steps for achieving an accurate and reliable model that reflects real-world conditions. InfraWorks is used to simulate various alignment scenarios, assess traffic flow, evaluate environmental impact and estimate construction costs. Calibration aligned the model with observed data, enhancing the reliability of simulations. Traffic flow is calibrated by adjusting parameters based on field traffic counts, ensuring that vehicle speeds, congestion and travel times matched actual conditions[28].

Terrain and structural elements were calibrated by aligning topographic data, cut-and-fill volumes and utility placements, creating a realistic foundation for cost estimation. Simulation scenarios provided insights into each alignment's effectiveness, revealing travel time differences, congestion hotspots and environmental impacts, such as air and noise pollution near residential areas.

Cost simulations estimated earthwork requirements and utility relocation expenses, guiding economic feasibility analysis. Final calibration results confirmed model accuracy, with traffic and cost data validated against independent datasets, ensuring a high degree of confidence in the alignment selection.

## 3.5 Development of Alignment Alternatives

The development of alignment alternatives is a critical phase in highway planning, as it allows for the evaluation of different design options based on multiple project objectives.

The purpose of developing alignment alternatives is to identify a design that optimally balances traffic flow, environmental conservation, cost and community impact. Alignment studies, especially in the context of BIM-based modeling, provide a structured approach to test multiple scenarios, ensuring that each alternative satisfies project objectives, safety standards and regulatory requirements.

Using InfraWorks, the research study generated several alignment alternatives for the D.G. Khan Northern Bypass, each tailored to address unique challenges related to traffic efficiency, environmental sustainability, construction cost and community impact. The primary goal was to determine an alignment that minimizes disruption to both the natural and built environment while ensuring safe, efficient traffic flow and cost-effectiveness.

Alignment alternatives are evaluated based on the following main criteria:

- **Geometric Efficiency**: Includes factors such as alignment length, curvature and gradient. Efficient geometry minimizes travel time and enhances safety by reducing sharp turns, steep grades and sudden sightline changes. Alignments are tested to ensure they meet geometric standards suitable for high-speed travel while maintaining safe sight distances and gradual transitions.
- **Environmental Impact**: A critical consideration for sustainable infrastructure design, this includes assessing alignments for proximity to sensitive areas, such as water bodies, natural habitats and agricultural land. InfraWorks' environmental analysis tools allow for simulation of potential impacts on ecosystems, including erosion, runoff and deforestation, helping to prioritize alternatives with the least environmental disruption.
- **Cost-Effectiveness**: Each alignment alternative's cost is calculated based on earthwork volume, bridge construction, utility relocation and other structural requirements. Cost considerations also extend to long-term maintenance. By analyzing alternatives through cost-simulation models, the research ensures that the selected alignment remains within budget constraints while delivering optimal value.

- **Community and Socioeconomic Impact**: This criterion focuses on how the alignment affects local communities, including proximity to residential areas, relocation requirements and access to public services. Minimizing the disruption to communities, especially those near the proposed bypass, is crucial to enhancing public acceptance and aligning with social responsibility objectives.

### 3.6 Simulation and Analysis of Alignment Alternatives

The research study involves detailed simulations of each alignment, testing traffic flow, environmental interaction and construction feasibility in InfraWorks. The simulation includes:

- **Traffic Flow Simulations**: Evaluates travel speed, congestion points and flow efficiency for each alignment. Real-time feedback from InfraWorks enables adjustments to curves and gradients to improve travel performance, especially for high-speed or heavy vehicles.

- **Environmental Impact Simulations**: Uses data overlays to measure potential effects on local ecosystems, including water bodies and green spaces. Each alignment's proximity to these areas is visualized, aiding in prioritizing alternatives with reduced ecological risk.

- **Cost Estimation Models**: Earthwork volume, bridge requirements and relocation costs are simulated for each alignment, allowing comparisons of estimated project costs. Cost-effectiveness is further analyzed through projected maintenance requirements, ensuring that the selected alignment remains financially viable in the long term[29].

### 3.7 Optimization and Selection of Alignment

The optimization and selection of alignment alternatives are key to ensuring that the chosen route meets project requirements while balancing cost, efficiency, environmental impact and community needs. Using the BIM capabilities of InfraWorks, each alignment alternative could be refined based on real-time feedback from simulation results. Optimization focused on improving travel efficiency, minimizing environmental disruption and reducing construction costs.

In the optimization phase, adjustments were made to curves, gradients and route proximity to sensitive areas. For example, alignments with sharper curves or steep gradients were modified to enhance safety and maintain traffic flow at optimal speeds. Environmentally sensitive zones, such as water bodies and agricultural land, were also key considerations; alignments were shifted to minimize ecological impact, reducing the need for extensive mitigation measures. Cost simulations further informed the optimization by highlighting areas where earthwork volumes, bridge requirements, or utility relocations could be minimized.

Following optimization, each alignment alternative was evaluated against the study's core criteria. The selection process considered travel efficiency, cost-effectiveness, environmental sustainability and socio-economic impact on the local community. After comprehensive analysis, the alignment that achieved the best balance across these factors could be chosen. This selected alignment provided a sustainable solution with reduced environmental impact, optimized traffic flow and manageable construction costs. The process underscored the value of a data-driven, BIM-based approach, demonstrating how simulation and optimization can lead to an alignment that meets both immediate project needs and long-term infrastructure goals.

# CHAPTER 4

# CASE STUDY OF DG KHAN BY-PASS

## 4.1 Overview of the Study Area (D.G Khan City)

Dera Ghazi Khan (D.G. Khan) is a strategic city located at the intersection of two major highways, the N-55 Indus Highway and the N-70 National Highway, linking all four provinces of Pakistan. D.G. Khan's role as a central transportation hub has made it vital for the movement of freight and passengers across the country. Heavy vehicle traffic from Karachi Port, carrying goods like cement, stone aggregates and other materials, passes through the city, leading to congestion in the urban center. To alleviate traffic congestion and enhance connectivity, the National Highway Authority (NHA), in collaboration with consulting engineers, proposed a bypass to divert heavy traffic from the city, thereby reducing travel time, improving traffic safety and supporting economic growth in Southern Punjab. The project, utilizes InfraWorks to conduct a comprehensive analysis and develop an optimized road alignment from multiple alternatives.

**Transportation Network:** D.G Khan City is served by two major national highways:

1. **Indus Highway (N-55):**
   - Indus Highway is a crucial route that connects Karachi Port, the largest port of Pakistan, with other parts of the country.
   - It serves as a major artery for goods transportation, particularly between the port and the northern regions.
2. **National Highway (N-70):**
   - National Highway (N-70) connects D.G Khan City with other major cities in Punjab, such as Multan and Bahawalpur.
   - This highway is of significant importance for transportation, especially for goods coming from stone crushing plants and the D.G Khan Cement factory.

### 4.1.1 Traffic Congestion Issues:

Despite the presence of the eastern bypass constructed under the Indus Highway project in 1999, D.G Khan City continues to face significant traffic congestion issues. The city center becomes heavily congested as the traffic from both National Highway (N-70) and Indus Highway (N-55) passes through it. This congestion leads to frequent blockages, especially for heavy vehicles, causing delays and inconvenience for commuters and hindering the smooth flow of goods transportation.

#### 4.1.2 Industrial Significance:

D.G Khan City is home to several stone crushing plants that supply crushed aggregates and sand to the southern areas of Punjab. Additionally, the city hosts a large cement-producing factory named D.G Khan Cement, which is one of the major cement producers in the country. These industrial facilities contribute significantly to the local economy and also add to the traffic volume on National Highway (N-70) and Indus Highway (N-55).

#### 4.1.3 Need for Bypass Construction:

To address the traffic congestion and facilitate commuters and goods transportation, there is an urgent need for the construction of a bypass. The proposed bypass would divert traffic from both National Highway (N-70) and Indus Highway (N-55) away from the congested city center. By providing an alternative route, the bypass would alleviate traffic congestion, reduce travel times and enhance road safety for both commuters and heavy vehicles.

### 4.2 Data Collection

Data collection is a critical component of highway planning and design, as it provides the empirical evidence required to make informed decisions. For the Dera Ghazi Khan bypass project, a comprehensive data collection strategy was implemented to ensure a robust foundation for the alignment study.

Data collection involved gathering traffic volume statistics, road network maps and geospatial data pertinent to the N-55 and N-70 highways.

Existing utilities, including water supply lines, power grids and sewer systems, were mapped using GIS tools. This information was necessary to identify areas where the proposed alignment might conflict with existing infrastructure, potentially requiring rerouting or protective measures.

Field surveys and satellite imagery were used to record the locations of water bodies, agricultural lands and built-up areas. Data on environmentally sensitive zones helped the team understand the potential ecological impacts and enabled alignment adjustments to minimize disruption.


Figure 3: Google Image of Traffic Count Locations

### 4.2.1 Geospatial Data Collection

Geospatial data provides essential information about the physical characteristics of the study area. The following methods were employed to collect geospatial data:

### 4.2.2 Topographic Data:

- Topographic surveys were conducted to gather detailed information about the elevation, contours and features of the land in the study area.
- Surveying equipment such as total stations and GPS devices were used to collect accurate topographic data.

### 4.2.3 Land Use Data:

Land use data provides information about the distribution of land uses within the study area. The following methods were employed to collect land use data:

- **Satellite Imagery:**
    - High-resolution satellite imagery was obtained from Google Earth.
    - Satellite imagery was analyzed to identify different land use categories such as residential areas, agricultural lands, industrial zones and natural features.

### 4.2.4 Terrain Data:

Terrain data provides information about the slope, aspect and roughness of the terrain in the study area. The following methods were employed to collect terrain data:

- **Digital Elevation Models (DEM):**
  - DEMs were created using topographic survey data to represent the elevation of the terrain across the study area.
  - DEMs were used to analyze terrain features such as hills, valleys and ridges.

### 4.2.5 Traffic Data Collection

Traffic data is essential for understanding traffic patterns, volumes and flow within the study area. The collection of traffic data is a fundamental step in the planning and management of road development schemes. For the Dera Ghazi Khan bypass project, traffic volume studies were meticulously conducted to ascertain the number, movements and classifications of vehicles at specific locations. This data collection is pivotal for identifying peak flow periods, assessing the impact of heavy vehicles on traffic flow and documenting traffic volume trends for future projections.

#### 4.2.5.1 Objectives of Traffic Study

The primary objective of this traffic study is to determine the current traffic plying at different sections of N-55 and N-70 to evaluate the existing traffic pattern and an estimate of future traffic statistics on DG Khan Bypass including calculation of traffic ESALs.

#### 4.2.5.2 Scope and Methodology of Traffic Study

The traffic study comprises of following main tasks:

i. Classified Trafficcounts
ii. Estimation of GrowthFactors
iii. Estimation of Projectedvolumes
iv. Calculation ofESALs
v. Axle load Survey

#### 4.2.5.3 Classified Traffic Counts

Traffic Counts have been carried out manually using traffic enumerators. Detailed forms were provided to the enumerators along with site training was provided. Separate enumerators are used for each direction. At each location one chief enumerator was stationed to overall review the quality of the traffic surveys.

Current traffic counts were conducted for different categories of traffic in both directions of National Highways. The following 3 locations have been selected:

Table 1: List of National Highways Surveyed for Traffic Data

| Sr. No. | Highway | Location | |
|---|---|---|---|
| 1 | N-55 | Dera Ghazi Khan – Taunsa Road | @ Near D.G Khan |
| 2 | N-70 | Dera Ghazi Khan - Multan | @ PSO Pump |
| 3 | N-70 | Dera Ghazi Khan – Sakhi Sarwar | @ Al Ghazi Tractor Limited |

The traffic survey was stratified by the vehicle type and was carried for 3 days (24 Hours) (3 X 24). **Error! Reference source not found.** lists the vehicle types counted during traffic study:

Table 2: Traffic Survey Vehicle Types

| Fast Moving Vehicles | | | |
|---|---|---|---|
| **Sr. No.** | **Vehicle Type** | **Sr. No.** | **Vehicle Type** |
| 1 | Motor Cycle | 7 | Truck 2. Axle |
| 2 | Rickshaw | 8 | Truck 3. Axle |
| 3 | Car/ Taxi / jeep | 9 | Truck 4. Axle |
| 4 | Mini Bus | 10 | Truck 5, 6 Axle &Above |
| 5 | Large Bus | 11 | Tractor Trolley |
| 6 | Pickup / Van | | |

Locations of the traffic stations are provided in the Figures below:

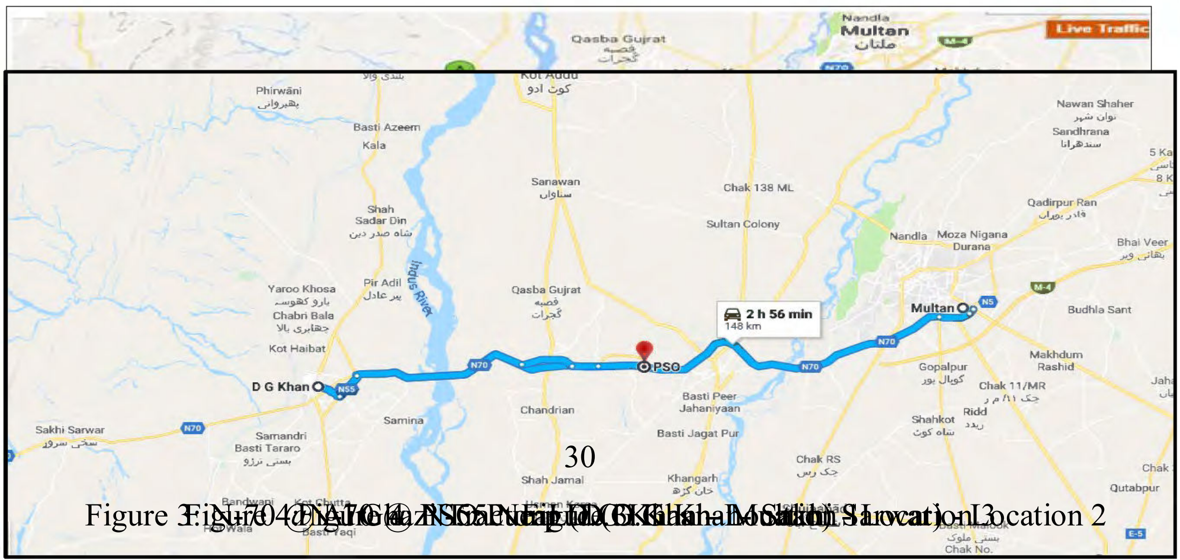



Figure 3 … Location 2

### 4.2.5.4 Calculation of ADT at 3 Locations

The traffic counts were conducted direction wise in the field, while they were combined for the calculation of Average Daily Traffic (ADT). Table 3 provide the ADT for March – 2019.

Table 3: Summary of Average Daily Traffic (ADT) at 3 Locations of NH

| Sr. No. | Highway | Location | M.Cycle/ Rikshaw | Car | Pickup | Van | Mini Bus | Bus | Mini Truck | Tractor Trolley | 2-Axle Truck | 3-Axle Truck | 4-Axle Truck | 5-Axle & above | Total ADT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | N-55 | N-55 Near DG Khan(Towards Taunsa) | 2,787 | 1,713 | 550 | 161 | 28 | 743 | 66 | 165 | 1,317 | 1,307 | 1,188 | 1,511 | 11,536 |
| 2 | N-70 | N-70 Near DG Khan at PSO Pump (Towards Multan) | 5,190 | 2,346 | 1,491 | 608 | 156 | 342 | 239 | 173 | 951 | 1,301 | 140 | 252 | 13,189 |
| 3 | N-70 | N-70 Near DG Khan At Al Ghazi Tractor Factory (Towards Sakhi Sarwar) | 5,108 | 1,582 | 355 | 560 | 85 | 175 | 104 | 133 | 823 | 1,240 | 16 | 36 | 10,217 |

### 4.2.5.5 Calculation of AADT at 3 Locations

Traffic counts were conducted for different categories of traffic at N-55 & N-70 at 3 locations. The traffic counts were conducted direction wise in the field, while they were combined for the calculation of Average Annual Daily Traffic (AADT).

### 4.2.5.6 Adjustments for Seasonal Effect

NTRC (National Transport Research Council) has established seasonal and daily factors which are compiled in "Traffic Factors for Pakistan-II (1992)".

**Daily Factors:** Daily Factors from NTRC Report has been used.

Table 4: Daily Factors from NTRC Report

| Station | Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday |
|---|---|---|---|---|---|---|---|
| Shikarpur | 1.01 | 1.03 | 1.01 | 1 | 1.01 | 0.96 | 0.99 |

**Seasonal Factor:** Seasonal Factor from NTRC Report has been used for the month of March for following station (closet available):

| Sr. # | Station | March |
|---|---|---|
| 1 | Shikarpur | 0.99 |

**WDMF = Week Day Multiplying Factor**

**SVF = Seasonal Variation Factor**

Table 5 provide the Average Annual Daily Traffic

Table 5: Summary of Average Annual Daily Traffic (AADT)

| Sr. No. | Highway | Location | M.Cycle/ Rikshaw | Car | Pickup | Van | Mini Bus | Bus | Mini Truck | Tractor Trolley | 2-Axle Truck | 3-Axle Truck | 4-Axle Truck | 5-Axle & above | Total ADT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | N-55 | N-55 Near DG Khan(Towards Taunsa) | 2,798 | 1,719 | 553 | 162 | 28 | 746 | 67 | 166 | 1,322 | 1,312 | 1,193 | 1,517 | 11,583 |
| 2 | N-70 | N-70 Near DG Khan at PSO Pump (Towards Multan) | 5,210 | 2,355 | 1,496 | 611 | 158 | 343 | 240 | 175 | 955 | 1,306 | 141 | 253 | 13,242 |
| 3 | N-70 | N-70 Near DG Khan At Al Ghazi Tractor Factory (Towards Sakhi Sarwar) | 5,126 | 1,588 | 357 | 562 | 86 | 177 | 105 | 134 | 826 | 1,244 | 16 | 36 | 10,258 |

#### 4.2.5.7 Sampling Period

The duration of the sampling period was determined based on the type of count and the intended use of the data. For this study, a continuous 72-hour (3 days) traffic count was deemed sufficient to provide a representative sample of the traffic patterns.

#### 4.2.5.8 Data Verification and Analysis

Following the collection, the data underwent a rigorous verification process to ensure accuracy. The verified data was then analyzed to project traffic volumes over the design life of the bypass. These projections were converted into Equivalent Standard Axle Loads (ESALs), which serve as a critical metric for the structural design of pavement.

#### 4.2.5.9 Traffic Study Objectives

The primary objective of the traffic study was to:

- Determine the current traffic on different sections of N-55 and N-70.
- Evaluate the existing traffic patterns.
- Estimate future traffic statistics for the DG Khan Bypass.

- Calculate traffic ESALs.

#### 4.2.5.10 Main Tasks of the Traffic Study

The traffic study encompassed the following key tasks:

- **Classified Traffic Counts**: Manual counts were conducted by traffic enumerators, who received detailed forms and on-site training. Separate enumerators were assigned for each direction of traffic, with a chief enumerator overseeing the quality of the surveys.
- **Estimation of Growth Factors**: Growth factors were estimated to project future traffic volumes, accounting for regional development and economic trends.
- **Estimation of Projected Volumes**: Using the growth factors, projected traffic volumes were calculated for the design life of the bypass.
- **Calculation of ESALs**: The projected volumes were then translated into ESALs for pavement design purposes.
- **Axle Load Survey**: An axle load survey was conducted to determine the distribution and frequency of various axle types, which is crucial for pavement design.

#### 4.2.5.11 Traffic Count Locations

Traffic counts were conducted at three strategic locations to capture a comprehensive view of the traffic entering and exiting Dera Ghazi Khan:

- **N-55**: Near D.G Khan on the Dera Ghazi Khan – Taunsa Road.
- **N-70**: At the PSO Pump on the Dera Ghazi Khan - Multan route.
- **N-70**: Near Al Ghazi Tractor Limited on the Dera Ghazi Khan – Sakhi Sarwar road.

1. **Vehicle Types Counted**

The traffic survey differentiated between various vehicle types to ensure a detailed analysis. The following vehicle types were included in the count:

- Motorcycles
- Rickshaws
- Cars, Taxis, Jeeps

- Mini Buses
- Large Buses
- Pickups, Vans
- Trucks (ranging from 2 to 6 axles and above)
- Tractor Trolleys

### 4.3 Base Model Creation using InfraWorks

The data collected was integrated into InfraWorks to create a comprehensive 3D base model of the D.G. Khan Northern Bypass project area. This model served as the foundation for analyzing and optimizing the alignment options.

- **Terrain Import and Creation of Digital Terrain Model (DTM)**: The topographic data was imported into InfraWorks, generating a DTM that provided an accurate representation of the terrain. Contours and slopes were visualized to aid in designing the alignment that would work with, rather than against, natural landscape features.

- **Utility Overlay**: Utility data was overlaid on the terrain model to highlight water, power and sewer lines. This layering enabled immediate detection of potential conflicts, such as alignment segments crossing utility lines, which would require additional planning for either relocation or protection.

- **Integration of Environmental and Land Use Data**: Environmental and land use data, including water bodies and agricultural lands, were incorporated to identify impact zones. This helped the team assess the environmental implications of each alignment alternative and prioritize routes that minimized disruption.

- **Traffic Simulation Setup**: Traffic data, including ESAL values and projected growth rates, was entered into InfraWorks to simulate traffic flow on each alignment alternative. This allowed for real-time evaluation of traffic performance, aiding in the assessment of each alignment's potential to reduce congestion and improve efficiency.

### 4.4 Alignment Alternatives

A holistic approach is required to develop alternative alignments, considering various elements of roadway design as a whole, along with the expectations of the community affected by the road in the long run. The best results are achieved when the engineering requirements of the road are considered together with the characteristics of the area in which the road is located.

A bypass is designed to provide a high-speed facility on the outskirts of a city or major town, allowing through traffic to bypass the inner-city traffic, thus reducing travel time and congestion. The design of a bypass needs to prioritize safety due to its high-speed nature. The overall quality, appearance and safety of the road are determined by the alignment design, both horizontal and vertical and its relationship to the surrounding environment. A good alignment, along with horizontal and vertical geometry complementing the topography, should also incorporate future growth and envision the road project 10 years down the line.

### 4.4.1 Main FactorsAffecting Alignments

The alignment of any road project is greatly affected by several factors, including:

- Built-up areas along the alignment

- Road network in the project area

- Presence of graveyards, shrines, mosques along the alignment

- Large canals and other water channels

- Sensitive areas such as army camps, barracks and cantonment areas

- Intersection with railway lines

- Project scope, feasibility and construction cost

- Client requirements and international design standards for a safe design

- Connectivity with major roads in the project area such as N-55 and N-70 in the case of Dera Ghazi Khan Bypass

### 4.4.2 Principles for Alignment Design

Based on the functional requirements of the project and the existing urban planning status, the alignment design follows the following principles:

- Fully embodying the functions of the proposed roadway as a high-speed access-controlled facility meeting the functional requirements of a bypass road and design criteria set by the client.

- Considering the layout of the existing and planned extensions to the road network and other modes of transportation to provide reasonable connections with the proposed bypass.
- Enhancing ease of transit between different areas for economic and social development.
- Properly treating the relationship between the project and town planning, providing major developments along the alignment access to the project road via underpasses and ensuring the organic integration of the project road construction with the location of the main urban center of D.G.Khan.
- Cherishing the existing or planned highway resources and coordinating the proposed road alignment with the local road network.
- Emphasizing environmental protection, avoiding adverse effects on the ecological environment and paying attention to technical investigation for important structures across water channels, railways, etc.
- Paying attention to the layout and type selection of interchanges to improve the operational level of the project road.
- Considering geological conditions along the alignment to avoid adverse geological sections.
- Avoiding settlements and acquisition of built-up areas as much as possible while obeying local customs and using technical indices flexibly to reduce project investment and save transportation costs.

### 4.5 Development of Alignment Alternatives

The development of alignment alternatives is a central component in planning the D.G. Khan Northern Bypass, as each potential route must balance traffic efficiency, environmental impact, construction feasibility and social considerations. Using InfraWorks, three main alignment alternatives were created and analyzed to determine which configuration would best achieve project objectives with the least disruption. These alternatives—each offering unique design characteristics—were thoroughly evaluated based on travel efficiency, environmental conservation, cost implications and impact on local communities.

### 4.5.1 NHA Proposed Alignment - Direct Rout

The first alignment, initially proposed by the National Highway Authority (NHA), follows a direct route from approximately 5 km from Airport Road on N-70 to an endpoint on N-55. This alignment spans 18.885 km and offers the shortest distance, prioritizing reduced travel time for high-speed traffic. The design is relatively straightforward, with minimal turns and deviations, making it attractive from a geometric and travel efficiency perspective.

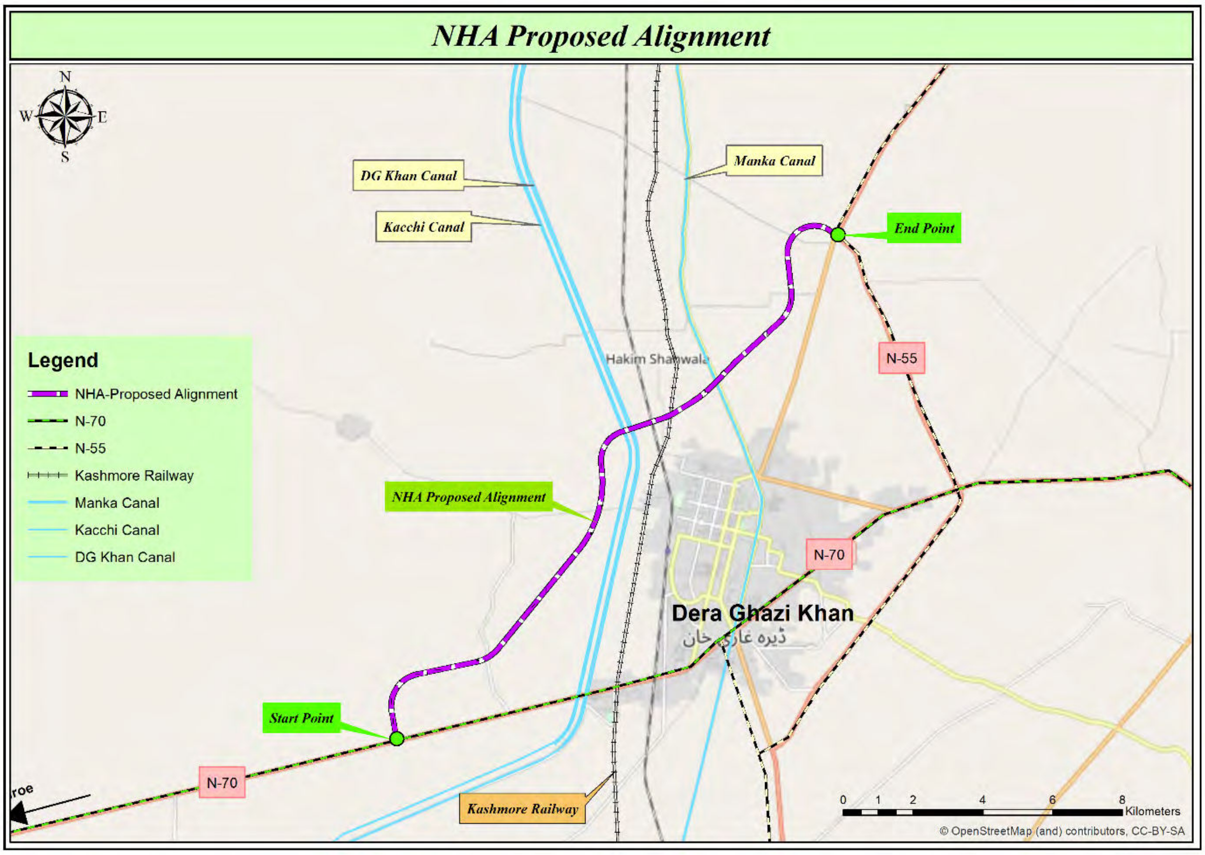



Figure 5: NHA Proposed Alignment

However, this route intersects several sensitive areas, including agricultural fields and water bodies, such as the Manka Canal and Vidor Nala. The proximity to these features means that extensive embankments and multiple bridges are required, raising both construction costs and environmental concerns. In addition, the alignment is near several built-up areas, which increases the risk of social and ecological disruption. While the NHA's direct route could provide efficient traffic movement, the potential environmental and community impacts necessitated exploration of alternative paths.

- **Key Features**:
    - Direct path, prioritizing shortest distance and travel time.
    - Multiple bridges and culverts required for waterway crossings.
    - High impact on agricultural lands and sensitive ecological zones.
    - Potential for increased community and environmental disruption.

### 4.5.2 Alignment Option – 1: Optimized Direct Route

The second alternative, termed the "Optimized Direct Route," builds upon the NHA's proposal by introducing improvements to reduce the environmental footprint and enhance the geometric properties of the alignment. This alignment spans 18.3 km, making it slightly shorter than the initial route and was designed with adjustments to curves and angles, especially at water crossings, to reduce the complexity of bridge construction.

By carefully shifting segments of the alignment away from high-impact zones, this alternative reduces the need for sharp turns and steep gradients, which improves travel safety and reduces construction difficulties. The Optimized Direct Route still impacts agricultural land but less so than the original NHA route, due to its refined path and fewer crossings over major water channels. The alignment offers a balance between travel efficiency and reduced structural complexity, though it still requires some environmental mitigations due to its proximity to agricultural zones.

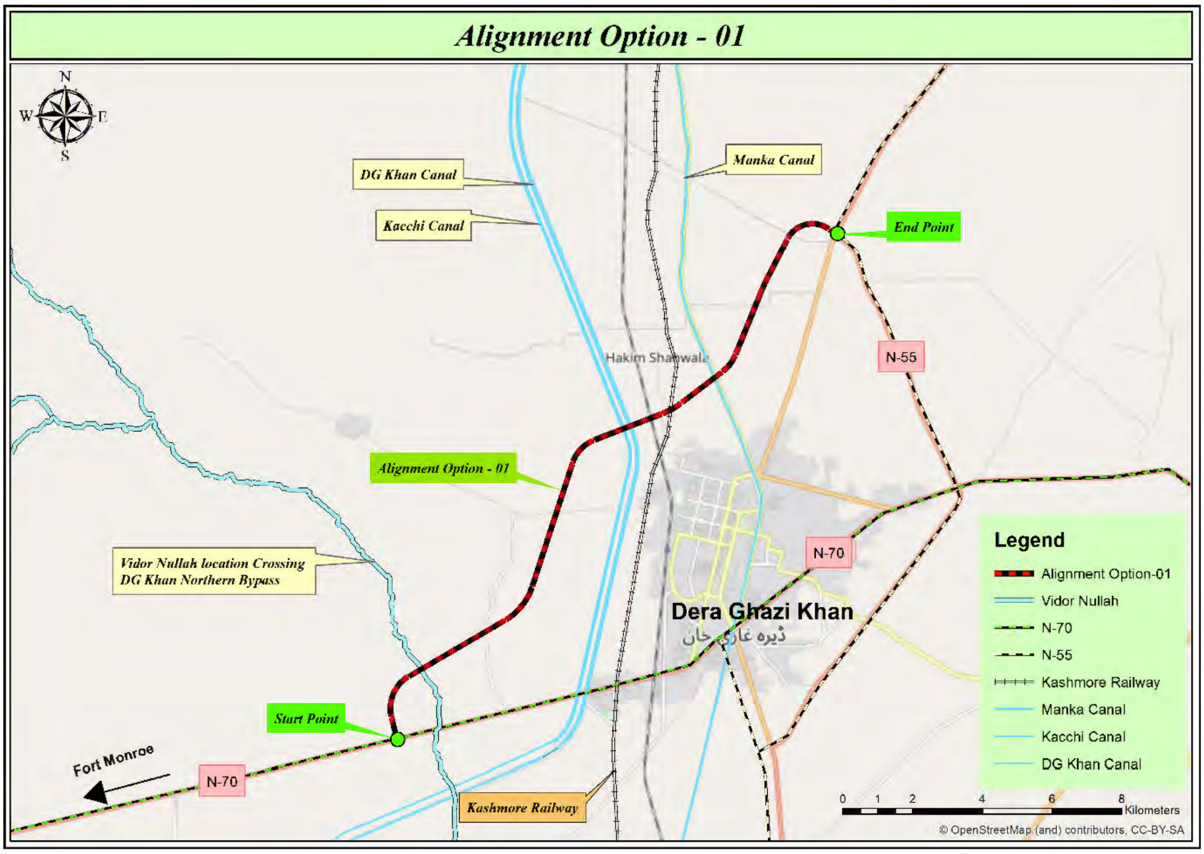



Figure 6: Alignment Option – 1: Optimized Direct Route

- **Key Features**:
  - Shorter distance (18.3 km) with improved geometry for safer, high-speed travel.
  - Reduces skew angles at crossings, decreasing bridge construction costs and complexity.
  - Moderate impact on agriculture, with partial avoidance of high-sensitivity areas.
  - Lower environmental footprint than NHA's original alignment.

### 4.5.3 Alignment Option – 2: Northern Bypass

The third alternative, the "Northern Bypass with Maximum Avoidance," was positioned further north, away from dense urban areas, agricultural land and water bodies. This alignment spans approximately 20 km, making it the longest route of the three options, but it minimizes social and environmental disruption by bypassing most sensitive areas. By avoiding intersections with water channels, this route requires fewer bridges and embankments, reducing both construction costs and long-term maintenance needs associated with waterway crossings.

Although it adds a small increase in travel distance, the Northern Bypass is sustainable, as it avoids densely populated areas, minimizes the acquisition of agricultural land and reduces impact on local ecosystems. This alignment supports future regional development, as it can accommodate projected traffic growth without compromising safety or environmental integrity. Despite the longer route, the reduced need for complex structural work and the minimized ecological and community impact makes this a favorable option for long-term sustainability.

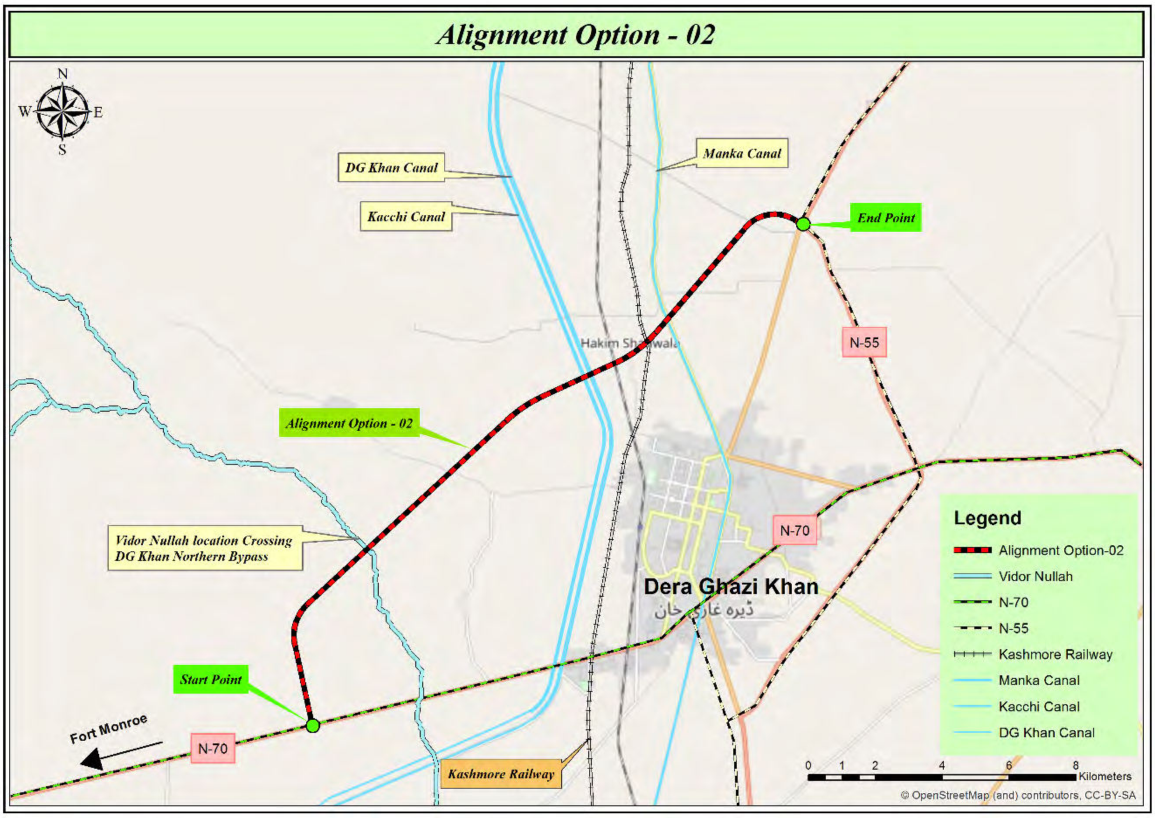



Figure 7: Alignment Option – 2: Northern Bypass

- **Key Features**:
  - Longest distance (20 km) but maximizes avoidance of populated and sensitive zones.
  - Requires fewer bridges and embankments, lowering structural complexity and costs.
  - Minimal impact on agricultural land, water bodies and residential areas.
  - Enhanced sustainability with lower environmental and social disruption.

## 4.6 Alignment Audit & Review

After setting preliminary alternative alignments based on the aforementioned principles and concepts, these alignments undergo a review and audit stage, evaluating them in terms of various factors:

### 4.6.1 Review of Topographic Features of Project Area:

Topographic surveys of the area along the preliminary alignments are conducted to identify existing features on the surface of the earth or slightly above or below the earth's surface, such as existing roads, watercourses, settlements, terrain, graveyards and culturally and religiously significant buildings. These features are used to:

- Identify deviations/modifications required in the preliminary alignment
- Compare alignment alternatives
- Allocate structures to be installed for integration of the highway into the current road and irrigation network

### 4.6.2 Review of Geometric Design Features:

The alignments are reviewed based upon geometric design standards. Features such as super elevation, curve radius and sight distance are evaluated. Based on the observation of topographic survey, alignments are moved at certain points to avoid obstacles due to topographic features, graveyards and culturally and religiously significant buildings. Adjustments of the modified alignments to geometric design standards are also made in this stage.

### 4.6.3 Review of Proposed Location of Structures:

Based on topographic survey, satellite imagery and on-site photographs, the number and location of needed structures (such as interchanges, bridges, underpasses, flyovers and culverts) are identified. These structures are identified so they can be integrated with the highway design. In case of bridges coming at a high skew and on curves, the horizontal alignment of the motorway shall be realigned to minimize skew and avoid providing a bridge on a curve.

### 4.6.4 Review of Environmental Conditions:

Highway alignments are reviewed based on environmental considerations. The impact that a project will have on the environment of an area is evaluated. This review is conducted as per the specifications of the local authority on environmental protection.

### 4.6.5 Review of Any Planned Future Extensions:

The proposed bypass aims to move through traffic from N-70 and N-55 without interference from local traffic. For this purpose, the bypass should provide a fast route to through traffic while allowing access to the city center and major intercity developments. Plans for future extensions, such as the extension till Rawalpindi, are considered in the alignment review.

### 4.6.6 Design Standards

#### 4.6.6.1 Carriageway Cross-section

The proposed road will be a four-lane divided carriageway with the following specifications:

- Median: 1.0m New Jersey Barrier
- Carriageway Width: 7.3m width (Two lanes (3.65*2)) in each direction
- Bridge: 4-lane (Each lane as per Carriageway Width specifications)
- Shoulder Width:Inner: 0.6m&Outer: 2.5m paved
- Crossfall normal:

  Carriageway: 2%

  Outer Shoulder: 4%

  Inner Shoulder: 4%
- Full Superelevation: 6%
- Geometric Design Standard: "A Policy on Geometric Design of Highway & Streets 2011"
- Classification of Highways: Rural Arterial
- Design Speed: 100 kph
- Design Vehicle: 6-Axle Trailer (1.22+222)
- Minimum Grade: 0.5% in cut and 0.3% in fill
- Maximum Grade: 3%
- Drainage: Curb, Gutter and Chutes for controlled drainage

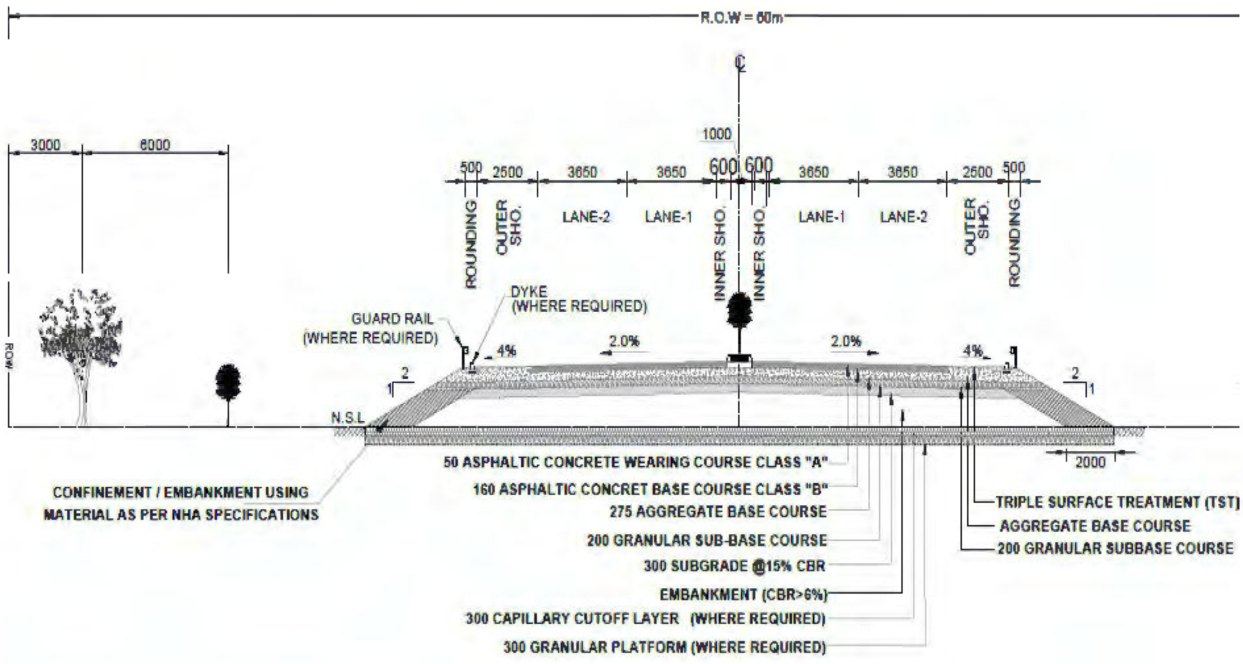



Figure 8: Typical Cross Section (4-Lane)

#### 4.6.6.2 Codes and Standards

For analysis and design of structures following codes, standards and loads will be adopted.

- **AASHTO-(LRFD):** For analysis and design for all loads and load combinations.
- **Pakistan Highway Code of practice for Bridges 1967:** For vehicular loads, their spacing & impact factors.
- **UBC/IBC 2003:** For seismic zoning in addition to the revised seismic risk map of Pakistan.
- **ASTM:** For material specifications & testing
- **ACI:** For analysis, design and detailing, only incase such details are not specified in AASHTO.

#### 4.6.6.3 GeometricDesign:

Geometric Design standards are tabulated in Table 6.

Table 6: Geometric Design Standards

| Sr.No. | Designelement | Unit | Standard |
|---|---|---|---|
| 1 | Designspeed | KPH | 100 |
| 2 | Min.stoppingsightdistance | m | 185 |
| 3 | Maxrateofsupperelevation. | % | 6 |
| 4 | Horizontalcurvature | | |
| | i) Absolute min. radius @ 120KPH | m | 437 |
| | ii)Radius above which no Superelevation is required | m | 3510 |
| 5 | Road formation width | m | 22 |
| 6 | Max. Grade | % | 3% |
| 7 | Min. Grade | In Fill 0.3%<br>In Cut 0.5% | |
| 8 | Rate of Vertical Curvature; | | |
| | Absolute Min ‘K’ value for crest curves: | K/%A | >52 |
| | Absolute Min ‘K'valueforSagcurves: | K/%A | >45 |
| 9 | Min.vertical clearanceoverroad | m | 5.2 |
| 10 | Min.verticalclearanceoverrailwayline. | m | 7.0 |
| 11 | Clearance under Flyover Bridge | m | 5.5 |
| 12 | Subway Clearance | m | 4.5 |
| 13 | Underpass/Standard Road Underpass | m | 5.3 |
| 14 | Min Clearance for Cattle Creep/Pedestrian Crossing | m | 2.8 |
| 15 | Rightofway. | m | 60 |

## 4.7 Simulation and Analysis of Alignment Alternatives

The simulation and analysis of alignment alternatives for the DG Khan Bypass were conducted using InfraWorks software, providing insights into the performance and feasibility of each proposed alignment. Through this simulation, each alignment was assessed across multiple key parameters—such as travel time, congestion levels, safety features, geometric design and cut-and-fill requirements—to identify the most effective solution. The results of this analysis provided a comprehensive understanding of each alignment's performance and impact.

### 4.7.1 Travel Time and Congestion Analysis

- **NHA Proposed Alignment:** The simulation showed that this alignment would reduce travel time moderately, with an initial congestion reduction of 20%. However, over a projected 10-year and 20-year period, congestion levels are expected to increase by 15% and 25%, respectively, limiting the long-term effectiveness of this alignment in managing traffic growth.

- **Alignment Option-1:** This alignment demonstrated a better initial reduction in congestion (25%) and showed a slower rate of congestion increase, with a projected 10% increase over 10 years and 20% over 20 years. Travel time was optimized in this option due to improved traffic flow.

- **Selected Alignment Option-2:** The simulation indicated that Option 2 provided the highest congestion reduction of 30% initially. It also displayed the least congestion increase in the long term, with only 8% over 10 years and 18% over 20 years. This alignment significantly reduced travel time, indicating superior performance in both current and future traffic conditions.

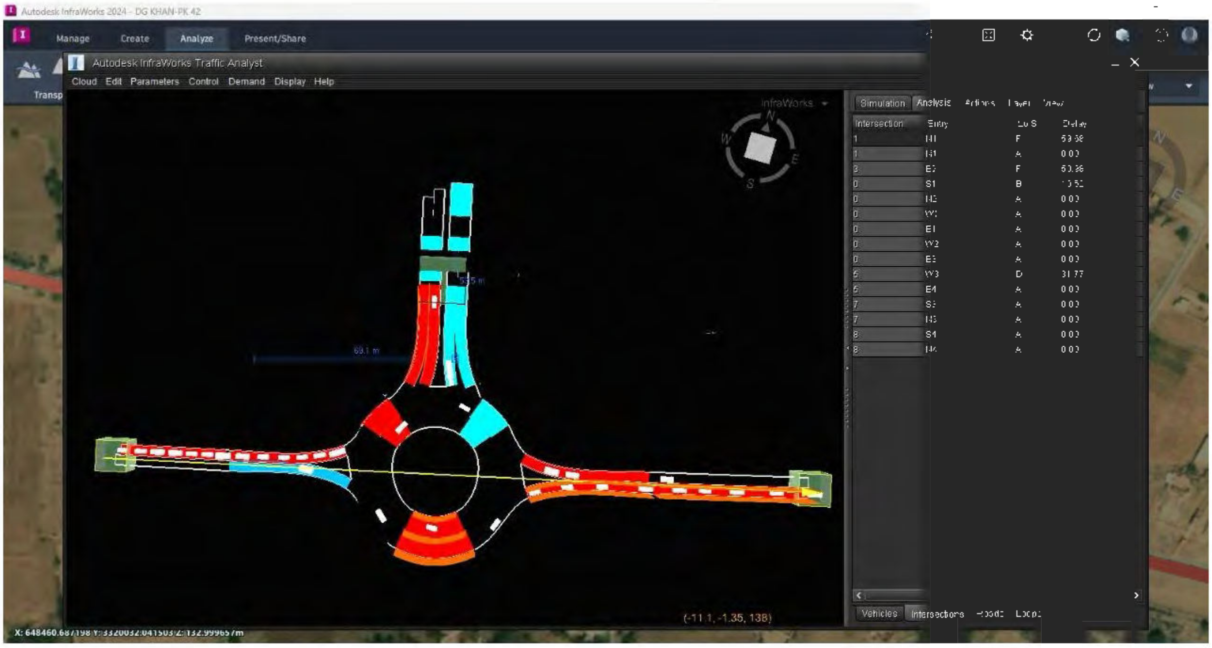



Figure 9: Alignment Option-2 Roundabout Traffic Simulation

### 4.7.2 Geometric Design and Safety Analysis

- **NHA Proposed Alignment:** This alignment met basic geometric standards, but sharp curves and steeper grades in certain sections could pose safety risks at higher speeds. The InfraWorks simulation highlighted these areas as needing potential adjustments to improve sight distances and reduce accident risks.

- **Alignment Option 1:** The geometric design for this alignment was moderately optimized, with smoother curves and better sight distances compared to the NHA proposal. Simulation analysis suggested moderate safety improvements, although some sections still required enhancements to meet optimal safety criteria.

- **Alignment Option-2:** Option 2 presented the best geometric characteristics, with smoother curves, consistent grades and improved sight distances throughout. The InfraWorks simulation indicated this alignment as the safest, with minimal risk factors related to curvature and gradient. These design elements enhanced overall driving conditions and safety.

### 4.7.3 Cut-and-Fill Volume Analysis

- **NHA Proposed Alignment:** This alignment required significant earthwork, with cumulative cut and fill volumes of approximately 118,310 cubic meters and 3,368,151 cubic meters, respectively. The high volume of fill added to both construction cost and environmental impact, making this alignment less desirable.

- **Alignment Option-1:** Option 1 showed reduced cut and fill requirements, with a cumulative cut volume of 125,270 cubic meters and a fill volume of 3,174,249 cubic meters. The InfraWorks analysis indicated that this reduction in earthwork would positively impact cost and environmental disruption.
- **Alignment Option-2:** Option 2 minimized earthwork requirements, with no significant cutting and a cumulative fill volume of 2,779,851 cubic meters. The InfraWorks simulation confirmed that this reduced cut-and-fill requirement significantly lowered construction costs and environmental impact, making it the most efficient option in terms of earthwork.

### 4.7.4 Cost Analysis

- **NHA Proposed Alignment:** The simulation indicated high overall costs due to substantial earthwork and land acquisition, with total estimated costs significantly exceeding those of the other alternatives.
- **Alignment Option-1:** Although less costly than the NHA proposal, Option 1 still presented higher costs compared to the selected alignment due to moderate earthwork and land acquisition requirements.
- **Alignment Option-2:** The analysis showed that Option 2 offered the lowest overall cost, benefiting from minimized earthwork, efficient land use and reduced construction complexities. This cost efficiency was confirmed through both cost modeling and InfraWorks simulation.

### 4.7.5 Environmental and Social Impact Analysis

- **NHA Proposed Alignment:** The InfraWorks simulation highlighted significant social and environmental impacts due to this alignment's proximity to built-up areas, which would require extensive land acquisition and displacement.
- **Alignment Option-1:** Option 1 had moderate environmental impacts, as it affected fewer residential areas but still required some land acquisition and environmental disruption.
- **Alignment Option-2:** This alignment was found to be the most environmentally sustainable, avoiding dense populated areas and limiting land acquisition requirements. The InfraWorks simulation confirmed minimal disruption to the local community and natural habitats.

## 4.8 Optimization and Final Selection of Alignment

The optimization and final selection of alignment for the DG Khan Bypass was a rigorous process that involved balancing multiple factors, including cost efficiency, geometric design, traffic flow, environmental impact and land acquisition requirements. Using InfraWorks, we evaluated several alignment alternatives through simulation and analysis to determine the most viable option that met project goals while minimizing adverse effects.

### 4.8.1 Optimization Criteria:

The optimization process was structured around key criteria such as construction costs, earthwork volumes (cut and fill requirements), traffic performance, safety and projected maintenance costs. Additional considerations included minimizing disruptions to existing infrastructure, preserving natural landscapes and ensuring alignment with local regulations.

### 4.8.2 Comparative Analysis of Alternatives:

For the DG Khan Bypass, three primary alignment alternatives were evaluated:

- NHA Proposed Alignment
- Alignment Option-1
- Alignment Option-2 (Northern Bypass)

Through detailed simulation, each alternative was analyzed for traffic efficiency, cost implications, environmental impact and construction feasibility. InfraWorks software was used to model the performance of each alignment based on these criteria, producing quantifiable data for a comprehensive comparison.

### 4.8.3 Cost-Benefit Analysis:

A cost-benefit analysis was conducted to weigh the economic implications of each alternative. While the NHA Proposed Alignment and Alignment Option 1 required extensive earthwork and incurred higher construction costs, the Selected Alignment Option-2 demonstrated significant cost savings. Specifically, Option 2 minimized cut and fill volumes, thereby reducing material handling and associated costs, leading to an estimated 10-15% cost reduction compared to the NHA alignment.

### 4.8.4 Traffic and Geometric Optimization:

The geometric design of the Selected Alignment Option-2 provided smoother curvature and gradients, which were found to improve overall traffic flow and safety. Traffic simulation results indicated that Option 2 could reduce congestion by up to 30% initially and maintain better traffic performance over a 20-year period compared to the other alternatives. Its optimized geometry also aligns with standards for safe sight distance, minimizing accident risk.

#### 4.8.5 Environmental and Social Impact Minimization:

The Selected Alignment was also optimized to reduce environmental and social impacts, avoiding sensitive ecological zones and minimizing land acquisition requirements. This approach reduced potential conflicts with local communities and preserved valuable natural resources.

### 4.9 Final Selection:

Based on the analysis, Alignment Option-2 is chosen as the optimal alignment for the DG Khan Bypass. This decision is made after carefully considering the balance between cost, traffic efficiency, environmental impact and construction feasibility. The selected alignment not only offers the best financial outcome but also aligns with sustainable development principles, ensuring that the bypass will serve the community's long-term needs with minimal impact on the surrounding environment.

The final selection of Alignment Option-2 demonstrates a strategic approach to highway planning and design, leveraging InfraWorks' advanced modeling capabilities to achieve a balanced solution that meets technical, economic and environmental objectives.

# CHAPTER 5

# RESULTS

Using a BIM-based methodology within InfraWorks, each alignment option for the D.G. Khan Northern Bypass was rigorously tested for traffic flow, environmental impact, cost and community effects. These results informed the selection of the most suitable alignment and provided valuable insights into the application of BIM technology in large-scale infrastructure projects.

## 5.1 Traffic Simulation and Analysis Results

Traffic flow analysis for the D.G. Khan Northern Bypass project was conducted to evaluate each alignment's effectiveness in managing existing and projected traffic volumes. Using traffic data inputs InfraWorks simulations modeled how each alignment would perform under

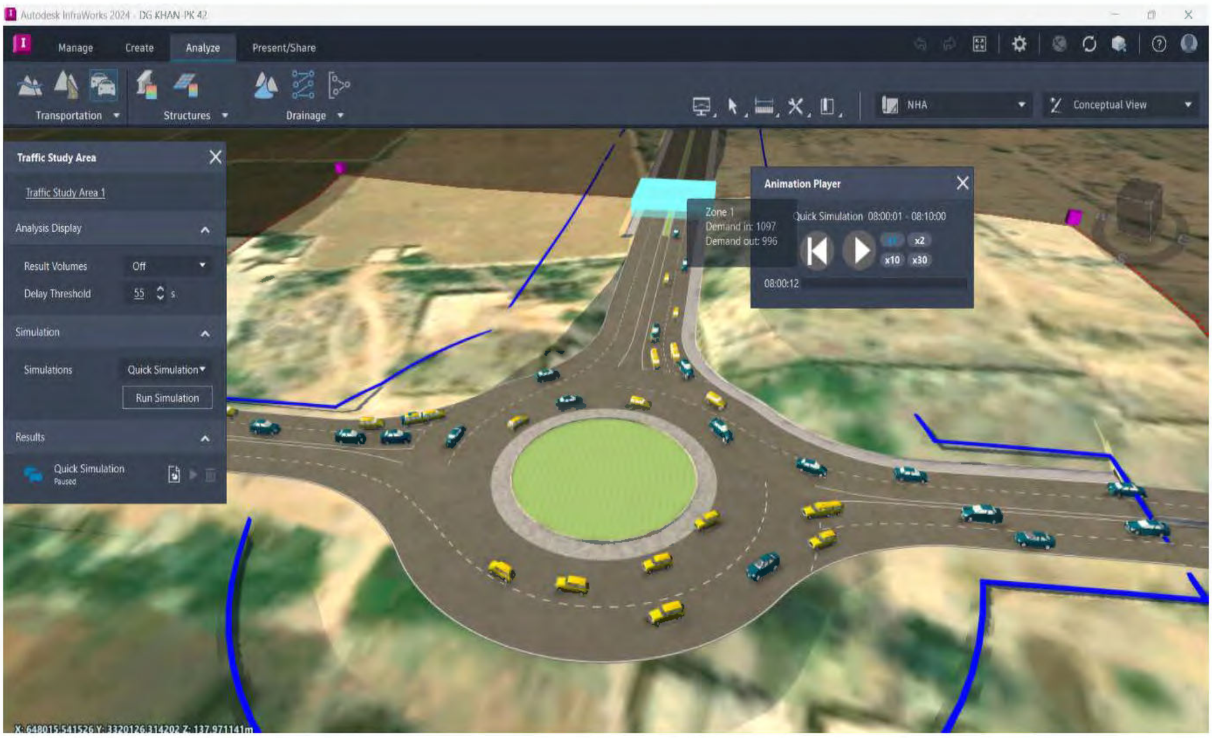



Figure 10: Traffic Simulation in InfraWorks

peak and off-peak conditions, as well as in scenarios of increased future demand.

### 5.1.1 Congestion Reduction Analysis

The congestion reduction analysis evaluates the effectiveness of each alignment in mitigating current and future traffic congestion. By diverting significant traffic volume away from the city center, each alignment offers an initial reduction in congestion. However, over a projected 10- and 20-year period, these benefits vary depending on alignment geometry, proximity to urban areas and expected traffic growth. TheTable 7 provides a comparative analysis of the initial congestion reduction and anticipated congestion increases for each alignment:

Table 7: Congestion Reduction and Projected Congestion Increases for Alignments

| Alignment | Initial Congestion Reduction (%) | Projected 10-Year Congestion Increase (%) | Projected 20-Year Congestion Increase (%) |
|---|---|---|---|
| **NHA Proposed Alignment** | 20% | 15% | 25% |
| **Alignment Option-1** | 25% | 10% | 20% |
| **Alignment Option-2 (Northern By-pass)** | **30%** | **8%** | **18%** |

- **NHA Proposed Alignment**: Provides a moderate congestion reduction, with initial relief of around 20%. However, due to its route partially through urban sections, congestion could increase by 25% over 20 years, impacting traffic flow.
- **Alignment Option-1**: Achieves better congestion relief at 25% due to strategic alignment choices that bypass more populated areas. Long-term congestion is projected to increase by 20% in 20 years.
- **Alignment Option-2**: Delivers the highest congestion reduction at 30%, fully diverting traffic from D.G. Khan City and maintaining lower congestion increases of only 8% at 10 years and 18% at 20 years, supporting the best long-term traffic flow.

### 5.1.2 Level of Service (LOS)

The Level of Service (LOS) analysis assesses the performance of each alignment in handling projected traffic volumes over time. LOS provides a measure of traffic flow quality, from free-flow conditions (LOS A) to heavily congested conditions (LOS E and F). Each alignment's ability to maintain an acceptable LOS over a 20-year period is critical for long-term traffic efficiency and reduced travel delays. Table 8 compares the initial LOS and projected changes at 10- and 20-year intervals for each alignment.

Table 8: Level of Service (LOS) Comparison for Alignments

| Alignment | Initial LOS (Years 1-5) | Projected LOS at 10 Years | Projected LOS at 20 Years |
|---|---|---|---|
| **NHA Proposed Alignment** | LOS C | LOS D | LOS E |
| **Alignment Option-1** | LOS B | LOS C | LOS D |
| **Alignment Option-2 (Northern By-pass)** | **LOS A** | **LOS B** | **LOS C** |

- **NHA Proposed Alignment:** Begins with a LOS C, likely degrading to LOS E by year 20 due to higher congestion in urban areas.
- **Alignment Option-1:** Starts with LOS B, shifting to LOS D by year 20, showing moderate long-term performance.
- **Alignment Option-2:** Maintains the highest initial LOS A, with capacity to handle traffic growth, reaching LOS C at 20 years, making it the most resilient choice in the long term.

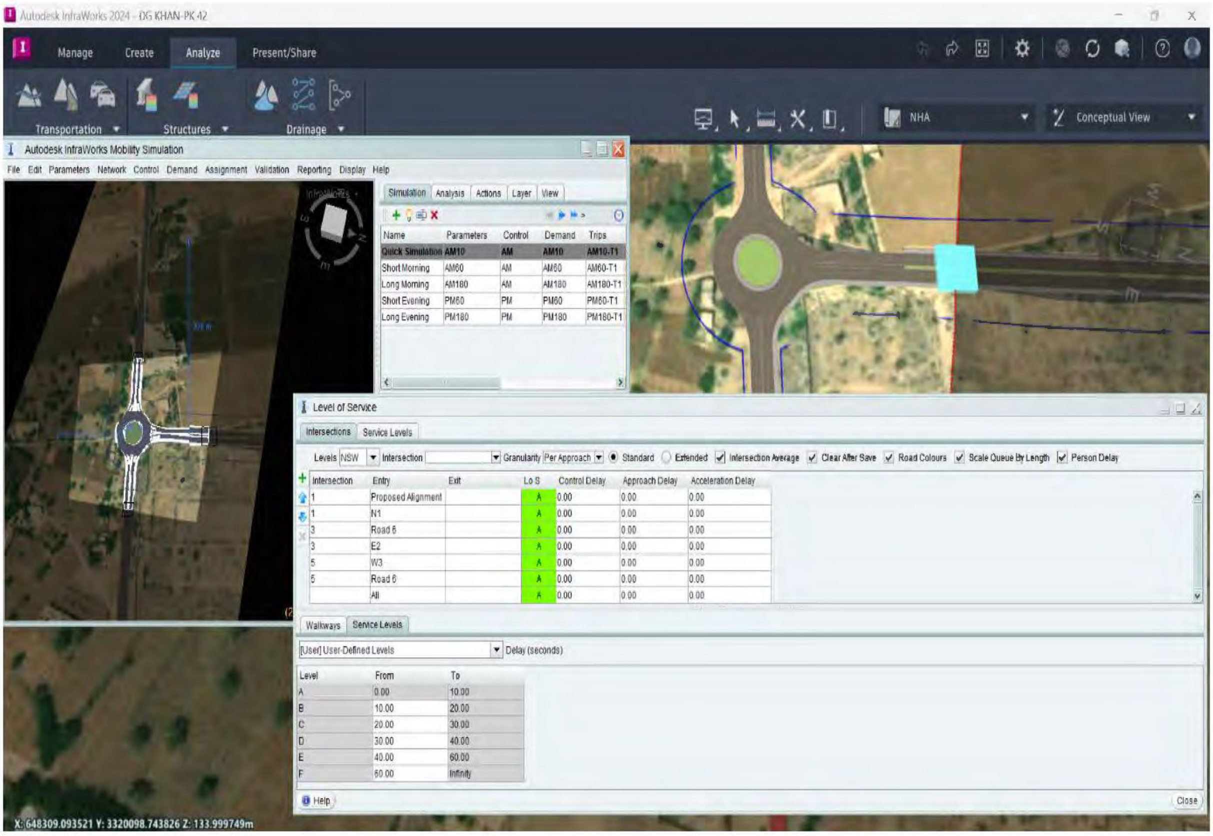



Figure 11: LOS for Alignment Option-2, visualized in InfraWorks

### 5.1.3 Travel Time Reduction

The travel time reduction analysis compares the effectiveness of each alignment in decreasing travel duration for bypass users. By optimizing traffic flow and reducing congestion, each alignment offers varying levels of time savings, which are crucial for improving commuter efficiency and lowering vehicle operating costs. The table below provides a comparison of travel time reductions and average savings per trip for each alignment.

Table 9: Travel Time Reduction and Average Trip Savings for Alignments

| Alignment | Travel Time Reduction (%) | Average Savings per Trip (Minutes) |
|---|---|---|
| **NHA Proposed Alignment** | 12% | 5 minutes |
| **Alignment Option-1** | 15% | 8 minutes |
| **Alignment Option-2 (Northern By-pass)** | **20%** | **10 minutes** |

- **NHA Proposed Alignment:** Achieves a moderate travel time reduction of 12%, with an average savings of 5 minutes per trip, benefiting local commuters minimally due to urban intersections.
- **Alignment Option-1:** Reduces travel time by 15%, with an average savings of 8 minutes per trip by avoiding more urban areas.
- **Alignment Option-2:** Delivers the highest travel time reduction of 20%, saving an average of 10 minutes per trip by completely bypassing urban congestion zones, offering the best option for efficient long-distance travel.

Figure 12: Traffic Analyst interface in InfraWorks

Overall, Alignment Option-2 (Northern By-pass) performs best across all key traffic metrics, making it the optimal choice for enhancing traffic efficiency, reducing travel costs and supporting sustainable long-term infrastructure for the D.G. Khan

## 5.2 Geometric Analysis of D.G. Khan Alignments

In evaluating each alignment's geometric suitability for 100 km/h travel, factors such as curve radius, gradient and sight distance were analyzed based on optimal highway design standards for high-speed routes. The design aims to ensure smooth traffic flow, minimal deceleration and enhanced safety for both freight and passenger vehicles.

### 5.2.1 Alignment Curvature and Length

This analysis examines the curvature and total length of each alignment, assessing how curvature impacts travel speed, safety and comfort. Optimal curvature enhances safety and supports higher travel speeds, especially for heavy vehicles.

Table 10: Comparison of Alignment Curvature and Total Length of Alignments

| Alignment | Average Curve Radius (m) | Total Length (km) | Curvature Type |
|---|---|---|---|
| **NHA Proposed Alignment** | 250 | 18.9 | More weaving and sharp curves |
| **Alignment Option-1** | 300 | 18.3 | Moderate curves with weaving |

| | | | |
|---|---|---|---|
| **Alignment Option-2 (Northern By-pass)** | **450** | **20** | Straight, fewer curves |

- **NHA Proposed Alignment**:The alignment with an average curve radius of 150 meters, includes several sharp curves, which reduce sight distance and travel comfort. Designed with an average curve radius of 250 meters in most sections to adapt to the local terrain. While suitable for moderate-speed travel, this alignment may necessitate some speed adjustments, especially in urban-adjacent zones.

- **Alignment Option 1**: Slightly Improved curve radius averaging 300 meters, which better supports high-speed travel but includes a few sections with curves as low as 250 meters due to terrain constraints.

- **Alignment Option-2:** Achieves an optimal curve radius of 450 meters throughout, ensuring consistency with 100 km/h speed requirements. This alignment's smoother geometry allows for a higher design speed of 100 kph, optimizing the bypass for fast, uninterrupted travel.

### 5.2.2 Grades and Elevation Profile

The grade and elevation profile analysis evaluates the gradient and slope consistency of each alignment, which are essential for safe and efficient travel, particularly for heavy vehicles. Gentle slopes improve fuel efficiency and reduce wear on vehicles.

Table 11: Grade Comparison of Alignments

| Alignment | Average Gradient (%) | Maximum Gradient (%) | Terrain Adaptation |
|---|---|---|---|
| **NHA Proposed Alignment** | 4% | 6% | High embankments, steep slopes |
| **Alignment Option-1** | 3.50% | 5% | Moderate slopes with embankments |
| **Alignment Option-2 (Northern By-pass)** | **1.5%** | **2%** | Minimal embankments, gentle slopes |

- **NHA Proposed Alignment:** Features an average gradient of 4% with some sections reaching up to 6%, leading to steep embankments and slopes, affecting travel flow and vehicle stability.

- **Alignment Option-1:** An improvement with an average 3.5% gradient, reducing the need for excessive embankments but still requiring some adjustments.
- **Alignment Option-2:** With an average gradient of 1.5% and a maximum of 2%, this alignment adapts gently to the terrain, which minimizes embankment work and enhances vehicle safety and operational efficiency. The minimized gradient supports heavy vehicle stability, reduces braking needs and aligns with optimal highway design standards.

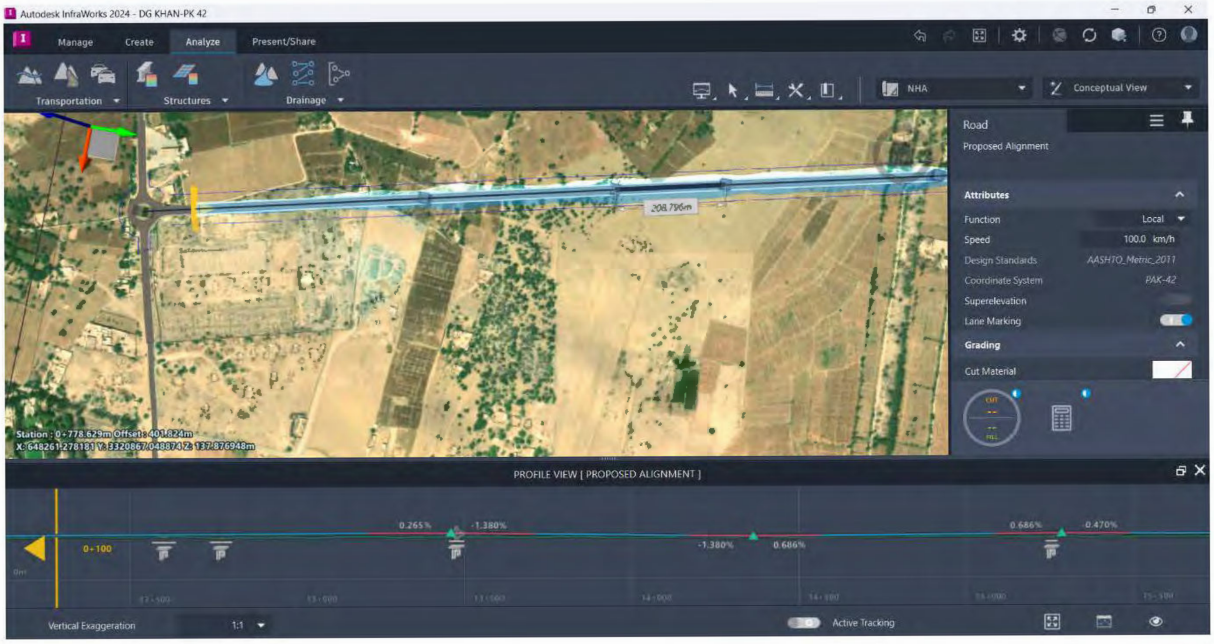


Figure 13: Elevation Profile in InfraWorks

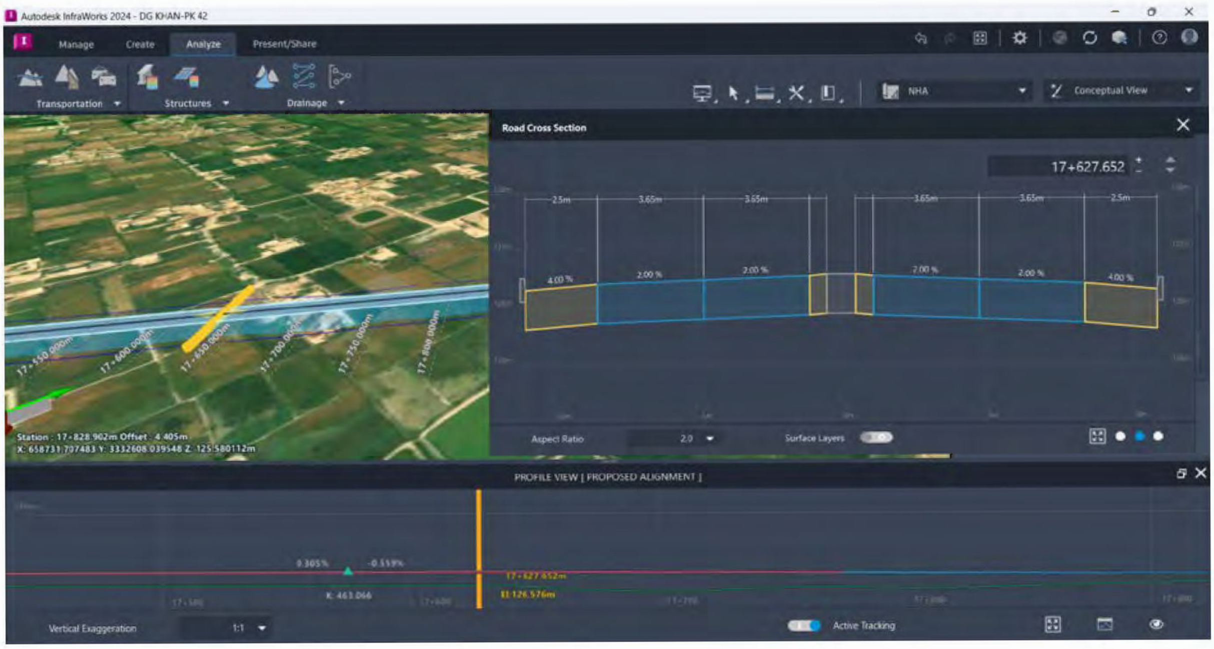



Figure 14: Cross section &Elevation Profile in InfraWorks

### 5.2.3 Sight Distance Analysis

Sight distance analysis evaluates the visibility along each alignment, which is crucial for safety and driving comfort, especially at higher speeds. Better sight distances enhance reaction time and reduce accident risks.

Table 12: Sight Distance Comparison of Alignments

| Alignment | Sight Distance Compliance (%) | Crossfall | Super Elevation (%) | Safety Structures |
|---|---|---|---|---|
| **NHA Proposed Alignment** | 60% | 2% carriageway | 6% | Higher need for guardrails at sharp curves |
| **Alignment Option-1** | 80% | 2% carriageway | 6% | Moderate safety features in weaving areas |
| **Alignment Option-2 (Northern By-pass)** | **97%** | **2% carriageway** | **6%** | Reduced need for extensive safety features |

- **NHA Proposed Alignment:** Sight distance compliance is limited to 60% due to sharp curves and steep gradients, requiring additional guardrails and signage to alert drivers of reduced visibility zones.
- **Alignment Option-1:** An improvement with 80% sight distance compliance, though some weaving sections still require moderate safety features.
- **Alignment Option-2:** Offers the best sight distance compliance at 95%, reducing the need for extensive safety installations due to its gradual curves and consistent super-

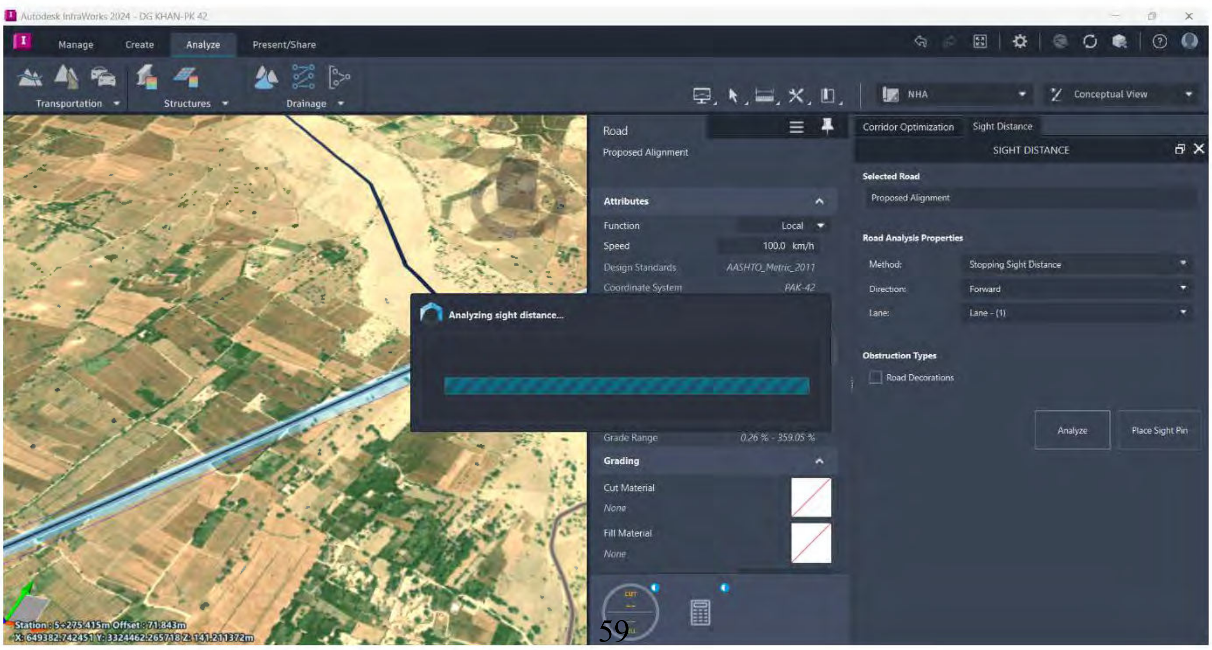





Figure 15: InfraWorks Analyzing Alignment for Sight Distance

elevation, enhancing overall driving safety.

The Sight Distance Analysis assesses visibility along each alignment, with Alignment Option-2 achieving 97% compliance, ensuring optimal safety and minimal need for

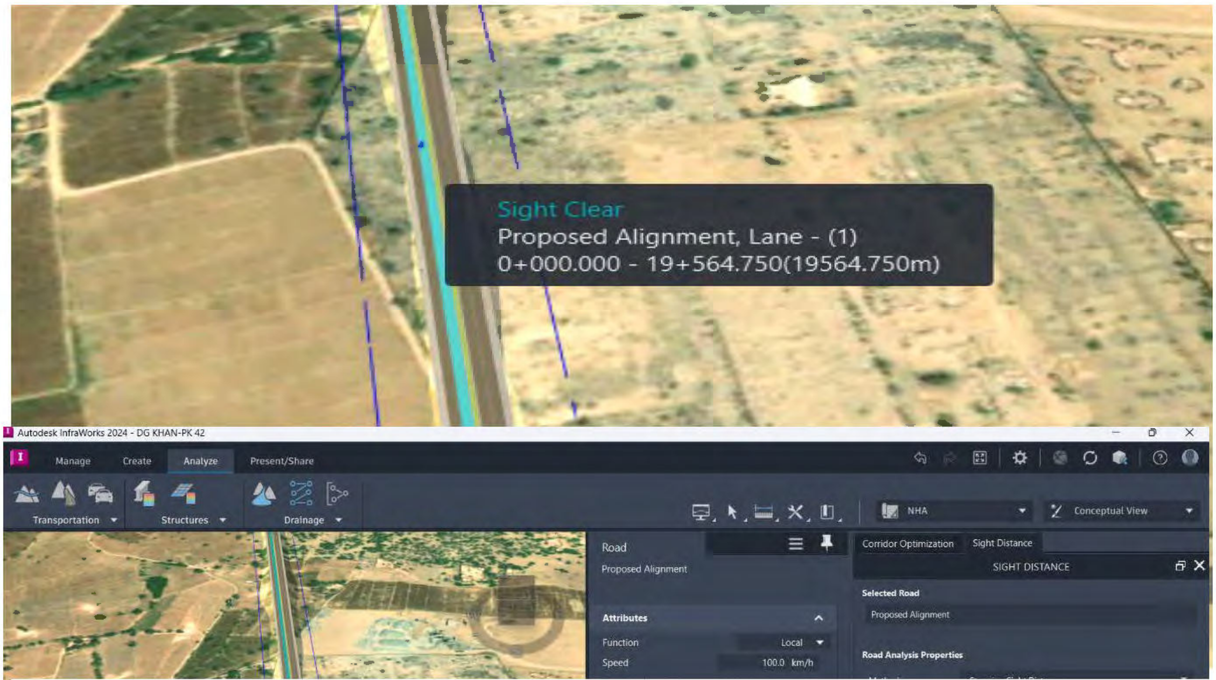



Figure 17: Sight Distance Analysis of Alignment Option-2


Figure 16: Sight Distance Visualization Report in InfraWorks

additional guardrails or safety features.km/h.

## 5.3 Cost Analysis Results

Each alignment's feasibility is evaluated through simulations of earthwork volumes, structural requirements and utility relocation, contributing to an overall assessment of construction costs.

This cost analysis evaluates the total project expenses for each alignment, covering construction, bridge structures, utility relocation and land acquisition cost.

Table 13: Cost Comparison of Alignments

| Cost Component | NHA Proposed Alignment Cost (PKR Million) | Alignment Option-1 Cost (PKR Million) | Alignment Option-2 Cost (PKR Million) |
|---|---|---|---|
| Earth Work | 2035 | 1987 | 1,757 |
| Sub Base & Base | 1,863 | 1,923 | 1,937 |
| Surface Course & Pavement | 513 | 518 | 520 |
| Structures (Culverts, Underpasses & Subways) | 795 | 737 | 722 |
| Structures Bridges | 982 | 953 | 914 |
| Drainage and Erosion Works | 274 | 257 | 241 |
| Guide Banks | 60 | 55 | 53 |
| Ancillary Works | 370 | 360 | 348 |
| General Items | 80 | 75 | 72 |

| | | | |
|---|---|---|---|
| Shifting of Utilities | 143 | 115 | 107 |
| Land Acquisition Cost | 297 | 285 | 261 |
| **Total Cost (PKR Million)** | **7,412** | **7,265** | **6,932** |

**Earthwork and Embankment Volumes:**Earthwork simulations showed that the NHA Proposed Alignment required substantial cut-and-fill activities due to challenging terrain near water channels, resulting in higher costs and increased environmental impact. Alignment Option-1 (Optimized Direct Route) reduced earthwork volumes with improved geometric alignment, but still required moderate embankment work in agricultural zones. The Alignment Option-2 (Northern Bypass), benefiting from flatter terrain, required minimal earthwork and embankments, reducing both environmental disturbance and construction costs.

The Detail of Earth work for the Alignment has been provided in **Annexure A.**

Table 14: Comparative Analysis of Cut and Fill Volume of Alignments

| Alignment | Length (KM) | Cum. Cut Vol. (Cu.m.) | Cum. Fill Vol. (Cu.m.) |
|---|---|---|---|
| NHAs Proposed Alignment | 18+885 | 118.31 | 3,368,151.34 |
| Alignment Option-1 | 18+383 | 125.27 | 3,174,248.93 |
| Alignment Option-2 | 20+017 | 0 | **2,779,851.18** |

The NHA Proposed Alignment spans 18.885 km, requiring a cumulative cut volume of 118.31 cubic meters and a significant fill volume of 3,368,151.34 cubic meters. Alignment Option-1, with a length of 18.383 km, has a slightly higher cut volume at 125.27 cubic meters and a lower fill volume of 3,174,248.93 cubic meters. The optimized Alignment Option-2 with a length of 20.017km shows no required cut volume and has the lowest fill volume of 2,779,851.18 cubic meters. This makes the optimized Alignment Option-2 the most efficient in terms of earthwork, minimizing both environmental impact and construction costs.

**Structural Requirements (Bridges and Culverts):** The alignment options intersecting water channels, particularly the NHA Proposed Alignment, required multiple bridges and culverts, adding to construction complexity and cost. In contrast, the Northern Bypass, by avoiding water crossings, significantly reduced structural requirements, which in turn lowered initial costs and reduced future maintenance needs.

The summary of list of structures for the Alignment has been provided in **Annexure B.**

**Utility Relocation Costs:** Alignments that intersected utility networks, such as the NHA Proposed and Alignment Option-1 (Optimized Direct Route), increased construction complexity due to the need for rerouting power, water and sewer lines. The Northern Bypass avoided major utilities, reducing the cost and time required for utility relocation and minimizing disruption to services.

# CHAPTER 6

# DISCUSSION

The findings of this research highlight the transformative potential of using BIM technology in highway alignment optimization. Through the DG Khan Northern Bypass case study, the integration of BIM tools, such as Autodesk InfraWorks, facilitated a systematic, data-driven approach to evaluating and refining highway alignments. Key aspects, including traffic efficiency, geometric compliance, cost reduction and environmental sustainability, were analyzed, providing significant insights into the broader implications of BIM in highway infrastructure projects.

The optimized alignment (Option 2) demonstrated substantial improvements in traffic efficiency, with a 30% reduction in congestion and a 20% decrease in travel time compared to alternative options. These results align with existing studies, such as Zhao et al.[30] , which highlights BIM's capacity to improve transportation performance by enabling enhanced alignment designs. By simulating real-world traffic conditions in a virtual environment, BIM identified bottlenecks and allowed iterative refinements to the alignment geometry, ensuring optimal traffic flow and safety.

In terms of geometric compliance, Option 2 adhered closely to AASHTO standards, offering superior horizontal curvature, vertical gradients and sight distances. This ensures improved road safety and driving comfort while meeting international safety guidelines, consistent with the findings of Halim et al. [31], Furthermore, the advanced visualization and analysis capabilities of BIM played a crucial role in aligning the design with regulatory standards.

Cost-effectiveness and environmental sustainability emerged as key findings of the study. Option 2 emerged as the most cost-efficient alignment, with a construction cost of PKR 7,324 million—a 10.7% reduction compared to the NHA Proposed Alignment. Additionally, this alignment minimized environmental disruptions by strategically avoiding urban settlements, agricultural land and ecologically sensitive zones, a balance often challenging in conventional approaches. These outcomes echo findings by Biancardo et al.[32], emphasizing the dual benefits of cost reduction and sustainability achievable through BIM integration.

Despite these advantages, challenges in adopting BIM were identified, including issues related to data integration, interoperability and stakeholder acceptance. Addressing these challenges through standardized protocols for data exchange and enhanced user training is essential for the wider adoption of BIM in infrastructure projects.

Finally, the study highlights the significant differences between BIM-based methodologies and traditional practices. Conventional highway alignment methods often rely on static processes that fail to account for dynamic factors such as real-time traffic patterns and environmental constraints. By contrast, BIM's integrated approach enabled real-time simulations, iterative design refinements and stakeholder collaboration, resulting in superior and more sustainable design outcomes.

In conclusion, this study demonstrates that BIM technology provides a robust platform for highway alignment optimization, balancing technical, economic and environmental considerations. Its application in the DG Khan Northern Bypass project exemplifies the potential of BIM to revolutionize highway planning and design, paving the way for future advancements in sustainable infrastructure development.

# CHAPTER 7

# CONCLUSION AND RECOMMENDATION

## 7.1 Conclusion

The study concludes that BIM technology, exemplified through the application of InfraWorks, significantly enhances the process of highway alignment optimization. The evaluation and selection of the most suitable alignment for the DG Khan Bypass is conducted through a comprehensive, data-driven approach, leveraging InfraWorks for advanced simulation and analysis. By comparing the NHA Proposed Alignment, Alignment Option-1 and Alignment Option-2, each alternative's strengths and weaknesses were quantified, providing a clear basis for decision-making.

The key findings are as follows:

- The optimized alignment (Option 2) achieved a 30% reduction in congestion and a 20% reduction in travel time, highlighting the capability of BIM to improve traffic performance.
- By adhering to AASHTO standards, the selected alignment ensures safety and comfort for road users, with optimized curvature, gradients and sight distances.
- Option 2 demonstrated the lowest construction cost (PKR 7,324 million), achieved through reduced earthwork volumes and minimized utility relocations.
- The alignment minimized disruption to urban settlements, agricultural lands and sensitive ecological zones, underscoring the environmental benefits of BIM integration.

Overall, the research highlights the value of a BIM-based methodology in addressing the complexities of modern highway projects, providing a replicable framework for infrastructure planning.

## 7.2 Recommendations

Based on the findings of this study, the following recommendations are proposed:

- Future research should explore the integration of artificial intelligence (AI), the Internet of Things (IoT) and real-time data into BIM platforms to further enhance decision-making capabilities.

- Training programs for engineers, planners and decision-makers should be implemented to maximize the potential of BIM in transportation infrastructure projects.
- The methodology demonstrated in this study should be applied to other infrastructure projects, such as urban roads, tunnels and bridges, to validate its scalability and adaptability.
- Future projects should prioritize environmental sustainability by integrating GIS-based environmental assessments within BIM workflows to identify and mitigate potential ecological impacts.
- Incorporating real-time traffic data into BIM models can improve the accuracy of simulations and enable dynamic adjustments during the planning phase.

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## ANNEXURE-A

### Details of Earthworks for Alignment Option-2 (Northern By-pass)

| Station | Fill Area (Sq.m.) | Fill Volume (Cu.m.) | Cum. Cut Vol. (Cu.m.) | Cum. Reusable Vol. (Cu.m.) | Cum. Fill Vol. (Cu.m.) |
|---|---|---|---|---|---|
| 0+000.000 | 0.36 | 0 | 0 | 0 | 0 |
| 0+100.000 | 19.08 | 972.01 | 609.36 | 609.36 | 972.01 |
| 0+200.000 | 16.23 | 1765.56 | 609.36 | 609.36 | 2737.57 |
| 0+300.000 | 39.9 | 2806.82 | 609.36 | 609.36 | 5544.4 |
| 0+400.000 | 43.47 | 4168.55 | 609.36 | 609.36 | 9712.94 |
| 0+500.000 | 63.4 | 5343.36 | 609.36 | 609.36 | 15056.3 |
| 0+600.000 | 78.73 | 7106.37 | 609.36 | 609.36 | 22162.68 |
| 0+700.000 | 94.05 | 8638.87 | 609.36 | 609.36 | 30801.54 |
| 0+800.000 | 84.58 | 8931.71 | 609.36 | 609.36 | 39733.26 |
| 0+900.000 | 107.99 | 9628.53 | 609.36 | 609.36 | 49361.79 |
| 1+000.000 | 112.17 | 11007.6 | 609.36 | 609.36 | 60369.38 |
| 1+100.000 | 127.32 | 11974.15 | 609.36 | 609.36 | 72343.53 |
| 1+200.000 | 88.99 | 10815.16 | 609.36 | 609.36 | 83158.69 |
| 1+300.000 | 78.34 | 8366.39 | 609.36 | 609.36 | 91525.08 |
| 1+400.000 | 67.4 | 7287.11 | 609.36 | 609.36 | 98812.19 |
| 1+500.000 | 68.51 | 6795.4 | 609.36 | 609.36 | 105607.59 |
| 1+600.000 | 69.12 | 6881.33 | 609.36 | 609.36 | 112488.93 |
| 1+700.000 | 66.6 | 6785.79 | 609.36 | 609.36 | 119274.71 |
| 1+800.000 | 75.21 | 7090.12 | 609.36 | 609.36 | 126364.84 |
| 1+900.000 | 83.85 | 7952.9 | 609.36 | 609.36 | 134317.73 |
| 2+000.000 | 69.68 | 7676.57 | 609.36 | 609.36 | 141994.3 |
| 2+100.000 | 71.44 | 7055.77 | 609.36 | 609.36 | 149050.07 |
| 2+200.000 | 65.07 | 6824.7 | 609.36 | 609.36 | 155874.77 |
| 2+300.000 | 81.66 | 7336.49 | 609.36 | 609.36 | 163211.26 |
| 2+400.000 | 96.82 | 8924.64 | 609.36 | 609.36 | 172135.91 |
| 2+500.000 | 96.39 | 9656.8 | 609.36 | 609.36 | 181792.71 |
| 2+600.000 | 95.43 | 9586.43 | 609.36 | 609.36 | 191379.14 |
| 2+700.000 | 91.74 | 9359.2 | 609.36 | 609.36 | 200738.33 |
| 2+800.000 | 110.6 | 10117.63 | 609.36 | 609.36 | 210855.96 |
| 2+900.000 | 122.13 | 11635.68 | 609.36 | 609.36 | 222491.64 |
| 3+000.000 | 108.13 | 11513.88 | 609.36 | 609.36 | 234005.52 |
| 3+100.000 | 112.85 | 11045.93 | 609.36 | 609.36 | 245051.46 |
| 3+200.000 | 108.73 | 11074.99 | 609.36 | 609.36 | 256126.44 |
| 3+300.000 | 91.5 | 10011.78 | 609.36 | 609.36 | 266138.22 |
| 3+400.000 | 97.79 | 9464.83 | 609.36 | 609.36 | 275603.05 |
| 3+500.000 | 87.19 | 9249.04 | 609.36 | 609.36 | 284852.09 |
| 3+600.000 | 83.57 | 8537.69 | 609.36 | 609.36 | 293389.78 |
| 3+700.000 | 88.7 | 8613.43 | 609.36 | 609.36 | 302003.21 |
| 3+800.000 | 100.6 | 9465.18 | 609.36 | 609.36 | 311468.39 |

| Station | Fill Area (Sq.m.) | Fill Volume (Cu.m.) | Cum. Cut Vol. (Cu.m.) | Cum. Reusable Vol. (Cu.m.) | Cum. Fill Vol. (Cu.m.) |
|---|---|---|---|---|---|
| 3+900.000 | 108.26 | 10442.91 | 609.36 | 609.36 | 321911.3 |
| 4+000.000 | 106.32 | 10728.88 | 609.36 | 609.36 | 332640.18 |
| 4+100.000 | 107.01 | 10666.47 | 609.36 | 609.36 | 343306.64 |
| 4+200.000 | 93.26 | 10013.31 | 609.36 | 609.36 | 353319.95 |
| 4+300.000 | 80.39 | 8682.57 | 609.36 | 609.36 | 362002.53 |
| 4+400.000 | 68.78 | 7458.62 | 609.36 | 609.36 | 369461.15 |
| 4+500.000 | 68.63 | 6870.51 | 609.36 | 609.36 | 376331.66 |
| 4+600.000 | 61.62 | 6512.46 | 609.36 | 609.36 | 382844.12 |
| 4+700.000 | 66.79 | 6420.55 | 609.36 | 609.36 | 389264.66 |
| 4+800.000 | 74.26 | 7052.62 | 609.36 | 609.36 | 396317.28 |
| 4+900.000 | 108.67 | 9146.34 | 609.36 | 609.36 | 405463.62 |
| 5+000.000 | 152.93 | 13079.91 | 609.36 | 609.36 | 418543.53 |
| 5+100.000 | 199.18 | 17605.65 | 609.36 | 609.36 | 436149.18 |
| 5+200.000 | 266.65 | 23291.49 | 609.36 | 609.36 | 459440.67 |
| 5+300.000 | 308.08 | 28736.32 | 609.36 | 609.36 | 488177 |
| 5+400.000 | 291.55 | 29981.22 | 609.36 | 609.36 | 518158.21 |
| 5+500.000 | 252.31 | 27192.87 | 609.36 | 609.36 | 545351.08 |
| 5+600.000 | 162.5 | 20740.4 | 609.36 | 609.36 | 566091.48 |
| 5+700.000 | 115.16 | 13883.06 | 609.36 | 609.36 | 579974.53 |
| 5+800.000 | 92.91 | 10403.76 | 609.36 | 609.36 | 590378.3 |
| 5+900.000 | 73.96 | 8343.81 | 609.36 | 609.36 | 598722.11 |
| 6+000.000 | 57.46 | 6571.17 | 609.36 | 609.36 | 605293.28 |
| 6+100.000 | 64.8 | 6113 | 609.36 | 609.36 | 611406.29 |
| 6+200.000 | 81.96 | 7338.23 | 609.36 | 609.36 | 618744.52 |
| 6+300.000 | 98.42 | 9019.16 | 609.36 | 609.36 | 627763.68 |
| 6+400.000 | 124.54 | 11148.01 | 609.36 | 609.36 | 638911.68 |
| 6+500.000 | 181.39 | 15296.48 | 609.36 | 609.36 | 654208.16 |
| 6+600.000 | 200.59 | 19099.21 | 609.36 | 609.36 | 673307.38 |
| 6+700.000 | 101.15 | 15087.21 | 609.36 | 609.36 | 688394.58 |
| 6+800.000 | 86.09 | 9361.97 | 609.36 | 609.36 | 697756.56 |
| 6+900.000 | 73.98 | 8003.47 | 609.36 | 609.36 | 705760.02 |
| 7+000.000 | 61.32 | 6764.9 | 609.36 | 609.36 | 712524.92 |
| 7+100.000 | 67.36 | 6434.17 | 609.36 | 609.36 | 718959.09 |
| 7+200.000 | 68.62 | 6799.08 | 609.36 | 609.36 | 725758.18 |
| 7+300.000 | 64.5 | 6655.83 | 609.36 | 609.36 | 732414.01 |
| 7+400.000 | 60.53 | 6251.34 | 609.36 | 609.36 | 738665.35 |
| 7+500.000 | 76.36 | 6844.2 | 609.36 | 609.36 | 745509.55 |
| 7+600.000 | 88.48 | 8241.84 | 609.36 | 609.36 | 753751.39 |
| 7+700.000 | 99.28 | 9388.19 | 609.36 | 609.36 | 763139.58 |
| 7+800.000 | 128.28 | 11378.34 | 609.36 | 609.36 | 774517.93 |
| 7+900.000 | 180.69 | 15448.55 | 609.36 | 609.36 | 789966.48 |
| 8+000.000 | 218.17 | 19943.06 | 609.36 | 609.36 | 809909.53 |

| Station | Fill Area (Sq.m.) | Fill Volume (Cu.m.) | Cum. Cut Vol. (Cu.m.) | Cum. Reusable Vol. (Cu.m.) | Cum. Fill Vol. (Cu.m.) |
|---|---|---|---|---|---|
| 8+100.000 | 255.5 | 23683.73 | 609.36 | 609.36 | 833593.26 |
| 8+200.000 | 295.36 | 27542.85 | 609.36 | 609.36 | 861136.11 |
| 8+300.000 | 295.52 | 29543.87 | 609.36 | 609.36 | 890679.98 |
| 8+400.000 | 285.63 | 29057.42 | 609.36 | 609.36 | 919737.4 |
| 8+500.000 | 253.37 | 26949.8 | 609.36 | 609.36 | 946687.2 |
| 8+600.000 | 223.86 | 23861.26 | 609.36 | 609.36 | 970548.46 |
| 8+700.000 | 177.41 | 20063.46 | 609.36 | 609.36 | 990611.92 |
| 8+800.000 | 139.35 | 15838.2 | 609.36 | 609.36 | 1006450.12 |
| 8+900.000 | 140.83 | 14008.86 | 609.36 | 609.36 | 1020458.98 |
| 9+000.000 | 115.21 | 12801.58 | 609.36 | 609.36 | 1033260.56 |
| 9+100.000 | 85.14 | 10017.09 | 609.36 | 609.36 | 1043277.64 |
| 9+200.000 | 48.43 | 6678.1 | 609.36 | 609.36 | 1049955.74 |
| 9+300.000 | 61.67 | 5504.94 | 609.36 | 609.36 | 1055460.68 |
| 9+400.000 | 57.91 | 5979.22 | 609.36 | 609.36 | 1061439.9 |
| 9+500.000 | 55.65 | 5678.28 | 609.36 | 609.36 | 1067118.18 |
| 9+600.000 | 84.82 | 7023.53 | 609.36 | 609.36 | 1074141.71 |
| 9+700.000 | 98.8 | 9180.92 | 609.36 | 609.36 | 1083322.64 |
| 9+800.000 | 115.63 | 10721.48 | 609.36 | 609.36 | 1094044.11 |
| 9+900.000 | 144.88 | 13025.4 | 609.36 | 609.36 | 1107069.52 |
| 10+000.000 | 152.12 | 14850.02 | 609.36 | 609.36 | 1121919.54 |
| 10+100.000 | 143.03 | 14757.53 | 609.36 | 609.36 | 1136677.07 |
| 10+200.000 | 150.79 | 14690.83 | 609.36 | 609.36 | 1151367.91 |
| 10+300.000 | 138.87 | 14482.88 | 609.36 | 609.36 | 1165850.79 |
| 10+400.000 | 129.81 | 13433.98 | 609.36 | 609.36 | 1179284.77 |
| 10+500.000 | 114.28 | 12204.56 | 609.36 | 609.36 | 1191489.32 |
| 10+600.000 | 111.61 | 11296.09 | 609.36 | 609.36 | 1202785.41 |
| 10+700.000 | 114.57 | 11311.12 | 609.36 | 609.36 | 1214096.54 |
| 10+800.000 | 103.03 | 10880.25 | 609.36 | 609.36 | 1224976.78 |
| 10+900.000 | 96.61 | 9981.36 | 609.36 | 609.36 | 1234958.15 |
| 11+000.000 | 92.54 | 9456.59 | 609.36 | 609.36 | 1244414.74 |
| 11+100.000 | 74.94 | 8373.5 | 609.36 | 609.36 | 1252788.23 |
| 11+200.000 | 63.99 | 6946.03 | 609.36 | 609.36 | 1259734.26 |
| 11+300.000 | 58.95 | 6146.11 | 609.36 | 609.36 | 1265880.37 |
| 11+400.000 | 58.02 | 5847.94 | 609.36 | 609.36 | 1271728.31 |
| 11+500.000 | 44.53 | 5127.54 | 609.36 | 609.36 | 1276855.85 |
| 11+600.000 | 42.79 | 4365.84 | 609.36 | 609.36 | 1281221.69 |
| 11+700.000 | 45.39 | 4408.95 | 609.36 | 609.36 | 1285630.64 |
| 11+800.000 | 44.23 | 4480.76 | 609.36 | 609.36 | 1290111.4 |
| 11+900.000 | 50.02 | 4712.21 | 609.36 | 609.36 | 1294823.61 |
| 12+000.000 | 85.6 | 6781.06 | 609.36 | 609.36 | 1301604.67 |
| 12+100.000 | 110.33 | 9796.51 | 609.36 | 609.36 | 1311401.18 |
| 12+200.000 | 127.34 | 11883.47 | 609.36 | 609.36 | 1323284.65 |

| **Station** | **Fill Area (Sq.m.)** | **Fill Volume (Cu.m.)** | **Cum. Cut Vol. (Cu.m.)** | **Cum. Reusable Vol. (Cu.m.)** | **Cum. Fill Vol. (Cu.m.)** |
|---|---|---|---|---|---|
| 12+300.000 | 155.59 | 14146.38 | 609.36 | 609.36 | 1337431.03 |
| 12+400.000 | 177.62 | 16660.2 | 609.36 | 609.36 | 1354091.23 |
| 12+500.000 | 192.51 | 18506.51 | 609.36 | 609.36 | 1372597.74 |
| 12+600.000 | 207.51 | 20000.94 | 609.36 | 609.36 | 1392598.68 |
| 12+700.000 | 142.87 | 17518.94 | 609.36 | 609.36 | 1410117.62 |
| 12+800.000 | 291.38 | 21712.75 | 609.36 | 609.36 | 1431830.37 |
| 12+900.000 | 308.71 | 30004.45 | 609.36 | 609.36 | 1461834.82 |
| 13+000.000 | 384.09 | 34640.07 | 609.36 | 609.36 | 1496474.89 |
| 13+100.000 | 423.5 | 40379.98 | 609.36 | 609.36 | 1536854.87 |
| 13+200.000 | 465.02 | 44426.14 | 609.36 | 609.36 | 1581281.01 |
| 13+300.000 | 498.3 | 48165.77 | 609.36 | 609.36 | 1629446.78 |
| 13+400.000 | 495.19 | 49674.58 | 609.36 | 609.36 | 1679121.36 |
| 13+500.000 | 460.94 | 47806.62 | 609.36 | 609.36 | 1726927.98 |
| 13+600.000 | 451.07 | 45598.76 | 609.36 | 609.36 | 1772526.75 |
| 13+700.000 | 387.08 | 41907.21 | 609.36 | 609.36 | 1814433.95 |
| 13+800.000 | 323.66 | 35536.92 | 609.36 | 609.36 | 1849970.87 |
| 13+900.000 | 257.76 | 29071.12 | 609.36 | 609.36 | 1879041.99 |
| 14+000.000 | 197.67 | 22773.07 | 609.36 | 609.36 | 1901815.06 |
| 14+100.000 | 145.16 | 17143.06 | 609.36 | 609.36 | 1918958.12 |
| 14+200.000 | 96.05 | 12060.6 | 609.36 | 609.36 | 1931018.72 |
| 14+300.000 | 70.48 | 8326.33 | 609.36 | 609.36 | 1939345.04 |
| 14+400.000 | 64.36 | 6742.02 | 609.36 | 609.36 | 1946087.06 |
| 14+500.000 | 57.98 | 6115.81 | 609.36 | 609.36 | 1952202.88 |
| 14+600.000 | 93.18 | 7555.96 | 609.36 | 609.36 | 1959758.83 |
| 14+700.000 | 125.29 | 10922.95 | 609.36 | 609.36 | 1970681.79 |
| 14+800.000 | 152.26 | 13876.16 | 609.36 | 609.36 | 1984557.95 |
| 14+900.000 | 198.34 | 17530.16 | 609.36 | 609.36 | 2002088.11 |
| 15+000.000 | 240.19 | 21926.49 | 609.36 | 609.36 | 2024014.6 |
| 15+100.000 | 270.66 | 25542.13 | 609.36 | 609.36 | 2049556.72 |
| 15+200.000 | 300.95 | 28580.47 | 609.36 | 609.36 | 2078137.2 |
| 15+300.000 | 294.79 | 29787.38 | 609.36 | 609.36 | 2107924.57 |
| 15+400.000 | 349.91 | 32234.97 | 609.36 | 609.36 | 2140159.54 |
| 15+500.000 | 334.94 | 34242.52 | 609.36 | 609.36 | 2174402.07 |
| 15+600.000 | 321.16 | 32805.19 | 609.36 | 609.36 | 2207207.25 |
| 15+700.000 | 302.19 | 31167.65 | 609.36 | 609.36 | 2238374.9 |
| 15+800.000 | 285.54 | 29386.45 | 609.36 | 609.36 | 2267761.36 |
| 15+900.000 | 265.71 | 27562.34 | 609.36 | 609.36 | 2295323.7 |
| 16+000.000 | 252.16 | 25893.75 | 609.36 | 609.36 | 2321217.45 |
| 16+100.000 | 252.37 | 25226.76 | 609.36 | 609.36 | 2346444.21 |
| 16+200.000 | 248.74 | 25055.59 | 609.36 | 609.36 | 2371499.8 |
| 16+300.000 | 282.68 | 26571.08 | 609.36 | 609.36 | 2398070.88 |
| 16+400.000 | 299.25 | 29096.77 | 609.36 | 609.36 | 2427167.65 |

| Station | Fill Area (Sq.m.) | Fill Volume (Cu.m.) | Cum. Cut Vol. (Cu.m.) | Cum. Reusable Vol. (Cu.m.) | Cum. Fill Vol. (Cu.m.) |
|---|---|---|---|---|---|
| 16+500.000 | 288.11 | 29368.24 | 609.36 | 609.36 | 2456535.89 |
| 16+600.000 | 260.49 | 27429.89 | 609.36 | 609.36 | 2483965.78 |
| 16+700.000 | 226.32 | 24340.18 | 609.36 | 609.36 | 2508305.96 |
| 16+800.000 | 173.09 | 19970.27 | 609.36 | 609.36 | 2528276.23 |
| 16+900.000 | 138.08 | 15558.43 | 609.36 | 609.36 | 2543834.66 |
| 17+000.000 | 108.28 | 12317.86 | 609.36 | 609.36 | 2556152.52 |
| 17+100.000 | 50.27 | 7927.52 | 609.36 | 609.36 | 2564080.04 |
| 17+200.000 | 73.66 | 6196.8 | 609.36 | 609.36 | 2570276.84 |
| 17+300.000 | 96.47 | 8506.76 | 609.36 | 609.36 | 2578783.6 |
| 17+400.000 | 97.63 | 9705.21 | 609.36 | 609.36 | 2588488.81 |
| 17+500.000 | 123.35 | 11048.99 | 609.36 | 609.36 | 2599537.8 |
| 17+600.000 | 123.63 | 12349.1 | 609.36 | 609.36 | 2611886.9 |
| 17+700.000 | 90.68 | 10715.77 | 609.36 | 609.36 | 2622602.67 |
| 17+800.000 | 95.08 | 9288.04 | 609.36 | 609.36 | 2631890.71 |
| 17+900.000 | 72.06 | 8356.83 | 609.36 | 609.36 | 2640247.54 |
| 18+000.000 | 59.49 | 6577.11 | 609.36 | 609.36 | 2646824.65 |
| 18+100.000 | 46.13 | 5280.76 | 609.36 | 609.36 | 2652105.41 |
| 18+200.000 | 46 | 4606.32 | 609.36 | 609.36 | 2656711.73 |
| 18+300.000 | 50.02 | 4800.72 | 609.36 | 609.36 | 2661512.45 |
| 18+400.000 | 53.39 | 5170.35 | 609.36 | 609.36 | 2666682.79 |
| 18+500.000 | 70.41 | 6189.96 | 609.36 | 609.36 | 2672872.75 |
| 18+600.000 | 59.79 | 6510.9 | 609.36 | 609.36 | 2679383.65 |
| 18+700.000 | 86.86 | 7333.01 | 609.36 | 609.36 | 2686716.67 |
| 18+800.000 | 70.68 | 7878.04 | 609.36 | 609.36 | 2694594.71 |
| 18+900.000 | 67.37 | 6903.98 | 609.36 | 609.36 | 2701498.69 |
| 19+000.000 | 17.21 | 4229.21 | 609.36 | 609.36 | 2705727.9 |
| 19+100.000 | 42.96 | 3006.16 | 609.36 | 609.36 | 2708734.06 |
| 19+200.000 | 28.8 | 3582.42 | 609.36 | 609.36 | 2712316.49 |
| 19+300.000 | 28.99 | 2885.85 | 609.36 | 609.36 | 2715202.34 |
| 19+400.000 | 53.36 | 4111.69 | 609.36 | 609.36 | 2719314.03 |
| 19+500.000 | 70.25 | 6178.12 | 609.36 | 609.36 | 2725492.15 |
| 19+600.000 | 106.56 | 8844.29 | 609.36 | 609.36 | 2734336.44 |
| 19+700.000 | 141.29 | 12397.22 | 609.36 | 609.36 | 2746733.66 |
| 19+800.000 | 136.95 | 13915.78 | 609.36 | 609.36 | 2760649.44 |
| 19+900.000 | 99.53 | 11824.37 | 609.36 | 609.36 | 2772473.81 |
| 20+000.000 | 40.71 | 7011.92 | 609.36 | 609.36 | 2779485.74 |
| 20+017.954 | 0 | 365.45 | 609.36 | 609.36 | 2,779,851.18 |

## ANNEXURE-B

### Summary of List of Structures

| *Summary Underground Structure* | | | | |
|---|---|---|---|---|
| ***Sr.No*** | ***Size*** | ***Span*** | ***Type*** | ***Total Number of Structures*** |
| *1* | *1.2Dia* | *1.2* | *Pipe Culvert* | *57* |
| *2* | *2X2* | *2* | *Box Culvert* | *42* |
| *3* | *2-2x2* | *2* | *Multi Cell Box Culvert* | *11* |
| *4* | *3-2x2* | *2* | *Multi Cell Box Culvert* | *4* |
| *5* | *3x3* | *3* | *Box Culvert* | *1* |
| *7* | *3-3x3* | *3* | *Multi Cell Box Culvert* | *2* |
| *Total No of Structure* | | | | *117* |

| *Summary S.W,SRUP & Cattle creep* | | | | |
|---|---|---|---|---|
| ***Sr.No*** | ***Size*** | ***Span*** | ***Type*** | ***Total Number of Structures*** |
| *1* | *4.5x4.5* | *4.5* | *Sub Way* | *8* |
| *2* | *7.3x5.3* | *7.3* | *Standard Road Underpass* | *2* |
| *3* | *2.5x2.5* | *2.5* | *Cattle Creep* | *7* |
| *Total No of Structure* | | | | *17* |

| *Summary Flyover & Bridges* | | | | |
|---|---|---|---|---|
| ***Sr.No*** | ***Length*** | ***Span*** | ***Type*** | ***Total Number of Structures*** |
| *1* | *210* | *(30 x 7)* | *VIDOR NULLAH* | *1* |
| *2* | *50* | *(25 x 2)* | | *1* |
| *3* | *50* | *(25 x 2)* | | *1* |
| *4* | *70* | *(35 x 2)* | *KACHI CANAL* | *1* |
| *5* | *70* | *(35 x 2)* | *D.G. KHAN CANAL* | *1* |
| *6* | *45* | *(45 x 1)* | *RAILWAY CROSSING* | *1* |
| *7* | *35* | *(35 x 1)* | *MANKA CANAL* | *1* |
| *8* | *80* | *(40 x 2)* | *Flyover* | *1* |
| *Total No of Structure* | | | | *8* |