INTERNSHIP REPORT

Jacobs Solutions India Pvt Ltd

Jacobs

Challenging today.
Reinventing tomorrow.

Carried out by

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(Indian Institute of Technology, Guwahati)

26/05/2025 – 31/07/2025

ACKNOWLEDGEMENT

The successful completion of this internship program at Jacobs Solutions India Pvt. Ltd. has been a highly rewarding and enriching experience, and I am deeply indebted to all those who have supported and guided me throughout this journey.

I would like to begin by expressing my sincere appreciation to the Indian Institute of Technology Guwahati and its Placement Cell for facilitating this valuable opportunity and for their continued efforts in bridging the gap between academic learning and industry experience.

I am especially thankful to Mr. Deepak Sharma and other senior managers at Jacobs for offering me the opportunity to intern with their esteemed organization. Their support and leadership created an environment that encouraged learning and professional growth.

I extend my heartfelt gratitude to my Line Manager, Mr. Mahalingam Murugappan, my mentor, Sushmitha Shivappa and my buddy, Sahana Upadhye, for their guidance, encouragement, and constructive feedback throughout the internship. Their mentorship played a vital role in shaping both my technical understanding and professional outlook.

I would also like to thank all the colleagues and team members I had the privilege of working with. Their openness, patience, and collaborative spirit greatly contributed to a positive and engaging work environment.

This internship has not only enhanced my technical skills but also provided valuable insights into workplace culture, communication, and team dynamics.

Finally, I wish to express my sincere and lasting appreciation to everyone who contributed in any capacity to this internship. Their support and guidance have made a meaningful impact on my personal and professional development, for which I am truly grateful.

ABSTRACT

This report presents a comprehensive overview of the internship undertaken at Jacobs Solutions India Pvt. Ltd., Bengaluru, as part of the M.Tech. program in Transportation Engineering, conducted from May 26^{th}, 2025, to July 31st, 2025.

During the course of the internship, I received training sessions in Autodesk Civil 3D, OpenRoads Designer, and basic pavement design principles. I was assigned to the geometric design of highways for a pilot project titled “Design of Roads and Infrastructure in Al Sakhama Project”, a Qatar-based roadway infrastructure initiative, utilizing Civil 3D software as the primary design tool.

My responsibilities included preparing 2D layout plans, developing horizontal and vertical alignments, and modelling assemblies and corridors in accordance with the Qatar Highway Design Manual (QHDM). I was also involved in the geometric design of various intersections, such as T-intersections, right-in/right-out junctions, and roundabouts, in both 2D and 3D formats. In addition, I carried out swept path analysis for selected roadway components.

This internship significantly enhanced my technical proficiency, software skills, and provided valuable exposure to real-world highway geometric design practices in a professional engineering environment.

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ABOUT THE COMPANY

Jacobs Solutions Inc. is a global leader in delivering professional and technology-enabled solutions across a broad range of sectors including infrastructure, environmental services, national security, transportation, water, energy, and life sciences. Headquartered in Dallas, Texas, Jacobs operates in more than 40 countries and employs over 60,000 professionals worldwide. The company is listed on the Fortune 500 and is a member of the S&P 500, consistently recognized for its innovation, sustainability efforts, and inclusive work culture.

Driven by the mission *"Challenging today. Reinventing tomorrow,"* Jacobs focuses on creating sustainable and transformative solutions that address the world's most critical challenges—from climate change and urbanization to digital transformation and public health.

Global Delivery Model and Presence in India

Jacobs follows an integrated global delivery model, supported by its Global Delivery Centers (GDCs) located in India, the Philippines, and Poland. The India GDC, with offices in cities like Bengaluru, Hyderabad, Mumbai, Kolkata, and Gurgaon, plays a crucial role in executing both global and domestic projects.

Approximately 70–80% of project work delivered from India supports international clients across regions such as the Middle East, North America, Europe, and Asia-Pacific, while 20–30% serves domestic Indian infrastructure projects in transportation, water, and urban development.

Indian teams support Jacobs' multidisciplinary design and engineering services, including:

- Highway and rail geometry design
- Environmental modelling
- Water supply and drainage systems
- Digital delivery and BIM modelling
- Structural and MEP design
- CAD, GIS, and data visualization support

Software and Digital Capabilities

Jacobs employs a comprehensive suite of engineering and design tools to ensure precision, efficiency, and digital integration across project phases. Commonly used software includes:

- **Autodesk Civil 3D** – for highway geometry and land development design
- **Bentley OpenRoads Designer** – for roadway and corridor modelling
- **AutoCAD / MicroStation / InfraWorks** – for 2D drafting and concept visualization
- **Vehicle Tracking** – for swept path analysis and intersection design
- **Navisworks** – for 3D model coordination and clash detection
- **ProjectWise** – for document and data management
- **ArcGIS** – for geographic and spatial analysis
- **Revit and BIM 360** – for building information modelling
- **SmartPlant and AECOM tools** – for plant and system design in advanced facilities

Digital twins, AI-enabled modelling, and cloud-based collaboration platforms are increasingly integrated into Jacobs' project workflows, improving project delivery speed and resilience.

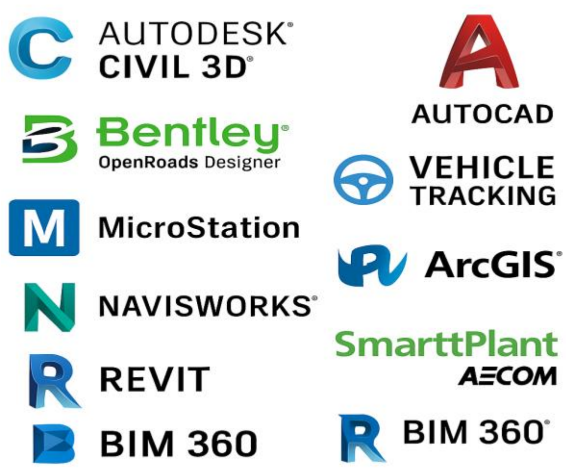


Figure 1.1: Software used in Jacobs

Workplace Culture and Values

Jacobs fosters a workplace guided by four key values:

1. **We do things right** – With integrity, safety, and ethical conduct.
2. **We challenge the accepted** – Innovating through curiosity and ambition.

3. **We aim higher** – Striving for excellence and client satisfaction.
4. **We live inclusion** – Promoting diversity, equity, and a sense of belonging.

Signature programs like **BeyondZero** reinforce Jacobs' commitment to health, safety, and well-being across its global workforce.

Transportation is one of Jacobs' most significant and mature sectors, forming a core pillar of its People & Places Solutions business unit. The company delivers end-to-end services across highways, urban roads, rail and metro systems, aviation infrastructure, and ports. With decades of experience and a forward-looking focus on sustainable and smart mobility, Jacobs works with national and regional governments, multilateral agencies, and private infrastructure developers to enhance connectivity and mobility across the globe.

Jacobs Solutions Inc. stands as a premier engineering and technology partner, shaping a more connected, sustainable, and resilient world. With a robust global presence, a forward-thinking approach to innovation and sustainability, and a strong delivery footprint in India, Jacobs continues to set industry benchmarks in infrastructure and professional services.

CHAPTER 2

TRAINING AND SKILL DEVELOPMENT

During the internship, I took part in structured technical training sessions aimed at strengthening my understanding of key design software and foundational concepts in transportation engineering. These sessions were led by experienced professionals within the organization and focused on three core areas: OpenRoads Designer (ORD), Autodesk Civil 3D, and basic pavement design. The training combined live demonstrations, theoretical insights, and hands-on exercises, providing a well-rounded learning experience that reinforced core concepts and practical skills.

2.1 AUTODESK CIVIL 3D

The training in Autodesk Civil 3D provided a detailed and professional introduction to the fundamental components of roadway geometric design within the software environment. The focus was on guiding participants through the end-to-end process of developing a comprehensive roadway model, beginning with terrain data and progressing to final corridor generation.

2.1.1 Points

In Autodesk Civil 3D, points are a foundational element used extensively in surveying, surface modelling, and geometric design. At their core, points represent spatial data—specifically, stored coordinate values.

Civil 3D uses Cogo Points (Coordinate Geometry Points), which are uniquely numbered entities that store not only geographic location (Northing and Easting) but may also include elevation, description, and additional metadata.

Points can be created manually or imported from external files. One common method is through the "Create Points - Miscellaneous: Northing/Easting" command, accessible from the Home tab → Create Ground Data panel → Points dropdown. This tool allows users to manually enter coordinate data and assign an elevation to define the point's location in the drawing.

For larger datasets, points are often imported using a CSV file containing coordinate information. These imported points can then be grouped using Point Groups, which help in organizing, styling, and controlling point display behaviour.

2.1.2 Surface Creation

This segment addressed the development of an existing ground surface using survey data such as spot levels, contour lines, and point files. The surface, modelled as a Triangulated Irregular Network (TIN), serves as the foundational element for terrain analysis, alignment planning, and volume estimation. Key tasks included importing and managing survey data, defining breaklines and boundaries to improve surface fidelity, and configuring surface properties to support subsequent design activities.

Once a surface is created, it is automatically listed in the Prospector Tab under the Surfaces collection, enabling further modification, data input, and analysis. Initially, the surface may appear empty and not be visible in the drawing until data is added. Its visibility and representation are governed by the assigned surface style settings, which control aspects like contours, triangles, and points.

Autodesk Civil 3D supports several surface types, each suited for different applications:

- **TIN Surface**: The most commonly used surface type, created by triangulating irregularly spaced data points into a *Triangulated Irregular Network (TIN)*. TIN surfaces are made up of triangles formed by connecting the nearest surface points with *TIN lines*. These triangles allow Civil 3D to interpolate elevations at any location within the network.
- **Grid Surface**: Created from points arranged on a regular grid, such as Digital Elevation Models (DEMs). Less flexible than TIN surfaces but useful for large-area terrain representation.
- **Volume Surfaces**:
    - **TIN Volume Surface**: A composite or differential surface generated by comparing a base surface (e.g., existing ground) with a comparison surface (e.g., proposed design). Commonly used for cut-and-fill analysis.
    - **Grid Volume Surface**: Similar to TIN volume surfaces but uses grid-based elevation data for both base and comparison surfaces.
- **Corridor Surface**: Extracted from a corridor model and used to represent specific design features such as finished grade, subgrade, or top of pavement. Useful in defining cross-sectional geometry over a project alignment.

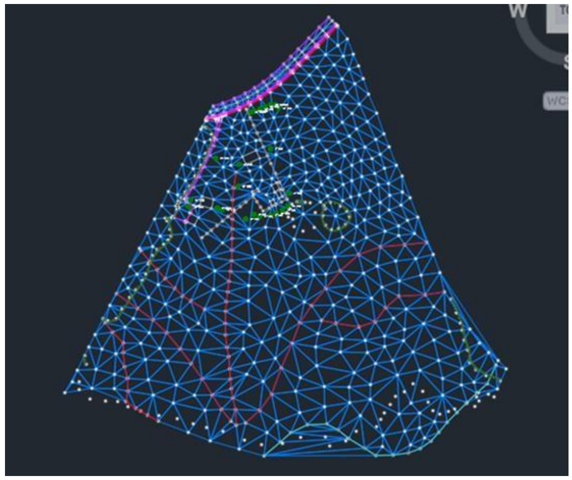


Figure 2.1: Surface created in Civil 3D from survey data

2.1.3 Horizontal Alignments

In Civil 3D, horizontal alignments represent the linear path of infrastructure elements such as roadways, railways, utility corridors, channels, and bridges. These alignments are defined using a combination of straight-line tangents, circular curves, and spiral transitions. They serve as the foundational reference for designing other components like profiles, corridors, and cross-sections.

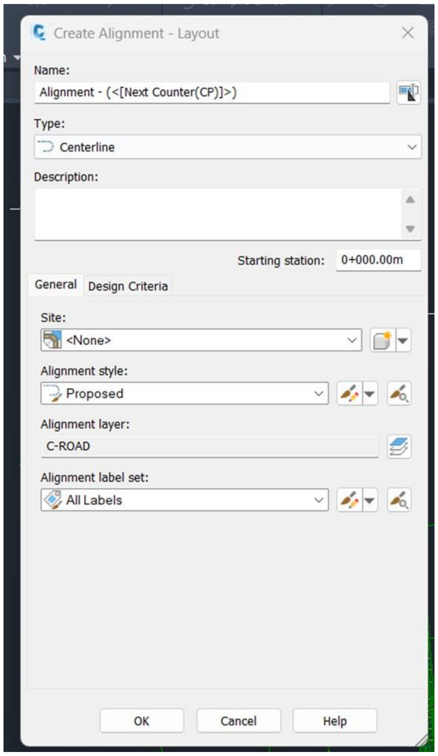
Alignments can act as parent objects for features such as profiles and corridors, and changes made to them automatically update associated components. Elements like curb return alignments, offset alignments, and widenings can be linked dynamically to the main alignment or created independently. Additionally, intersection design in Civil 3D can automate the generation of return curves and offset alignments.

The training covered four primary methods for creating alignments:

- **Manual Alignment Design (By IP or Element Method):** Users create alignments by specifying intersection points (IPs) or geometric elements like lines, curves, and spirals, allowing for high precision and control.
- **Alignment from Objects:** This method converts existing AutoCAD polylines or feature lines into Civil 3D alignments, which is particularly useful when working with base plans or survey drawings.
- **Best Fit Alignment:** The Best Fit tool generates a smooth alignment through a series of existing survey points or lines, ideal for irregular or pre-defined paths where manual input may

be inefficient.

- **Alignment from Corridor:** A feature line extracted from an existing corridor model can be used to create a new alignment, supporting more advanced workflows such as the development of secondary roads or parallel baselines.



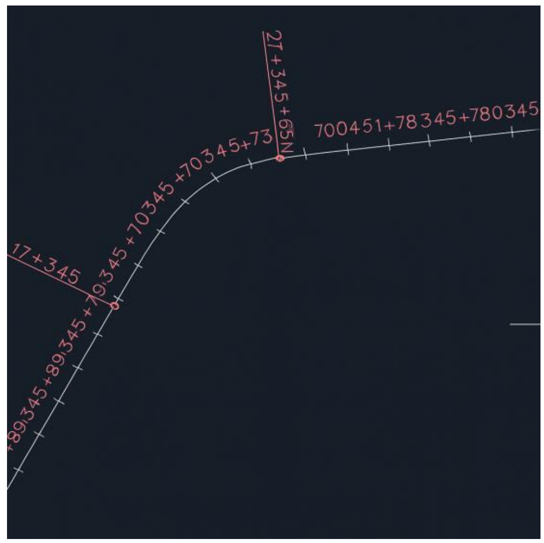


Figure 2.2: The horizontal alignment creation dialogue box in Civil 3D

Figure 2.3: Centerline alignment

2.1.4 Vertical Alignment

Vertical alignment refers to the longitudinal configuration of a roadway along its defined horizontal path, representing changes in elevation and grade. It plays a crucial role in ensuring appropriate drainage, adequate sight distance, and a smooth driving experience. Vertical alignments are made up of straight longitudinal grades and vertical curves—parabolic transitions between differing slopes—classified as crest curves (at hilltops or downward grade transitions) and sag curves (in valleys or upward grade transitions).

In Civil 3D, the Create Surface Profile tool is used to generate a profile of the existing ground (EG) surface along a selected alignment. To develop the design or finished ground (FG) profile, the Profile Layout Tools are utilized. These tools allow the user to design custom elevation changes along the alignment, incorporating appropriate grades and curves based on design criteria like the Rate of Vertical Curvature (K), which determines the length of the vertical curves for safety and comfort.

Civil 3D supports various types of profiles:

- **Surface Profiles**: Automatically extracted from a terrain surface, these represent the existing topography along a selected path.
- **Layout (Design) Profiles**: Manually designed profiles representing proposed elevations, often used for roadways and infrastructure projects.
- **Superimposed Profiles**: Display another alignment's profile within the profile view of a selected alignment for comparative design and coordination. These profiles dynamically update when source data changes.
- **Quick Profiles**: Temporary, non-editable profiles used to quickly assess elevation along lines or feature paths.
- **Corridor Profiles**: Derived from corridor feature lines, such as edges of pavement, used in detailed corridor modelling.

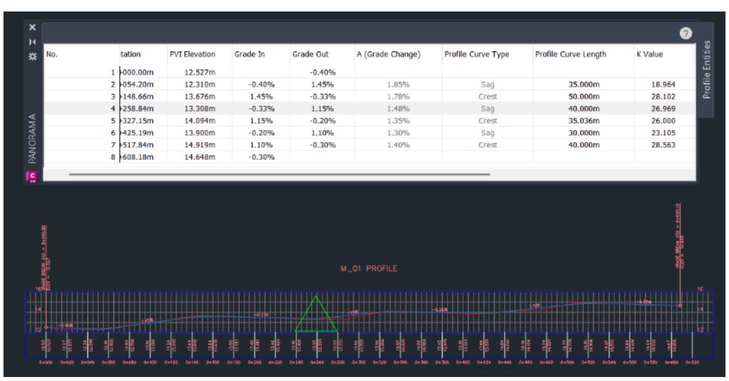


Figure 2.4: Profile creation & Profile view

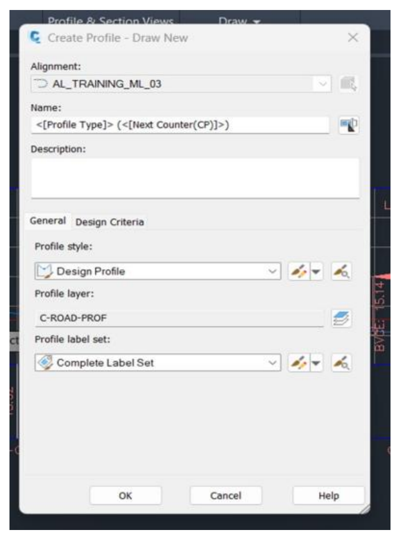


Figure 2.5: The vertical alignment creationdialogue box in Civil 3D

2.1.5 Assemblies and Subassemblies

In Civil 3D, subassemblies are the fundamental components used to define the elements of a roadway cross-section, such as lanes, shoulders, medians, curbs, sidewalks, ditches, and barriers. These subassemblies are selected from the Tool Palettes and serve as modular units that can be configured and combined to form complete roadway sections.

Each subassembly is composed of three core elements:

- **Points** – Define key locations such as edges of pavement or curb return points.
- **Links** – Connect points to form linear features (e.g., lane slopes or curb faces).
- **Shapes** – Enclosed areas formed by links, used for volume calculations, visualization, and material quantity estimation.

Multiple subassemblies are combined to create an assembly, which represents a full typical cross-section of a roadway. Assemblies are essential templates that are applied repetitively along a horizontal alignment during corridor modelling. The Create Assembly command on the ribbon tab is used to define new assemblies.

Assemblies can incorporate advanced features such as superelevation, conditional daylighting, and intersections, enabling the design of complex road systems. Civil 3D provides a wide range of pre-configured subassemblies, from basic offset links to detailed superelevated lanes with customizable pivot points. For specialized applications, custom subassemblies can also be created using AutoCAD entities or the Subassembly Composer.

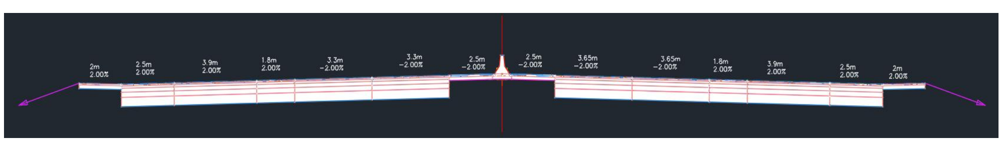


Figure 2.6: Assembly creation in Civil 3D

2.1.6 Corridor Modelling

Corridor modelling in Civil 3D is the process of creating a dynamic 3D representation of a proposed roadway or other linear infrastructure by integrating the horizontal alignment, vertical profile, and assemblies. This model captures the full geometric definition of the route, including widths, slopes, and elevation transitions.

Corridors are composed of several key elements:

- **Baseline**: Represents the core path of the corridor by combining the horizontal alignment and its corresponding design profile (vertical alignment).
- **Assembly**: Defines the typical cross-sectional structure of the roadway, built from a combination of subassemblies such as lanes, medians, curbs, and sidewalks.
- **Regions**: Sections along the corridor where different design characteristics apply. These are defined by station ranges and allow smooth transitions between varying cross-sections or design conditions.
- **Targets**: Dynamic references used by subassemblies to adapt the corridor design to existing features. These can include surfaces, alignments, feature lines, profiles, polylines, and survey figures. For example, a lane may widen to follow an alignment, or a ditch invert may tie to a profile.

The Create Corridor command initiates the corridor modelling process, while Corridor Properties are used to define inputs such as assembly placement frequency, region limits, and subassembly targets. Although corridors can be built without surfaces, surface targeting is essential for certain analyses such as earthwork calculations and daylighting.

2.2 OPENROADS DESIGNER

OpenRoads Designer (ORD), developed by Bentley Systems, is a comprehensive roadway design software tailored for the geometric and corridor modelling of highways. It offers integrated tools for creating horizontal and vertical alignments, terrain modelling, cross-section development, and 3D corridor modelling within a unified platform.

As part of the internship, training sessions were conducted to introduce the core functionalities of the software. These included the creation of horizontal alignments using precise geometric inputs, generation of vertical profiles, and development of cross-sections for design verification. A key focus was placed on corridor modelling, where typical cross-sections (templates) are applied along the alignment and profile to generate a complete three-dimensional representation of the roadway.

Additionally, the software's compatibility with various industry-standard file formats—such as Bentley's DGN, AutoCAD's DWG and DXF, GIS-related SHP files, and raster images including

TIFF, JPEG, and PNG—was demonstrated, emphasizing its flexibility in data integration and documentation.

2.3 INTRODUCTION TO BASIC PAVEMENT DESIGN

The training on basic pavement design began with an overview of road classifications, both functional and administrative. Functionally, roads were classified into freeways, expressways, arterial roads, sub-arterial roads, collector roads, and local roads. From an administrative standpoint, the Indian classification system includes National Highways (NH), State Highways (SH), Major District Roads (MDR), and Village Roads (VR).

The session also covered common intersection types used in highway networks:

- **At-grade intersections**: including T-junctions, four-legged crossroads, and multi-leg intersections where roads intersect at the same elevation.
- **Grade-separated interchanges**: such as diamond, cloverleaf, trumpet, partial cloverleaf, dumbbell, and directional interchanges—each serving specific traffic and spatial needs.

Further, key geometric design parameters were introduced, including design speed, horizontal and vertical curves (crest and sag), stopping sight distance, overtaking sight distance, and superelevation. These parameters are essential in ensuring the safety, efficiency, and comfort of road users.

A standard roadway cross-section was also discussed, highlighting components like traffic lanes, shoulders, medians (central reserve), hard strips, and verge areas. The functional role and layout of each element within the cross-section were explained to provide a foundational understanding of structural and geometric design principles.

CHAPTER 3

PILOT PROJECT- DESIGN OF ROADS AND INFRASTRUCTURE IN AL-SAKHAMA

As part of the internship framework, design tasks were undertaken for the project titled Doha North – Package 88: Design of Roads and Infrastructure in Al-Sakhama. The scope focused on a designated section of the road network in Al-Sakhama, supported by data that included the existing surface model, road layout plan, and typical cross-section details. All design work was carried out in accordance with the Qatar Highway Design Manual (QHDM). The accompanying figures illustrate the provided road network and cross-sectional information, with the highlighted area indicating the specific section addressed during the internship period.

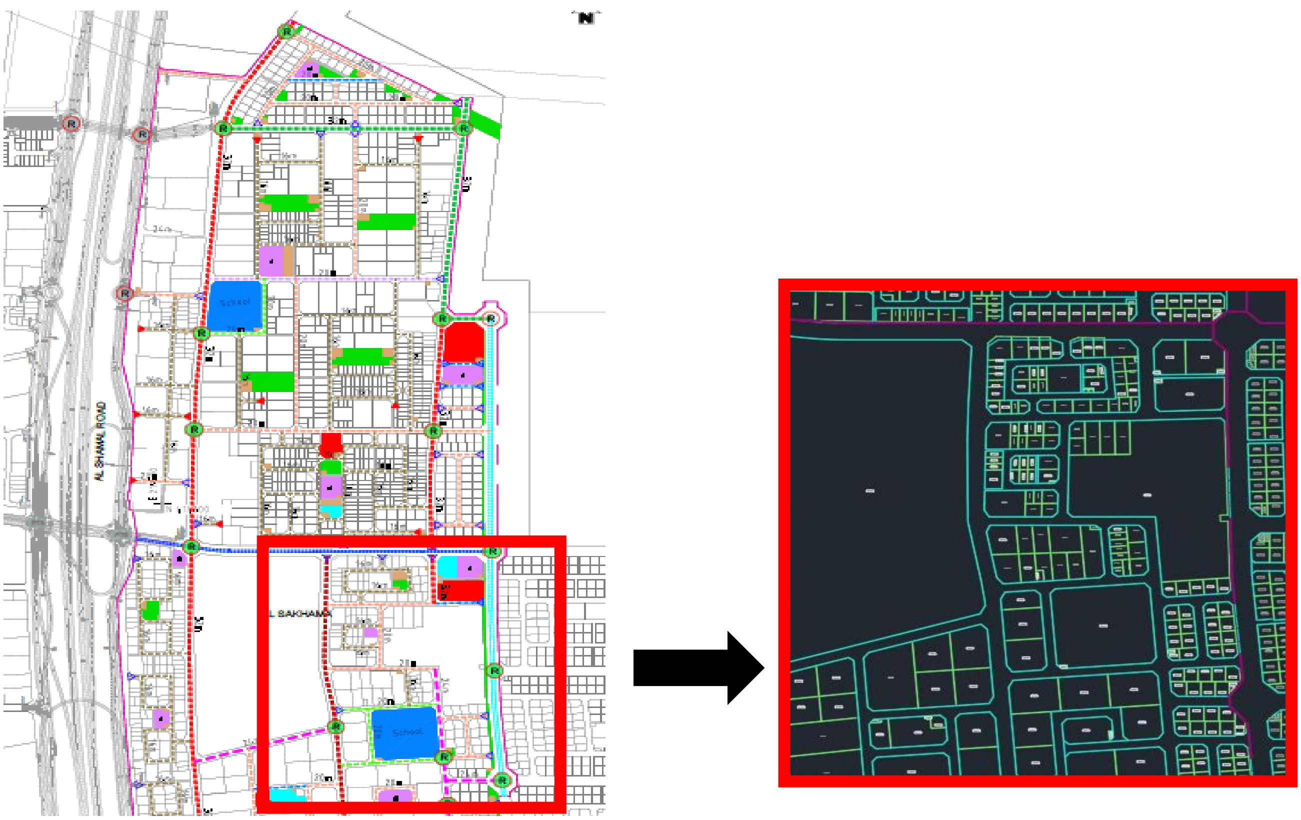


Figure 3.1 The plan view of the road network plan

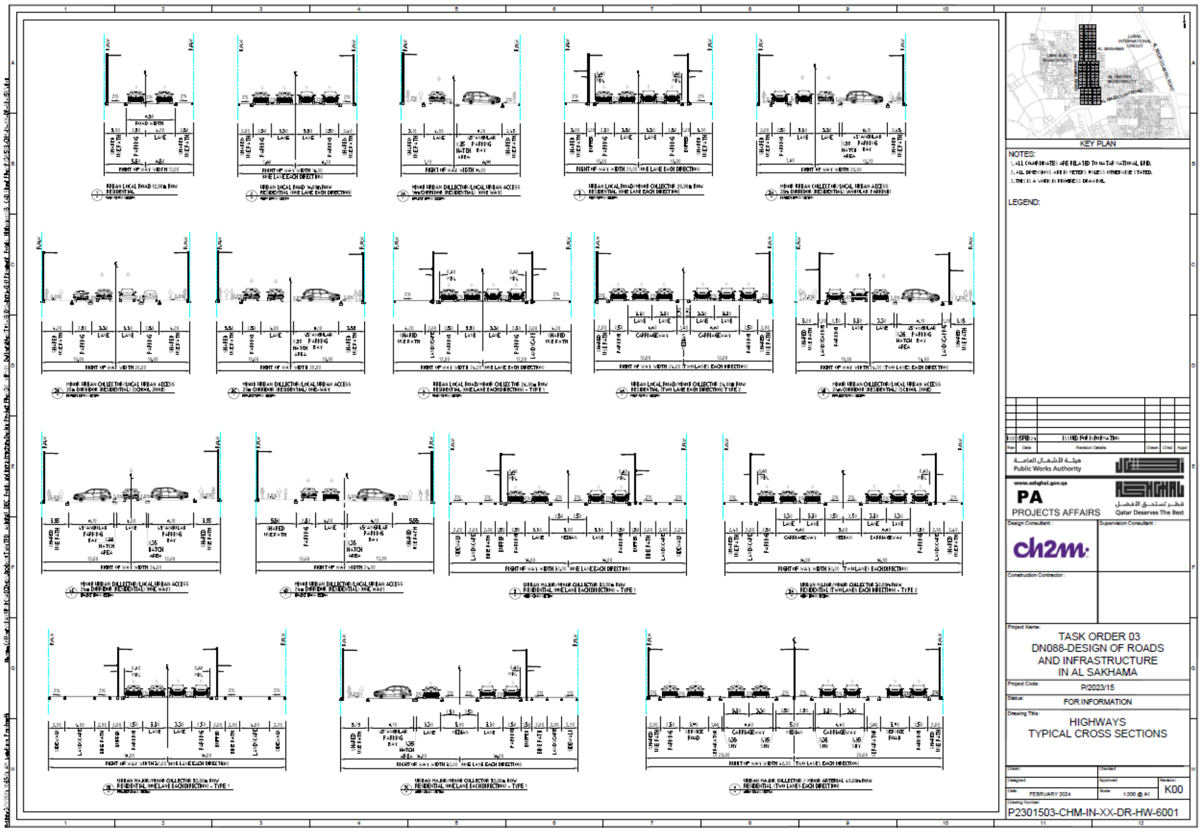


Figure 3.2: The cross-section view of the road network

3.1 MODIFICATION OF THE ROAD NETWORK PLAN

The modification of the road network plan constituted the initial stage of the design process. This step involved analysing the surrounding land use to identify high-activity zones such as commercial establishments and educational institutions. These areas were recognized as key trip generators, attracting higher volumes of vehicular and pedestrian traffic.

While revising the layout, consideration was also given to the expected traffic flow patterns to ensure functional and efficient circulation. However, as specific traffic volume data was not provided, assumptions were made based on land use characteristics and standard planning practices. Accordingly, the typical cross-section was adjusted in selected areas to incorporate angular parking bays, optimizing the use of available Right of Way (ROW) and increasing parking capacity. These modifications aimed to enhance accessibility and operational performance in zones with higher activity levels, while remaining aligned with standard geometric design principles.

Figure 3.3: The modified Road Network Plan

Table 3.1: Road Classification and Design Criteria

TCS	ROAD CLASSIFICATION	RoW	SPEED	COLOUR
6	URBAN MINOR ARTERIAL ROAD	40m	80kmph	
6	URBAN MAJOR COLLECTOR ROAD	40m	80kmph	
5A	URBAN MAJOR COLLECTOR ROAD	32m	50kmph	
5C	URBAN MINOR COLLECTOR	32m	30kmph	
4	URBAN MINOR COLLECTOR ROAD	24m	30kmph	
4B	URBAN MINOR COLLECTOR ROAD	24m	30kmph	
3	URBAN LOCAL ROAD	20m	30kmph	
3A	URBAN LOCAL ROAD (RESIDENTIAL)	20m	30kmph	

3B	URBAN LOCAL ROAD (SCHOOL)	20m	30kmph	
2	URBAN LOCAL ROAD	16m	30kmph	

3.2 DESIGNING 2D LAYOUT

The initial stage of 2D road design involves establishing the centerline alignment, which should be optimized for minimal length, cost-effectiveness, safety, and constructability, while also considering long-term maintenance. A well-designed horizontal alignment facilitates smooth transitions between tangents, minimizing abrupt directional changes that could compromise user comfort or vehicle stability. To ensure both safety and driving comfort, the alignment must correspond to the specified design speed and maintain sufficient stopping sight distance throughout its length. Once the centerline is finalized, in 2D drafting, the process begins with accurately drawing the centerline, followed by incremental offsetting to delineate the extents of each lane and associated road components including median, carriageway, shoulder, parking and shared path. This structured approach provides a clear and precise geometric framework, serving as the foundation for detailed design and subsequent modeling.

Figure 3.4: The 2D layout of the plan

3.3 PRIORITY INTERSECTION

A priority intersection is an at-grade junction where right of way is assigned to one roadway over another to regulate traffic flow. The major road is granted uninterrupted movement, allowing vehicles to proceed without stopping. In contrast, vehicles on the minor road are required to either yield or stop before entering or crossing the major road, depending on the level of control applied. This priority is typically reinforced through regulatory signage, such as ‘Stop’ or ‘Yield’ signs, placed on the approaches of the minor road.

Priority intersections are commonly utilized in networks with moderate traffic volumes and are often favoured for their operational simplicity and lower implementation cost compared to signalized alternatives. They can be configured in various forms, including T-junctions, where a minor road meets the major road at a single point; crossroads**,** where two roads intersect at approximately right angles; and staggered junctions, where opposing minor roads connect to the major road at offset locations. Additionally, Right-In/Right-Out (RIRO) configurations are often employed at priority intersections along divided highways or roads with high-speed traffic. The geometric design of these intersections must ensure safe and efficient traffic operations, with appropriate sight distances, turning paths, and conflict point management to minimize delay and enhance overall safety.

3.3.1 Simple T-Intersection

A simple T-intersection represents the most fundamental form of a priority intersection, where a single minor road intersects a major road at an angle typically ranging between 70° and 110°. In this configuration, vehicles on the minor road must yield to the continuous flow of traffic on the major road. These intersections are not channelized, meaning they do not include any painted or physical islands, and are most applied on local urban roads where traffic intensity is low and adequate sight distance is available for safe turning movements.

According to the Qatar Highway Design Manual (QHDM), Volume 1, Part 6: Design for Priority Intersections, Simple T-Intersection (Page 494), the recommended corner radii for simple T-intersections are:

- 6 m for urban local and service roads
- 10 m for other urban roads

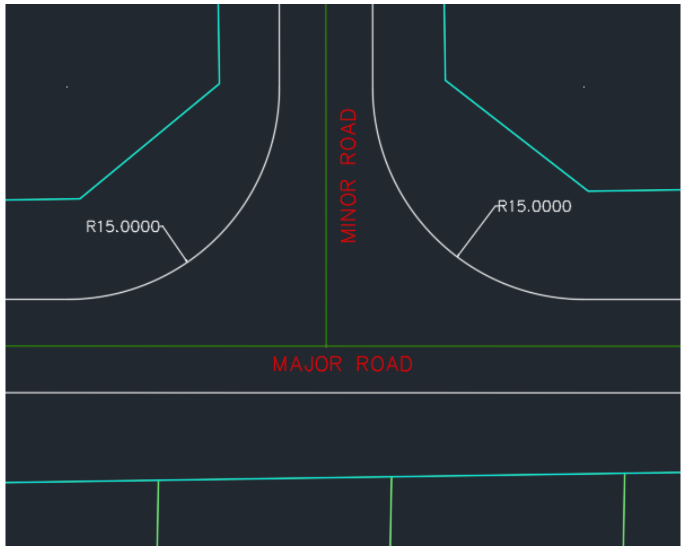


Figure 3.5: 2D Layout of simple T- Intersection

However, these corner radii are not fixed and can vary based on the type of design vehicle, which is determined according to the functional classification of the intersecting roads. The minimum turning radius of the selected design vehicle is used to establish the appropriate corner radii. This consideration is essential to ensure that the intersection geometry can accommodate turning manoeuvres safely and efficiently.

Proper corner radii are particularly important for conducting a swept path analysis, which verifies that the turning movement of the design vehicle can be executed without encroaching on adjacent lanes, curbs, or other roadside elements. This process ensures both operational functionality and safety compliance within the intersection layout.

3.3.2 Right-In Right-Out intersection (RIRO)

A Right-In Right-Out (RIRO) intersection is a form of multi-lane priority junction where turning movements are restricted to right turns only when entering or exiting the minor road. This configuration is achieved by introducing a central median along the major road, thereby eliminating conflict-prone left-turn movements. The RIRO layout enhances safety and improves traffic control by simplifying vehicle paths and reducing the number of potential collision points.

At RIRO intersections, vehicles turning right from the major road into the minor road typically yield to oncoming or crossing traffic and may require a dedicated deceleration lane to safely reduce speed. Similarly, vehicles entering the major road from the minor road are often accommodated with an acceleration lane to facilitate safe merging into higher-speed traffic flows.

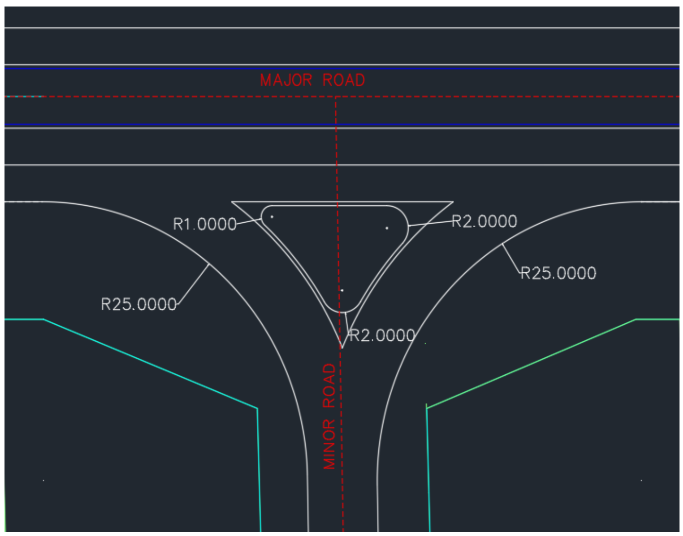


Figure 3.6: 2D Layout of Right-In Right-Out (RIRO) Intersection

According to the Qatar Highway Design Manual (QHDM), Volume 1, Part 6: Design for Priority Intersections – Priority Intersections for Multi-Lane Arterials and Collector Roads (Page 509), the following geometric standards apply:

- Minimum corner radii for design speeds up to 80 km/h: 25 meters
- Single lane turning roadway width around a 25 m corner radius: 5.7 meters.
- Minimum width of the minor road approach around a channelizing island: 4 meters

These parameters are essential to ensure adequate turning space, safe vehicle manoeuvrability, and efficient traffic flow at RIRO intersections, particularly on roads with higher operating speeds.

3.4 ROUNDABOUTS

A roundabout is a type of at-grade circular intersection in which traffic circulates counterclockwise around a central island. Vehicles entering the roundabout are required to yield to traffic already within the circulating carriageway, ensuring smoother flow and reduced delays. Roundabouts are employed as an alternative to conventional intersections to improve both safety and operational efficiency. Roundabouts reduce vehicle-to-vehicle conflict points from 32 in traditional intersections to 8, significantly lowering the risk of severe collisions by eliminating direct crossing and opposing turns. The operational performance and safety of a roundabout are highly dependent on its geometric layout.

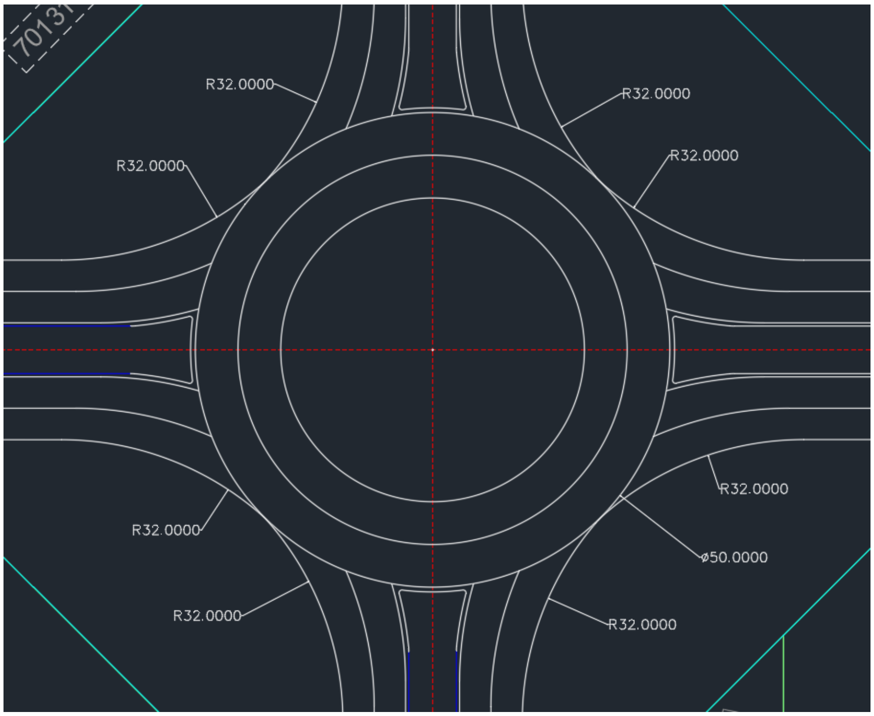


Figure 3.7: 2D Layout of roundabout

Key Geometric Elements of a Roundabout

The geometric design of a roundabout significantly influences its operational efficiency, safety, and capacity. The following are the primary design elements considered during the planning and layout of a roundabout:

- **Approach Half-Width**: The lateral distance from the centerline to the outer edge of the approach lane, influencing lane configuration and entry capacity.
- **Average Effective Flare Length**: The effective length over which the approach roadway widens to accommodate additional entry lanes, enhancing vehicle stacking.
- **Entry Angle**: The angle formed between the approaching leg and the circulating carriageway; a lower entry angle increases deflection and contributes to speed reduction.
- **Entry Curb Radius**: The curvature of the outer curb at the entry, designed to guide vehicles into the roundabout while maintaining appropriate entry speeds.
- **Central Island**: A raised, non-traversable circular island that facilitates counterclockwise vehicle circulation and provides visual guidance.
- **Circulatory Roadway Width**: The annular width around the central island used by circulating vehicles; its dimension varies based on design vehicle and expected traffic volume.
- **Entry Path Radius**: The radius of the swept path followed by a vehicle entering the roundabout, influencing vehicle speed and deflection.
- **Splitter Island**: A raised or painted island located on each approach to separate entering and exiting traffic flows, assist in speed reduction, and provide pedestrian refuge.
- **Exit Width**: The width of the roadway at the exit point, designed to accommodate exiting traffic volume and ensure safe departure.
- **Exit Curb Radius**: The curvature of the curb on the exit side, facilitating smooth and safe vehicle movement away from the roundabout.

Table 3.2 Geometric parameters of Roundabout

Geometric Parameters	QHDM		Design Values			
	Referred to	Standard Value	North	South	East	West
Inscribed Circle Diameter (ICD)	Volume 01, Part 07; Design for Roundabouts; Table 3.1: Minimum ICD for Roundabout	Minimum 28m	50m			
Central Island Diameter	Volume 01, Part 07; Clause:3.2.3- Central Island	Minimum 4m	32m			
Circulating Roadway Width	Volume 01, Part 07; Clause 3.2.2 - Circulatory Roadway	1-1.2 times the entry width	9m			
Entry Width	Volume 01, Part 07; Clause 3.2.8 -Entry Width	7.5-9m	8m	8m	8m	8m
Exit Width	Volume 01, Part 07; Clause 3.2.12 - Exit Width	Greater than or equal to entry width	8m	8m	8m	8m
Entry Curb Radius	Volume 01, Part 07; Table 3.3 -Entry Curb Radius	Minimum 20m	32m	32m	32m	32m
Exit Curb Radius	Volume 01, Part 07; Table 3.4-Exit Curb Radius	Maximum 100m	32m	32m	32m	32m

Critical design elements such as entry width, entry flare length, and entry path radius determine the roundabout's capacity, influence vehicle deflection, and control entry speeds; hence, design checks are carried out for these parameters to ensure safety and operational efficiency.

Table 3.3: Design checks of Roundabout

Parameter	**Referred to**	**Standard Values**	**Design Values**			
			North	South	East	West
Average effective flare length	Volume 01, Part 07; Clause 3.2.9 -Average Effective Flare Length	Minimum 5m	5.2m	5.2m	5.2m	5.3m
Entry angle	Volume 01, Part 07; Clause 3.2.10 – Entry angle	Between 20º - 60º	31º	31º	31º	31º
Entry path radius	Volume 01, Part 07; Clause 3.2.11 – Entry path radius	Maximum 100m	61m	61m	61m	61m

3.5 SWEPT PATH ANALYSIS

Swept Path Analysis is an essential technique used to assess the manoeuvrability of design vehicles at intersections and roadway layouts. It involves analysing the dynamic path traced by the vehicle's extremities—known as the swept path—while executing turning movements. This ensures that sufficient clearance is available for safe vehicle navigation, particularly in constrained or complex geometries.

The methodology is especially important when designing for large vehicles such as buses, heavy trucks, and articulated lorries. Design software tools such as Vehicle Tracking and AutoTURN are commonly employed to simulate and evaluate these movements. In this project, Vehicle Tracking was used to perform the analysis for selected design vehicles and turning configurations.

Swept Path Analysis is specified in QHDM Volume 1, Part 3, Clause 6.2.25, which outlines the requirements for evaluating vehicular turning movements as part of intersection and access design.

The key vehicle parameters considered in Swept Path Analysis are:

- **Articulation Angle**: The maximum angle formed between a towing vehicle and its trailer during a U-turn at full steering lock.
- **Centerline Turning Radius (CTR)**: The radius of the path followed by the vehicle's outer front wheel.
- **Curb-to-Curb Turning Radius**: The arc formed between outer front wheels, measured from curb to curb during a turn.
- **Off tracking**: The difference in the paths followed by the front and rear wheels during a turn, which is more significant in longer vehicles and can be reduced using steerable rear axles.
- **Steering Angle**: The angle between the front wheels and the vehicle's longitudinal centerline at full steering lock.
- **Swept Path Width**: The total width of road required for a vehicle to complete a turning movement at full lock.

Based on the classification of the road and its functional hierarchy, the appropriate design vehicles were selected in accordance with QHDM guidelines. These vehicles were then used in AutoTURN to perform the Swept Path Analysis and evaluate manoeuvrability across various intersection types.

The following design vehicles were considered for analysis:

- **Corner**: Passenger car
- **T Intersection**: SU -9 (Single Unit Truck)
- **RIRO (Right-In/Right-Out) Intersection**: SU -9 (Single Unit Truck)
- **Roundabout**: WB-15 (Tractor semi-trailer)
- Emergency vehicle for all intersections

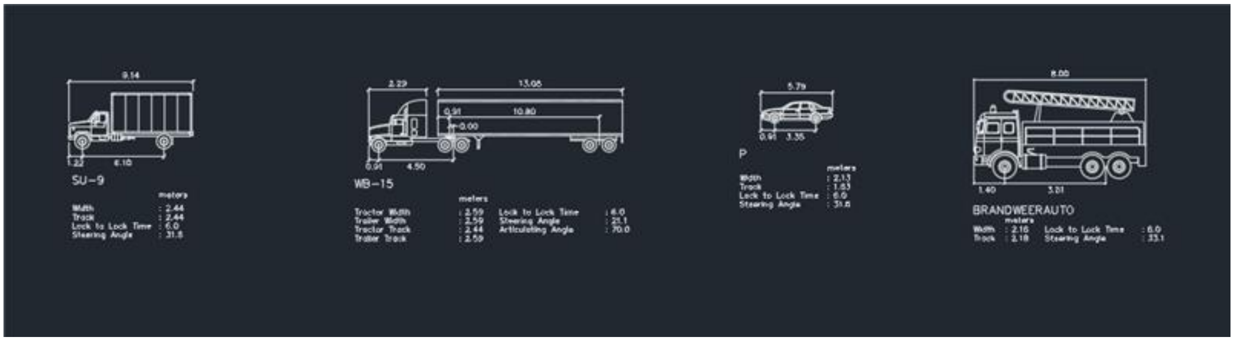


Figure 3.8 The design vehicles used for the Swept path analysis.

The figures below illustrate the Swept Path Analysis conducted for each of these intersections, demonstrating the clearance requirements and ensuring conformance with design standards specified in QHDM Volume 1, Part 3.

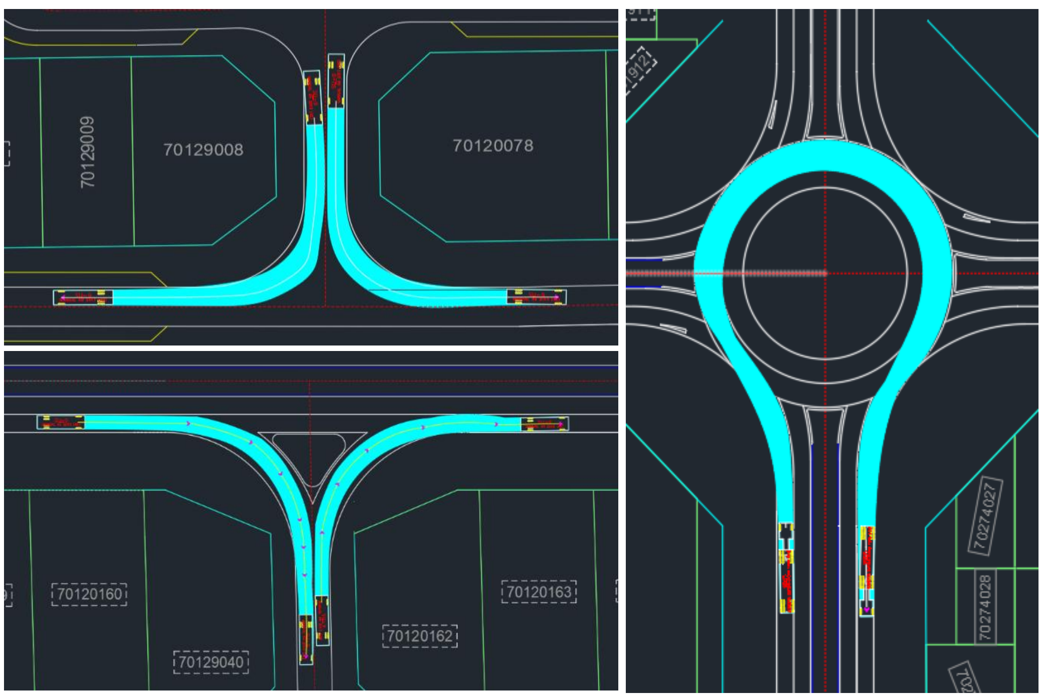


Figure 3.9 Swept path analysis done on T- Intersection, RIRO Intersection & Roundabout

3.6 CREATION OF ALIGNMENT AND PROFILE FOR 3D MODELLING

To initiate the 3D modelling process, the existing ground surface was first imported into Civil 3D. The horizontal alignment for the centerlines was then generated from the 2D layout using the "Create

Alignment from Objects" tool. Subsequently, profiles corresponding to each alignment were created by extracting elevation data from the existing surface. Profile views were generated, and using the Profile Creation Tools, a design profile was developed by referencing the existing ground profile. This established the basis for vertical geometry and further corridor modelling. The figures below illustrate the horizontal alignments and profiles developed as part of this process.

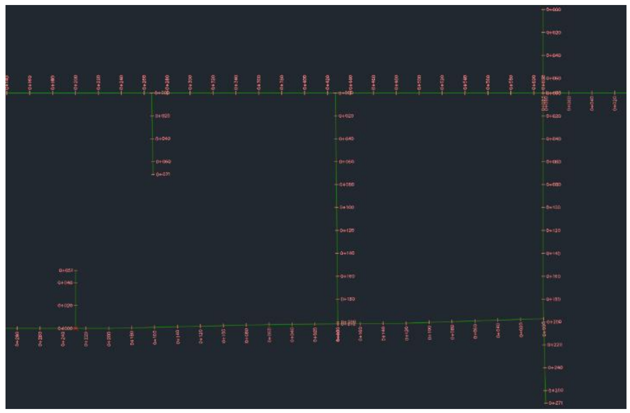


Figure 3.10: Segment of Created Horizontal Alignment

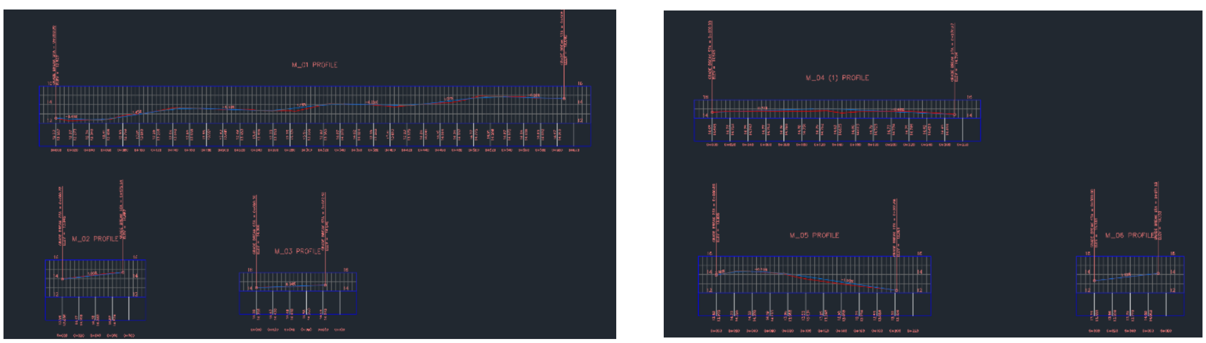


Figure 3.11: Generated Profile Views for Alignments

3.7 ASSEMBLY CREATION AND CORRIDOR MODELLING

In Civil 3D, an assembly serves as a cross-sectional template that represents the structural composition of the roadway. It is constructed by combining various subassemblies, each corresponding to specific roadway components such as lanes, shoulders, medians, curbs, sidewalks, and other elements. These subassemblies are sourced from the predefined tool palettes available within the software. The assembled template is then used in corridor modelling to define the roadway geometry along the designed alignment and profile.

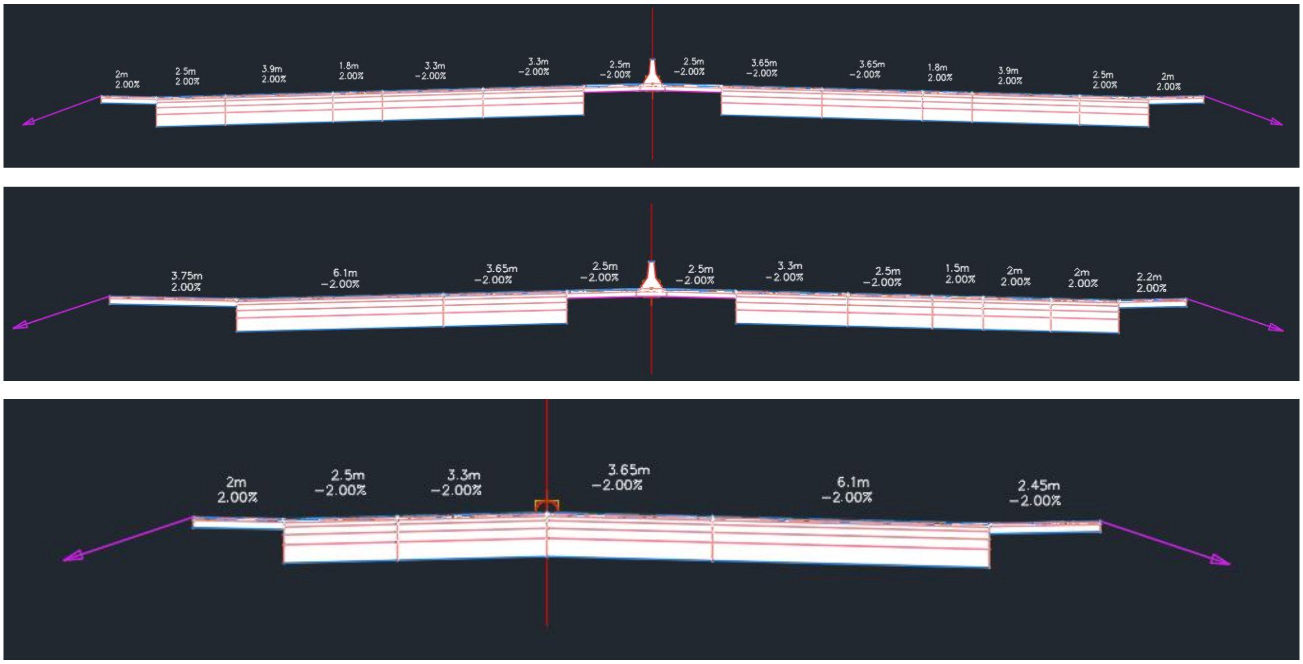


Figure 3.12: Typical Cross Section Assemblies Created in Civil 3D

A corridor in Civil 3D is a comprehensive 3D model that represents the full roadway design along a specified alignment. It is generated by integrating the horizontal alignment, vertical profile, and the corresponding typical assembly. The corridor is constructed using the Create Corridor tool, which combines these elements into a continuous design model. Following corridor creation, corridor surfaces can be extracted to facilitate volume calculations, assess grading consistency, and verify slope direction and drainage flow through slope arrows.

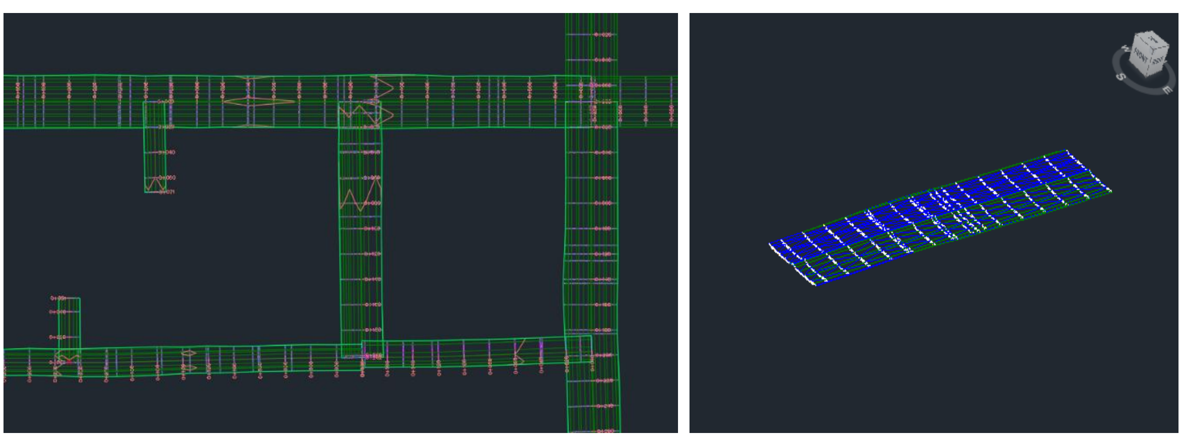


Figure 3.13: Designed corridor

3.8 3D MODELLING OF T- INTERSECTION & RIGHT-IN RIGHT-OUT (RIRO) INTERSECTION

The 3D modelling of the T-intersection and RIRO (Right-In Right-Out) intersection begins with the creation of corridors for the major and minor roads using the Create Corridor tool in Civil 3D. The curb return radii**,** which define the geometric transition between connecting roads, are constructed using arc geometry based on applicable design standards. These arcs are then converted into horizontal alignments using the Create Alignment from Objects tool, followed by the generation of vertical profiles through profile creation tool, referencing the existing ground and adjacent road elevations.

Corridors are then developed along this curb return alignments by assigning appropriate assemblies from the Tool Palettes and setting targets to the corresponding edge of pavement and adjacent alignments. This targeting ensures that the curb returns seamlessly connect to the intersecting roads both geometrically and vertically. In the case of the RIRO intersection, additional attention is given to channelized islands and turning lanes to model controlled turning movements accurately.

Once the curb return corridors are created, corridor surfaces are extracted and analysed to ensure continuity and eliminate mismatches or gaps. This process results in a complete and accurate 3D model of the intersections, including smooth transitions, realistic turning paths, and proper integration with the main roadway corridors.

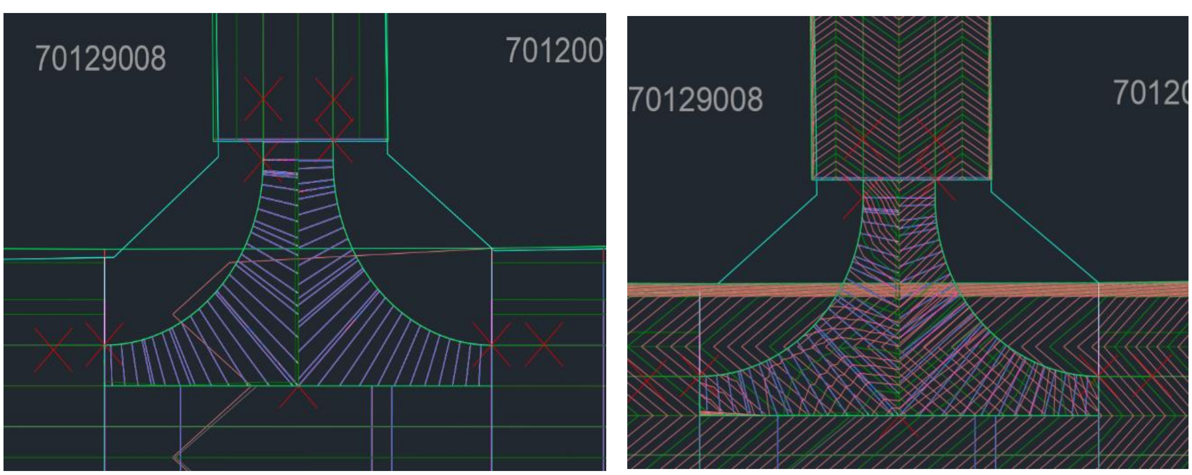


Figure 3.14: 3D modelling of T- Intersection

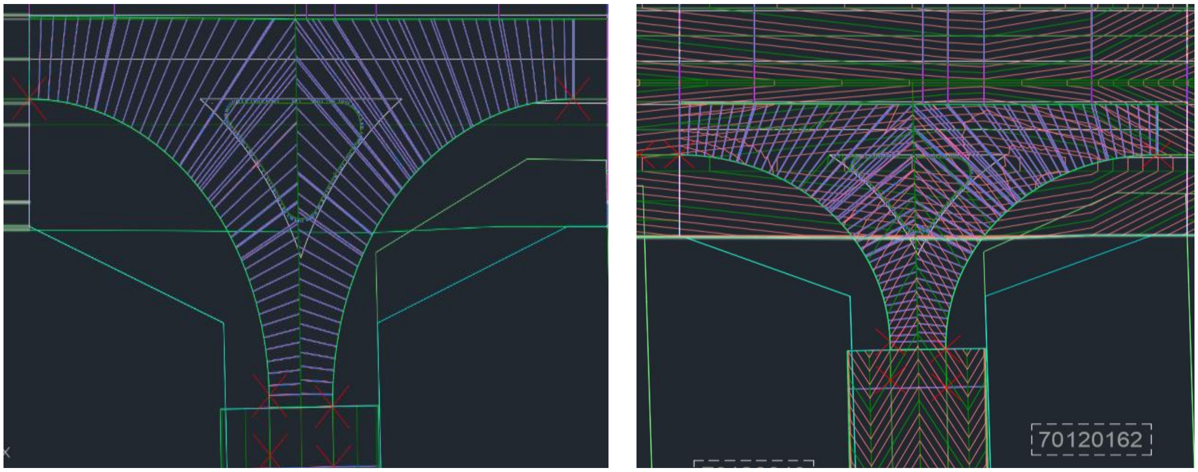


Figure 3.15: 3D modelling of RIRO

3.9 3D MODELLING OF ROUNDABOUT

The 3D modelling of the roundabout begins with the creation of corridors for the approach roads that connect to the roundabout. Subsequently, the Inscribed Circle Diameter (ICD), entry curb radius, and exit curb radius are imported into the 2D model. A horizontal alignment and vertical profile are then developed for the ICD by referencing the elevations at its intersection points with each approach road, ensuring a smooth vertical transition across all connecting roads. The design profile of the ICD is modelled using a sinusoidal curve to facilitate efficient surface drainage.

An appropriate assembly representing the circulatory carriageway is applied along the ICD alignment to form the primary corridor of the roundabout. Following this, horizontal and vertical alignments for each entry and exit curb radius are created, referencing both the ICD and the adjoining approach road elevations. Corridors are then constructed for these curbs return alignments using suitable assemblies, with targets accurately set to the ICD alignment and respective approach road alignments. This ensures seamless geometric and elevation continuity between the roundabout and the approach roads. Finally, surfaces are extracted from all constructed corridors and refined to eliminate inconsistencies or mismatches, resulting in a complete and precise 3D model of the roundabout.

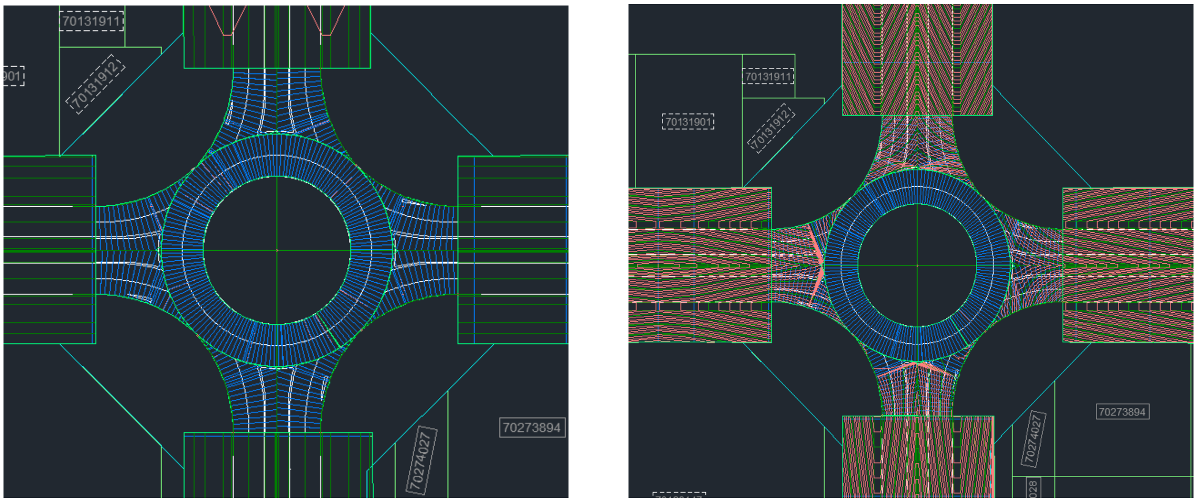


Figure 3.16: 3D Modelling of roundabout

CHAPTER 4

INTERNSHIP INSIGHTS AND LEARNINGS

The internship offered a well-rounded and practical introduction to how design principles are applied in real-world infrastructure projects. Working alongside an experienced and approachable team made it easier to learn and contribute meaningfully to ongoing tasks. The supportive work environment helped build confidence in technical discussions and decision-making.

This experience helped bridge the gap between academic learning and professional application, giving valuable exposure to current tools, design standards, and collaborative project workflows. Beyond technical skill-building, the internship also encouraged professional growth in terms of communication, time management, and adapting to new challenges. The key outcomes from the internship are as follows:

4.1 TECHNICAL OUTCOMES

- **Enhanced Design and Technical Competency**
  Strengthened understanding of civil design principles and engineering concepts through hands-on exposure to the pilot project.
- **Software Proficiency**
  Gained practical experience in using industry-standard software tools such as AutoCAD Civil 3D, OpenRoads Designer, and Vehicle Tracking.
- **Application of Codes and Standards**
  Developed familiarity with relevant design codes and standards, particularly those outlined in QHDM, ensuring compliance in all phases of the project.
- **Real-World Project Exposure**
  Worked on actual roadway design projects, applying academic knowledge to solve real-world engineering challenges.

4.2 NON-TECHNICAL OUTCOMES

- **Insight into Professional Work Culture**
  Understood the dynamics of working in a multidisciplinary team within a corporate environment, including project coordination and workflow management.

- **Improved Communication Skills**
  Strengthened both verbal and written communication through regular interactions, documentation, and collaborative reviews.
- **Increased Confidence and Professionalism**
  Developed confidence in participating in technical discussions, presenting ideas, and taking responsibility in a professional setting.

CHAPTER 5

REFERENCES

- Qatar Highway Design Manual (QHDM) – 2021