EXPRO National Manual for Projects Management

Volume 6, chapter 7

Civil Design Guideline

Document No. EPM-KEC-GL-000001 Rev 003

Document Submittal History:

Revision:	Date:	Reason For Issue
000	26/10/2017	For Use
001	08/05/2018	For Use
002	19/11/2018	For Use
003	15/08/2021	For Use

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1.0 GENERAL

1.1 Introduction

The purpose of this document is to provide design guidelines of civil works. This design guidelines apply to the following in subsequent subsections.

1) Traffic Analysis and Transportation Planning
2) Signalization
3) Roadway Design
4) Interchanges, Intersections and Roundabouts
5) Road Pavement Design

1.2 Definitions

The following definitions apply to this section:

Definitions	Description
Auxiliary Lane	A lane other than a through lane on a roadway, provided for acceleration, deceleration, emergency stopping, storage at accesses, weaving, passing, parking, transfer and truck climbing.
Carriageway	The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.
Design Speed	A speed determined for design and correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that may be maintained over a specified section of highway when conditions are favorable and the design features of the highway govern. The design speed shall be 20% greater than the posted speed limit.
Divided Road	A freeway or road with carriageways traveling in opposite directions separated by a median.
Freeway	A multilane, divided highway with a minimum of two lanes for the exclusive use of traffic in each direction with no at-grade intersections and full control of access without traffic interruption.
Left-turn Lane	An auxiliary lane in the median to accommodate the deceleration and storage of vehicles making left turn maneuvers.
Median	The inner portion of a divided road separating carriageways traveling in opposite directions.
Parking Lane	An auxiliary lane used primarily for vehicle parking.
Roadside	A general term denoting the area adjoining the outer edge of the roadway. Extensive areas between the roadways of a divided highway may also be considered roadside.
Roadway	The portion of a road including the carriageway, auxiliary lanes and shoulders, for vehicular use.
Shoulder	The portion of the roadway contiguous with the carriageway for accommodation of stopped vehicles, emergency use and lateral support of the sub-base, base and surface courses.
Traffic Lane	The portion of the carriageway for the movement of a single line of vehicles.

1.3 Abbreviations

The following abbreviations apply to this section:

Abbreviations	Description
AASHTO	American Association of State Highway and Transportation Officials
AASHTO Green Book	AASHTO Geometric Design of Highways and Streets
FHWA MUTCD	Federal Highway Administration Manual on Uniform Traffic Control Devices
FHWA RSA	Federal Highway Administration Roadside Safety Audit Guideline

Abbreviations	Description
HCM	Highway Capacity Manual
HDM	The Kingdom of Saudi Arabia Ministry of Communication (Currently Ministry of Transport) Highway Design Manuals
ITE DWUT	Institute of Transportation Engineers - Designing Walkable Urban Thoroughfares
ITS	Intelligent Transportation Systems
KSA MUTCD	The Kingdom of Saudi Arabia Ministry of Communication (Currently Ministry of Transport) Manual on Uniform Traffic Control Devices
LOS	Level of Service
NACTO Urban	National Association of City Transportation Officials Bikeway Design Guide Second Edition
RDG	AASHTO Roadside Design Guide
RHGCH	Railroad-Highway Grade Crossing Handbook

2.0 TRAFFIC AND TRANSPORTATION

2.1 General

2.1.1 Introduction

This Subsection provides the evaluation of traffic and transportation prior to preparing the design of roadway networks. The guidelines apply to the following planning and design activities:

- Traffic Analysis and Transportation Planning
- Signalization

2.1.2 General Requirements

- This section covers the design criteria for the road network. This design requirements Subsection and the road classifications, set forth herein, are intended to provide guidance and direction in the planning and design of roads in both community and industrial areas.

  The governing Codes and Standards shall be in accordance with the requirements of AASHTO.

2.2 Traffic Analysis and Transportation Planning

2.2.1 General

- The Transportation Planning and Traffic Analysis must be part of the Planning and Concept Design stage of a project. Its outcome is prerequisite to detailed design.
- The Transportation Planning and the Traffic Analysis must be conducted by a qualified consultant.
- It will be the responsibility of the A/E and/or EPC Contractor to establish the current status of the District Plan prior to commencing work.
- Where there is no District Plan, the A/E and/or EPC Contractor shall complete the following tasks.

  - Establish land use and employment assumptions for the District or for the Study Area
  - Develop the internal road hierarchy to facilitate safe access and mobility for the development area
  - Develop connectivity of the internal roadway network with the external roadway network and continuity of links to the adjacent Districts
  - Develop a concept for public transportation networks and identify integration with any planned networks to the adjacent Districts

- Prepare a VISSIM Microsimulation Model for the District to assess the performance of the traffic infrastructure: internal intersections, external junctions, roadway links and other travel modes
- Prepare recommendations for junction types
- Prepare pedestrian circulation plans
- Prepare a bicycle circulation plan
- Prepare a transit circulation plan

- The requirements of Transportation Planning and Traffic Analysis are based on the scale of the development. There are three categories:
  - Circulation Plan
    - Minimal assessment is required for small developments to assess parking requirements, internal and external circulation, service and emergency access, provision and access to/from the development.
    - Small development typically generates less than 100 trips during any peak hour (highest total generation during AM, Noon, PM, or Evening peak)
  - Traffic Impact Study (TIS)
    - For developments generating more than 100 trips during any peak hour, a TIS is usually required.
    - However, if the development is located in a sensitive area, or it is part of larger development, then a TIS is required to be conducted, even if the generated trips are less than 100 trips.
    - For a development/lot that is located within approved Transportation Master Plan (TMP), the TIS mainly focuses on consistency with the TMP, parking requirements, circulation, provision, access/egress, and development of the surrounding infrastructure.
    - A Methodology Report is required before conducting the study.
  - Transportation Master Plan (TMP)
    - The TMP focuses on large area impacts, internal network operations, and integration of all transport modes.
    - A Methodology Report is required to be submitted and approved before conducting the study.

- The main objectives of these guidelines are to
  - Determine if and when a Circulation Plan, Traffic Impact Study (TIS) and/or Transportation Master Plan (TMP) is/are needed.
  - Determine the necessary requirements for the proposed development(s) in terms of the transportation infrastructure.

2.2.2 Circulation Plan

- Circulation Plans must be submitted and approved for all projects that are generating less than 100 trips during the peak hour. A Circulation Plan is to be conducted for small developments that propose to have two or more access points, depending on the location of the site and the surrounding roadway network.
- Components of a Circulation Plan
  - Project Description
    - Include the land use type, unit, and quantity in tabular format
    - Include the trip generation information (in, out, total) in tabular format. Typically this would include AM peak, Noon, and PM peak periods.
    - The trip generation calculation shall not include any reductions for public transportation, internal capture or pass-by trips.
    - Land use class and trip rate must be approved.
  - Service and Emergency Access
    - Demonstrate delivery and service routes, locations and accesses on drawings.
    - Illustrate drop-off and pick-up facilities for taxi and private vehicles on drawings (as applicable).
    - Display emergency vehicle access on drawings.
  - Site Access and Exit Provision
    - Show on drawings the locations and proposed design of all site access and adjacent roads. Include the road markings and traffic signage on the drawings.
    - Show on the drawings the pedestrian and cycling routes (as applicable).
  - Parking Demand and Supply
    - Provide calculations for parking demand and parking supply in tabular format.
    - Show all parking spaces on drawings, and number them sequentially. Geometric design of the parking spaces and access including turning radii and dimensions must be checked using swept path analysis software.
    - Show the location and design of disabled parking bays.
    - Capacity analysis must be conducted for the vehicular access points.
  - Queuing Analysis
    - Queuing analysis must be conducted for the entrances and exits for the site, drop-off area as well as for the parking facilities.
    - Analysis must take into consideration the proposed access control systems (gates, barriers, ticketing, etc.) and their capacities.
    - Storage must accommodate the 95th percentile of queue lengths inside the lot for exiting traffic and on the auxiliary lane for entering traffic.

- Pedestrian sidewalks should remain clear and should not be considered in the queuing length.
- Queue assessment is required for access points with a volume to capacity ratio (v/c ratio) greater than 0.5.
- Access points with v/c ratio greater than 1.0 are not acceptable.

2.2.3 Methodology Report

- A Methodology Report is required for all TIS and TMP studies.
- The Methodology Report identifies the methods and assumptions to be utilized in the study.
- Approval is required before progressing with the Methodology Report.
- Methodology Report should include, as a minimum:
  - Project Description
    - The description of the project should include at least the location of the proposed development, proposed land uses and their relation to the surrounding area, constraints and issues, and phases of the development, if any.
    - Specify the trip generators and trip attractors, including special generators, if any.
  - Study Area
    - It is the A/E and/or EPC Contractor's responsibility to identify and check the study area for completeness and comprehensively study it to include all major facilities that will be impacted by the development.
    - All links and junctions affected by the development with an additional 10% of traffic due to the development must be included in the assessment.
    - All links and junctions that are directly impacted by the development must be included.
    - If strategic modelling is utilized, the study area might be identified at a later stage to incorporate most changes in transport demand.
    - The study area must include at least the major junctions and roadways in the vicinity of the development, even if the increase of traffic volumes due to the development is minimal.
  - Existing Transport Infrastructure
    - The roadway network and infrastructure for the existing and future conditions without the development must be determined.
    - Identify public transportation facilities in close proximity to the development.
    - Identify pedestrian and cycling infrastructure.
  - Baseline Traffic (Existing and Future)
    - List the traffic surveys conducted and to be utilized in the study.

- Use future flows implementing the growth rate or utilize the modelling output considering all land uses and infrastructure for the particular horizon year(s).
- A comparison of base traffic flow with the forecasted flows should be highlighted.

- Trip Generation
    - The calculations for trip generation shall not include any reductions for transit, internal capture or pass-by trips.
    - Trip generations rates must be approved.
- Parking Demand
    - Parking demand must be calculated for each lot based on its land use characteristics.
    - Parking demand should be accommodated within lot boundaries.
- Proposed Strategic Modelling Approach
    - Submit Modelling Synopsis Report and Model Development Report.
- Assumptions
    - List all factors, assumptions, attributes, parameters and default values used in the studies.
    - List all trip generation assumptions.
    - List all variations from standards.

2.2.4 Traffic Impact Study (TIS)

- General
    - All criteria and requirements of the Circulation Plan mentioned above must be met in addition to the following subsections.
    - Traffic impact studies assess the transportation needs and traffic impacts of a development on the surrounding road network. The need for a traffic impact study is based on several factors, including the type and size of development, existing network, available network and parking capacity.
    - The A/E and/or EPC Contractor shall complete a Traffic Impact Study for developments generating from 100 trips up to 2500 trips during any one peak hour (highest total generation during AM, Noon, PM or Evening Peak).
    - Master planning updates shall be required for developments that generate more than 2500 trips during any one peak hour.
    - A circulation plan shall be created and submitted for any sized development that generates two or more access points.
    - The A/E and/or EPC Contractor shall use the existing model data for the typical TIS for any plot within a District Plan.

- All assumptions shall be submitted to entity for review and approval prior to completing the analysis of the network or intersection requirements.
- For smaller developments the A/E and/or EPC Contractor shall submit a circulation plan that addresses all mobility modes (vehicle, pedestrian, cyclist and transit) as appropriate.

- Study Area
  - The study area limits shall be based upon the types of land use, size of development, street system patterns, and the terrain.
  - A frequently used method is to carry the analysis to the locations where site- generated traffic will represent five percent (5%) or more of the roadway's peak hour approach capacity.

- Traffic Impact of the Development
  - All analysis must be conducted for all peak periods (AM, Noon, PM, and Evening).
  - As a minimum, the following scenarios must be assessed:
    - Base year. The assessment is based on the existing condition, without the development.
    - Opening year.
    - Interim years. If the development has more than one phase, an assessment must be conducted for each phase of a major development.
    - Medium Term (5 – 10 years).
    - Long Term (10+ years) Ultimate Development.
  - Developed Strategic Models must be used for studies using the strategic modelling approach.

- Trip Generation Rates
  - Trip generation rate is the average number of trips that are going to be generated by a particular type of land use. Average trip generation rate represents a weighted average from studies conducted in the real world. The rates are typically provided for morning and evening peak periods on a weekday and also the weekend (Friday and Saturday) peak hours of generation.
  - The A/E and/or EPC Contractor shall collect site specific data. Trip rates will be established locally. If there are no local examples available to establish a suitable trip generation rate then regional, national or international trip generation resources may be used.
  - Trip generation rates for the District Plans are based on the land use distribution of population and employment.

- Parking Generation Rates
  - Parking requirements shall be established.
  - If additional analysis is required for parking, the following may be used:
    - Parking generation focuses on data from parking occupancy studies as a basis for a better understanding of parking demand characteristics. The effective parking supply that a designer shall use is subject to several factors unique to individual business, area type, turnover characteristics; customer service desires and demand variations whether it is hourly, daily, monthly or seasonal.

    - Mixed Use areas within a District Plan may develop a shared parking plan that would allow an overall reduction in parking provided.

- Capacity Analysis

  - A principal objective of capacity analysis is the estimation of maximum number of vehicles that may be accommodated by a given facility in reasonable safety in a given period of time. However, because facilities operate poorly at or near capacity, they are rarely planned to operate in this range. Accordingly, capacity analysis also provides a means of estimating the maximum amount of traffic that may be accommodated by a facility while prescribed operational qualities are maintained at a "Level of Service C" (LOS C) or better. The following are the assumed parameters for capacity analysis:

    - Type of facility and its development environment
    - Lane widths
    - Shoulder widths and lateral clearance
    - Design speed
    - Horizontal and vertical alignments
    - Availability of queuing space at the intersection
    - Presence of pedestrians
    - Terrain and grades
    - Number of access points
    - Ramp Density

  - Capacity used for analysis of facilities and intersections

    - All capacity assumptions shall be submitted for review and approval prior to analysis of facilities and intersections.
    - All capacity analysis results for intersections, weaving, merging, and diverging must be presented in tabular format for all scenarios and all agreed peak periods.
    - Intersection capacity analysis results should include delay, LOS, v/c ratio, and queue length, as minimum, for each intersection as well as for the worst movement in the intersection.
    - Merging/Diverging analysis results should include the number of lanes, speed, volume, density and LOS, as minimum, for freeway and ramp facilities.
    - Weaving analysis results should include, as minimum, the weave type, number of weaving lanes, weaving length, freeway speed, and LOS.
    - Mitigation measures shall be identified for all movement that has LOS D or worse. Any junction with an overall LOS F is not acceptable.

  - Capacity analysis must be conducted for all scenarios and the mitigation measures for all peak periods agreed on.
  - Capacity analysis must be conducted based on the Highway Capacity Methodology.
  - Link performance should be presented in terms of flow, v/c ratio, speed, and LOS for all scenarios during all peak periods analyzed.
  - Intersection performance should be presented in terms of flow, average delay, stopped delay, queue lengths, and LOS.

- o Intersection performance should be presented for the entire intersection as well as for the critical movement(s).
- o Analytical tools.

  - There is an abundance of tools available for analysis falling into two main categories:

    – Those that consider the mass movement of the individual vehicles (Macroscopic)
    – Those that consider movement of individual vehicles in a group (Microscopic)

  - Macroscopic Tools:

    Analytical tools are those that are based on the Highway Capacity Manual. These include Synchro, Sidra Intersection (SIDRA) and Highway Capacity Software (HCS).

  - Microscopic Tools:

    Analytical tools include VISSIM, CORSIM and Simtraffic.

- o After assigning the traffic to the transportation network using the site traffic analysis software, the level of service is calculated for all major roadways and intersections.

- Circulation

  All site circulation shall be accommodated on-site and include, in particular, vehicles circulating looking for parking. The adjacent roadway network shall not be used as part of the parking circulation activities.

- Site Access and Exit.

  - o Conflict of access points with pedestrian movements must be assessed for safety, as appropriate.
  - o Where the access with v/c ratio is greater than 0.5, a queue assessment is required.
  - o Access points with v/c ratios greater than 1.0 are not acceptable.

- Parking

  - o Parking shall be established using typical parking requirements.
  - o For particular circumstances where shared parking capacity is to be considered, parking inventory is conducted for central and outlaying business districts and for major activity centers such as universities and medical centers. The inventory generally collects the following information:

    - Number of legal and illegal parking space by location and type of facility.
    - Owner of parking spaces (public or private).
    - Availability of spaces.
    - Time limit and hours of operation.
    - Rates including meter locations.
    - Special curb-use regulations.

   - The parking inventory typically is done in total, although in some jurisdictions a previous study may serve as a starting point. Inventory data is preferably recorded in a computer format for the ease of usage and updating when conditions change.
   - Provide disabled parking spaces according to standards and codes.
   - Parking access shall be assessed for the highest peak traffic flow.

- Pedestrian and Cycling

   - The need to move vehicles and pedestrians efficiently and safely at the same locations presents a significant challenge. All site circulation shall comply with the zoning requirements.
   - Provide pedestrian accessibility to the nearest public transportation facilities, as appropriate.
   - Assess cycling routes as applicable.

- Public Transit

   The roadways that will ultimately accommodate transit shall be documented in the District Plan.

- Queue Analysis.

   - All intersection operations shall be reviewed and queuing analysis performed to establish if additional queuing distances are required for left and right turn movements.
   - All increases in standard bay lengths must be reviewed and approved.

- Mitigation

   - After the initial forecast and level of service are calculated, various test street improvements and signal timing changes for mitigating the impacts at an intersection may be completed.
   - For each mitigation measure, the modelling results of the “with”, “without” and “mitigated” scenarios must be compared and highlight the critical movement.
   - Proposed mitigation measures must be feasible and reasonable.

- Geometric and R.O.W

   - The Typical Construction Detail Drawings (TCDD’s) shall be used to establish all typical geometric and right-of-way (ROW).
   - Development requiring additions to ROW for site access shall be submitted for review and approval.
   - Recommended mitigation measures must be feasible and practical.
   - The A/E and/or EPC Contractor shall check the availability of ROW for the proposed geometric mitigations.

- Report Contents

TABLE 1.1 illustrates sample report contents. This outline might change based on the details of the study.

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2.2.5 Transportation Master Plan (TMP)

- General

  All criteria and requirements for the Circulation Plan and Traffic Impact Study shall be conducted and included as part of the TMP.

- Demographic and Socioeconomic Data
  - Existing demographic and economic data is obtained from the census data collection of the Ministry of Transport.
  - Local data shall be used to augment regional data.
  - Land use is inextricably linked to the distribution of population, household and employment. These in turn are primary inputs to the regional model set. Once a land use plan is established a set of demographic estimates shall be submitted for review and approval.

- Traffic Analysis Zones
  - General
    - A traffic analysis zone (TAZ) is a small, homogeneous geographic area defined to be used in the transportation planning and analysis.
    - A TAZ may be as small as a city block or as large as a few square miles in the outlying reaches of transportation network. The boundaries of a zone are typically defined by geographic barriers or by transportation features such as rivers and roads.
    - Zone boundaries shall follow census tract or block group boundaries where possible to make it easier to correlate the census demographic data to the zones. Within a zone the land use and spatial distribution shall be fairly homogeneous.
  - Land Use Characteristics
    - Define the local amenities (schools, shops, restaurants, mosques) for the forecasted population.
    - Define any special generator

    - Account for visitors parking
    - Highway Network

  - General

    - The highway network is composed of various nodes and links. Nodes are typically intersections or may simply be placed to give the network a proper shape when it is plotted; while links connect various nodes together. Roads are entered in as links.
    - Network assumptions and attributes shall be reviewed and approved.

  - The A/E and/or EPC Contractor shall document all scenarios and peak periods to be analyzed for approval before conducting the analysis.

    - Peak periods are the AM, Noon, PM and Evening.
    - Minimum scenarios include:

      - Opening year
      - Interim year's corresponding to projects' phases
      - Horizon years
      - Full build-out, ultimate development

    - A strategic modelling approach must be utilized
    - Present traffic flows and turning movements for all scenarios and all peak periods.
    - Present link capacity analysis on links for all scenarios and all peak periods.
    - Link performance should be presented in terms of flow, v/c ratio, speed, and LOS.
    - For links with v/c ratio of greater than 0.7, further analysis is required.
    - Major intersections must be assessed and analyzed in details.
    - Intersection performance should be presented in terms of flow, average delay, stopped delay, queue lengths, and LOS.
    - Intersection performance should be presented for the entire intersection as well as for the critical movement(s).
    - Proposed mitigation must be presented at a conceptual design level.
    - Analysis must include comparisons without and with mitigations.

- Transit Network

  - A transit network is composed of various nodes and links. Links connect various nodes together. Transit lines are entered as a sequence of nodes.
  - Network assumptions shall be reviewed and approved.
  - Account for a pedestrian and bicycle network.
  - Identify whether mode share and internal capture targets can be achieved.

- Trip Generation

  - Trip generation is the total number of person trips that are produced (Trip Production) by and attracted (Trip Attraction) to each defined zone in a study area.
  - The estimation of person trip ends is stratified by the trip purpose. It is based on the characteristics of both trip maker and the land uses. Trip maker characteristics are based on the household attributes like household size, income, number of workers and vehicles owned.
  - Land use is functionally described in terms of its character, intensity and location of activities. It may also be described as type and quantity of employment that it generates. Exclusive models are in use for trip production and trip attraction.
  - All trip generation assumptions shall be reviewed and approved.

    Trip Generation Model:

    - The A/E and/or EPC Contractor shall document trip generation modeling methodology, aspects and development.
    - The A/E and/or EPC Contractor shall proceed with the TMP.

- Trip Distribution

  - Trip distribution is connecting trip ends to one another to create and flow of trips in each interchange.
  - A typical trip distribution model is a gravity model as in theory number of trips from one analysis zone to another is directly related to the magnitude of the activity within each zone as well as the accessibility between the zones.
  - The inter-zonal accessibility is the inverse of the travel impedance which may be measured by the automobile or the transit time. Or by composite impedance, which could include times, parking fees and other costs.
  - All trip distribution assumptions shall be reviewed and approved.

- Trip Distribution Model

  - The A/E and/or EPC Contractor shall document the trip distribution modeling methodology, aspects and development.
  - After approval of the trip distribution model, the A/E and/or EPC Contractor shall proceed with the TMP.

- Mode Choice

  - Mode choice refers to the proportions of the travelers travelling by different modes of transportation, such as public transportation, private automobile, bicycling or walking.
  - The primary modes are further subdivided into sub modes. This could include various types of transit modes such as commuter rail, light rail. express buses, local buses, trolleys and monorails. Even the carpooling auto modes may be further divided into a two person car pool, a three person car pool and a four person car pool.
  - All mode choice splits shall be reviewed and approved.

- Trip Assignment

  - In trip assignment, the mode-specific trips are assigned to the appropriate network. The auto vehicle trips are assigned to the roadway network while the transit person trips are assigned to the transit network. In case of park-n-ride trips, the highway portion of the trip is assigned to the roadway network and the transit portion to the transit network.
  - All trip assignments shall be reviewed and approved.

- Freight Modeling

  - General:

    The A/E and/or EPC Contractor shall submit all freight usage information to review and approve.

  - Freight Model:

    The A/E and/or EPC Contractor shall document the Freight Modeling methodology, aspects and development.

2.2.6 Engineering Software

- For the development of network requirements and intersection controls, each District Plan shall have a VISSIM model. The VISSIM model shall be augmented as each plot within the District Plan is developed.
- For corridor analyses, Synchro shall be used.
- For isolated intersections, HCM methodology shall be used to evaluate the traffic control needs.
- For weaving, merging, and diverging analysis, HCM methodology shall be used.
- For roundabout analysis, SIDRA INTERSECTION shall be used.

2.2.7 Roadside Safety Audits

- The majority of the crashes occurring on surface streets occur at intersections. One of the recommendations to reduce the number of crashes is to perform Road Safety Assessments as a regional initiative to help identify and address safety issues at high risk intersections.
- Roadside Safety Audits (RSAs) are formal examinations of particular intersections or entire road corridors from a safety performance viewpoint. The concept of RSAs originated in the UK in the 1990s and has been adopted by many countries with much success.
- Roadside Safety Audits are performed by an independent multi-disciplinary team and led by a person trained in performing Roadside Safety Audits. The Roadside Safety Audits team considers the safety of all road users, qualitatively estimates and reports on potential road safety issues, and identifies opportunities for safety improvement. The Roadside Safety Audits team reviews police crash reports and conducts field observations during different times of the day, such as day/night and peak/non-peak hours.
- The purpose of a Roadside Safety Audit is to answer the following questions:

  - What elements of the road may present a safety concern: to what extent, to which road users, and under what circumstances?
  - What opportunities exist to eliminate or mitigate identified safety concerns?

- All Roadside Safety Audits shall follow the approach outlined by FHWA RSA.

2.3 Signalization

2.3.1 Traffic Signal Design

- Warrant Evaluation and Analysis
  - Typical Intersection control has been established in the District Master Plans. The A/E and/or EPC Contractor shall review the traffic control proposed in the existing District Plans. The A/E and/or EPC Contractor shall analyze the intersection(s) and establish appropriate traffic control for existing and future conditions. Any proposed signalized intersections that do not currently meet signalization warrants must be constructed with all underground infrastructures. In addition, future pole locations shall remain clear of utilities that will affect the installation of pole bases.
  - Traffic planning and assessment data shall be used to establish if signalization of an intersection is warranted.
  - The MUTCD has established criteria for the evaluation of signalization needs. Signalization shall only be installed if the criterions are met.
- Operational Requirements (Phasing, control, detection, interconnection, etc.)
  - The intersection phasing and corridor coordination shall be established by the Traffic Signal Analysis study.
  - All signalized left turn movements shall operate as a protected phase only.
  - All arterial networks and the portion of the collector network with future signalization shall include conduit and the associated fixtures to allow the installation of future traffic signal fiber.
- Signal Display and Design Configuration
  - Pole Placement
    - A/E or EPC Contractor shall use AASHTO RDG and the Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities.
    - Poles supports shall be placed as far as practical from the edge of the traveled way without adversely affecting the visibility of the signal indications.
    - Where support cannot be located based on the recommended AASHTO clearances, consideration shall be given to the use of appropriate safety devices.
    - In order to minimize hindrance to the passage of persons with physical disabilities, a signal support or controller cabinet shall not obstruct the sidewalk, or access from the sidewalk to the crosswalk.
    - Controller cabinets shall be located as far as practical from the edge of the roadway.
    - On medians, the minimum clearances provided in the above items for signal poles shall be obtained if practical.
  - Traffic Signal Indications
    - If a signalized through movement exists on an approach, a minimum of two primary signal faces shall be provided for the through movement. If a signalized through movement does not exist on an approach, a minimum of two primary signal faces shall be provided for the signalized turning movement that is considered to be the major movement from the approach.

        - If the number of overhead primary signal faces for through traffic is equal to the number of through lanes on an approach, one overhead signal face shall be located approximately over the center of each through lane.
        - Except for shared left-turn and right-turn signal faces, any primary signal face required for an exclusive turn lane shall be located overhead approximately over the center of each exclusive turn lane.
        - In addition to the primary signal faces, one or more supplemental pole-mounted or overhead signal faces shall be considered to provide added visibility for approaching traffic that is traveling behind large vehicles.
        - Refer to the KSA MUTCD Part 4 and augment signal head requirements with the requirements of the FHWA MUTCD.
    - Mounting Hardware
        - Mouting Hardware shall be according to KSA MUTCD

- Pedestrian Control Features
    - Pedestrian Control Features shall be according to the KSA MUTCD
    - The existing KSA MUTCD may be augmented with pedestrian control systems approved in the FHWA MUTCD. These include: Pedestrian Light Control Activation (PELICAN) system, Two Groups CAN cross (TOUCAN) system and High Intensity Activated Cross Walk (HAWK).
- Lighting Requirements for Traffic Signal Installations.
    - The intensity and distribution of light from each illuminated signal lens shall comply with the ITE publications entitled -Vehicle Traffic Control Signal Heads and -Traffic Signal Lamps. Research has resulted in signal optical units that are not lenses, such as, but not limited to, light emitting diode (LED) traffic signal modules. Some units are practical for all signal indications, and some are practical for specific types such as visibility-limited signal indications. If a signal indication is so bright that it causes excessive glare during nighttime conditions, some form of automatic dimming shall be used to reduce the brilliance of the signal indication.
    - Lighting Requirements for Traffic Signal Installations shall be according to KSA MUTCD
- Traffic Signal Controllers (Controller Cabinet and Electrical Service Pedestal)
    - The A/E and/or EPC Contractor shall coordinate the electrical and communication requirements.
    - The A/E and/or EPC Contractor shall show the connection from the electrical and communication services pedestal to the controller.
    - In District Plan areas the controller box must be sized to accommodate the future installation of fiber.
- Communication and Intelligent Transportation Systems (ITS) related issues.
    - General
        - Where ITS is being implemented, the A/E and/or EPC Contractor is required to follow all existing ITS protocols.
        - Where ITS is not being implemented in the District Plans, the A/E and/or EPC Contractor will be required to provide and install a conduit and the associated fixtures in a joint trench along all roadways with future signalization.
- Other Traffic Signal Equipment (e.g., pre-empt systems)

- Where pre-empt systems are being implemented, the A/E and/or EPC Contractor is required to follow all existing pre-empt system protocols.
- Other Traffic Signals
  - Intersection Control Beacons Follow KSA MUTCD for Intersection Control Beacons.
  - Warning Beacons.
    - If a sign is installed to warn approaching road users of the traffic control signal, the sign may be supplemented by a Warning Beacon.
    - A Warning Beacon used in this manner shall be interconnected with the traffic signal controller assembly in such a manner as to flash amber during the period when road users passing this beacon at the legal speed for the roadway might encounter a red signal indication (or a queue resulting from the display of the red signal indication) upon arrival at the signalized location.
    - If the sight distance to the signal faces for an approach is limited by horizontal or vertical alignment, supplemental signal faces aimed at a point on the approach at which the signal indications first become visible may be used.
    - Supplemental signal faces shall be used if engineering judgment has shown that they are needed to achieve intersection visibility both in advance and immediately before the signalized location.
  - Pedestrian Crossing Beacons.

    Pedestrian Crossing Beacons shall be in accordance with KSA MUTCD.

2.3.2 Traffic Surveillance

Where traffic surveillance is being implemented the A/E and/or EPC Contractor is required to follow all existing traffic surveillance protocols.

2.3.3 Traffic Calming

Within urban areas and for roadway classification with 2-lanes of traffic, the A/E and/or EPC Contractor must apply the principals outlined in the ITE-DWUT.

2.3.4 Mobility Measures

- Within urban areas, the A/E and/or EPC Contractor must apply the principals outlined in the ITE- DWUT.
- The A/E and/or EPC Contractor must accommodate the requirement for alternate modes of travel based on context sensitive design approaches.

2.3.5 Traffic Optimization

- Within urban areas, the A/E and/or EPC Contractor must apply the principles outlined in the ITE- DWUT.
- The A/E and/or EPC Contractor must accommodate the requirement for alternate modes of travel based on context sensitive design approaches.

2.4 Streets and Roadways

2.4.1 General

- Introduction

  This section provides the basis for the design of roadway network.

- General Requirements

  This Subsection covers the design criteria for the road network. The road network will be planned, engineered and constructed over a 10 year period.

2.5 Roadway Design

2.5.1 Systems and Classifications

The roadway network classification is defined in the following paragraphs. There are a number of elements of the roadway network terms that are used within the following paragraphs.

2.5.2 Road Classifications

- Freeway
  - A freeway is a high speed multi-lane divided road with grade separation of all cross roads and complete control of access. At-grade intersections and direct access to fronting property are prohibited. Access to and from a freeway is permitted only by way of on/off ramps or grade separated interchanges. In addition, all freeways shall be fenced to deter the access of pedestrians and animals.
  - Freeways shall be designed for speeds of 120 km/h in urbanized areas and 140 km/h in rural areas.
- Expressways
  - Expressways are medium speed multi-lane divided roads with at grade intersections with other roads and interchanges with freeways. Access to expressways is controlled and direct access connections involving median openings will only be permitted in the most exceptional circumstances.
  - Intersections shall be controlled by traffic signals with appropriate coordination to ensure the optimum flow of traffic to the expressway. Intersections shall be provided with full curbed channelization. Acceleration and deceleration lanes shall be provided by widening the hard shoulder to one full lane width and marking it as an auxiliary lane. Left turn lanes shall be provided with adequate storage capacity to prevent turning traffic from backing up onto the through lanes.
  - Expressways shall generally be designed for speeds of 100 km/h.
- Collector/Boulevard Roads
  - Collector roads are medium speed divided roads which link local roads in industrial or community areas with the freeways and expressways serving those areas.
  - Collector road intersections shall require curbed channelization. Left-turn lanes shall be provided with adequate storage length to provide a smooth flow of traffic through the intersection and to prevent turning traffic backing up onto the through lanes.
  - At intersections with divided local roads and other four lane local roads, raised channelization shall be provided for left-turn lanes. Separate right-turn lanes are not required.
  - Collector roads shall be designed for speeds of 90 km/h although it is recognized that instances will arise where posted speeds may have to be significantly lower than this.
- Corniche

  Corniche roads may be considered a subset of collector roads which provide scenic drives along the water frontage.

- Four Lane Local Road
  - Four lane local roads are divided or undivided roads which provide access to community area or industrial plants. They shall have four lanes but no shoulder away from intersections. Sidewalks shall be provided on both sides of four lane local roads where pedestrians may be expected.
  - Design speeds shall be 70 km/h for four lane local roads.

  - o At intersections with divided roads and other four lane local roads, raised channelization shall be provided for left-turn lanes. Separate right-turn lanes are not required.

- Two Lane Local Road
  - o Two lane local roads are low speed roads which provide access to industrial plants/community areas. They have two lanes and a hard shoulder away from intersections. Sidewalk shall be provided on both sides of two lane local roads where pedestrians may be expected such as in the secondary industry area, support industry area and Airport Area.
  - o Design speed shall be 70 km/h for two lane local road.
  - o Raised channelization shall be provided for left-turn lanes at intersections with divided roads. At intersections with four lane local roads and other two lane local roads, left-turn lanes shall not be installed unless the intersection requires signalization.

- Residential Roads
  - o Residential roads are low speed two-lane roads which provide access to residences. Residential roads intersect other residential roads and local roads. They shall not intersect collector roads or expressways.
  - o The design speed of residential roads shall be 50 km/h although it is recognized that instances will arise where the driving speed will be significantly lower than this.

2.5.3 Geometrics and Alignment

- Sight Distance
  - o General

    The AASHTO GREEN BOOK Chapter 3 shows the standards for passing and stopping sight distance related to design speed.

- Horizontal and Vertical Curves
  - o Horizontal Curves
    - Horizontal alignment shall be designed using the following methods to meet the sight distance requirements set forth in the AASHTO GREEN BOOK Chapter 3.
  - o Vertical Curves

    Vertical alignments of roads shall be designed using the following methods/standards to accommodate for stopping and passing sight distances related to design speed on crest and sag vertical curves. Under no circumstance shall the stopping and passing sight distance be less than shown in the AASHTO GREEN BOOK Chapter 3.
  - o Decision Sight Distance on Horizontal and Vertical Curves.
    - At certain locations, sight distance greater than stopping sight distance is desirable to allow drivers time for decisions without making last minute erratic maneuvers. Because decision sight distance offers drivers additional margin for error and affords them sufficient length to maneuver their vehicles at the same or reduced speed, rather than to just stop, its values are substantially greater than stopping sight distance.
    - The decision sight distances in the AASHTO GREEN BOOK Chapter 3 provide values for sight distances that may be appropriate at critical locations and serve as criteria in evaluating the suitability of the available sight distances at these locations.

- Grades

  Maximum Grades - Maximum Grades of about 4 percent are considered appropriate for the design of roadways. However, this may increase up to 6 percent for interchange ramps due to limited space. Minimum Grades - Flat grades may typically provide proper surface drainage on uncurbed highways where the cross slope is adequate to drain the pavement surface laterally. With curbed streets, longitudinal grades shall be provided to facilitate surface drainage. An appropriate minimum grade is typically 0.5 percent. Additional information is presented in the AASHTO GREEN BOOK.

- Superelevation
  - Standard Superelevation - Under normal circumstances, the standard superelevation rates for various curve radii a 6% maximum rate is used to provide the maximum safety benefit while minimizing the potential low-speed operational problems. The actual superelevation provided is determined using the appropriate e_{max} table referenced in the AASHTO GREEN BOOK.
  - Substandard Superelevation - Lower superelevation rates may be necessary in areas where restricted speed zones or road intersections are controlling factors. Such conditions may warrant, for example, a reduction in the superelevation rate, different rates for each half of the roadbed, or both.
  - In warping road areas for drainage, adverse superelevation shall be avoided.
  - Axis of Rotation.
    - Undivided Highways
      - In general, for undivided highways, the axis of rotation for superelevation shall be the centerline of the roadbed. However, in special cases where curves are preceded by long relatively level tangents, the plane of superelevation may be rotated about the inside edge of the pavement to improve perception of the curve.
      - On flat gradients, drainage pockets caused by superelevation may be avoided by changing the axis of rotation from the centerline to the inside edge of the pavement.
    - Ramps and Freeway to Freeway Connection.

      The axis of rotation may be about either edge of pavement or centerline for multi-lane highways. Appearance and drainage considerations shall always be taken into account for the selection of the axis of rotation.
    - Divided Highways

      The axis of rotation shall generally be taken at the median edges of the carriageway. However, the axis of rotation may be moved to the centerline of the median to meet particular circumstances. The selection of the axis of rotation shall always be considered in conjunction with the design of the profile and superelevation transition.
  - Superelevation Transition.
    - The superelevation transition generally consists of the superelevation runoff (length of roadway needed to accomplish the change in cross slope from a horizontal line to a fully superelevated section or vice versa) and the tangent runout.
    - A superelevation transition shall be designed to satisfy the requirements of safety and comfort and be pleasing in appearance. The length of superelevation transition shall be based upon the combination of superelevation rate and width of rotated plane.
    - With respect to the beginning or ending of a curve, two thirds of the superelevation run-off is on the tangent approach and one third within the curve. This results in two thirds of the full superelevation rate at the beginning or ending of a curve. This may be altered to 50% transition to occur within the curve to adjust for flat spots or unsightly sags and humps when alignment is tight.
    - Superelevation transitions shall be designed in accordance with the AASHTO GREEN BOOK.
    - In restrictive situations, such as on two lane highways in mountainous terrain, interchange ramps, collector roads, frontage roads, etc., where curve radius and length and tangents between curves are short, standard superelevation rates and/or transitions may not be attainable. In such situations, the highest possible superelevation rates and transition length shall be used, but the rate of change of cross slope shall not exceed 4% per 20 m.
    - Superelevation transitions for shoulders cannot be indicated properly on the same superelevation transition diagram with the carriageway for the type of diagram shown. The shoulder plane's rotational axis lies on the edge of pavement of the adjacent

carriageway. Shoulder superelevation transitions shall be smooth and compatible with the transition and shall not have an algebraic difference greater than 3% on the higher end and equal to the slope on the lower end of the adjacent pavement.

   - After a superelevation transition is designed, profiles of edges of pavement and shoulder shall be reviewed and irregularities removed by introducing smooth curves. Flat areas which are undesirable from a drainage stand-point shall be avoided.
   - Pronounced and unsightly sags may develop on the low side of the superelevation. These may be corrected by adjusting the grades on the two edges of pavement throughout the curve.

- Transitions: Widening and Reductions.

  For roadways that transition from an undivided to divided highway or where the addition of turn lanes requires an alignment deflection of the approach lanes, the length of these transitions is a function of design speed and the horizontal deflection where:

  L = (2/3) WS for design speed 70 km/h or greater

  L = $WS^2/_150$ for design speed less than 70 km/h

  Where:

  L = transition length -m

  S = design speed –km/hrW = horizontal deflection –m

  For Temporary traffic zones, use the criteria mentioned in KSA MUTCD.

- Typical Cross-sections
  - General

    The AASHTO GREEN BOOK provides guidance on cross sectional elements as a function the rural or urban environment and the functional classification of the roadway.

  - Lane Widths and Number of Lanes
    - Freeways - Standard lane widths of 3.8 m are to be used.
    - Expressways, Collectors, Boulevards, Corniches, Local and Residential Roads- Standard lane widths of 3.65 m are to be used.
    - The number of lanes is generally determined through a planning study that considers traffic growth forecasts, design period, and desired level of service.
  - Shoulders
    - Freeways, Expressways, Collectors and Boulevards - Hard shoulders on the outside edge of the carriageway shall be 3.0 m wide. On freeways, 2.0 m paved shoulders shall be provided up to a median barrier.
    - Corniches Local and Residential Roads- Parking lanes when provided shall be 2.5 m and separated from the travel way with valley gutter.
  - Curbs

    Curb and gutter shall be used on secondary roads with design speeds of 70 km/h or less in areas of limited right-of-way or urban type land use.

  - Median Types and Uses
    - In industrial area, freeway medians shall be a minimum of 14 m wide, and with cross slopes 1:10 or flatter. In the community area, the freeway medians shall be curbed and 8 m wide.
    - Unpaved medians up to 20 m wide shall be sloped downward from the adjoining shoulders to form a shallow valley in the center. Cross slopes shall be 1:10 or flatter; 1:20 being preferred. Slopes as steep as 1:6 are acceptable in exceptional case when necessary for drainage, stage construction, etc. In medians that are 20 m and wider, the cross slopes shall be treated as separate roadways.
  - On-Street Parking

Where used, a parallel parking lane a least 2.5 m wide shall be provided on one or both sides of the street, as appropriate to the conditions and intensity of development.

- Cross-slopes and Side-Slopes.
  - Normal cross-slope on the carriageway shall be 2%. Except as described below, hard shoulders may be sloped away from the carriageway up to 5% (carriageway on normal cross-slopes) to provide efficient drainage. On super elevated sections, the break in cross-slope between the hard shoulder and carriageway shall never exceed 3%.
  - For safety, aesthetics and erosion protection, fore slopes shall be 1V:6H up to 3.0 m fill height. For fore slopes steeper than 1V:4H, provision of guardrail protection shall be determined based on the AASHTO Roadside Design Guide.
  - Back slopes shall be 1V:3H or flatter to accommodate maintenance equipment. Back slopes steeper than 1V:3H shall be evaluated with regard to soil stability and potential crash severity. Retaining walls or slope stabilization shall be considered where space restrictions would otherwise result in slopes steeper than 1V:2H.
  - Additional guidance regarding pavement cross slopes and side slopes may be found in the AASHTO GREEN BOOK.
- Right-of-Way Widths

  Roadway right-of-way is only a single component of the overall right-of-way required. A/E and/or EPC Contractor must establish the actual right-of-way required for each roadway segment based on the roadway classification and configuration, as well as all master-planned utilities in each corridor.
- Clearances
  - Horizontal Clearances
    - The horizontal clearance to bridge piers, abutments and retaining walls and other obstructions for freeways and expressways shall be determined on the basis of engineering judgment with the objective of eliminating fixed objects from near the edge of the shoulder wherever economically feasible. A horizontal clearance of 9 m or more from the edge of the carriageway is desirable, with 5 m as a minimum. Lesser clearances may be used where span length, median width or other controls make the desired clearance unreasonable.
    - The following are absolute minimum horizontal clearance standards for bridge piers, abutments, and retaining walls and other obstructions which, in the case of freeways and expressways, may be used only under restrictive conditions.
    - Clearances are measured from the edge of the carriageway.
    - On the outer edges of all roads the minimum clearance shall be 5 m. On the median edges of multi-lane divided roads the minimum clearance shall be 3.5 m for freeways and 2 m for other roads.
    - Greater clearances than the above minimums shall be provided wherever physically/economically viable and additional clearances must be provided where dictated by sight lines.
    - Guardrails shall be considered for all abutments and piers closer than 6 m to the edge of carriageway.
  - Vertical Clearances
    - The minimum vertical clearance shall be 5.5 m over the entire width of the carriageway including hard shoulders; clearance to overhead power lines shall conform to Saudi Electric Company (SEC) Standards.
    - Lateral Clearance for Elevated Structures
    - The minimum horizontal clearance between elevated highway structures, such as freeway viaducts and ramps, and adjoining buildings, or other structures, shall be 4.5 m for single-deck structures and 6 m for double-deck structures.

- Structures Across or Adjacent to Railroads

  Normal Horizontal and Vertical Clearances:

  – A minimum vertical clearance of 7.3 m above tracks, on which freight cars, not exceeding a height of 4.7 m, are transported, is to be used in design to allow for re-ballasting and normal maintenance of track.

  – All curbs, including median curbs, shall be designed with 3 m of clearance from the track centerline measured normal thereto.

  – The principal clearances which affect the design of highway structures and curbs shall be in accordance with Section1.06 HDM.

- Off-Track Maintenance Clearance

  5.5 m of horizontal clearance is required. This clearance is intended for sections of railroad where the railroad company is using or definitely plans to use off-track maintenance equipment. This clearance is provided on one side of the railroad ROW. The railroad is required to present a statement that off-track maintenance equipment is being used, or is definitely planned to be used, along that section of the railroad ROW crossed by the overhead structure.

- Walkway Clearances Adjacent to Railroads

  All plans involving construction adjacent to railroads shall be such that there is no encroachment on the walkway adjoining the track. Where excavations encroach into walkway areas, the Contractor is required to construct a temporary walkway with handrail.

2.5.4 Roadway Elements

- Design Criteria
- Design Vehicle
- Design Vehicle shall be established using the Design Classes and typical distribution of traffic characteristics as per HDM
- Driver Performance
- The Road Safety Audit will evaluate if there is any need for special design requirements to accommodate driver performance.

- Design Speed
- Typical design speeds are outlined in Table 1.02.02 & 1.02.03 of HDM
- Access Criteria and Driveway Design
  - The HDM Volume 2 shall be used to establish the level of access control for each facility.
  -
  - Access spacing shall be based on the District Master Plan. Accesses to individual sites must comply with the roadway classification access control. Access Points shall be coordinated with adjacent development and joint access points shall be used whereever practical.

- Pedestrian Access

  The District Master Plans illustrate the primary pedestrian circulation routes within the Community.

- Sidewalks

  The typical sidewalk width requirements shall be adopted from HDM.

- Bicycle Facilities

  The District Plans have documented the bicycle systems that will be required.

2.5.5 Guardrails and Traffic Control Devices

- Regulatory Measures
  - General
    - Highway conditions that are shielded by a roadside barrier may generally be placed into one of two basic categories: (1) embankments or (2) roadside obstacles (fixed objects).
    - The reason for installing guardrail on embankments and adjacent to fixed objects is to reduce the combined effect of accident severity and frequency of occurrence of "run-off-road" type of accidents. This is accomplished by deflecting a vehicle away from the embankment slope or the fixed object and by reducing the deceleration rate.
    - Guardrails will reduce accident severity only for those conditions where the overall severity of striking the guardrail is less than the overall severity of going down the embankment or striking the fixed object.
    - Guardrails will also reduce accident frequency only if it provides increased delineation at "run-off-road" accident locations of high frequency. Delineation, however, is considered only an incidental benefit stemming from other uses because delineation may be effected by other means at less cost. Generally, it would be expected that installing guardrail adjacent to fixed objects would increase the frequency of occurrence because the guardrail presents a larger obstacle.
    - Guard railing shall generally be metal beam rail as shown on guideline drawings. In particular circumstances. However, it may be more desirable to use rigid concrete "safety shape" railing where the min deflection area behind the guardrail is not free of obstacles.
  - Guardrail on Embankments

    The embankment height and side slope are the basic factors in determining barrier need. The criteria are based on studies of the relative severity of encroachments on embankments versus impacts with roadside barriers. The height and slope criteria determining need is demonstrated in AASHTO Roadside Design Guide (RDG). Additional factors for consideration are also discussed in the RDG.
  - Guardrail at Roadside Obstacles

    Barrier recommendations for roadside obstacles are a function of the obstacle itself and the likelihood that it will be hit. Guidelines for non-traversable terrain and roadside obstacles are provided in Table 5-2 of the AASHTO Roadside Design Guide.
  - Barrier type selection

    The type of roadside barrier (i.e. guardrail or concrete barrier) shall include consideration such as the percentage of heavy trucks and the probability and consequences of a heavy vehicle penetrating the barrier. Types of roadside barriers and selection considerations are discussed in the AASHTO Roadside Design Guide.
  - Barrier Placement and End Anchorages

    Factors determining the optimum barrier placement location relative to the roadway and obstacle it is designed to protect include: 1) clearance from the traveled way and obstacle, 2) lateral slope and terrain, and 3) angle of departure and length of advance need. Special anchorages and in particular approach end anchorages are required for satisfactory performance. Additional discussion and guidance is provided in the AASHTO Roadside Design Guide.

- Operational and Control Measures for Right-Turn Maneuvers
  - General
    - Intersection capacity analysis shall be used to establish the number of right turn lanes required.

    - Intersection signal analysis shall be used to establish if a right turn phase is warranted.
    - Traffic control needs shall be reviewed based on roadway configuration and classification.
    - Roadway classification shall be used to establish the typical
    - The radius of the outside edge of the carriageway for right turn movements shall be in accordance with Section 1.07 of HDM.

  - Islands

    - Channelizing islands shall define the traffic channels to drivers and pedestrians alike in the clearest manner possible. To prevent confusion, the number of islands shall be kept to a minimum and the use of small islands be avoided. The approach end of an island shall be designed to give the driver adequate warning of its presence and shall never require a sudden change in direction or speed. Transverse lane shifts shall begin far enough in advance of the intersection to show gradual transitions. Islands on horizontal or vertical curves shall be avoided. If the use of islands on curves cannot be avoided, adequate sight distance, illumination, and illuminated terminal nosings shall be provided.
    - The design must provide minimum turning radii for all types of vehicles moving through the intersection.
    - Shying Distance
      - Shying distance is needed where barrier-type curbs are used.
      - When mountable curbs are used on ramps, no shying distance is needed.
    - Flaring

      A 14 m flare shall be used on the left and a 33 m flare on the right wherever island length permits. Flares of 9 or 4.5 m on the left and 15 or 7.5 m on the right may be used for shorter islands. Islands less than 4.5 m on the left and 7.5 m on the right need not be flared.
    - Curbing

      Raised traffic curbing used for islands shall be cast-in place in accordance with the applicable standards.
    - Size

      Triangular islands must be at least 4.7 m2 in size with legs no less than 2.4 m long out-to-out after rounding of corners.

- Operational and Control Measures for Left-Turn Movements
  - Intersection capacity analysis shall be used establish the number of turn lanes required.
  - Intersection signal analysis shall provide a protected turn phase.
  - Roadway classification shall be used to establish the typical requirements for provision of turn lanes.
  - Median lanes are authorized for any channelization divided roads where left turns are permitted from the through lane regardless of whether or not traffic signals are to be installed. Where it is necessary to store stopped vehicles, additional length of median lane shall be provided on the basis of 7.6 m per vehicle.

- Regulation of Curb Parking
  - Parking Zones
    - The A/E and/or EPC Contractor shall furnish drawings showing the definite location of all parking spaces on roadways.
    - The desirable dimensions of parallel parking spaces are 2.5 by 7.3 m with a minimum length of 6.7 m.

   - At all intersections, one space length on each side shall have parking prohibited. Clearance also shall be provided at driveways.
   - At signalized intersections, parking shall be prohibited for a minimum of two stall lengths on the near side and one space length on the far side.
  - Stall Arrangement

    Parking plus maneuvering space may occupy up to 5.5 m of road width for parallel parking and will range up to 12.2 m for angle parking. The 7 m stall for parallel curb parking accommodates the longer automobiles and permits entering or leaving movements with one maneuver.
  - Parking Space Markings

    Parking lines when placed shall be white stripes.

- Markers, Markings and Delineations

  Roadway signing and marking shall comply with the KSA MUTCD Parts 2 and 3.

2.5.6 Noise Barriers

- The KSA HDM Volume 2 Book 2 shall be used to determine need for noise barriers.
- The noise analysis shall be used to establish the current or future need for noise barriers.
- If there is a future need for noise barriers, the barrier location and type shall be established and shown as future on all A/E and/or EPC contractor drawings to ensure the future installation may be accommodated.

2.5.7 Fencing

- All freeways shall be continuously fenced to control access in accordance with the Master Plan.
- Generally, roads other than freeways will not require fencing.
- Facilities such as transformers and load centers shall be provided with fence enclosures.

2.5.8 Bus Stops and Taxi Stops, other public transit

- General

  Bus curb-loading zones normally shall have the following distinct characteristics:
  - The area in the roadway adjacent to the curb shall be reserved for use by the stopped bus, plus maneuver space.
  - There shall be adequate uniform signs to inform pedestrians of the location of bus stops.

- Illumination

  When bus curb-loading zones are located where the general street lighting is not sufficient to provide adequate illumination for maximum safety in passenger boarding or disembarking and for their security, adequate supplemental lighting shall be provided.

- Signs and Markings

  Adequate uniform signs for prohibiting vehicular parking and for marking the extreme limits of the zones shall be installed and properly maintained. Solid yellow curb markings will aid in enforcing regulations prohibiting use of these spaces by private automobiles taxicabs and trucks. Painted lines or markings on the pavement designating the limits of the zone are frequently used; a legend such as "BUS STOP NO PARKING" is sometimes painted on the pavement.

- Location

- Bus curb-loading stops shall not be located so as to cause hazard and delay due to obstruction of other vehicular traffic flow. Where curbs are recessed for bus stops, approach and departure tapers shall not be less than 8:1. It is sometimes desirable to recess the curb sufficiently to provide a turn-out bay for the entire bus which is completely shielded from moving lanes of traffic.
- Bus curb-loading zones are located on the near-side or far-side of intersections or at a mid-block location. The selection of the location shall be based on a consideration of bus routings, number of buses, the origin and destination of transit passengers, the transfer of patrons between bus routes, traffic and pedestrian movements, and the desired operation of traffic control devices.
- At intersections where buses turn, a far-side or mid-block stop has some advantages. A far-side stop is particularly advantageous where a left turn is made. When right turns are made and the curb radius is short a mid-block stop has definite advantages other conditions being equal.
- At complicated intersections where streets meet at other than right angles, far-side stops often provide better operation and less traffic interference.
- At bus transfer points where there is a considerable volume of transferring passenger traffic, pedestrian travel across the intersection may be minimized by having the buses on one route stop at the near side while buses on the intersecting street stop on the far side.
- At intersections where the predominant number of arriving and leaving passengers come from or are destined for a specific building or industrial plant, the bus stop shall be located to minimize pedestrian traffic at the intersection. Far-side stops are seldom found satisfactory where there is apt to be even an occasional accumulation of buses greater than the capacity of the bus curb-loading zone.
- At intersections where numerous vehicles turn right, near-side bus stops may result in conflicts and traffic accidents and thus be inferior to far-side stops.
- Factors such as sidewalk obstructions, inferior alighting surfaces, street paving, or roadway grades frequently may be the key in the final determination of the proper bus stop location.
- Bus stops shall be located so that the maximum walking time to a bus stop does not exceed 10 minutes.

- Operation
  - Where buses make right turns, it is desirable to increase the curb radii to a degree sufficient to permit buses to make such turns without swinging out into the adjacent traffic lanes and without climbing or rubbing the corner curb.
  - A desirable curve which will provide an easy right-turning movement consists of a compound curve, the center radius of which is 7.5 m and the radius of each end is 30 m. The equivalent simple-curve radius is 10 m. The lengthening of the curb radii as suggested above will not lengthen the pedestrian crosswalk materially, but such action will reduce sidewalk capacity and therefore may not be feasible at some locations where sidewalk space cannot be sacrificed.

2.5.9 Commuter Lots

- General
  - Location

    The location of parking facilities will depend upon:

    - The degree of demand in a specific area;
    - Location of traffic generators;
    - Adequacy of existing parking facilities;
    - Geographical area within which the demand exceeds the supply;

        - Land costs; AND
        - Location of suitable access roads.
    - Entrances and Exits
        - Plans for parking facilities shall be integrated with the road plan, traffic volumes, and road capacities (vehicular and pedestrian). The location of entrances and exits on two or more roads will distribute the traffic load so that there is less interference with road to lot movement. Lots having an 18.3 m frontage, or multiples of 18.3 m, or a 7.3 m aisle side, constitute parking units which provide sufficient maneuvering space and permits access from either direction.
        - Acute angle parking gives fewer stalls for a given distance and requires one-way aisles unless cars are backed into some stalls; but entry is easier for drivers, and narrower aisles may be used.
        - Stall marking lines or curbs are recommended for all types of stalls; wheel blocks or bumper guards are essential for the protection of fences and elimination of collisions with parked vehicles. Every lot shall be enclosed by a curb, guardrail, wall, fence, or hedge for safety and landscaping. Pedestrian safety may be improved by providing pedestrian walkways and illumination; it is frequently difficult to confine the pedestrian to these walkways. Drainage, grading, and dust-prevention are minimum requirements.
    - Parking Lots

        The most efficient use of land area in larger parking lots is obtained by placing all vehicles perpendicular to the aisles. A perpendicular layout is readily adaptable and is desirable, except where one way street traffic indicates that movement shall be clockwise to reduce conflicts.

2.5.10 Roadside Parking Areas

Roadside development shall be consistent with the KSA HDM Volume 2.

2.5.11 Vehicle Barriers

Vehicle barriers shall be consistent with the KSA HDM Volume 2.

2.6 Interchanges, Intersections and Roundabouts

2.6.1 Design Considerations

A corridor study shall be completed based on the requirements outlined in the HDM Volume 1.

2.6.2 Types of Intersections

The corridor study shall establish the various levels of roadway classification and the associated intersection requirements.

2.6.3 Grade Separations

- General
    - Design Criteria

        The design criteria to be used for grade separations is given in these guidelines and shall be used in conjunction with the standard specifications for highway bridges adopted by the American Association of State Highway and Transportation officials, AASHTO, latest edition.
    - Locations
        - Bridges are located to conform to the general alignment of the highway. Ideally, the location for a bridge crossing shall be determined in accordance with the following guidelines:
            - The crossing may be made at right angles.

  - Alignment of the approach pavement is tangent and sufficiently long to eliminate superelevation on the bridge.
  - Soil conditions are adequate for installation.
- Structures shall not be placed on vertical and horizontal curvature when alternate locations are available. The final decision for location shall be based on a complete analysis of the factors involved, including those relating to traffic safety, operating conditions, and economics.

2.6.4 Capacity Analysis

Using the roadway classification, traffic volumes from the corridor study and the operational requirements of the roadway network, intersections shall be evaluated and any capacity deficiencies shall be addressed during the development of corridor study.

2.6.5 Alignment and Profile

- A center line location and preliminary design shall be completed based on the requirements outlined in the HDM Volume 1 Section 2.05
- Additional information is required at all intersections to ensure proper matching between roads and proper drainage is maintained. Intersection grading details may be required.

2.6.6 Auxiliary Lanes

- In order to insure satisfactory operating conditions, auxiliary lanes may be added to the basic width of carriageway.
- Where an entrance ramp of one interchange is closely followed by an exit ramp of another interchange, the acceleration and deceleration lanes may be joined with an auxiliary lane. This shall be dependent upon the weaving segment capacity which varies with configuration, number of lanes, free flow speed of highway, length, and volume ratio. Refer to Auxiliary lanes, Chapter 10 AASHTO Green Book.
- Where interchanges are more widely spaced and ramp volumes are high, the need for an auxiliary lane between the interchanges shall be determined by an across-freeway lane volume check. This check shall include consideration of freeway grade and volume of trucks.
- Auxiliary lanes may be used for the orientation of traffic at two-lane ramps or branch connections. The length and number of auxiliary lanes in advance of two-lane exits are based on percentages of turning traffic.

2.6.7 Frontage Roads

The requirement for and design of frontage roads shall be based on the HDM Volume 2 Book 1

2.6.8 Lighting at Intersections

The requirement for and design of roadway lighting shall be based on the HDM Volume 2.

2.6.9 Railroad Grade Crossings

Railroad Grade Crossing must be controlled in accordance with the KSA MUTCD Part 7.

2.6.10 Interchanges

- Types

The location of interchanges is largely predetermined by the Work Plan. In general, full clover leaf, partial cloverleaf, or trumpet type interchanges are used for freeway to freeway connections whilst compact diamond interchanges are used for connecting freeways to other classes of road.

- Warrants for Interchanges and Grade Separations.
  - The design criteria to be used for grade separations is given in these guidelines and shall be used in conjunction with the standard specifications for highway bridges adopted by the American Association of State Highway and Transportation officials, AASHTO, latest edition.
  - Interchange type and layout configuration must satisfy the forecasted traffic demand.

- Access Management
  - Access control is to be exercised along interchange ramps to their junction with the nearest "collector" road. At such a junction, access shall be controlled to the end of the ramp pavement taper. At locations where curb returns are used in lieu of tapers, access restrictions may extend 15 m beyond the end of the curb return.
  - Where traffic leaves a ramp situation and enters a local traffic situation and the freeway ride is clearly and obviously ended, the access control shall also end.

- Grade Separation Structures
  - Structures shall not be placed on vertical and horizontal curvature when alternate locations are available. The final decision for location shall be based on a complete analysis of the factors involved, including those relating to traffic safety, operating conditions, and economics.
  - Location and type of bridge requirements shall be recommended by the A/E and/or EPC Contractor.

- Design Standards

  Location and type of bridge requirements shall be recommended by the A/E and/or EPC Contractor.

- Freeway Entrances and Exits
  - All freeway entrances and exits shall connect to the right of through traffic.
  - Location on a Curve
    - Freeway entrances and exits shall be located on tangent Sections wherever possible in order to provide maximum sight distance and optimum traffic operation. Where ramps have to be located on curves the ramp tapers shall also be curved. At freeway exits the radius of the taper shall be about the same radius as the freeway edge of pavement in order to develop the same degree of divergence as the standard design. At freeway entrances on a curve, the ramp alignment will vary with the radius of curvature of the freeway.
    - Where an exit in a cut section must be on a curve, cut widening for visibility may be needed. If this is not feasible, an auxiliary lane in advance of the exit may be provided. The length of the auxiliary lane need not exceed 300 m and may be less if the beginning of the lane occurs on a tangent section of the freeway.

- Weaving Movement
  - Design requirements for weaving sections shall be analyzed in accordance with an internationally recognized standard
  - Weaving between closely spaced loop ramps when adjacent to high speed highways, will be accomplished by using Collector-Distributor (C-D) roads. Weaving without C-D roads will be allowed on the low speed crossroad. The following design criteria shall be used in either case:
    - The algebraic difference between crown slopes shall not exceed 0.05 m per m.
    - Edge of pavement profiles shall be plotted to insure smooth transition and adequate drainage.

  - Tangent takeoffs for off ramps are to be avoided; therefore the proper location of the weaving sections shall preferably be on an approximate tangent section of the collector-distributor road or crossroad.

- Other Design Features
  - Testing

    When a section of freeway includes a series of closely spaced exits and entrances, it shall be tested for capacity and ease of operation from the driver's point of view, experiencing the signing, merging, diverging, and weaving movements involved. This testing shall be completed soon after the preliminary design. It shall be performed by tracing the paths of drivers undertaking various origination and destination points, with the designer visualizing traffic, signage and other features along each route being traveled.
  - Ramp Metering

    Ramp meters are traffic signals placed on freeway entrance ramps or freeway connectors to control the flow of vehicles entering the freeway. They are designed to improve the average speed of all vehicles traveling on a freeway mainline by decreasing congestion that may result when too many cars enter at certain points. The traffic signals may be pre-timed or traffic-actuated to release the entering vehicles in small platoons. Pre-timed metering releases vehicles at regular intervals that have been determined by traffic studies and simulation modeling.
  - Grading

    Preliminary alignment and profiles of the intersecting roads are developed to determine the controls governing bridge design. Alternative slopes and wall configurations shall be evaluated before final decisions are made for the bridge and wingwall designs. Flat slopes shall be used wherever practical to facilitate economical maintenance and facilitate regaining of control for vehicles that run off the road.
  - Models

    Computer software may be used to provide 3D visualizations and traffic simulations for the purpose of analyzing and comparing alternatives for various interchange configurations. Design models may be easily adjusted, allowing the designer to experiment with different concepts. They are also useful in communicating the design team's ideas to stakeholders and public officials.

2.6.11 Railroad Highway Crossings

- All railroad crossing shall be evaluated using the RHGCH to establish the necessary crossing treatment.
- All signing and marking shall be compliant with MUTCD Part 7.

2.7 Flexible Pavement Design

Flexible pavements consist of prepared roadbed underlying layers of subbase, base, and bituminous asphaltic concrete surface courses. The prepared roadbed is a layer of in-situ soils or select borrow material which has been compacted to a specified density. The subbase usually consists of a compacted layer of granular material, or of a layer of soil treated with an admixture, and it shall be of significantly better material than the roadbed soil. The base course is the portion of the pavement structure located immediately beneath the surface course. Its major function in the pavement is structural support. It usually consists of aggregates such as crushed stone, crushed slag, crushed gravel and sand, or combinations of these materials.

2.7.1 Pavement Structure Layers

Freeway, Expressway, Collector, Local and Residential Facilities - Layer thickness design methodology shall be in conformance with in the Kingdom of Saudi Arabia Ministry of Communication (Currently Ministry of Transport) Highway Design Manual (HDM) Section 1.09.

2.7.2 Pavement Design Life

- A pavement design life of 20 years shall be used for flexible pavement design.
- Pavement design life is defined as from construction completion and opening of traffic to when the first major maintenance event (resurfacing) is required.

2.7.3 Traffic Considerations

- The primary traffic input needed to design pavement thickness for freeways and expressways in accordance with the HDM is the number of equivalent 8-tonnes single-axle loads (ESAL) that will travel over the pavement over the design life.
- A Traffic Impact Statement shall be included for all roadway designs.

2.7.4 Soil Characteristics

Soil strength values to be used with the HDM design methodology shall be:

- the California Bearing Ratio (CBR) based on MRDTM 213 test procedures. The aforementioned thicknesses for pavement layers are based on CBR more than or equal to 10. If CBR values for the area are low, it may be possible to specify replacing or improving the soil in this area by soil stabilization techniques, excavation and recompaction, dig out and replace or other approved measures to increase the soil strength.
- Resilient Modulus based on AASHTO Test Method T 274. MR = 1500 (CBR)

2.7.5 Materials

- Pavement Structure Layer materials shall be in accordance with the General Construction Specifications.
- Recycled Materials.

2.7.6 Maintainability and Constructability

There are various maintenance operations which are carried out for a highway. Maintenance of pavement, shoulders, drainage, erosion, vegetation, and structures, are some of the major categories. Constructability of pavement is related to placement and compaction of base and sub base, and largely a function of the suitability and stability of the underlying soils on which the pavement will be constructed.

2.7.7 Life-Cycle Cost Analysis

It is essential when comparing costs of design alternatives that an economic analysis considers all costs that will occur during the entire life cycle of the facility. Life-cycle costs include construction costs, maintenance costs, and rehabilitation costs.

2.7.8 Pavement Drainage

Drainage of water from pavements is an important consideration in road design. Excess water combined with increased traffic volumes and loads may lead to early pavement distress. To obtain adequate pavement drainage, the designer shall consider providing three types of drainage systems: (1) surface drainage, (2) groundwater drainage, and (3) structural drainage. Maintenance practices shall recognize the necessity of sealing joints and cracks in the pavement surface. Removal of subsurface water can be accomplished by designing the pavement to drain vertically into the subgrade, or laterally through a drainage layer into a system of pipe collectors.

2.7.9 Base and Subbase

When roadbed soils are of relatively poor quality and the design procedure indicates that a substantial thickness of pavement is required, several alternate designs shall be prepared for structural sections with and without subbase. The selection of an alternate may then be made on the basis of availability and relative costs of materials suitable for base and subbase. Because lower quality materials may be used in the lower layers of a flexible pavement structure, the use of a subbase course is often the most economical solution for construction of pavements over poor road-bed soils.

2.7.10 Structure Approach Slabs

The highway bridge approach slab is a thick, heavily reinforced Portland cement concrete slab that provides a transition between the roadway pavement and the bridge. The approach slab acts as an intermediate bridge to span the portion of embankment directly behind the abutment/backwall which was excavated to construct the abutment/backwall. This area is difficult to compact after construction of the bridge abutment. By being supported on one end by the bridge abutment, the approach slab bridges the gap between the rigid abutment and the undisturbed embankment beyond the area excavated.

2.7.11 Superpave

- Superpave, short for "superior performing asphalt pavement" is a pavement method increasing stone-on-stone contact improving load bearing capacity. It is a comprehensive method of pavement design mix tailored to the expected performance requirements dictated by the traffic, environment (climate) and structural section at a particular pavement site.
- It relies on performance-based properties to designate the optimum mix design by selecting and combining asphalt binder, aggregate and necessary modifiers to achieve the expected pavement performance. The objective of the superpave mix design is to define an economical blend of asphalt binder and aggregates which yields the mix having sufficient asphalt binder, sufficient voids (VMA) in the mineral aggregate, sufficient workability and satisfactory performance over the service life of the pavement.

2.8 Rigid Pavement

Rigid pavements consist of a prepared roadbed underlying a layer of sub base and pavement slab. The sub base may be stabilized or unstabilized. The subbase consists of one or more compacted layers of granular or stabilized material placed between the subgrade and the rigid slab. The pavement slab consists of Portland cement concrete, reinforcing steel, load transfer devices, and joint sealing material. Rigid pavement is generally associated with higher initial capital costs, but may prove more cost effective that flexible pavement over the entire life cycle of the facility.

2.9 Resurfacing, Restoration and Rehabilitation

Resurfacing, restoration and rehabilitation (RRR) work is defined as all work undertaken to extend the service life of existing pavement, enhance operations and safety, and return an existing roadway to a condition of structural and functional adequacy. Typical RRR work will include rehabilitation of the pavement through slab repair/replacement and/or installation flexible pavement overlays. RRR also often includes upgrades to roadside safety that may include relocation of roadside hazards and installation or upgrades to roadside barrier and hardware.

2.10 Utilities

- Sleeves shall be included at all intersections
- On long, straight roads, spare sleeves shall be included at 500m to 1000m intervals based on engineering requirements.