Preface

The Ministry of Works has prepared this Road Geometric Design Manual - 2011 Edition for design of roads in order to promote uniformity in design procedures in the country.

The major benefits to be gained in applying this manual are the harmonization of professional practice and the assurance of satisfactory levels of safety, health and economy with due consideration of the objective conditions and need of the country. The Road Geometric Design Manual will be useful to designers, researchers, academia and professionals interested in geometrics of roads. The 2011 Edition Road Geometric Design Manual supersedes the Ministry of Communications and Works Draft Road Manual - 1989 Edition.

Standards in this manual are general since they cannot cover all site specific conditions. The standards are based on prevailing and anticipated future conditions of vehicle dimensions and performance characteristics and transportation demands. Since there is no absolute optimum design the principles and techniques in this manual must be adhered to. Unless otherwise it is envisaged that a combination of good practices with the judgment and expertise of the engineering profession will be applied to produce innovative and favourable outcomes that benefit the travelling public and our communities.

It is our hope that the manual continues to be comprehensive in recognition of the diverse needs of transportation professionals for effective planning, design guidance, construction, maintenance, operational and safety performance of new facilities as well as major reconstruction of road projects in the country.

Also, the manual provides a wide range of potential applications of road design as well as explaining to the public the trade-offs associated with the geometrics of roads in our country.

In addition, the manual is a technical working document that might evolve from time to time due to dynamic nature of the transportation industry as well as socio and technological development, it is imperative to be updated periodically. Therefore, the Ministry wishes to welcome comments that might arise in the application of this manual so as to come up with the future revisions of the manual that addresses effective design.

Dar-es-Salaam
May 2012

Ambassador Herbert E. Mrango
Permanent Secretary
Ministry of Works
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Also, the Working Group acknowledges use of valuable information from corresponding manuals in the neighbouring countries. Particularly the Geometric Design Manual of Uganda was of great value in developing this Manual.
Abbreviations and Definitions

This list of abbreviations and definitions sets forth the meanings of various terms, which are relevant to the geometric design as well as terminologies used for cross-section, horizontal curve and super-elevation.

It is recommended that, whenever more than one term exists for a particular subject, the term included in this list is adopted in order to promote a clear and consistent terminology for road design.

### Abbreviations

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<th>Abbreviation</th>
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<tr>
<td>AADT</td>
<td>Average Annual Daily Traffic</td>
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<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
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<td>ADT</td>
<td>Average Daily Traffic</td>
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<td>CAD</td>
<td>Computer-Aided Design</td>
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<td>CL</td>
<td>Centre Line</td>
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<td>CMP</td>
<td>Corrugated Metal Pipe</td>
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<td>CWW</td>
<td>Carriageway Width</td>
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<td>DHV</td>
<td>Design Hourly Volume</td>
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<td>DS</td>
<td>Design Standard</td>
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<td>DTM</td>
<td>Digital Terrain Model</td>
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<td>DV</td>
<td>Design Vehicle</td>
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<td>EGDM</td>
<td>Ethiopian Geometric Design Manual</td>
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<td>FSE</td>
<td>Full Superelevation</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<td>GVM</td>
<td>Gross Vehicle Mass</td>
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<td>HAL</td>
<td>Horizontal Alignment Listing</td>
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<td>HCM</td>
<td>Highway Capacity Manual (By American Transportation Research Board)</td>
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<td>LC</td>
<td>Long Chord</td>
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<td>Abbreviation</td>
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<tr>
<td>LOS</td>
<td>Level of Service</td>
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<td>LW</td>
<td>Lane Width</td>
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<td>MOFEA</td>
<td>Ministry of Finance and Economic Affairs</td>
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<td>MOID</td>
<td>Ministry of Infrastructure Development</td>
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<td>MOW</td>
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<td>MUTCD</td>
<td>Manual on Uniform Traffic Control Devices</td>
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<td>NPRA</td>
<td>Norwegian Public Roads Administration</td>
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<tr>
<td>PC</td>
<td>Point of Curvature</td>
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<td>PCN</td>
<td>Project Concept Note</td>
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<td>PI</td>
<td>Point of Intersection</td>
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<td>PIP</td>
<td>Public Investment Plan</td>
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<td>POT</td>
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<td>PSD</td>
<td>Passing Sight Distance</td>
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<td>PT</td>
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<td>PVC</td>
<td>Point of Vertical Curvature</td>
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<td>PVI</td>
<td>Point of Vertical Intersection</td>
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<td>PVT</td>
<td>Point of Vertical Tangency</td>
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<td>RCP</td>
<td>Reinforced Concrete Pipe</td>
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<td>RFCS</td>
<td>Road Functional Classification System</td>
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<td>ROW</td>
<td>Right-Of-Way</td>
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<td>RP</td>
<td>Reference Point</td>
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<td>RPSD</td>
<td>Reduced Passing Sight Distance</td>
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<td>RRW</td>
<td>Road Reserve Width</td>
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<td>SATCC</td>
<td>Southern African Transport and Communications Commission</td>
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<tr>
<td>SC</td>
<td>Spiral to Circular Curve</td>
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<td>SSD</td>
<td>Stopping Sight Distance</td>
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<td>ST</td>
<td>Spiral to Tangent</td>
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<td>TANROADS</td>
<td>Tanzania National Roads Agency</td>
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<td>TRL</td>
<td>Transport Research Laboratory</td>
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<td>TRRL</td>
<td>Transport and Road Research Laboratory</td>
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<td>TS</td>
<td>Tangent to Spiral</td>
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<td>UGDM</td>
<td>Ugandan Geometric Design Manual</td>
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**Definitions**

**A**

**Access**
Way whereby the owner or occupier of any land has access to a public road, whether directly or across land lying between his land and such public road.

**Access control**
The condition whereby the road authority either partially or fully controls the right of abuttion owners or occupiers to direct access to and from a public highway or road.

**Acceleration Lane**
An auxiliary lane to enable a vehicle to increase its speed so that it can more safely merge with through traffic.

**At-Grade Intersection (Junction)**
A junction where all carriageways join or cross at the same level.

**Auxiliary Lane**
The part of the carriageway adjoining the travelled way for parking, speed change, turning, storage for turning, weaving, truck climbing, and for other purposes supplementary to through traffic movement.

**Average Annual Daily Traffic (AADT)**
Total yearly traffic volume in both directions divided by the number of days in the year.

**Average Daily Traffic (ADT)**
The total traffic volume during a given time period in whole days greater than one day and less than one year divided by the number of days in that time period.

**Average running speed**
The distance summation for all vehicles divided by the running time summation for all vehicles. Also referred to as space mean speed whereas time speed is simply the average of all recorded speeds.

**Axis of rotation**
The line about which the pavement is rotated to super-elevate the carriageway.

**B**

**Back Slope**
The area proceeding from ditch bottom to the limit of the earthworks.

**Barricade**
A portable or fixed barrier used to close all or a part of a road to vehicular traffic.

**Bollard**
A device placed on a street refuge or traffic island to provide a measure of protection for pedestrians and to warn drivers of these obstructions. It also usually indicates by means of a traffic sign the direction to be taken by vehicles. The device is generally illuminated at night.
**Bridge**
A structure erected for carrying a road over a river or any other gap with a single span-length or sum of span-lengths of 2.0 m or more. Where the clear span is less than two metres, reference is to a culvert.

**Bus-bay**
A lay-by reserved for public service vehicles.

**Bypass**
A road on the fringe of a town or village to enable through traffic to avoid congested areas or other obstructions to movement.

**C**

**Camber**
The convexity given to the curved cross-section of an un-super-elevated carriageway or footpath.

**Capacity**
The maximum number of vehicles that can pass a point on a road or in a designated lane in one hour without the density being so great as to cause unreasonable delay or restrict the driver’s freedom to manoeuvre under prevailing roadway and traffic conditions.

**Carriageway**
That part of the road normally used by vehicular traffic. Auxiliary traffic lanes, passing places, lay-bys and bus bays are included in this term but excluding shoulders.

**Centre Lane**
On a dual three-lane road, the middle lane of the three lanes in one direction.

**Centreline**
The axis along the middle of the road.

**Central Reserve**
An area separating the carriageways of a dual carriageway road that can be used for future development as traffic lanes.

**Circular Curve**
The usual curve configuration used for horizontal curves.

**Channelising Island**
A traffic island located in the carriageway area to control and direct specific traffic movements to definite channels.

**Channelisation**
The separation or regulation of conflicting traffic movements into definite paths of travel by the use of pavement markings, raised islands, or other suitable means to facilitate the safe and orderly movement of traffic, both vehicular and pedestrian.

**Channelised Junction**
An at-grade junction in which traffic is directed into definite paths by traffic islands.


**Climbing Lane**
An auxiliary lane in the upgrade direction for use by slow moving vehicles to maintain capacity and freedom of operation on the travelled way.

**Cloverleaf**
A four-way interchange in which inner loops are provided for right-turn movements and direct outer connections for left-turn movements. A cloverleaf has ramps for turning movements in each quadrant.

**Coefficient of Friction**
A ratio of the frictional force on the vehicle and the component of the weight of the vehicle perpendicular to the frictional force.

**Compound Curve**
A curve consisting of two or more arcs of different radii curving in the same direction and having a common tangent or transition curve where they meet.

**Control of Access**
The conditions where the right of owners or occupants of adjoining land or other persons to access, light, air or view in connection with a road is fully or partially controlled by public authority.

**Controlled Pedestrian Crossing**
A pedestrian crossing marked by two white transverse lines across the width of the carriageway and accompanied by traffic sign R360 [“Pedestrian (zebra) Crossing”], where the passage of pedestrians and vehicles is regulated by traffic signals or an authorised officer.

**Crash Cushion**
A crash cushion, also known as an impact attenuator or crash attenuator, is a device intended to reduce the damage done to structures, vehicles, and motorists resulting from a motor vehicle collision.

**Crest Curve**
A convex vertical curve with the intersection point of the tangents above the road level.

**Criterion**
A yardstick according to which some or other quality of the road can be measured. Guideline values are specific numerical values of the criterion.

**Critical Slope**
The side slope on which a vehicle is likely to overturn.

**Critical Length of Grade**
The maximum length of a specific upgrade on which a loaded truck can operate without an unreasonable reduction in speed. A speed reduction of 20 km/h or more is considered “unreasonable”.

**Cross-fall**
The tilt or transverse inclination of the cross-section of a carriageway which is not cambered, expressed as a percentage.
Abbreviations and Definitions

Cross-Roads
A four-leg junction formed by the intersection of two roads approximately at right angles.

Cross-Section
A vertical section showing the elevation of the existing ground, ground data and proposed works, usually at right angles to the centreline.

Crown
The highest portion of the cross-section of a cambered carriageway.

Culvert
A structure other than a bridge, which provides an opening under the carriageway, median or access road for drainage or other purposes.

Cycle Track
A way or part of a road for use only by pedal cycles.

Deceleration Lane
An auxiliary lane to enable a vehicle leaving the through traffic stream to reduce speed without interfering with other traffic.

Deflection Angle
Successive angles from a tangent subtending a chord and used in setting out curves.

Departure from Standards
Deviation from values given in the reference, requiring prior approval of the Ministry.

Design Capacity
The maximum number of vehicles that can pass over a lane or a carriageway during a given time period without operating conditions falling below a pre-selected design level.

Design Speed
A speed selected for purposes of design and correlation of those features of a road, such as curvature, superelevation and sight distance, upon which the safe operation of vehicles is dependent.

Design Traffic Volume
The number of vehicles or persons that pass over a given section of a lane or carriageway during a time period of one hour or more.

Design Vehicle
A vehicle whose physical characteristics and proportions are used in setting geometric design.

Design Volume
A volume determined for use in design, representing traffic expected to use the road.
**Deviation Angle**
The external angle formed by two successive straights measuring the angular change of direction.

**Diamond Junction**
A four-way interchange with a single one-way ramp in each quadrant. All right-turns are made at grade on the minor road.

**Diverging**
The movement of a vehicle out of a traffic stream.

**Diversion**
An alternative route for traffic to avoid congestion, obstruction or other hazard.

**Dual Carriageway Road**
A road in which there are two physically separated carriageways reserved for travelling in opposite directions.

**E**

**Economical Limit of Haul**
A distance through which it is more economical to haul excavated material than to waste and borrow.

**Embankment**
That portion of the road prism composed of approved fill material, which lies above the original ground and is bounded by the side slopes, extending downwards and outwards from the outer shoulder breakpoints and on which the pavement is constructed.

**Eye Height**
An assumed height of drivers’ eyes above the surface of the carriageway used for the purpose of determining sight distances.

**F**

**Feeder Road**
The road within urban area that links a collector road and other minor road within the vicinity and collects or distributes traffic between residential, industrial and principal business centres of the town including village access roads linking wards to other wards centres.

**Fill**
The material which is used for the construction of embankments.

**Filtering**
The permitted movement of one or more lines of traffic streams while the remaining lines are stopped.

**Flat (Terrain)**
Flat terrain with largely unrestricted horizontal and vertical alignment; transverse terrain slope between 0 and 10 percent.
Flush Kerb
A concrete structure, usually continuous at the edges of the carriageway and/or paved shoulder, providing them with lateral support. It is usually flush with their surfaces.

Footway
That portion of a road reserved exclusively for pedestrians.

Fork-junction
A Y-junction in which one arm of the Y does not deviate from the stem.

Free Haul
A maximum distance through which excavated material may be transported without added cost above the unit bid price.

Freeway
A freeway is a road with full access control and designed for safer high-speed travel by large numbers of motor vehicles through minimization of traffic lights, stop signs, and elimination of at-grade intersections.

Geometric (Design) Standards
Guidelines for limiting values of road alignment and cross-section design.

Grade Separated Junction
A junction where two roads cross at different levels and are connected by ramps.

Grade Separation
A crossing of two roads, or a road and a railway at different levels.

Gradient
A rate of rise or fall on any length of road with respect to the horizontal. It is usually expressed as a percentage of vertical rise or fall in metres / 100 metres of horizontal distance.

Guardrail
Continuous barrier erected alongside a road to prevent traffic from accidentally leaving the carriageway or from crossing the median.

Gyratory Traffic
Vehicular traffic flowing round a system of one-way streets or a roundabout.

Gyratory System
A system of one-way carriageways which together allow a continuous passage of traffic around a central area which may or may not contain buildings.
H
Half-cloverleaf
A four-way interchange in which loops and outer connections are provided in two quadrants to give
grade separation to the major road, but on the minor road the right-turning movements take place at
grade.

Hilly (Terrain)
Terrain with hills having some restrictions in both horizontal and vertical alignment; transverse terrain
slope between 25 and 60 percent.

Horizontal Alignment
The direction and course of the road centreline in plan.

Horizontal Clearance
The lateral clearance between the edge of shoulder and obstructions.

Horizontal Curve
A curve in plan.

I
Interchange
A network of roads at the approaches to a junction at different levels which permits traffic movement
from one to the other on two or more carriageways or roads.

Intersection Angle
The internal angle formed by two successive straights.

J
Junction (Intersection)
a) A common zone of two or more roads allowing vehicles to pass from one to the other;
b) The meeting of one road with another.

K
Kerb
A border of stone, concrete or other rigid material formed at the edge of the carriageway or footway.

K-value
A ratio of the length of vertical curve in metres to the algebraic difference in percentage gradients
adjoining the curve.

L
Lane
A strip of carriageway intended to accommodate a single line of moving vehicles.

Lay-by
A part of the road set aside for vehicles to draw out of the traffic lanes for short periods.
**Left -Hand Lane**
On a dual carriageway, the traffic lane nearest to the verge or shoulder.

**Left Turn Lane**
An auxiliary lane to accommodate deceleration and storage of left-turning vehicles at junctions.

**Left-right Stagger**
A cross-roads at which a driver intending to cross a major road, turns to his left on entering the intersecting road, and then to his right in order to continue on his route.

**Level of Service**
A qualitative rating of the effectiveness of a road in serving traffic, measured in terms of operating conditions.

**Limited Access Road**
A road with right of access only at a limited number of places.

**Local Road**
Road (or street) primarily for access to adjoining property. It may or may not be a classified road.

**Longitudinal Profile**
An outline of a vertical section of the ground, ground data and proposed works along the centreline.

**Marker Post**
A post, generally fitted with reflective material or small reflecting studs, but not usually lit, erected off the carriageway to give warning or guidance to traffic.

**Meeting Sight Distance**
The distance required to enable the drivers of two vehicles travelling in opposite directions on a two-way road with insufficient width for passing to bring their vehicles to a safe stop after becoming visible to each other. It is the sum of the stopping sight distances for the two vehicles plus a short safety distance.

**Median**
An area between the two carriageways of a dual carriageway road. It excludes the inside shoulders (if provided).

**Merging**
The movement of a vehicle or vehicles from one or more lanes into a traffic stream.

**Minister**
The Minister for the Ministry responsible for Roads.

**Ministry**
The Ministry responsible for Roads.
**Mountainous (terrain)**
Terrain that is rugged and very hilly with substantial restrictions in both horizontal and vertical alignment; transverse terrain slope above 60% percent.

**Motorway**
A road having multi lanes with limited access and with complete grade separation.

**Multi-leg Junction**
A junction with five or more legs.

**N**
**Network (Hierarchy)**
Classification of roads according to National and District roads.

**Non-recoverable Slope**
A transversible side slope, where the motorist is generally unable to stop or return to the carriageway.

**Normal Cross-fall**
Difference in level measured transversely across the surface of the carriageway.

**O**
**Object Height**
Assumed height of a notional object on the surface of the carriageway used for the purpose of determining sight distance.

**Operating Speed**
The highest overall speed at which a driver can travel on a given road under favourable weather conditions and under prevailing traffic conditions without at any time exceeding the safe speed as determined by the design speed on a section-by-section basis.

**Optimum Speed**
The speed at which the maximum possible traffic flow (traffic capacity) can be attained.

**Overpass**
A grade separation where the subject road passes over an intersecting road or railway.

**P**
**Parking Bay**
An area provided for taxis and other vehicles to stop outside of the carriageway.

**Passenger Car Unit (PCU)**
A unit of road traffic, equivalent for capacity purposes to one normal private car. The private car is thus the unit and other vehicles are converted to the same unit by a factor depending on their type and circumstances.
Abbreviations and Definitions

Passing bay
A widened section of an otherwise single lane road where a vehicle may move over to enable another vehicle to pass.

Passing Sight Distance
The minimum sight distance on two-way single carriageway roads that must be available to enable the driver of one vehicle to pass (overtake) another vehicle safely and comfortably without interfering with the speed of an oncoming vehicle travelling at the design speed, should it come into view after the overtaking manoeuvre is started.

Pavement
A multi-layered horizontal structure which is constructed for the purpose of carrying traffic.

Pavement Layers
The layers of different materials, which comprise the pavement structure.

Peak Hour Traffic
The highest number of vehicles found to be passing over a section of lane or carriageway during 60 consecutive minutes.

Pedestrian Crossing
A transverse strip of carriageway intended for the use of pedestrians crossing the road. The crossing may be uncontrolled or controlled.

Pedestrian Barrier
A protective fence between two carriageways to discourage pedestrians from crossing the road.

Pedestrian Refuge
An island designed for the use and protection of pedestrians.

Point of Intersection (PI)
The point where two successive tangents intersect.

R
Ramp
a) An inclined section of way over which traffic passes for the primary purpose of ascending or descending so as to make connections with other ways.
b) An interconnecting length of road of a traffic interchange or any connection between roads of different levels, on which vehicles may enter or leave a designated road.

Ramp Terminal
The general area where a ramp connects with a through carriageway.

Reaction Time
The time taken by the driver to perceive the hazard ahead plus the time taken to activate the brake.
Recoverable Slope
Side slope of limited grade such that a motorist can generally bring the vehicle to a safe stop or return to the carriageway.

Refuge
A raised platform or a guarded area so sited in the carriageway as to divide the streams of traffic and to provide a safety area for pedestrians.

Reverse Curve
A composite curve consisting of two arcs or transitions curving in opposite directions.

Right Hand Lane
On a dual carriageway, the traffic lane nearest to the median or near to the central reserve.

Right-left Stagger
A cross-roads at which a driver, intending to cross a major road turns to his right on entering the intersecting road, and then to his left in order to continue on his route.

Right-Turn Lane
An auxiliary lane to accommodate deceleration and storage of right-turning vehicles at junctions.

Ring Road
A road around a town centre or urban area enabling traffic to avoid the central business District.

Road
A way for vehicles and for other types of traffic which may or may not be lawfully usable by all traffic.

Road Authority
Any local Government Authority, Institution, Agency or Any other body entrusted by the Minister with the duties to develop, manage and maintain roads.

Road Bed
The natural in-situ material on which the embankment or capping layers are to be constructed.

Road Functional Classification
The classification of roads according to service provided in terms of the road hierarchy.

Road Hump
A physical obstruction, normally of semi circular or trapezoidal profile placed transversely on the surface of the carriageway for the purpose of reducing traffic speed.

Road Prism
The cross-sectional area bounded by the original ground level and the sides of slopes in cuttings and embankments excluding the pavement.

Road Reserve
A strip of land legally awarded to the Road Authority specifically for the provision of public right of way, in which the road is or will be situated and where no other work or construction may take place.
without permission from the Road Authority. The width of the road reserve is measured at right angles to the centreline.

**Roadside**
A general term denoting the areas adjoining the outer edges of the shoulders.

**Roadway**
Part of the road comprising the carriageway, shoulders and median.

**Roadway Width**
A measurement at right angles to the centreline incorporating carriageway, shoulders and, when applicable, median.

**Rolling (Terrain)**
Terrain with low hills introducing moderate levels of rise and fall with some restrictions on vertical alignment; traverse terrain slope between 10 and 25 percent.

**Roundabout**
A road junction designed for movement of traffic in one direction around a central island.

**Rumble Strip**
A warning device consisting of a series of transverse bars or recesses in a road or alongside a carriageway.

**S**

**Safety Barrier**
A continuous barrier erected alongside a road to prevent traffic from accidentally leaving the carriageway or verge or from crossing the central reserve.

**Safety Rest Area**
A roadside area with parking facilities for the motorist to stop and rest.

**Sag Curve**
A concave vertical curve with the intersection point of the tangents below the road level.

**Scenic Overlook**
A safety rest area primarily for viewing scenery.

**Scissors Junction**
A four-leg junction formed by the oblique intersection of two roads.

**Service Area**
Land with access to and from a road allocated for the provision of certain amenities and services.

**Service Road**
A subsidiary road connecting a principal road with adjacent buildings or properties facing thereon, and connected with the principal road only at selected points.
Shift
The lateral displacement of a circular curve, measured along the radius, consequent upon the introduction of a transition curve.

Shoulder
That part of the verge adjacent to the carriageway designed to provide a safe stopping area in an emergency, a travel path for pedestrians and cyclists (where there is no other facility for them) and lateral support for the road pavement.

Shoulder Breakpoint
The point on a cross section at which the extended flat planes of the surface of the shoulder and the outside slope of the fill and pavement intersect.

Side Drain
A longitudinal drain offset from, and parallel to, the carriageway.

Side Slope
The area between the outer edge of shoulder or hinge point and the ditch bottom.

Sight Distance
The distance visible to the driver of a passenger car measured along the normal travel path of a carriageway to the carriageway surface or to a specified height above the carriageway surface, when the view is unobstructed by traffic.

Single Lane Road
A road consisting of a single traffic lane serving both directions, with passing bays.

Speed
The rate of movement of vehicular traffic or of specified components of traffic, expressed in kilometres per hour (km/h).

Stopping Sight Distance
The distance required by a driver of a vehicle travelling at a given speed, to bring his vehicle to a stop after an object on the carriageway becomes visible. It includes the distance travelled during the perception and reaction times and the vehicle braking distance.

Street
A road which has become partly or wholly defined by buildings established along one or both frontages.

Superelevation
The inward tilt or transverse inclination given to the cross section of a carriageway throughout the length of a horizontal curve to reduce the effects of centrifugal force on a moving vehicle. It is expressed as a percentage.

Super-elevation Run-off
The length of road over which the super-elevation is reduced from its maximum value to zero.
Switchbacks
The sequence of sharp curves at or near minimum radius employed to traverse a mountainous terrain section.

T
T-Junction
A three-leg junction in the general form of a T.

Tangent
Portion of a horizontal alignment of straight geometrics.

Taper
Transition length between a passing place, auxiliary lane or climbing lane and the standard roadway.

Tenth, Twentieth, Thirtieth, etc. Highest Annual Hourly Volume
The hourly traffic volume on a given section of a road that is exceeded by 9, 19, 29, etc., respectively, hourly volumes during a designated year.

Through Road
A road primarily for through traffic in relation to the area considered, on which vehicular traffic is usually given priority over the traffic on intersecting roads.

Traffic
Vehicles, pedestrians and animals travelling along a route.

Traffic Capacity (possible capacity)
The maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane or a carriageway in one direction or in both directions, during a given time period under prevailing road and traffic conditions.

Traffic Flow
The number of vehicles or persons that pass a specific point in a stated time, in both directions unless otherwise stated.

Traffic Lane
Part of a carriageway intended to accommodate a single stream of traffic in one direction.

Traffic Island
A central or subsidiary area raised or marked on the carriageway, generally at a road junction, shaped and placed so as to direct traffic movement.

Traffic Volume
The number of vehicles or persons that pass over a given section of a lane or a roadway during a time period of one hour or more. Volume is usually expressed in one of the terms: Average Annual Daily Traffic (AADT), Average Daily Traffic (ADT) and Tenth, Twentieth, Thirtieth, etc. Highest Annual Hourly Volume.
**Transition Curve**
A curve whose radius changes continuously along its length, used for the purpose of connecting a straight with a circular arc or two circular arcs of different radii.

**Transition Length**
Length of the transition curve.

**Travelling Way**
That part of the carriageway used for the movement of vehicles, exclusive of auxiliary lanes, bus-bays, etc.

**Trumpet Junction**
A type of grade separated T-junction, which in plan resembles a trumpet.

**Turning Lanes**
The lanes which separate turning vehicles from the through traffic lanes.

**Typical Cross-Section**
A cross-section of a road showing standard dimensional details and features of construction.

**U**
**Underpass**
A grade separation where the subject road or footway passes under an intersecting road or railway.

**Uncontrolled Pedestrian Crossing (Zebra-crossing)**
A pedestrian crossing marked by a series of white longitudinal strips extended transversely across the width of the carriageway and accompanied by traffic sign R360 [“Pedestrian (zebra) Crossing”] and preceded by warning sign W306 (“Pedestrian Crossing”), where a pedestrian has right of way once he/she has stepped onto the crossing.

**V**
**Verge**
The area between the outer edge of the road prism and the boundary of the road reserve.

**Vertical Alignment**
The direction of the centreline of a road in profile comprising vertical curves and straights.

**Vertical Curve**
A curve on the longitudinal profile of a road.

**Visibility Splay**
A triangular area bordered by intersecting roads and kept free of obstructions (except essential traffic signs) to enable a driver who is required to give way to have unobstructed visibility along the major road.
**W**

**Waste**
Material excavated from roadway cuts but not required for making the embankments. It must be pointed out that this material is not necessarily wasted as the word implies, but can be used in widening embankments, flattening slopes, or filling ditches or depressions for erosion control.

**Weaving**
The movement in the same general direction of vehicles within two or more traffic streams intersecting at a shallow angle so that the vehicles in one stream cross other streams gradually.

**Weaving Length**
The length of carriageway in which weaving may take place.

**Weaving Section**
The area of carriageway in which weaving may take place.

**Y**

**Y-junction**
A three-leg junction in the general form of a Y.
**Terminologies**

**Road Reserve**

- Limit of Road Bed
- Roadway
- CARRIAGEWAY
- Shoulder Break Point
- Shoulder
- Traffic Lane
- Traffic Lane
- Shoulder
- Subgrade (Top of Fill Material)
- Subgrade (Bottom of Excavation)
- Capping Layer (if required)
- Side Drain
- Road Bed (Existing Ground)

**Road Cross Section Elements**

**Construction Width (Varies)**

- Roadway width
- Carriageway
- Verge
- Existing Ground
- Side Ditch
- Berm
- Slope of embankment (side slope)
- Shoulder
- Traffic Lane
- Traffic Lane
- Shoulder
- Side Ditch
- Slope of cutting (Back slope)
- Berm
- Cut of ditch

**a) Single Carriageway roads (Rural Section)**

**b) Single Carriageway roads (Urban Section)**
c) Dual Carriageway roads (Rural Section)

d) Dual Carriageway roads (Urban Section)
Alignment Terminologies

Horizontal Curve

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Radius of Circular Curve</td>
</tr>
<tr>
<td>A</td>
<td>Parameter of Spiral</td>
</tr>
<tr>
<td>TS</td>
<td>Tangent to Spiral</td>
</tr>
<tr>
<td>SC</td>
<td>Spiral to circular curve</td>
</tr>
<tr>
<td>CS</td>
<td>Circular curve to Spiral</td>
</tr>
<tr>
<td>ST</td>
<td>Spiral to Tangent</td>
</tr>
<tr>
<td>st</td>
<td>Station - Chainage</td>
</tr>
<tr>
<td>Ls</td>
<td>Length of Spiral</td>
</tr>
<tr>
<td>Lci</td>
<td>Length of circle</td>
</tr>
<tr>
<td>Lccc</td>
<td>Total Curve length (circle + Spiral)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔR</td>
<td>Shift</td>
</tr>
<tr>
<td>Xm</td>
<td>Abscissa of centre point</td>
</tr>
<tr>
<td>T</td>
<td>Tangent Length</td>
</tr>
<tr>
<td>Pl</td>
<td>Point of Intersection</td>
</tr>
<tr>
<td>Δ</td>
<td>Deflection Angle</td>
</tr>
<tr>
<td>Xn Yn</td>
<td>Coordinates of station n</td>
</tr>
<tr>
<td>c</td>
<td>Normal Crossfall</td>
</tr>
<tr>
<td>e</td>
<td>Superelevation</td>
</tr>
<tr>
<td>ΔS</td>
<td>Rate of change of Superelevation</td>
</tr>
</tbody>
</table>

Standard Symbols and Abbreviations for Horizontal Curves and Superelevation
**Terminologies**

**Vertical Curves**

![Diagram of Vertical Curves]

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>Gradient (%)</td>
</tr>
<tr>
<td>PVI</td>
<td>Point of vertical intersection of a curve</td>
</tr>
<tr>
<td>st</td>
<td>Station chainage</td>
</tr>
<tr>
<td>ht</td>
<td>Height above sea level (m)</td>
</tr>
<tr>
<td>Rv</td>
<td>Equivalent radius of vertical curve (m)</td>
</tr>
<tr>
<td>Lvc</td>
<td>Length of vertical curve</td>
</tr>
<tr>
<td>A</td>
<td>Algebraic difference in gradients (%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>Point of vertical curvature</td>
</tr>
<tr>
<td>PVT</td>
<td>Point of Vertical Tangency</td>
</tr>
<tr>
<td>T</td>
<td>Tangent Length of vertical curve</td>
</tr>
<tr>
<td>Y</td>
<td>Tangent offset (vertical)</td>
</tr>
<tr>
<td>x</td>
<td>Horizontal Length in plan</td>
</tr>
<tr>
<td>f</td>
<td>Centre correction</td>
</tr>
</tbody>
</table>

\[ g_1, \text{ and } g_2, \text{ Tangent grades in percent} \]
\[ A, \text{ Algebraic Difference between grades} \]
\[ L, \text{ Length of vertical curve} \]
# Road Geometric Design Manual

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- Acknowledgements
- Abbreviations and Definitions
- Terminologies
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- Chapter 2 Road Classification
- Chapter 3 Road Planning and Survey Requirements
- Chapter 4 Design Controls and Criteria
- Chapter 5 Cross Section Elements
- Chapter 6 Alignment Design
- Chapter 7 At Grade Intersections
- Chapter 8 Grade Separated Intersections
- Chapter 9 Road Furniture and Other Facilities
- Chapter 10 Improvement of Existing Roads
- Chapter 11 Drawings Requirements
- Bibliography
# Chapter 1 General

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<th>Title</th>
<th>Page</th>
</tr>
</thead>
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<td>1.1</td>
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<td>Purpose</td>
<td>1.2</td>
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<td>1.4</td>
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Chapter 1 General

1.1 INTRODUCTION

The Road Geometric Design Manual sets forth the policy and standards to be adopted for the design of roads in Tanzania.

This Road Geometric Design Manual supersedes the Draft Road Manual (1989).

The contents of this manual are partly guidelines and recommendations to be considered, and partly standards which as a general rule should be adhered to. In some instances special conditions may demand modifications to these standards, in which case special consideration should be given in consultation with and approval of the Ministry.

However, it is also the responsibility of the designer to put forward any proposals for modifications to the standards which he considers will result in a better and more economical design.

The following definitions apply in this Manual:

- **Must, Shall or Will:** A mandatory condition. When certain design criteria is described in a procedure or design of any specified class of road, it is mandatory that this condition be met.

- **Should:** An advisory condition. Where the word “should” is used, it is considered to be advisable usage, recommended but not mandatory.

- **May:** A permissive condition. Design or application is optional.

The Road Geometric Design Manual forms part of a set of manuals, some of which have a bearing on road design. These are:

- Road Maintenance Manual (2009) by TANROADS.

The standards to be adopted for the design will be affected and influenced by the following factors:

a) Road classification
b) Traffic
c) Speed
1.2 Geometric Design Philosophy

Road geometric design refers to the calculations and analyses made by the designer to fit the road to the topography of the site while meeting the safety, service and performance standards. It is mainly concerned with the elements of the road that are visible to the drivers and users. However, the designer must also take into consideration the social and environmental impacts of the road geometry on the surrounding facilities.

Usually, the road geometric design has the following objectives:

1. To design a road that provides, in a cost-effective and safe manner, an adequate level of service to meet the needs of all road users, including pedestrians, cyclists and motorcyclists.
2. Determine within the allowance permitted by the design standard and road reserve, the routing of the proposed road.
3. Incorporate, within the design standard, various physical features of the road alignment to ensure that drivers have sufficient view of the road (and obstacles) ahead for them to adjust their speed of travel to maintain safety and ride quality.
4. Provide a basis for the road designer to evaluate and plan for the construction of a section of the proposed road.
1.3 Units of Measurement and Language

The language of the manual is English.

The standard units of measurement to be used are based on the International System (SI) units. However, the units applicable to road design also include some units which are not strictly part of SI.

Multiples and sub-multiples of SI units are formed either by the use of indices or prefixes. Definitions of applicable prefixes are given in Table 1-1 below.

The basic units and the derived and supplementary units which will normally be required for road design are listed in the Table 1-2.

### Table 1-1: Definitions of Prefixes

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Factor by which the unit is multiplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mega</td>
<td>M</td>
<td>10^6</td>
</tr>
<tr>
<td>Kilo</td>
<td>K</td>
<td>10^3</td>
</tr>
<tr>
<td>Hecto</td>
<td>H</td>
<td>10^2</td>
</tr>
<tr>
<td>Deca</td>
<td>da</td>
<td>10</td>
</tr>
<tr>
<td>Deci</td>
<td>d</td>
<td>10^-1</td>
</tr>
<tr>
<td>Centi</td>
<td>c</td>
<td>10^-2</td>
</tr>
<tr>
<td>Milli</td>
<td>m</td>
<td>10^-3</td>
</tr>
<tr>
<td>Micro</td>
<td>μ</td>
<td>10^-6</td>
</tr>
</tbody>
</table>

### Table 1-2: Basic units, multiples and sub-multiples

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Symbol</th>
<th>Recommended Multiples and sub-multiples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Metre (m)</td>
<td>m</td>
<td>km, mm</td>
</tr>
<tr>
<td>Mass</td>
<td>Kilogram (kg)</td>
<td>kg</td>
<td>Mg, g, mg</td>
</tr>
<tr>
<td>Time</td>
<td>Second (s)</td>
<td>s</td>
<td>Day (d), hour (h), minute (min)</td>
</tr>
<tr>
<td>Area</td>
<td>Square metre (m^2)</td>
<td>m^2</td>
<td>km^2, hectare (1ha = 10,000m^2), mm^2</td>
</tr>
<tr>
<td>Volume (solids)</td>
<td>Cubic metre (m^3)</td>
<td>m^3</td>
<td>cm^3, mm^3</td>
</tr>
<tr>
<td>Volume (liquid)</td>
<td>Litre (l)</td>
<td>l</td>
<td>ml (1ml = 10^-3 l, 1ml = 1cm^3)</td>
</tr>
<tr>
<td>Density</td>
<td>Kilogram per cubic metre</td>
<td>kg/m^3</td>
<td>1Mg/m^3 = 1kg/10^3 l, g/ml</td>
</tr>
<tr>
<td>Force</td>
<td>Newton (N)</td>
<td>N</td>
<td>MN, kN (1N = 1 kgm/s^2; 1 kgf = 9.81N)</td>
</tr>
<tr>
<td>Pressure and Stress</td>
<td>Newton per square metre</td>
<td>N/m^2</td>
<td>kN/m^2, N/mm^2</td>
</tr>
<tr>
<td>Velocity (Speed)</td>
<td>Metre per second (m/s)</td>
<td>m/s</td>
<td>km/h (1 km/h = 1/3,6 m/s)</td>
</tr>
<tr>
<td>Angle</td>
<td>Degree or grade (° or g)</td>
<td></td>
<td>Minute (°), second (”) (360° circle) or (400° circle)</td>
</tr>
<tr>
<td>Temperature</td>
<td>Degree Celsius (°C)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1.4 Departures from Standards

It is anticipated that there may be situations where the designer will be compelled to deviate from these standards. An example of a departure from standard could be the use of a gradient greater than the absolute maximum value and also the use of radius less than the allowable minimum for any specified class of road. Where the designer departs from a standard, he/she must obtain a written approval and authorization from the Ministry. The designer shall submit the following information to the Ministry:

- The number, name, and description of the road
- The aspect of design for which a departure from Standards is desired;
- A description of the standard, including normal value, and the value of the Departure from Standards
- The reason for the departure from Standards, and
- Any mitigation to be applied in the interests of safety.

The designer must submit all departures from the standards and his/her proposal for approval. If the proposed departures from the standards are acceptable, the departures from the Standards will be given approval by the Ministry.

1.5 Organization of the Manual

The manual is divided into 11 chapters as follows:

Chapter 1 is dealing with general issues such as introduction, geometric design philosophy, units of measurements and language, departures from standards and organisation of the Manual.

Chapter 2 addresses road classification. This includes both administrative and functional classes. It also focuses on dimensions and selection of appropriate road design class.

Chapter 3 deals with road planning and survey requirements. Specifically, it lists procedures for road planning, identification of potential alignments in the route selection process, environmental considerations, economic evaluation and road survey requirements including survey procedure.

Chapter 4 is dedicated to design controls and criteria affecting the selection of the geometric design values. These include design vehicles, driver performance, traffic characteristics, capacity, level of service etc.

Chapter 5 is dealing with cross section elements, which discusses mainly on lane widths, shoulders, medians, clear zones, right of way, side and back slopes and gives typical cross sections of the different design classes of roads.

Chapter 6 is dealing with alignment design, which takes care of the various sight distances, horizontal alignment and vertical alignment including their co-ordination.

Chapter 7 discusses at-grade intersections, including design requirements and procedure, selection of intersection type, T-junctions, cross junctions and roundabouts; and intersection elements including turning lanes and traffic islands.

Chapter 8 is dealing with grade-separated intersections or interchanges.
Chapter 9 describes road furniture and other facilities including miscellaneous items.

Chapter 10 addresses improvement of existing roads.

Chapter 11 specifies design drawings requirements.
Chapter 2 Road Classification

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Table 2-2:  Linkage Between Road Design Class and Functional Class...............2.3
Table 2-3:  Cross Section Dimensions of the Road Design Classes......................2.4
Chapter 2 Road Classification

2.1 General

Roads have two basic traffic service functions which, from a design standpoint, are incompatible. These functions are:

a) to provide traffic mobility between centres and areas; and
b) to provide access to land and properties adjoining the roads.

For roads whose major function is to provide mobility, i.e. to cater for through and long-distance traffic, high and uniform speeds and uninterrupted traffic flows are desirable. For roads whose major function is to provide land access, high speeds are unnecessary and, for safety reasons, undesirable. Thus, the function of a particular road in the national and district road network has a significant impact on the design criteria to be chosen, and the designer has to give careful consideration to this aspect in the early stages of the design process. The following steps are required:

i) Classification of the road in accordance with its major function.
ii) Determination of the level of access control compatible with the function of the road.
iii) Selection of geometric design standards compatible with function and level of access control.

When the functional classification and level of access control are given, design standards can be applied, which will encourage the use of the road as intended. Design features that can convey the level of functional classification to the driver include carriageway width, continuity of alignment, spacing of junctions, frequency of accesses, standards of alignment, traffic controls and road reserve widths.

2.2 Administrative and Functional Classification

In Mainland Tanzania, the existing classification is partly based on administrative aspects of the facility and partly on functional aspects. The existing network is classified in accordance with the Road Act of 2007, i.e.:

- national roads, and
- district roads

(1) The national roads include:

Class A: Trunk Roads
A national route that links two or more regional headquarters; or an international through route that links regional headquarters and another major or important city or town or major port outside Tanzania.

Class B: Regional roads
Constitute the secondary national routes connecting a trunk road and district or regional headquarters in a region; or connecting regional and district headquarters.
(2) The district roads include:

**Class C: Collector roads:**
- i) A road linking a district headquarters and a division centre;
- ii) A road linking a division centre with any other division centre;
- iii) A route linking a division centre with a ward centre;
- iv) A road within urban area carrying through traffic which predominantly originates from and destined out of the town and links with either regional or a trunk road;

**Class D: Feeder roads:**
- i) A road within urban area that links a collector road and other minor road within the vicinity and collects or distributes traffic between residential, industrial and principal business centres of the town;
- ii) A village access road linking wards to other wards centres

**Class E: Community roads:**
A road within a village or a road which links a village to a village.

Roads of the highest functional classes, i.e. A and B, have as their major function to provide mobility and have longer trip lengths. They are required to provide a high level of service with a high design speed.

The roads of Class C, D and E serve a dual function in accommodating shorter trips and feeding the higher classes of the roads.

### 2.3 Access Control related to Functional Class

Access control is one of the most important means for preserving the efficiency and road safety of major roads. Roads without access control are, however, equally important to be able to serve the neighbouring facilities of the road. The following three levels of access control are applicable:

1. **Full access control:** means that access control is exercised by providing access connections with selected public roads only through the prohibition of crossings at grade
2. **Partial access control:** means that access control is exercised to give preference to through traffic
3. **Unrestricted access:** means that preference is given to local traffic, with the road serving the adjoining areas through direct access connection

Road function determines the level of access control needed. The following general guidelines are given for the level of access control in relation to the functional road classification:
Table 2-1: Level of Access Control in Relation to the Road Functional Class

<table>
<thead>
<tr>
<th>Functional class</th>
<th>Level of access control</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Trunk Roads</td>
<td>Desirable: Full, Reduced: Partial</td>
</tr>
<tr>
<td>B: Regional Roads</td>
<td>Desirable: Full or Partial, Reduced: Partial</td>
</tr>
<tr>
<td>C: Collector Roads</td>
<td>Desirable: Partial, Reduced: Partial or unrestricted</td>
</tr>
<tr>
<td>D: Feeder Roads</td>
<td>Desirable: Partial or unrestricted, Reduced: Unrestricted</td>
</tr>
<tr>
<td>E: Community Roads</td>
<td>Desirable: Unrestricted, Reduced: Unrestricted</td>
</tr>
</tbody>
</table>

2.4 The Relationship Between the Functional Class and the Design Class

The main requirement is that a road shall function satisfactorily during its service life without major improvements. In terms of serving the users, this requirement implies absence of major delays or breakdowns in the traffic flow on a regular basis during the design life of the project.

To ensure a satisfactory functioning of the road, a range of geometric design standards may be applicable to one functional class as shown in the Table 2-2.

Table 2-2: Linkage Between Road Design Class and Functional Class

<table>
<thead>
<tr>
<th>Road design class</th>
<th>AADT* (veh/day) in the design year</th>
<th>Functional Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC 1</td>
<td>&gt;8000</td>
<td>A E</td>
</tr>
<tr>
<td>DC 2</td>
<td>4000 - 8000</td>
<td>A E</td>
</tr>
<tr>
<td>DC 3</td>
<td>1000 - 4000</td>
<td>A B C D E</td>
</tr>
<tr>
<td>DC 4</td>
<td>400 - 1000</td>
<td>A B C M D E</td>
</tr>
<tr>
<td>DC 5</td>
<td>200 - 400</td>
<td>A B C M E</td>
</tr>
<tr>
<td>DC 6</td>
<td>50 - 200</td>
<td>A B C</td>
</tr>
<tr>
<td>DC 7</td>
<td>20 - 50</td>
<td>A B C M E</td>
</tr>
<tr>
<td>DC 8</td>
<td>&lt;20</td>
<td>A B C</td>
</tr>
</tbody>
</table>

Applies to roads in flat to rolling terrain
M: Minimum standard for the appropriate functional class

For example, a new link in the Trunk roads system belongs to the functional class A. Whether design class 1, 2, 3 or 4 should be adopted, depends on the traffic volume during the expected life span of the road. If the predicted traffic level (AADT) is, for example 3000 vehicles per day, then the natural selection would be design class 3. The design class 4 is considered to be the minimum standard for Trunk Roads even in cases where the daily traffic volume would be less than 400 vpd in the design year. Design class 5 is considered to be the minimum standard for Regional Roads.

The actual design class to be adopted for a particular project should in every case be justified economically. The optimum choice will vary with both construction and road user costs. Construction costs will be related to terrain type and choice of pavement construction, whereas road user costs will
be related to level and composition of traffic, journey time, vehicle operation and road accident costs. It is therefore not possible to stipulate precise design volumes for each class of road. The values given in the table above should therefore be used as a guide.

### 2.5 Dimensions of the Road Design Classes

A number of standardized road design classes have been defined. These are shown in Table 2-3 where the dimensions of the cross sections for each design class are given.

<table>
<thead>
<tr>
<th>Design class</th>
<th>Surface</th>
<th>Road reserve width [m]</th>
<th>Roadway width [m]</th>
<th>Carriage way</th>
<th>Shoulder width [m]</th>
<th>Median width [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC 1</td>
<td>Paved</td>
<td>60</td>
<td>28–31</td>
<td>2 x 7.0</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>DC 2</td>
<td></td>
<td>60</td>
<td>11.5</td>
<td>7.5</td>
<td>3.75</td>
<td>2</td>
</tr>
<tr>
<td>DC 3</td>
<td></td>
<td>60</td>
<td>11.0</td>
<td>7.0</td>
<td>3.5</td>
<td>2</td>
</tr>
<tr>
<td>DC 4</td>
<td></td>
<td>60</td>
<td>9.5</td>
<td>6.5</td>
<td>3.25</td>
<td>2</td>
</tr>
<tr>
<td>DC 5</td>
<td></td>
<td>60</td>
<td>8.5</td>
<td>6.5</td>
<td>3.25</td>
<td>2</td>
</tr>
<tr>
<td>DC 6</td>
<td>Gravel or paved</td>
<td>40</td>
<td>8.0</td>
<td>6.0</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>DC 7</td>
<td>Gravel</td>
<td>30</td>
<td>7.5</td>
<td>5.5</td>
<td>2.75</td>
<td>2</td>
</tr>
<tr>
<td>DC 8</td>
<td>Earth or gravel</td>
<td>20</td>
<td>6.0</td>
<td>4.0</td>
<td>4.0</td>
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* Inner shoulders of 2x0.9 metres are included in the median width

Any new road to be designed shall be selected from these design classes. Road design class 1 to 5 are planned as bitumen surfaced roads. This implies that the national roads shall be constructed to bitumen standard.

For the district roads network, the road design classes are also related to predicted daily traffic in the design year.

For road design class 6, i.e. for future traffic volumes between 50 and 200 vpd, both a gravel standard and a bitumen standard have been indicated. The availability of surface materials and the daily traffic on the particular road will determine whether a gravel surface or a bitumen surface may be the best solution. If gravel resources are scarce, a bitumen standard may be economic even at low traffic volumes.

If however, gravel resources are abundant in the vicinity of the project, a gravel surface standard may be the most economic solution.

At very low traffic levels, i.e. below 50 vpd in the design year, road design class 7 or 8 would be an appropriate selection.

Additional information related to design criteria of the road design classes such as the relationship between design speed and terrain is presented in Chapter 4: Design Control and Criteria.
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Chapter 3 Road Planning and Survey Requirements

3.1 General

The main purpose of this chapter is to outline a generalised approach to planning which is holistic in nature, taking into account the many external factors that affect the process. The chapter also highlights approaches that are typically adopted in appraisal, environmental issues and various methods available for mitigating the adverse impacts of road construction and maintenance. Finally, the chapter presents the survey requirements associated with the geometric design process.

3.2 Road Planning

Projects are planned and carried out using a sequence of activities commonly referred to as the project cycle. There are many ways of defining the steps in the sequence but the following terminologies in road projects are commonly used: identification, feasibility study and preliminary design, detailed engineering design, commitments and procurement, construction supervision and management, operation and project monitoring evaluation.

3.2.1 Planning Framework

Planners and engineers shall ensure that the plans and appraisal they produce, have full support of decision makers. Such a planning framework shall be transparent, relatively simple to carry out, unambiguous and equitable. Table 3.1 presents a generalised framework for this purpose.

<table>
<thead>
<tr>
<th>Project Cycle</th>
<th>Planning Activity</th>
<th>Typical Evaluation Tools</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>Selection</td>
<td>Policy resource analysis&lt;br&gt;Master Plans&lt;br&gt;Local/Regional plans</td>
<td>Long list of projects</td>
</tr>
<tr>
<td>Feasibility</td>
<td>Screening</td>
<td>Livelihoods analysis&lt;br&gt;Integrated Rural Accessibility Planning&lt;br&gt;Cost-benefit analysis&lt;br&gt;Environmental issues</td>
<td>Short list of projects</td>
</tr>
<tr>
<td>Detailed Design</td>
<td>Evaluation</td>
<td>- Technical Standards &amp; Specifications</td>
<td>Short list of projects</td>
</tr>
<tr>
<td>Commitment and procurement</td>
<td>Prioritisation</td>
<td>- Budget considerations&lt;br&gt;- Ranking by economic or socio-economic criteria</td>
<td>Final list of projects</td>
</tr>
</tbody>
</table>

In principle, the planning and appraisal processes are structured activities which start from the general and work towards the particular in relation to both data and project ideas. The main features of the planning and appraisal processes are as follows:
3.2 Selection: This is a multi-sectoral and multi-disciplinary process which should generate sufficient projects to ensure that no potentially worthwhile ones are excluded from consideration. The output is a long list of projects determined on the basis of an unconstrained policy resource analysis that satisfy national road transport policy.

3.2.2 Planning Considerations

The procedures described in the planning and appraisal framework shown in Table 3.2 hereunder are common to any type of road project. However, there are aspects of it that are of particular significance in the planning and appraisal of our roads that often do not emerge from conventional approaches.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Issues to be considered</th>
</tr>
</thead>
</table>
| Project identification | • Are the strategies being adopted supportive of government policy? (e.g. employment creation).  
• Are they relevant to the current and future needs of beneficiaries?  
• Are they cognisant of the multiple objectives and views of stakeholders?  
• Have effective communication channels with stakeholders been created? Are they gender sensitive?  |
| Feasibility     | • Is there adequate participatory planning and consultation with public and private sector stakeholders?  
• Are appropriate evaluation tools being used?  
• Has a base line environmental survey been undertaken?  
• Has a road safety audit been incorporated in the project?  |
| Design          | • Are the geometric, pavement design and surfacing standards technically appropriate?  
• Do the design criteria take full account of the specificities of roads, including non-motorised traffic?  
• Are they environmentally sound?  
• Are specifications and test methods appropriate to local materials being used?  
• Are road safety audit been incorporated?  
• Do designs accommodate construction by labour-based methods rather than fully plant based?  |
### Issues to be considered

#### Commitment & Procurement
- Do the designs accommodate construction by labour-based methods rather than fully plant based?
- Do the designs include environmental protection measures?
- Have tender documents been prepared and contract strategies adopted that facilitate involvement of small contractors?
- Are available funds sufficient to cover project costs?

#### Implementation
- Are environmental mitigation measures contained in the contracts? Are they enforceable?
- Have specific measures been included in the contract to cater for health and safety matters such as HIV/AIDS?
- Are construction works using proper materials and specifications?
- Are the works being executed in accordance with the specifications and standards?
- Is quality assurance adhered to?

#### Operation and maintenance
- Have the various indicators of socio-economic well-being been monitored and evaluated?
- Do maintenance budget funds available to meet project maintenance works?
- Are there adequate arrangements for community participation in road maintenance?
- What are the lessons for the future?

#### Evaluation
- Is the project receiving proper maintenance as required?
- Was the project implemented according to the proposed design?
- Does the project performance as assessed using various social-economic indicators, indicate value for money?

Thus, in the planning and appraisal of roads, the designer shall carefully consider the multi-dimensional range of issues highlighted in Table 3.2 that can significantly influence the output of the process.
3.2.3 **External Factors**

There are a number of external factors, many of them of a non-technical nature, that directly or indirectly affect the planning process itself or the outcomes from that process. It is important to be aware of them when devising an appropriate planning procedure and, where possible, to take them into account. These various factors are listed in Table 3.3.

**Table 3-3: External Factors that Affect the Planning of Roads**

<table>
<thead>
<tr>
<th>Factors</th>
<th>Issues</th>
<th>Implications on approach to road provision</th>
</tr>
</thead>
</table>
| Political    | • Government policy  
               • Political perceptions  
               • Political involvement | • Influences practice. Covers issues such as poverty alleviation, sustainable socio-economic development, technology choice, employment creation, standards and sources of funding.  
• Tendency to favour conventional approaches and standards with perceived minimum “risk” attached to them. There is a need to communicate effectively, quantify and “sell” innovative approaches and appropriate, non-traditional standards.  
• To be expected. Will tend to influence decision-making. Highlight pros and cons of alternative solutions in a balanced, transparent manner and maintain continuous dialogue with stakeholders. |
| Institutional | Organisation                        | • Growing trend towards establishment of more autonomous central and local roads authorities.  
• Greater scope for generating accountability for results in road programmes and moving from force account to contracting out work to the private sector. |
<p>| Technological | Technology choice                   | • Need for cost-effective strategies that utilise the dual output of road infrastructure and employment creation. |
| Economic     | Evaluation                          | • Road benefits are often not limited to use of road, but also from the way in which the road is financed, designed, constructed and maintained. There is a need to capture monetary and non-monetary benefits in the monitoring evaluation framework. |</p>
<table>
<thead>
<tr>
<th>Factors</th>
<th>Issues</th>
<th>Implications on approach to road provision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td>• Funding</td>
<td>• Usually very scarce. Financing proposals must look increasingly at minimum standards, limited donor funding and local funding of recurrent maintenance costs.</td>
</tr>
<tr>
<td></td>
<td>• Sustainability</td>
<td>• Sustainability of funding has become a critical issue. There is a need to commercialise operations where possible and involve stakeholders in the maintenance of facilities.</td>
</tr>
<tr>
<td>Environmental</td>
<td>Impact</td>
<td>• Need to capture environmental impacts related to the construction of the road such as preservation of natural land use of particular value i.e. national parks, historic and Cultural sites, forests, agricultural land of high value etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Need to capture environmental impacts related to traffic such as pollution, vibrations and barrier effect.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Address health-threatening impacts as a high priority.</td>
</tr>
<tr>
<td>Social</td>
<td>• Poverty alleviation</td>
<td>• Implies use of labour-based rather than fully plant-based methods, where feasible.</td>
</tr>
<tr>
<td></td>
<td>• Sustainable livelihood</td>
<td>• Enhance local participation and resource mobilisation by involving the people who will ultimately benefit from the projects.</td>
</tr>
<tr>
<td></td>
<td>• Gender considerations</td>
<td>• Understanding community strengths and weaknesses, assets, vulnerability to shocks and constraints, governance issues and policies needed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Eliminate gender biases by integrating the transport needs of women in the mainstream of policy and planning.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Promote participation by women in labour-based construction and maintenance programmes and training to assume supervisory roles.</td>
</tr>
</tbody>
</table>
3.3 **Route Selection**

Between any two points to be connected by road, there exist an infinite number of alternative routes. The designer at a stage of route selection bears a tremendous responsibility for defining an optimum alignment. This subchapter describes initial stages of road alignment selection that include desk study, preliminary identification of potential corridors and comparison and necessary site visits.

### 3.3.1 Desk Study for Identification and Feasibility

Road Design, Construction and Maintenance is highly influenced by the terrain of the area through which the road traverses. The shortest road alignment is not necessarily the easiest, quickest, safest or most economical option for construction and maintenance. Frequently, topography, slope stability, flood hazard and erosion potential are likely to be the most significant controls in the choice of the most suitable alignment and design of cross-section.

Variations in geology and slope greatly influence road design and hence the cost of construction and these variations can occur over very short lengths of alignment. Geology, geomorphology and hydrology, therefore, are key factors in the route corridor selection during the feasibility study, design, construction and maintenance of roads. Road geometry, earth works, retaining structures and drainage measures must be designed in such a manner as to cause the least impact on the stability of the surrounding slopes and natural drainage systems.

Excessive blasting, cutting, side tipping of spoil and concentrated or uncontrolled surface water runoff negatively affect the environment and can lead to instability and erosion. Although many of these effects are often unavoidable, the design and the construction method adopted shall aim to minimize them. This Section describes the methodology for analyzing possible corridors and selecting the optimum route from technical, economic, social and environmental considerations.

Before commencing with selection of the route corridors, the controlling requirements of the route need to be defined. These may include the following:

- What are the constraints in regard to the beginning and ending points of the road? Must these be at existing junctions in villages or towns? Do economic considerations such as amount of earthworks limit the alternatives?

- Through which villages must the route pass? Must the route pass directly through these villages, or can linking roads connect the villages? If so, what are the implications to the villages in terms of lost trade?

- If major rivers are to be crossed, what are the possible crossing locations, given constraints of topography and geology? What are the economics of the alternative bridge sites with the corresponding road geometries?

- What is the desired design speed and design standard requirement? How does this standard fit the terrain in terms of geometric parameters such as gradients, and horizontal and vertical curves?

The desk study should comprise a review of published and unpublished information concerning the physical, economic and environmental characteristics of the study area. Some of the data that should be reviewed during the desk studies are the following sources:
Published literature covering a range of topics including road construction and maintenance case histories and geological, economic and environmental reviews;

- Topographical maps;
- Geological maps, agricultural soil maps and other natural resource maps; and,
- Aerial photographs.

For studying and selecting suitable alignment corridors, a detailed analysis based on topographic maps, aerial photographs, geological maps, hydrological maps, land use and land cover maps and the like should also be reviewed.

### 3.3.2 Preliminary Identification of Potential Corridors and Comparison

The basic requirements of an ideal alignment between two terminal stations are that it should be short, easy to construct and maintain, safe in terms of stability of natural hill & embankment slope and economical in terms of initial cost, minimum environmental impact, maintenance cost and operational cost.

Using the 1:50,000 scale maps and with knowledge of the controlling requirements/constraints as listed in subchapter 3.4, it is possible to trace out some possible alternative alignments. This is readily accomplished by referring especially to the vertical geometric design criteria for maximum grade and plotting possibilities through correlation with the contour lines shown on the map.

For instance, assume that the road classification and terrain are such that a 10% maximum grade is permissible. Assume also that the contour interval on the 1:50,000 maps are 20 metres. A preliminary alignment needs to be selected in such a way that a distance of no less than 200 metres (0.4 cm on the map) is used to achieve the 20-metre interval, giving a 10% grade.

For each of the possible alternative alignment corridors, the existing maps should be studied and aerial photographs examined with a stereoscope. From this study it will be possible to assess the positive or negative influence of the following local factors:

- Topographic, geologic, and physical characteristics;
- Number, type and characteristics of water courses;
- Potential risk of slides, slope instability or floods;
- Human settlements affected by the road; and,
- Environmental impact of the selected route.

The proposed alternative alignments corridors are next studied, evaluated and compared based on the criteria below and best alternatives are to be selected for further studies and field assessment.

- What are the relative lengths of the alternatives? Normally the shortest distance is preferable.
- What are the average and mean gradients of the alternatives? Normally the least severe grade alternative is preferred.
- Which alternative more closely follows an existing road or track? This makes survey and construction easier and may indicate the route of least earthworks.
- Which alternative follows the least severe terrain type? An alignment through, for instance,
rolling terrain should be less costly to construct, have lower vehicle operating costs and maintenance costs, and less severe horizontal/vertical curves than a route through mountainous terrain.

- Which route remains for a longer period on the crest of the terrain? Such an alignment minimizes the need for drainage structures.

- Which alignment minimizes the need for land acquisition? The amount of farm land to be taken by the road. Which alignment minimizes the need to demolish buildings and houses less resettlement?

- What is the total number of bridges and their respective estimated span required for each alternative? What is the total aggregate length of these bridges?

- Which route results in the least environmental disturbance to the surrounding area?

- Which route has the least overall project cost, including both design and construction?

### 3.3.3 Site Visit

After the preliminary office work and when potential route corridors have been identified from the desk study analysis, a site visit must be made to the road. Where terrain constraints make such a visit problematic, a flight can be made over the terrain and all potential routes can be directly examined from the air.

During the site visit, a reconnaissance survey is employed to verify, modify and update the desk study and interpretations, to further assess the selected corridors during the desk study, to help determine the preferred corridor, and to identify factors that will influence the feasibility design concept and cost comparisons.

A team consisting of the following personnel shall make the site inspection visit:

- Highway Engineer;
- Soils & Materials Engineer/Geologist;
- Hydrologist;
- Surveyor;
- Bridge/Structures Engineer;
- Environmentalist/Sociologist,
- Transport Economist/Planner and,
- Local Administrative Personnel.

In most cases, the information obtained from the reconnaissance survey will require to significantly modify the desk study interpretations. During the reconnaissance survey, in addition to the data collected in respect of the evaluation criteria, the following information should be determined:

- Topographic and geomorphologic characteristics;
- The location of topographical constrains, such as cliffs, gorges, ravines, rock out crops, and any other features not identified by the desk study;
- Slope steepness and limiting slope angles identified from natural and artificial slopes (cutting for paths, agricultural terraces and existing roads in the region);
• Slope stability and the location of pre-existing land slides;
• Geology, tectonics, rock types, geological structures, rock outcrops, dip orientations, rock strength and rip-ability;
• Approximate percentage of rock in excavations;
• Availability of construction materials sources and their distribution;
• Soil types and depth (a simple classification between residual soil and colluvium is useful at this stage);
• Soil erosion and soil erodibility;
• Slope drainage and groundwater conditions;
• Hydrology, drainage stability and the location of shifting channels and bank erosion;
• Land use, land cover and their likely effect on drainage;
• Likely foundation conditions for major structures;
• Approximate bridge spans and the sizing and frequency of culverts;
• Flood levels and river training/protection requirements;
• Environmental considerations, including forest resources, land use impacts and socio-economic considerations;
• Verify the accuracy of the information collected during the desk study;
• The possibility of using any existing road alignments including local re-alignment improvements;
• Information on the physical accessibility to bridge sites and the proposed corridors, including the geomorphology of drainage basins, soil characteristics, slopes, vegetation, erosion and scouring; and
• Economic settings.

During the site inspection the team should examine all alternatives. This information can be combined with the results of the desk study to determine the most appropriate alignment alternative. Appropriate field assessment report of each alternative by each discipline will have to be prepared. Cost estimates of each alternative shall be determined for comparison purposes.

3.4 Environmental Considerations

No road project is without both positive and negative effects on the environment. The location and design of the road should aim at maximizing the positive effects and minimizing the negative effects. A positive effect could be to remove undesirable traffic from environmentally vulnerable areas, while at the same time minimizing the adverse effects of the project as much as possible.

3.4.1 Effects Related to the Road as a Physical Feature

The following factors, related to the road as a physical feature in the environment, should be considered in the location and design of the road projects:

i. The preservation of the natural beauty of the countryside and the adaptation to the conditions and architecture of the surrounding features;

ii. The preservation of areas and land use of particular value, including:
   - national parks and other recreational areas
   - wildlife and bird sanctuaries
   - forests and other important natural resources
   - land of high agricultural value or potential
   - other land use of great economic or employment importance and
   - historic sites and other man-made features of outstanding value
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iii. The prevention of soil erosion and sedimentation;
iv. The prevention of health hazards by ponding of water leading to the formation of swamps;
v. The avoidance or reduction of visual intrusion.
vi. The prevention of undesirable roadside development.

3.4.2 Effects Related to the Traffic

Negative effects related to the traffic can often be quantified, for example noise levels and air quality. The effects which should be considered are:

- Noise pollution;
- Air pollution;
- Ground water pollution;
- Vibrations; and,
- Severance of areas (barrier effect).

Among the solution to avoid the problems is to locate the road outside trading centres and towns. If this is not possible the best way to reduce the problems is to lower the speed and provide safe crossings for local traffic, pedestrians and cyclists. However, it is appropriate and necessary to seek the advice and service of Environmental Consultants and the National Environmental Management Council (NEMC) to properly evaluate the impacts and establish proper and adequate mitigation measures.

3.5 Economic Evaluation

Decisions as to the exact location and details of geometric design must be based on cost-benefit analysis that takes into account all factors concerned. The purpose of the analysis should be to determine whether or not the maximum benefits to be provided by the road are consistent with the costs involved.

The most economic design will often not involve the shortest route or the use of minimum standards. Savings in road maintenance costs, vehicle operating costs, travel time costs and accident costs etc may offset the extra construction costs for a road with higher design standards. The economic outcome of the design will depend upon both in the route selection and in the geometric design of the chosen route.

The designer is required to establish the costs of the project, as well as its benefits so that he can then compare the two. In working out the costs, the designer must recognise the economic resources that are to be used up by the project and at the same time identify economic costs separated from financial costs. The benefits of a project are worked out on the basis of the contribution the project will make towards improving the country’s public welfare.

When comparing the costs and benefits of a project, it is essential that both are brought to a common base year using a discounting formula, as follows:

\[
\text{Present value} = \frac{\text{future value}}{(1+i)^n}
\]

Where: \(i\) = discount rate; and \(n\) = number of years between present and future values.
In an economic appraisal of a road project, the following techniques should be used for evaluating costs and benefits, and for determining whether a project is economically viable or not:

a) Net Present Value (NPV)  
b) Internal Rate of Return (IRR)  
c) Benefit/Cost Ratio (B/C)

The net present value (NPV) involves discounting benefits and costs to a common year during the project life. If the NPV is positive, the project is economically viable.

The internal rate of return (IRR) involves calculating the rate of return at which the net present value is zero. The project is considered to be acceptable if the calculated rate of return is greater than opportunity cost of capital.

The benefit/cost ratio involves calculating the ratio between the present values of all benefits and the present value of all costs. The project is acceptable if the benefits/cost ratio is greater than one.

### 3.6 Important Key Planning Issues

The key points arising in road planning are:

i. Planning and appraisal procedures should consider a wide range of external factors, many of them of a non-technical nature, that affect the planning process if long-term sustainability of the investment is to be achieved.

ii. Stakeholder consultations are critical in the planning process for which there are a number of techniques which shall be undertaken as appropriately and as transparently as possible.

iii. The traditional methods of investment appraisal are generally not adequate for capturing the full range of benefits - often of a social rather than economic nature - arising from the provision of roads. More recently developed models shall be used for appraising the roads.

iv. The implications of adopting cost-reducing measures, such as the use of more appropriate pavement and geometric design methods and wider use of natural gravels rather than crushed stone.

v. Environmental and Social issues are of great importance in Tanzania. Environmental and Social impact assessments (ESIA) are an integral aspect of all road projects. The effectiveness of the ESIA will depend on the extent to which it is actively used and incorporated into different stages of the project planning process.

The important processes of planning and appraisal have been covered in this chapter together with environmental issues. Decisions made during the initial planning phase are particularly influential and have a high impact on the subsequent stages of roads provision, including those of geometric design and the associated road safety issues covered in Chapter 6.
3.7 **Road Survey Requirements and Procedure**

3.7.1 **Introduction**

The highway project may consist of either construction of a new road or improvements to an existing one. In either case, the working drawings have to be prepared after detailed surveys, design and investigations. The manner in which surveys are conducted has vital influence on designs, on production of quantities and cost estimates and finally on execution of the work. Thus, high responsibility rests upon those organizing the surveys and investigation.

This sub-chapter presents requirements on performing surveys associated with the road design process.

Technical requirements for planning and design of roads are outlined so that survey services are uniform and standardized. The survey data requirement is dependent on the project type and can be collected by aerial photography, ground survey, or a combination of the two.

The designer is responsible for identifying the appropriate survey data requirements (type of data, area of coverage and accuracy), selecting the method of data collection and obtaining the survey data.

**Units of Survey Measurement**

Metric system of measurement shall be used and all distances and heights shall be in metres following the best engineering and construction practices. Angular measurement shall be in degrees, minutes and seconds.

**Survey Datum and Measurements**

All survey for road projects shall be adequately referenced to the nationwide coordinate system directly derived from, or indirectly connected to, GPS satellite observations.

The Survey shall adhere to the Land Survey Act Cap 324, 1997 and regulations 1959. Therefore the horizontal datum/spheroid for all mapping, planning, design, right of way engineering and construction for road projects shall be, Clarke 1880 (modified) ellipsoid as defined by National Geodetic Survey network (NGS). The projection to be followed shall be the Universal Transverse Mercator (UTM).

The physical (on the ground survey station) reference network for Clarke 1880 (modified) datum for all road projects shall be the National Geodetic network with values re-computed in 1960 and 1965 arc Datum.

The position co-ordinates shall be based on the National horizontal geodetic control points unless otherwise authorised. All staked distance, must be horizontal.

Levels shall be referred to the mean sea level and related to a vertical network of national geodetically heightened primary, secondary and tertiary benchmarks unless otherwise authorised.

**Horizontal Control Monuments**

A system of primary and secondary horizontal control monuments originating from and closing upon existing national geodetic control shall be established on appropriate location.
Standard survey control establishment, coordination procedure and standard accuracy are to be followed with the following limitations to be adhered to:

- Pairs of inter-visible primary survey control points shall be established at a maximum interval of 4,000 metres, at locations where they are stable and secure and preferably close to the boundary of the road reserve. The primary control points can be established by Static and Kinematic GPS surveys and/or traverse, triangulation, or trilateration surveys from an established national horizontal control monuments.

- The secondary control points should generally not be more than 700 metres apart along the baseline of the road and shall be inter-visible.

- Standard Monuments shall be constructed as shown in Figure 3-1;

- Every survey control point shall be surveyed by appropriate self checking survey techniques and principal of “working from the whole to the part” adhered to.

- The standard of accuracy should be in accordance with the Land survey Act 1997, Cap 324.

**Vertical Control monuments/Bench Marks**

Vertical controls should consist of levels run in circuits originating from and closing upon the National primary levelling benchmarks.

Standard bench mark establishment and vertical elevation difference closure accuracy are to be followed with the following limitations to be maintained:

- The elevation of each primary and secondary control monuments shall be determined using the appropriate methods and to standard closure accuracy.

- Other benchmarks as deemed necessary shall be established at an interval of max. 400 metres, depending on the terrain and intervals between secondary control points, along the line close to the road reserve boundary, and at all major structures (bridges and box culverts etc);

- Standard Beacon/Bench Mark is shown in Figure 3-1;

- Every Bench mark is to be checked, levelled by a forward run and a subsequent backward run forming a closed “loop”; and,

- The following standard of closure accuracy is to be maintained:

  \[
  C = \pm \sqrt{K} \text{ cm}
  \]

  Where: \( C = \) maximum permissible error of closure in centimetres,  
  \( K = \) distance between benchmarks in kilometres

This gives Table 3-4 for comparison of accuracy.
Survey data
The use of proper field procedures is essential in order to prevent confusion in generating the final site plan map. Collection of survey points is a meaningful pattern that aids in identifying map features.

Survey data for road design purposes shall include planimetric features (roads, buildings, etc.), ground elevation data points needed to fully define the topography, defined break lines and field book sketch of planimetric features detailed sketches of facilities, utilities, or other features that cannot be easily developed (or sketched) in a data collector. A field sketch or video of planimetric features is an essential ingredient to proper translation of field data.

Topographic survey data shall be saved in acceptable electronic formats for future reference and actions.

3.7.2 Basis for Developing Maps and Digital Terrain Model
A variety of survey methods are used to develop maps and the terrain models for projects. The technique employed is a function of the type of survey equipment, the detail required, and specified elevation accuracy for bridge crossings, stream lines, towns, villages, all physical features etc.

Photogrammetry
The use of aerial photography at a scale of between 1:2,000 and 1:30,000 with proper ground controls is the basis of a photogrammetric survey. This method of data collection is preferable for mapping and DTM. It is more cost effective for large project sizes and for mapping of urban and big cities.

The scale of photography is an important factor to consider in the reliability and ground resolution of the interpretation. Table 3-5 gives guidance and indicates the optimum scales of photography required to perform various desk study and design tasks.
If a more precise vertical accuracy is required, such as for road pavement elevations or if obstructed views occur, photogrammetric data shall be supplemented with ground survey elevations or data shall come from ground surveys.

<table>
<thead>
<tr>
<th>Task Activity</th>
<th>Optimum Aerial Photo Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility Study:</td>
<td></td>
</tr>
<tr>
<td>Route corridor identification</td>
<td>1: 20,000 - 1: 30,000</td>
</tr>
<tr>
<td>Terrain classification</td>
<td>1: 15,000 - 1: 25,000</td>
</tr>
<tr>
<td>Drainage/Drainage Area mapping</td>
<td>1: 20,000 - 1: 30,000</td>
</tr>
<tr>
<td>Landslide hazard mapping</td>
<td>1: 10,000 - 1: 20,000</td>
</tr>
<tr>
<td>Contour Mapping for preliminary estimation of quantities</td>
<td>1: 15,000 - 1: 25,000</td>
</tr>
<tr>
<td>Preliminary Design:</td>
<td></td>
</tr>
<tr>
<td>Detailed interpretation of chosen corridor(s) for geotechnical purposes</td>
<td>1: 10,000 - 1: 15,000</td>
</tr>
<tr>
<td>Ground (contour) model for preliminary alignment design and quantities</td>
<td>1: 10,000 - 1: 15,000</td>
</tr>
<tr>
<td>Detailed Design:</td>
<td></td>
</tr>
<tr>
<td>Ground (contour) model for detailed alignment design and quantities</td>
<td>1: 2,000 - 1: 10,000</td>
</tr>
</tbody>
</table>

**Ground Survey**

Ground survey is based on survey methods—specifically, geo-referenced observations taken from survey instruments set up on tripods over fixed control points or benchmarks. These methods usually provide the highest accuracy for engineering surveys, and are necessary when surface and subsurface utilities must be definitively located and identified.

Topographical ground surveys shall use appropriate surveying equipment and method to collect data in respect of road alignment and cross sections and all bridge sites, particular sites and culvert sites that are considered necessary to complete the detailed design and the estimation of quantities.

Topographical ground survey has the capacity of achieving greater accuracy as compared to photogrammetry hence it is preferred for works which need greater accuracy. It is also more cost effective for small size projects and is appropriate for projects which have dense forests.
3.7.3 Types of Survey

The type of survey, map scale, and contour interval shall be selected in each case to interpret the character of the terrain most suitably for the purpose, and the tolerance or permissible error shall be prescribed in each instance. Detailed requirements will be presented in the terms of reference for each project. The minimum width of the survey corridor should be the road reserve width plus 2.5m on each side.

The road surveys are classified in terms of their purpose into three general groups, namely Reconnaissance Survey, Preliminary Survey, Final Location Survey and Detail Survey.

Reconnaissance Survey
The objective of this survey is to examine the general characteristics of the area with a view to determining the possible alternative routes which might serve the purposes for which the road is intended.

Preliminary Survey
The preliminary survey is conducted for the purpose of collecting all the physical information which affect the proposed route profile/or improvements to a road.

The survey results is a paper location and alignment that defines the line for the subsequent FINAL LOCATION SURVEY. The paper location and alignment should show enough ties of the existing topography to permit the survey team to peg (set-out) the centre-line.

In many cases field details for final design may also be obtained economically during the preliminary survey phase.

Two approaches are available for preliminary survey mapping; aerial surveys and ground surveys, either separately or in various combinations.

A preliminary map is prepared on the basis of the data collected by ground survey and plotted on a paper and a plot of the baseline and all planimetric detail.

On this map, the Horizontal alignment is plotted.

Final Location Survey
The final location survey serves the dual purpose of permanently establishing the final centreline of the road in the field and collection of necessary information for road design and preparation of detailed working drawings.

All beginning and end of circular and transition curves should be fixed and referenced.

The final centreline of the road should be suitably staked. Stakes should be fixed at 50m intervals in plain and rolling terrain and 25m intervals in hilly and mountainous terrain. In the case of existing roads, point marks or nails should be used instead of stakes.

Levels along the final centreline should be taken at all staked stations and at all breaks in the ground.
Cross sections should be taken at 50m intervals in the case of flat and rolling terrain and 25m intervals in the case of hilly and mountainous terrain.

**Detail Survey**
Detailed topographic survey of bridge crossings, stream lines, towns, villages etc shall be carried out. Road edges, cuts, ditch edges, culverts, hilltops, water crossings and embankments shall be taken. All physical features adjacent to the baseline whether natural or artificial shall be recorded within the required band width on either side of the centreline in open country and in small villages (market centres) and towns. Each cross section shall comprise such numbers of points as to enable it to properly define the existing road and such other spots as are required to define the ground shape for an adequate distance beyond the existing construction width. The data shall be used to generate a Digital Terrain Model (DTM) for the whole road. All pertinent features including buildings, drainage structures details, built up areas, etc. shall be recorded for inclusion on the design drawings. Detailed and extensive site investigation and surveys shall be carried out for areas susceptible to flooding or landslide and at all recommended new or replacement drainage structure locations including a sufficient length upstream and downstream to the structure.

The following are the important considerations in connection with detailed topographic surveys:

- Size and scope of the project;
- Time requirements to move from data collection to the start of design;
- Estimated data collection costs; and;
- Purpose of topographic surveys;
- Map scales and contour intervals;
- Accuracy and degree of detail needed;
- Horizontal control;
- Vertical control;
- Reference datum.

**Detail Survey of Particular and Susceptible Sites**
The collection of data shall be conducted in such a way as to acquire a complete and comprehensive field data on particular sites along the road project corridor.

For bridge sites, detailed topographic survey shall be done at 10 to 20 metres interval for a length of 100 - 400metres on both upstream and downstream. This activity shall also be done on both approaches of the bridge site for a length of 100 to 200 metres depending on the terrain.

On existing structures, the data shall be collected at the top deck surfaces, and corresponding invert (bed levels on both sides) and also at existing and high water marks including existing water levels, with the dates of data collection properly recorded, including all particular features of the bridges, flow channels and the surroundings. Additionally, data shall be taken at several points top and bottom on the wing walls and all feature points of approach roads and also high water marks and existing water levels with its dates of data collection. For new crossings data shall be collected on top of banks, bottom, centre, high water marks, existing water levels and other natural features of the flow channel. Figure 3-2: is a sketch for guidance to surveyors in topographic survey of water crossing or drainage structures sites.
3.7.4 Data Collection Requirements

Collection of Data
Survey data requests will typically originate from the unit responsible for the design, and these data shall also serve the requirements of construction. The designer has the responsibility to ensure that survey data obtained for design meets construction needs, eliminating the need for additional pre-construction ground data.

a) Field survey books
Field books must be used as a legal record of the survey, even though most of the observational data is referenced in a data file. Field books shall include notes, sketches, tabulations and descriptions. The designer shall keep the field book up to the end of guarantee period and reproduce it when required.

b) Surveyed Point Data
Data of observed topographic features shall be collected in a point form and recorded with the following information: Point number, Coordinates, Elevations and Feature code.

3.7.5 Presentation of Maps and Plans
Upon the map sheets, all control points and bench marks with their designating numbers and their elevations, all roads, railroads, streams, fence lines, utilities, poles, isolated trees 0.25 metres or more in diameter, boundaries of timbered areas, rock ledges or boulders, wells, buildings, cemeteries and any other physical data that will affect planning shall be shown. In addition to elevations shown by the contours, spot elevations at all summits, bottoms of depressions, tops of banks, stream or water surfaces, roads and railroad lines at breaks of grade, intersections, bridges, bases of isolated trees, and ground surfaces at wells etc. shall be shown. The contours shall correctly and clearly portray the terrain details and topographic shapes. The consultant shall together with other documents, submit survey control points description sheets (cards) to the respective Road Authority for future use.

Standard Scales to Drawings and Maps
Table 3-6 indicates different scale requirements for different types of maps and plans.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Typical Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 : 10 to 1 : 100</td>
<td>Large scale detail drawings, architectural plans</td>
</tr>
<tr>
<td>1 : 250 to 1 : 1000</td>
<td>Engineering site plans, facility design</td>
</tr>
<tr>
<td>1 : 1000 to 1 : 10,000</td>
<td>Intermediate scale: planning studies, drainage, route planning, detail design</td>
</tr>
<tr>
<td>1 : 10,000 and smaller</td>
<td>Small scale: topographic maps</td>
</tr>
</tbody>
</table>

Map scales greater than 1: 1,200 shall be used for detailed design purposes. Smaller scales between 1: 1,200 and 1: 12,000 shall be used for general planning purposes.
The project drawings (maps and plans), shall contain the following:

a) National Plane Coordinate System
The surveys and construction drawings for different projects must be correlated with each other and with other Government Departments and Agencies. This is accomplished by the use of the National Plane Coordinate System as the coordinate system of the project, and ensuring that this grid reference is adequately tied to the National Geodetic Reference System.

b) Coordinate grid lines
On all project maps (or CAD sheet files) the coordinate grid lines of the project/national coordinate system must be drawn to enable proper correlation between the various project maps and plans. These lines should be properly spaced apart; the outside coordinate lines should be the match lines for adjacent map sheets.

c) Plan scales
The determined drawing scales shall be shown on the topographic site plan/map.
Figure 3-2: Guide for topographic survey of water crossing or drainage structures sites.
Chapter 4 Design Controls and Criteria

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Chapter 4 Design Controls and Criteria

4.1 Introduction

The geometric form of a road consists of a number of geometric design elements. Appropriate standards and combinations of these elements should be determined on the basis of the following controls and criteria:

- Design Vehicle and Vehicle Characteristics
- Terrain
- Driver Performance
- Performance of Pedestrians and Other Road Users
- Speed
- Present and Future Traffic Volume
- Capacity
- Safety
- Design Criteria

The designer should consider all these controls and criteria, in order to arrive at final design which is in balance with the physical and social environment, which meets future traffic requirements and which encourages consistency and uniformity of operation. In this way it is possible to eliminate at the design stage any environmental and operational problems which would otherwise increase accident potential and other detrimental effects and incur costs for remedial measures in the future.

4.2 Design Vehicle and Vehicle Characteristics

Both the physical characteristics including turning capabilities of vehicles and the proportions of variously sized vehicles using the road are positive controls in geometric design. Therefore, it is necessary to examine all vehicle types, select general class groupings, and establish representatively sized vehicles within each class for design use. Vehicle characteristics affecting design include power to weight ratio, minimum turning radius, travel path during a turn, vehicle height and width. The main road elements affected are gradient, road widening in horizontal curves and junction design. In the design of a road facility, the largest design vehicle likely to use that facility with considerable frequency or a design vehicle with special characteristics that must be taken into account in dimensioning the facility is used to determine the design of such critical features as radii at intersections and radii of horizontal curves of roads.

The present vehicle fleet in Tanzania includes a high number of four-wheel drive passenger/utility vehicles, buses and trucks. Accordingly, the five design vehicles indicated in Table 4.1 will be used in the control of geometric design until a major change in the vehicle fleet is observed and detailed information on the different vehicle types using the roads in Tanzania becomes available.
### Table 4-1: Dimensions of Design Vehicle

(Source: SATCC Code of Practice for the Geometric Design of Trunk Roads)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Dimensions (m)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wheel Base</td>
<td>Front Overhang</td>
<td>Rear Overhang</td>
<td>Width</td>
</tr>
<tr>
<td>Passenger car (P)</td>
<td>3.1</td>
<td>0.7</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Single unit (SU)</td>
<td>6.1</td>
<td>1.2</td>
<td>1.8</td>
<td>2.5</td>
</tr>
<tr>
<td>Single unit + trailer (SU + T)</td>
<td>6.7+3.4*+6.1</td>
<td>1.2</td>
<td>1.8</td>
<td>2.5</td>
</tr>
<tr>
<td>Single unit bus (BUS)</td>
<td>7.6</td>
<td>2.1</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Semi-trailer (WB-15)</td>
<td>6.5+9.4</td>
<td>0.9</td>
<td>0.6</td>
<td>2.5</td>
</tr>
</tbody>
</table>

* Distance between SU rear wheels and trailer front wheels

The values quoted in the table above are 95 percentile values. Because of its application in the determination of passing sight distance, the fifth percentile value of height is selected. The height of passenger cars is thus taken as 1.3 m. A height of 2.6 m is adopted for all other vehicles.

### 4.2.2 Templates

The use of templates is recommended for establishing the layout of intersections and median openings. Once roadway edges have been established, it is recommended that they should, for ease of construction, be approximated by simple or compound curves.

Figures 4.1 and 4.2 give dimensions for the construction of templates for rigid chassis vehicles and articulated vehicles respectively.

For the purposes of construction of these templates it is assumed that the outside front wheel follows either a straight or a circular path, i.e. there is no allowance for a transition. The inner rearmost wheel follows a parabolic path from a point one wheelbase length before the start of the circular curve to a point two wheelbase lengths beyond it, where-after its path is also a true circular curve. This circular curve terminates one wheelbase length before the end of the circular curve described by the outside front wheel with the track width returning to its original value at a point two wheelbase lengths beyond the end of the circular curve.
Figure 4-1: Turning path for rigid chassis vehicles

\[ R_{IR} = R_K + (W-w)/2 + 0.6 \]

\[ R_{OF} = \left( (R_{IR} + w)^2 + L^2 \right)^{0.5} \]

where

- \( L \) = Wheelbase of design vehicle
- \( W \) = Track width
- \( W \) = Through lane width
- \( R_K \) = Kerb radius
- \( R_{IR} \) = Inner rear track radius
- \( R_{OF} \) = Outer front track radius

### Table

<table>
<thead>
<tr>
<th>DESIGN VEHICLE</th>
<th>L</th>
<th>W</th>
<th>( R_{OF} ) FOR ( W = 3.7 ) AND ( R_K = )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>( W = 15 ) ( 20 ) ( 30 ) ( 45 )</td>
</tr>
<tr>
<td>PASSENGER CAR</td>
<td>2.85</td>
<td>1.8</td>
<td>18.5 23.5 33.4 48.4</td>
</tr>
<tr>
<td>SINGLE UNIT TRUCK</td>
<td>6.10</td>
<td>2.5</td>
<td>19.6 24.4 34.2 49.0</td>
</tr>
<tr>
<td>BUS</td>
<td>6.00</td>
<td>2.6</td>
<td>19.6 24.4 34.2 49.1</td>
</tr>
</tbody>
</table>

Dimensions in metres
Figure 4-2: Turning path for articulated vehicles
4.2.3 Minimum Turning Radius

In constricted situations where the templates are not appropriate, the capabilities of the design vehicle become critical. Minimum turning radii for the outer side of the vehicle are given in Table 4.2. It is stressed that these radii are appropriate only to crawl speeds.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car (P)</td>
<td>6.8</td>
</tr>
<tr>
<td>Single unit truck (SU)</td>
<td>10.0</td>
</tr>
<tr>
<td>Bus (B)</td>
<td>11.5</td>
</tr>
<tr>
<td>Articulated vehicle (ARCTIC)</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Source: SATCC

4.2.4 Performance on Grade

Truck speeds on various grades have been the subject of much study under southern African conditions, and it has been found that performance is not significantly affected by height above sea-level. Performance can therefore be represented by a single family of curves calculated on the basis of the 95 percentile mass/power ratio of 275 kg/kW and as shown in Figure 6-17: Determining the climbing lane length which corresponds to the truck speeds on grades.

4.3 Terrain

The geometrical design is an exercise in three dimensional planning whose success will be measured not only by the efficiency of the road but by its appearance and impact upon the adjoining area.

A fundamental consideration in route selection and final design is to fit the road sympathetically into the landscape, with a broad awareness of the character and features of the area through which it passes.

The geometric design elements of a road depend on the transverse terrain of land through which the road passes. Transverse terrains are categorized into four classes as follows:

<table>
<thead>
<tr>
<th>Terrain</th>
<th>Transverse Terrain Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>0% - 10%</td>
</tr>
<tr>
<td>Rolling</td>
<td>10% - 25%</td>
</tr>
<tr>
<td>Hilly</td>
<td>25% - 60%</td>
</tr>
<tr>
<td>Mountainous</td>
<td>Above 60%</td>
</tr>
</tbody>
</table>

4.4 Driver Performance

4.4.1 Eye Height

Research has indicated that 95 per cent of passenger car drivers have an eye height at or above 1.05 m, and 95 per cent of truck drivers have an eye height of 1.8 m or more. An eye height of 1.15m has accordingly been adopted for use in this Manual.
4.4.2 Object Height
The road should be designed such that a driver could be able to see an object of 0.15m high at a distance of 100m away.

4.4.3 Reaction Time
Driver reaction time consists of two components: perception time and brake reaction time. Perception time is the time required for a driver to perceive the hazard ahead and come to realization that the brake must be applied. Break reaction time is a time taken by the driver to activate the brake.

A figure of 2.5 seconds has been generally adopted for reaction time for response to a single stimulus, typically where the response is to stop. American practice also makes provision for a reaction time of 5.7 to 10.0 seconds for more complex multiple-choice situations, where more than one external circumstance must be evaluated and the most appropriate response selected and initiated. This usually occurs at interchanges or complex intersections. These figures stated above have also been adopted in this manual.

4.5 PERFORMANCE OF PEDESTRIANS AND OTHER ROAD USERS
4.5.1 Pedestrians
The interaction of pedestrians and vehicles should be carefully considered in road design, principally because about 30 percent of all road fatalities are pedestrians.

Pedestrian actions are less predictable than those of motorists. Pedestrians tend to select paths that are the shortest distance between two points. They also have a basic resistance to changes in gradient or elevation when crossing roadways and tend to avoid using underpasses or overpasses that are not convenient.

Walking speeds vary from a 15th percentile speed of 1.2 m/s to an 85th percentile of 1.8 m/s, with an average of 1.4 m/s. The 15th percentile speed is recommended for design purposes.

Pedestrians’ age is an important factor that may explain behaviour that leads to collisions. It is recommended that older pedestrians be accommodated by using simple designs that minimize crossing widths and assume lower walking speeds. Where complex elements such as channelisation and separate turning lanes are featured, the designer should assess alternatives that will assist older pedestrians.

Pedestrian safety is enhanced by the provision of:

- median refuge islands of sufficient width at wide intersections, and
- lighting at locations that demand multiple information gathering and processing.
4.5.2 Cyclists

Bicycle use is increasing and should be considered in the road design process. Improvements such as:

- paved shoulders;
- wider outside traffic lanes and in case of separating from carriageway, cycle lane is to be provided;
- bicycle-safe drainage grates;
- adjusting manhole covers (if exist) to the grade; and,
- maintaining a smooth and clean riding surface can considerably enhance the safety of a highway or street and provide for bicycle traffic.

At certain locations it may be appropriate to supplement the existing road system by providing specially designated cycle paths.

4.6 Speed

Speed is a design controls and criteria and is one of the most important factors to the road user in selecting alternate routes or transportation modes. The attractiveness of a public transportation system and a new road are each weighed by the road user in terms of time, convenience, and money saved and this is directly related to speed.

4.6.1 Design Speed

Design speed is a measure of the quality of a road. Geometric design elements such as vertical and horizontal alignments, sight distances and superelevations, are directly related to design speed. It may be defined as the maximum safe speed that can be maintained over a given section of the road where conditions are so favourable that the design features of the road govern. It must be emphasized that the design speed adopted for a particular stretch of road is intended to provide an appropriate consistency between geometric elements rather than being an indicator of actual vehicle speeds at any particular location on the road system. It depends on topography and should be logical with respect to the adjacent land use, and functional classification of the road.

For a balanced road design, all permanent features of the road are related to the selected design speed. The cross-sectional elements are not directly related to the design speed, but they affect the vehicle speed, and higher standards should be accorded these features for higher design speeds.

Desirable and minimum design speeds are given in table 4.4 below:- Higher design speeds should be used so long as they are economically feasible and are consistent with the carriageway width adopted.

Caution should be taken in taking higher design speeds as they need wider carriageways for satisfactory performance.
4.6.2 Operating Speed
Operating speed is the highest overall speed at which a driver can travel on a given road under favourable weather conditions and under prevailing traffic conditions without at any time exceeding the safe speed as determined by the design speed on a section-by-section basis.

4.6.3 Running Speed
Running speed is the speed of a vehicle over a specified section of highway, being the distance travelled divided by running time (the time the vehicle is in motion).

4.7 Present and Future Traffic Volume
The design of a road, or any part thereof, should be based upon factual data on the traffic volumes which the road will have to accommodate. The usual design controls is the design volume, which is the estimated traffic volume at a certain future year, the “Design Year”.

The general measures of the vehicular traffic on a road are:

i. **Design Volume**: The volume of traffic estimated or expected to use a certain facility during the design year which is 20-30 years in the future.

ii. **Average Annual Daily Traffic (AADT)**: The total traffic volume for the year divided by 365. For a two-lane road the total traffic in both directions is taken.

iii. **Average Daily Traffic (ADT)**: The total volume of traffic during the given time period (in whole days), greater than one day and less than one year, divided by the number of days in that time period. For a two-lane road the total traffic volume for both directions of flow is taken.

4.7.1 Peak Hour Traffic, Design Hourly Volume and Design Volume
Capacity and other traffic analyses focus on the peak hour of traffic volume, because it represents the most critical period for operations and has the highest capacity requirements. If the highest hourly volumes for a given location were listed in descending order, a large variation in the data would be observed, depending on the type of facility. Rural and recreational routes often show a wide variation
in peak-hour volumes, while roads in built-up areas show less variation. Based on international studies and customary practice, the design hourly traffic is recommended to be the 30th highest hourly volume of the designated design year.

To be able to ensure that a road will function satisfactorily throughout the design life of the project, knowledge of the expected future use of the road is essential. Realistic traffic predictions are therefore an important input in making decisions regarding cross sectional dimensions, design speed requirements, pavement quality, etc.

By determining the traffic in the design year as a basis for selecting the geometric parameters, it is appropriate to take into account the fact that different projects will have different traffic growth potentials. Therefore, two projects with equal current traffic volumes may have significantly different traffic volumes in the design year. This may in turn lead to selection of different design parameters for the two projects which are well founded.

The normal procedure for establishing future traffic is to separate traffic into the following three categories

- **Normal traffic.** Traffic which would pass along the existing road being considered by the project if no investment took place, including normal growth.

- **Diverted traffic.** Traffic that changes from another route (or mode) to the project road, but still travels between the same origin and destination.

- **Generated traffic.** Additional traffic which occurs in response to the new / improved road. This traffic component includes traffic generated by new investments such as industrial developments and hotels, etc., which are expected to make use of the road.

From the above, it follows that the volume and composition of current and future traffic shall be established in terms of cars, light goods vehicles, trucks, buses, and non-motorised traffic. Once the future traffic has been predicted, the basis for selecting an appropriate design class has been established.

### 4.8 Capacity for a Two Lane Road

Capacity can be defined as the maximum number of vehicles per unit of time that can be handled by a particular roadway component or section under the prevailing conditions. Road capacity information is useful for:

(a) transportation planning studies to assess the adequacy or sufficiency of the existing road network to service current traffic and to estimate the time in the future when traffic growth may overtake capacity;

(b) it is important in design of road dimensions, number of lanes and minimum length of weaving length;

(c) traffic operation analysis in improvement of traffic operation.
4.8.1 Degrees of Congestion

The appropriate degree of congestion that should be used in planning and designing highway improvements is determined by weighing the desires of the road users against the resources available for satisfying these desires. The degree of congestion that should not be exceeded during the design year on a proposed highway can be realistically assessed by:

1. determining the operating conditions that the majority of motorists will accept as satisfactory;
2. determining the most extensive highway improvement that the governmental jurisdiction considers practical;
3. reconciling the demands of the motorists and the general public with the finances available to meet those demands.

This reconciliation of desires with available resources is an administrative process of high importance. The decision should first be made as to the degree of congestion that should not be exceeded during the design period. The appropriate design for a particular facility (such as number of lanes) can then be estimated from the concepts discussed in the following sections.

4.8.2 Estimating Level of Service Volumes in terms of Passenger Car Units

The traffic flow at capacity level is unstable and minor disturbances in the traffic streams may cause stop-go operations. Consequently a Design Capacity is instigated which is less than the maximum capacity and is related to a “Level of Service”. The level of service expresses the effectiveness of the road in terms of operating conditions. It is a qualitative measure of the effect of traffic flow factors, such as speed and travel time, interruptions, freedom of manoeuvre, driver comfort and convenience, and indirectly, safety and operation costs.

The choice of level of service shall generally be based on economic considerations. But the purpose of design is to provide a road which serve intended service flow without compromising safety of road users.

Six levels of service are defined; these vary from level A which is the free flow condition, where drivers can maintain their desired speed i.e. low volume and high speed; to level E where the traffic is approaching saturation with drivers travelling at low speeds due to high volume of traffic. The traffic volume at level of service E is the capacity of the facility. Level of service F is the forced flow condition where the traffic density is maximum with drivers subjected to frequent stops and queues. The Volume varies from 0 to capacity.

<table>
<thead>
<tr>
<th>Level of service</th>
<th>General operating conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Free flow</td>
</tr>
<tr>
<td>B</td>
<td>Reasonable free flow</td>
</tr>
<tr>
<td>C</td>
<td>Stable flow</td>
</tr>
<tr>
<td>D</td>
<td>Approaching unstable flow</td>
</tr>
<tr>
<td>E</td>
<td>Unstable flow</td>
</tr>
<tr>
<td>F</td>
<td>Forced or breakdown flow</td>
</tr>
</tbody>
</table>
The maximum number of vehicles which can pass a given section of a road for any given level of service is referred to as maximum service volume. That applicable to level of service E is also the capacity of the facility.

Maximum service volume under ideal conditions which a two–lane road can carry i.e. level terrain, at least 7.3 m carriageway, no obstructions within 1.8 m from the edge of carriageway, and no passing sight distance restrictions are given in the table 4.5 below:

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Passenger car units per hour (pcu/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>400</td>
</tr>
<tr>
<td>B</td>
<td>900</td>
</tr>
<tr>
<td>C</td>
<td>1400</td>
</tr>
<tr>
<td>D</td>
<td>1700</td>
</tr>
<tr>
<td>E</td>
<td>2000</td>
</tr>
<tr>
<td>F</td>
<td>Varies from 0 to 2000</td>
</tr>
</tbody>
</table>

*The above guide values for capacity are based on data from other countries and should be used only as a rough guide to capacity until more reliable values for Tanzanian roads have been determined.

Vehicles of different types require different amount of road space because of the various sizes and performance characteristics.

For traffic analysis purposes and especially for capacity measurements, all traffic volumes are expressed in terms of passenger car units. The basic unit is the car which is considered as equal to 1 pcu. Equivalent factors for other types of traffic are as follows:

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flat</td>
</tr>
<tr>
<td>Factor</td>
<td></td>
</tr>
<tr>
<td>Passenger cars</td>
<td>1.0</td>
</tr>
<tr>
<td>Light goods vehicle</td>
<td>1.0</td>
</tr>
<tr>
<td>Medium goods vehicle*</td>
<td>2.5</td>
</tr>
<tr>
<td>Heavy goods vehicle</td>
<td>3.5</td>
</tr>
<tr>
<td>Buses</td>
<td>2.0</td>
</tr>
<tr>
<td>Mopeds, Scooters</td>
<td>0.5</td>
</tr>
<tr>
<td>Pedal cycles</td>
<td>0.5</td>
</tr>
</tbody>
</table>

* also representative for combined group of medium and heavy goods vehicles and buses.
The following definitions apply to the different vehicle types mentioned in the above table.

- **Passenger cars**: Passenger vehicles, with less than nine seats.
- **Light goods vehicle**: Land rovers, minibuses and goods vehicles of less than 1,500kg unladen weight with payload capacities less than 760kg.
- **Medium goods vehicle**: Maximum gross vehicle weight 8,500 kg.
- **Heavy goods vehicle**: Gross vehicle weight greater than 8,500 kg.
- **Buses**: All passenger vehicles larger than minibus.

Example: An hourly traffic volume of 5 passenger cars, 10 light goods vehicles, 10 medium goods vehicles, 40 heavy goods vehicles, and 20 buses totalling 85 vehicles in rolling terrain represents \[(5 \times 1.0) + (10 \times 1.5) + (10 \times 3.0) + (40 \times 8.0) + (20 \times 4.0)] = 460\) passenger car units per hour.

The capacity and maximum service volume of a roadway is affected by a number of factors. These are:

- **a) Roadway factors** which include:
  - Carriageway and shoulder width
  - Alignment and sight distances (passing)
  - Surface condition
  - Grades
  - Intersections
  - Obstructions (lateral)

- **b) Traffic flow factors** such as:
  - Percentage of heavy vehicles
  - Traffic interruptions such as pedestrian crossing and parked vehicles
  - Speed range found within the traffic stream
  - Number of overtaking and passing manoeuvres required to maintain a desired speed

- **c) Environmental factors** such as weather.

On roads with two or more lanes in each direction, and on 2-lane single carriageway roads where important junctions are encountered or where additional lanes are to be provided later, knowledge of the hourly traffic volume in each direction of travel is essential for design.

For a more comprehensive treatment of capacity values and methods for calculating capacity, reference is made to the Highway Capacity Manual (2000).

It is emphasised here that pavement design requires different vehicle type classifications to that used for determining pcu factors which refers to payload, tare weight or number of axles, and further, a different definition of “design year” may be used, e.g. 5 years, 10 years or 15 years after opening of the new road.

### 4.8.3 Estimating typical AADTs at various Levels of Service

The most adequate control for low-volume roads is the future AADT in the design year, estimated from historical AADT data and the envisaged socio-economical development pattern. For routes with
large seasonal variations but still moderate traffic volume, it may be sufficient to determine the design
volume in the design year as ADT during the peak months of the year.

On major roads carrying heavy traffic volumes throughout the year (current AADT > 1,000),
hourly traffic has to be used for determination of the Design Volume. However, it would obviously be
wasteful to design the road for the maximum peak hour traffic in the design year, since this traffic
volume would occur only during one or a very few hours of the year. As a general rule, heavily
trafficable rural roads should be designed to accommodate the 30th to 50th percentile highest hourly
volume (DHV = Design Hourly Volume) predicted in the design year.

When the design volume exceeds 10,000 pcu’s dual carriageway may be considered, particularly if the
road traverses through a typical rural area. For roads close to major towns a single carriageway may
carry a design volume of up to 15,000 pcu’s. Road users are more willing to accept a higher degree of
restraint in short trips, like in towns, than they are in long trips. Hence we accept the use of lower level
of service in towns than in rural areas.

For planning procedures the estimated maximum AADT for two-lane roads presented in the table
for Maximum AADT may be used as a guideline. The table 4.7 below gives the maximum AADT
applicable to different levels of service and different types of terrain.

The planning criteria used in the table for maximum AADT assume the following:

• Traffic mix 25% of trucks;
• Directional split 60/40;
• No passing zone
  ○ Flat terrain 20%
  ○ Rolling to Hilly terrain 40%
  ○ Mountainous terrain 60%
  ○ Ratio of 30th HHV to AADT 0.15

<table>
<thead>
<tr>
<th>Level of service</th>
<th>Maximum AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flat terrain</td>
</tr>
<tr>
<td>A</td>
<td>1600</td>
</tr>
<tr>
<td>B</td>
<td>3200</td>
</tr>
<tr>
<td>C</td>
<td>5200</td>
</tr>
<tr>
<td>D</td>
<td>8700</td>
</tr>
</tbody>
</table>

For design volumes close to the maximum capacity of the road, operational analysis should be
performed for alternative designs to document the impact on traffic operations from horizontal and
vertical alignment.

Where computations indicate that a two-lane road is not adequate for the existing or projected
demands, various multi-lane options may be considered and analyzed, using the methodology
described in “TRB (Transportation Research Board) Highway Capacity Manual” (HCM). It should,
however, be borne in mind that the procedures in HCM reflect North American operating experience,
and should always be evaluated with respect to its applicability to the local prevailing conditions.
4.9 **Safety Considerations**

Safety is enhanced on highway by proper design controls and enforcement of the controls. The design can enhance safety if uniform speeds and other design features are used and there are no sudden changes in the alignment or the geometrics. Proper traffic signing and markings is also a must in this aspect.

It is important that safety features are built into the road from the very start of the design. Safety considerations in roads have two objectives to provide design features to:

- Prevent accidents, and
- Reduce the seriousness of the accidents that occur.

Road Safety Audit shall be carried out according to A Guide to Road Safety Auditing (2009), Ministry of Infrastructure Development.

4.9.1 **Accident Prevention**

For prevention of accidents the following points are especially important:

- Provision of physical separation between motor vehicles in opposing directions and also with other road users (especially pedestrians and cyclists);
- Provision of a balanced design, i.e. compatibility between the various design elements;
- Avoidance of surprise elements for the drivers, for example abrupt changes in standard, insufficient visibility or poor coordination of horizontal and vertical alignment;
- Avoidance of situations where drivers must make more than one decision at the time;
- Provision of design features that reduce speed differentials between vehicles, for example flat grades and speed change lanes;
- Proper location and design of intersections;
- Proper design, application and location of traffic signs, road markings and other traffic control devices;
- Provision of design elements compatible with traffic volumes and type of traffic; and,
- Provision of proper drainage of the road surface.

4.9.2 **Reducing the Severity of Accidents**

A lot can be done to reduce the severity of accidents that we fail to prevent. The basic principles are:

- There should be a clear zone (safety zone) along each side of the road that is clear of hazards such as lighting columns, other utility poles, rocks, drainage structures, etc.;
- Roadside slopes should be as flat as feasible (1:4 or flatter);
- Large diameter sign posts and other supports which must be located within the clear zone should be of a breakaway type; and,
- Safety barriers should be provided to protect vehicles from hitting dangerous obstacles that cannot be removed or made breakaway and also to protect vehicles from falling off the road down embankments.

4.9.3 **Speed and Traffic Safety**

Road and traffic history reveals that drivers tend to overestimate safe speeds. Speed limits should be imposed where speeding is a problem, but compliance with signs is low, and enforcement is
difficult. Consequently, it is crucially important to reinforce the speed limits with physical speed control measures, especially on through roads in trading centres and towns.

It is also considered necessary to separate vulnerable road users from motorised traffic in trading centres and towns. Whether and how to do this requires careful assessment. The main ways of achieving separation in rural areas are:

- paved shoulder separated from the traffic lane with an edge line marking; and,
- separate footway – in some circumstances it may also be used by cyclists.

For roads through trading centres and towns the options are:

- paved shoulders;
- a footway (or combined footway/cycleway) physically separated from the traffic lane by a barrier kerb or similar;
- a raised, kerbed footway; and,
- a raised, kerbed footway with a service road beyond it.

The general recommendations on separation are as follows: (see also chapter 5).

- A separate footway must be provided on Class A and B roads if they are to have a speed limit of 100 km/h and over (Road Design Classes 1 and 2);
- Roads with a speed limit of 80 km/h shall be provided with paved shoulders for use by pedestrians and cyclists – on sections where the volume of pedestrians is moderate or high a separate footway shall be provided; and,
- A separate footway shall normally be provided alongside through roads in built-up areas.

4.10 **Design Life**

The major requirement linked to the design life is that there shall be no need for major improvements during this period, unless a staged construction is planned.

The principal causes of a road not meeting its functional requirements are primarily due to:

1. a reduction in level of service, which implies that the traffic volume on the road has increased to a level where undue delays becomes inevitable, and/or
2. an increase in number of accidents due to roadside interference such as lack of access control and also the fact that the drivers become impatient with the delays and take chances in overtaking vehicles at the risk of meeting traffic, and/or
3. lack of maintenance which also can contribute to a poor performance of a road.

Internationally, a design life of 20 – 30 years has in the past often been used for new road projects. A number of countries have however adopted at longer planning horizon in their infrastructure development planning. 60 years planning period is now being used in some European countries.

A design life of 30 years is adopted for the development of national roads in Tanzania. For district roads, a design life of 15-20 years is recommended.
Chapter 4
Design Controls and Criteria

4.11 Design Criteria

4.11.1 During Preliminary or Route Selection Stage

The steps to be followed in route corridor selection are discussed in Chapter 3. To find the optimum alternative for each project several different routes should be tried. Some of these should be chosen and compared in a comprehensive study. The costs to be considered during preliminary design or route selection should include and not limited to the following:

- Land acquisition of road reserve and intrusion;
- Construction and operation costs;
- Road user costs including travel time, accidents, vehicle operating costs; noise, air pollution;
- Optimizing horizontal alignment with vertical alignment and cross section element
- Others such as increased safety, Environmental and Social effects, comfort etc.

A cost-benefit and objective analysis including as many effects as possible should be made for all studied alternatives.

4.11.2 During Detailed Engineering Stage

The design criteria and policies in this Manual provide a guide for the designer to exercise sound engineering judgment in applying standards in the design process. This guidance allows for flexibility in applying design standards and approving design exceptions that take the context of the project location into consideration; which enables the designer to tailor the design, as appropriate, for the specific circumstances while maintaining safety. In the event the designer considers that relaxation of standards is essential, he shall follow the procedure illustrated in Sub-chapter 1.4 of Chapter 1 – Departures from Standards.

The design standards used for any project should equal or exceed the minimum given in the Manual to the maximum extent feasible, taking into account costs (initial and life-cycle), traffic volumes, traffic and safety benefits, road reserve, socio-economic and environmental impacts, maintenance, etc.

The geometric standards of individual elements of the road will usually vary with the terrain. Elements for which the chosen geometric standards are difficult to obtain should be identified. The economic consequences of different standards for these elements should be considered and a cost-benefit analysis including construction and road user costs should be made. In general, the higher the class of road, and hence volume of traffic, the more likely will benefits from road user savings lead to the justification of a higher road standard.
Chapter 5 Cross Section Elements

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Chapter 5 Cross Section Elements

5.1 INTRODUCTION

A road cross section will normally consist of the roadway, drainage features, earthwork profiles and clear zones. The whole cross section, including the clear zone is defined as the road reserve.

For a one or two lane road, the roadway is the portion of the road, consisting of the shoulders and the carriageway. The carriageway is the portion of the road used for the movement of vehicles exclusive of shoulders. Earthwork profiles are the side and back slopes of the road cross section. Figure 5.1 illustrates the various components of the cross-section for a two lane road.

For a dual carriageway with for example four lanes, the roadway is the portion, consisting of the shoulders, the carriageways and the median. Figure 5.2 illustrates the various components of the cross-section for a dual carriageway.

Cross-sectional dimensions are given in this chapter.
5.2 **HEADROOM AND LATERAL CLEARANCE**

5.2.1 **Headroom Requirements**

Headroom is the required height to allow traffic to pass safely under objects restricting the height. The required headroom shall be provided over the full width of the carriageway. The maximum legal height of a vehicle in Tanzania is 4.6 m. In determining the headroom, the following considerations have to be made:

- The possibility of the road surface being raised during pavement overlay work
- The possibility of an over-pass bridge collapsing if hit by a vehicle
- The need to allow for occasional oversized vehicles.

The preferable headroom under bridge structures is 5.5 m and the minimum requirement is 5.2 metres.

The headroom should be 7 m under high-power cables and 6 m under low-power cables or any other cables that may be crossing the road reserve.

The minimum headroom over footways and cycleways will primarily depend on the height of the equipment being used for maintaining these facilities. The minimum headroom requirement is set to 2.5 m.

5.2.2 **Lateral Clearance Requirements**

The lateral clearance is the minimum distance between the edge of the traffic lane, the footway or cycle way and the nearest fixed object. Fixed objects must not be so close as to discourage the driver from making full use of the traffic lane or risk of them being hit by passing vehicles. The recommended lateral clearances are given in Table 5-1.

<table>
<thead>
<tr>
<th>Impacting object</th>
<th>Speed Limit</th>
<th>Footways and Cycleways</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>height lower than 0.2 m</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>height higher than 0.2 m</td>
<td>0.30</td>
<td>0.60</td>
</tr>
<tr>
<td>Guardrail</td>
<td>0.30</td>
<td>0.60</td>
</tr>
</tbody>
</table>

For siting and mounting of road signs and similar road furniture, reference shall be made to: “A Guide to Traffic Signing, Ministry of Infrastructure Development, 2009”.

5.3 **ROAD AND LANE WIDTH**

Road width should be sufficient to carry the traffic efficiently and safely. The selection of lane width is based on traffic volume and vehicle type and speed. High traffic volumes and speeds require wider lanes, and the widest lane width recommended is 3.75 m. The narrowest lane width recommended for national roads is 3.25 m, giving a clear space of approximately 0.35 m on either side of a vehicle that is 2.5 m wide (see Table 2-3).

For district roads the widest lane width recommended is 3.25 m with a total road width of 9.5 m. The narrowest lane width recommended for two lane district roads is 2.75 m with a total road width of 7.5 m.
Details of the cross section dimensions for all design classes are given in Sub-Chapter 5.15 of this Manual.

The designer should note that in the case of paved roads, the lane width is measured excluding width of edge line markings. The painted edge line is consequently part of the shoulder as shown in Figure 5-3, below.

![Figure 5-3: Edge line, end of lane](image)

**5.4 Shoulders**

A shoulder is the portion of the roadway that runs parallel to the carriageway for the following functions:

- To provide lateral support of pavement structures;
- To provide emergency space for vehicles that need to be rescued;
- To enable non-motorized traffic (pedestrian and cyclist) to travel with minimum encroachment on the carriageway; and
- To enable drivers to recover control.

Shoulders are specified for all Road Design Classes. The width of shoulder varies from 2.5 metres for Road Class 1, to 1.0 metres for road design class 5 to 8 (see Table 2-3).

It is recommended that all shoulders of paved roads be paved with the same material as the carriageway, though exceptions may be made for low volume roads. The surface of the shoulder must be level with that of the adjacent traffic lane, as any discontinuity (edge drop) will reduce the usefulness of the shoulder and could be dangerous.

Shoulders intended for use by pedestrian and cyclists must be at least 1.5 m wide. Where the present pedestrian and bicycle traffic in the range of 200 - 300 units per day, the shoulder shall be widened to 2.0 metres. If the number of pedestrians and bicyclists per day is higher than 300, a separate footway should be considered as shown in Sub-chapter 9.3.1.

**5.5 Normal Cross Fall**

The normal cross fall for paved carriageway on tangent sections and on very flat curves with larger radii, shall be:

- Asphalt concrete surfaces: 2.5%
- Surface dressing surfaces: 3.0%
- Stone paved surfaces: 3.0%
- Gravel and earth surfaces: 4.0%
5.6 **Side Slope and Back Slopes**

Side-slopes should be designed to ensure the stability of the roadway and to provide a reasonable opportunity for recovery of an out-of-control vehicle. Three areas of the roadside are important when evaluating the safety aspects:

1. the top of the slope (hinge point)
2. the side slope, and
3. the toe of the slope (intersection of the fore slope with level ground or with a back slope, forming a ditch)

Figure 5-4 illustrates these three areas.

The hinge point may contribute to loss of steering control and a rounding off at this point may reduce the chances of an errant vehicle becoming airborne. This rounding off will however necessitate a vertical curve from the end of the paved shoulder to the side slope. A curve with 1 metre to 1.2 metre radius is often used. The implication is however that the actual shoulder break is 0.5 metre to 0.7 metre outside the end of the paved shoulder. Such a widening will also improve the lateral support for the pavement.

Similarly, rounding off at the toe of the slope is also considered to be beneficial.

Embankment or fill slopes parallel to the flow of traffic may be defined as

- recoverable
- non-recoverable or critical

Recoverable slopes include all embankment slopes, 1:4 (1 vertical to 4 horizontal). Motorists, who encroach on recoverable slopes, can generally stop their vehicles or slow them enough to return to the roadway without serious human injury.

Embankments between 1:4 and 1:3 normally fall into the non-recoverable category. Motorists will normally be unable to stop and can be expected to reach the bottom. A critical slope is one on which a
vehicle is likely to overturn. Slopes steeper than 1:3 generally fall into this category.

The selection of a side slope and back slope is dependent on safety considerations, depth/height of cut or fill, characteristic of soil or natural ground material, and economic considerations. The side slope ratios specified for use in the design are related to the height of fill and the type of material in the cut

Recommended maximum rates of side slopes for embankment (fills) are as follows:

<table>
<thead>
<tr>
<th>Embankment height (m)</th>
<th>Slope (Vertical : Horizontal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1.0 m</td>
<td>1:4</td>
</tr>
<tr>
<td>1.0 to 3.0</td>
<td>1:2</td>
</tr>
<tr>
<td>Greater than 3.0</td>
<td>1:1.5</td>
</tr>
</tbody>
</table>

For sections with high embankments and where installation of guardrail is required according to the specifications given in chapter 9, it may be less costly to eliminate the use of guardrail for embankment heights up to 4 to 5 metres by using side slope of 1:4. This will for example apply to sections with horizontal curves of a radius < 450 metres on high-speed, high-volume roads.

Recommended maximum rates for back slope are as follows:

<table>
<thead>
<tr>
<th>Type of material</th>
<th>Slope (Vertical : Horizontal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Rock</td>
<td>1:1 to 4:1</td>
</tr>
<tr>
<td>Decomposed Rock and/Compact lateritic soils</td>
<td>1:2 to 1:1</td>
</tr>
<tr>
<td>Ordinary soils</td>
<td>1:2 to 1:1.5</td>
</tr>
</tbody>
</table>

It is stressed that the recommended side slopes and back slopes are an indication of normally used values. The detailed design of a project should include a geotechnical/stability analysis which will indicate the steepest slopes appropriate for the construction materials.

5.7 DRAINAGE

Drainage is the most important factor in determining the technical performance of a road. When roads fail, it is often due to inadequacies in drainage. Failure can happen suddenly as the case of slip failure (parts of cutting or embankment breaking off), or more slowly, as when water penetrates into the road pavement and sub-grade, weakens them to the extent they are no longer strong enough to support traffic.

Drainage problems can be grouped into two general categories: surface and subsurface.

- Surface drainage deals with collection, transportation and disposal of surface water on the roadway and near the roadway. The water is usually either runoff from rainfall or from streams bordering or crossing the road reserve.

- Subsurface drainage is concerned with water in pavement layers and underlying soils. It deals with the interception and control of such water which may flow laterally under the influence of gravity or rise vertically by capillary action to soften the foundation soils.
Proper drainage design is thus an essential feature of overall highway design and planning. In drawing up a drainage plan information concerning the following factors is essential.

- Hydrological consideration such as maximum rainfall and intensity, rate of runoff and nature and amount of stream flow.
- Characteristics of the drainage basin (area to be drained) such as size, shape, general slope, nature and type of vegetation and land use (existing and future).
- Nature and type of basin soils including their permeability and tendency to erode.

Longitudinal drainage

Water is drained from the carriageway and shoulders by virtue of the cross-fall or transverse slope and longitudinal grade. Such water is either allowed to flow down the face of the side slope (for small embankments) or collected at the edge of the shoulder by the use of kerbs, dykes or paved ditches and carried longitudinally for disposal at a convenient place.

The water from the roadway and surrounding areas is drained away by use of roadside ditches, mitre drains or cut-off drains. These usually carry the water for disposal at a convenient place or to a bridge or culvert inlets.

Roadside ditches

Drainage ditches are constructed along the edge of the roadway to receive the runoff from the pavement surfaces and water from subsurface drains. Where the surrounding area is sloping toward the roadway, these ditches also serve to intercept and carry away water which would otherwise reach the roadbed.

With open drains, the slope next to the road should not be steeper than 1:4, so as to avoid the risk of severe damage and injury when errant vehicles fall into the drain.

Generally trapezoidal shape ditches with side slope of 1 in 1 to 1 in 4 (depending upon soil type) and bottom width of 0.6 to 2.5m (depending upon excavation method) are used. In rolling to hilly terrain where space is limited, V-shaped drains can be used. The capacity of drainage ditch can be increased by widening or deepening the channel. Widening is preferred to limit potential scouring.

The minimum depth of ditches should be 0.5m measured from the bottom of the ditch to the formation level.

Maximum velocity of the water in the ditch, which will cause erosion or scour depends on the material of the ditch. An average value of 1 metre/second for loam or fine sand and 2 metres/second for coarse gravel will not cause erosion. However, in cases when velocities are expected to exceed 2 metre/second a lining shall be used.
To assure flow, ditches should have minimum longitudinal slope of 0.5 percent if unpaved and 0.3 percent if paved.

Key points to consider in the design of safe side drains are:

• There should be sufficient discharge points and culverts to ensure that the drain never gets very deep;
• With open drains, the slope next to the road should as much as possible be flat enough to reduce the risk of errant vehicles overturning;
• In built-up areas channel drains deeper than 500mm should be covered or under-drain system be used for the safety and convenience of both pedestrians and vehicles;
• The drain should terminate or discharge in a satisfactory manner without risk of causing erosion or other problems; and,
• The drain should be capable of being cleaned and maintained easily.

**Median drains**
Median drains not only drain the median but also, in the case of a horizontal curve, prevent water from the higher carriageway flowing in a sheet across the lower carriageway. The transverse slopes should be in the range of 1:4 to 1:10. Unlike side drains, median drains, are generally constructed with a shallow V-profile with the bottom gently rounded.

**Chutes**
Chutes are intended to convey a concentration of water down a slope which, without such protection, would be subject to scour. They may vary in size from large structures to half-round precast concrete product, but they are all open channels. Flow velocities are high, so that stilling basins are required if down-stream erosion is to be avoided. An example of the application of chutes is the discharge of water down a fill slope from an edge drain. The entrances to chutes require attention to ensure that water is deflected from the edge drain into the chute, particularly where the road is on a steep grade.

The chutes and stilling basins should be such that these drainage elements do not present an excessive risk to errant vehicles. Generally, they should be as shallow as is compatible with their function. Depths in excess of 150 mm should be viewed with caution.

**Mitre drains**
The water which is collected on side drains must be disposed of by diverting the drains away from the road before it has become too long and collected too much water. If there is no stream or river into which it can be diverted, mitre drains with small check bends should be constructed pointing away from the road and running down hill. Thus, putting up large size culverts is avoided. If it is not possible to construct mitre drains because the surrounding ground is sloping towards the road, then it will be necessary to provide a culvert to take the water across the road away on the other side.

**Catchwater drains**
Where the surrounding area consists of higher ground, as in a cut or where the highway runs along the side of a hill, additional drains known as catchwater cut-off or interceptor drains should be provided (see Figure 5-6). These are effective in preventing erosion of the slope and consequent blocking of the side drain.
5.8 Chapter 5

Cross Section

Elements

Catchwater drains are constructed at the back of the top of the cut or on benches in the cut slope. The practice of providing catchwater drains along the top of the cutting may sometimes cause a slope failure. Therefore, when it is necessary, it should be provided behind a line at 45 degrees through the toe of the cutting and at least 6 m away from the top of the cutting.

Subsurface drainage

The road base must be designed either to exclude water completely or alternatively to permit egress of water which has entered. When impermeable bases such as stabilized soils or densely graded bituminous concrete are used, drainage of base is not necessary. When permeable and porous base materials are used, particular attention must be paid to the drainage of the base layer. The base and sub-base should extend the full width across the roadway and the surface of the sub-base layer given adequate cross fall to assist drainage.


Capillary Cut-off

The purpose of capillary cut off is to collect and lead to drains any water which may pass through the road surface (from top) or rising into the pavement from below by capillary action as shown in Figure 5-7.

Capillary cut-off can either be a layer of porous materials such as sand or gravel, or an impervious membrane such as layer of primer, tar felt or polythene.

The cut-off should be located at least 0.6m below top of subgrade. It is should also be at least 0.15m above the general ground level or stagnant water level.
**Control of seepage flow**

There are two methods of dealing with condition of seepage flow. If the seepage zone is narrow and within 0.6 to 1.0m from the surface then the usual procedure is to install an intercepting drain in the impermeable strata underlying the seepage zone as shown in Figure 5-8.

![Figure 5-8: Interception of seepage zone](image)

If the seepage zone is wider or the impermeable strata is at a considerable depth below he surface, it is generally impracticable to construct the drainage trench sufficiently deep to intercept all the seepage water. In this case, the intercepting drain is usually well above the impervious strata, leading to a partial interception of seepage zone.

Where a road is on sloping ground, longitudinal drains may not be capable of intercepting all the seepage water. In such cases it may be necessary to install transverse intercepting drains too.

**Control of high water-table**

A high water table can be lowered by the installation of a drainage system similar to the system displayed in Figure 5-8, above. It is desirable that the water table should be maintained at a depth not less than 1.2m below the formation level. The actual spacing and depth of drains to achieve this requirement will depend on the soil conditions and the width of the road formation. In the case of dual carriageway, drains may be necessary under the median as well as under the edges of the formation.

**Cross Drainage Structures**

Cross drainage structures comprise a wide range of measures from major bridges to drifts and minor culverts. The major structures that are most commonly used for passing water from one side of a road to the other can be slabs, beam/composite, box girders, trusses, frames, arches and cable bridges.

Collection of water from the roadway should be properly channelled to the bridges to avoid erosion of abutments.

Culverts in various shapes and materials are used to convey water from streams below the road and to carry water from one side ditch to the other. Culverts should have inlet headwalls on the upstream side and outlet headwalls on the downstream side. Wing walls on the upstream are intended to direct the flow into the culvert and provide transition from the culvert to normal or regular channel on the downstream. Both help to protect the embankment from flood water.

An example is shown in Figure 5-9, below:
5.8 Clear Zone

Many accidents involve drivers losing control of their vehicle, which then runs off the road and collides with a tree or other rigid object and overturns. The severity of these crashes can be reduced if the concept of the “forgiving roadside” is adopted, in which a clear zone is created. The clear zone is a safety zone adjacent to the traffic lanes. It is an unobstructed, relatively flat area provided beyond the edge of carriageway for the recovery of errant vehicles.

The clear zone must be kept free of rigid objects and other hazards, such as steep embankment slopes, and open, steep-sided drainage ditches. If a hazard cannot be removed or relocated from the clear zone, it should be shielded by safety barrier. If shielding by safety barriers is not possible or not economically justified, consideration should be given to signing the feature so that is readily visible to a motorist”.

Once a vehicle has left the roadway, an accident may occur. The end result of an encroachment depends upon the physical characteristics of the roadside environment. Flat, traversable, stable slopes will minimize overturning accidents, which are usually severe.

For adequate safety, it is desirable to provide a roadside recovery area as wide as practical on a specific road section. A clear zone shall have gentle slopes and a rounded cross-sectional design, is desirable.

Fore slopes steeper than 1:3 cannot be counted as part of the clear zone because they are too steep. Slopes that can be traversed safely by out-of-control vehicles need to be at least 1:4 or gentler. Slopes between 1:3 and 1:4 are marginal; the normal practice is that half the width of these slopes is counted as part of the clear zone – see Figure 5-10.
It is obvious that the need for clear zones increases with speed and curvature. The following clear zone widths (Table 5-2), measured from the edge of the traffic lane, are considered to give an acceptable standard of safety. Traffic volume is also a factor, as, generally, the higher the traffic volume the greater the frequency of run-off-road incidents—which supports the use of wider clear zone widths.

<table>
<thead>
<tr>
<th>Speed Limit</th>
<th>Standard Desired</th>
<th>Standard Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>5 m</td>
<td>3 m</td>
</tr>
<tr>
<td>80</td>
<td>6 m</td>
<td>4 m</td>
</tr>
<tr>
<td>100</td>
<td>9 m</td>
<td>6 m</td>
</tr>
</tbody>
</table>

The clear zone widths given in Table 5-2 should be increased at sharp bends on high-speed roads by a correction factor to be obtained from Figure 5-11 depending on the radius of curve.
5.9 Road Reserve

The road reserve shall accommodate the planned roadway, including all cross sectional elements and enhance traffic safety, operation and appearance of the road. The width of road reserve depends on class of the road, the cross section elements of the road, topography and other physical controls together with economic considerations.

Figures 5-12 shows the cross-sectional elements to be considered when determining road reserve. A uniform width of road reserve may be convenient, but there are special cases where additional road reserve may be desirable. These special cases could be locations where the side slopes extend beyond the normal road reserve, where greater sight distance is desirable, at intersections and junctions and for environmental considerations. In all cases the road reserve should always be determined and shown on the final design plans of road projects.

Road reserve widths applicable for the different road design classes are given in Sub-chapter 5.15.
5.10 Multi-lane Divided Roads / Dual Carriageways

In the case that the traffic volumes cannot be accommodated by a two lane road, there will be a need to increase the roadway to a multi-lane facility when a certain traffic volume is reached.

In such a case, traffic safety considerations dictate the need for separation of traffic in opposite direction by means of a median. In addition, a median provides a recovery area for out-of-control vehicles, a stopping area in case of emergencies, a space for speed changes and storage of right-turning and U-turning vehicles, it minimizes headlight glare, it provides width for future lanes, and it provides a refuge for pedestrian crossing the road in case of urban and populated areas. For maximum efficiency, a median should be highly visible both night and day and contrast with the through traffic lanes.

Medians may be depressed, raised, or flush with the carriageway. Medians should be as wide as feasible but their dimensions shall be in balance with other components of the road cross section.

In determining median width, consideration should be given to the possible need for median barrier. Where possible, median width should be such that a median barrier is not warranted. In general, the median should be as wide as practical. Where the median is less than 1.5 x Minimum Clear Zone width, consider installing a median barrier. However, economic factor and availability of land (right-of-way), and also terrain often limit the width of median. The minimum width of median is as narrow as 1.2 to 1.8 m. Where provision for right turn lane is required the minimum width of median will be 4.8 – 5.0 m. In some cases for future upgrading of the road a central reserve of minimum 12.0 m could be introduced to serve as median. The 12m central reserve could accommodate in the future two lanes each having 3.5m in addition to a 5.0 m median.

Figure 5-13 gives recommendations on median design and width on high-speed rural dual carriageway roads.

![Figure 5-13: Median at speed limit 80 and 100 km/h](image)

Medians on urban dual carriageways should normally be designed to function as a refuge for pedestrians. The median should have a minimum width of 2.0m, but this can be reduced to an absolute minimum of 1.2m where space is very restricted. A 2.0 m width will also give sufficient space for most signs, signals and lighting columns. Median barriers should not normally be necessary on urban dual carriageways with speed limits of less than 80km/h.
5.11 Single-Lane Roads
For low traffic volume roads (<20ADT), single lane operation is adequate as there will be only a small probability of vehicles meeting, and the few passing manoeuvres can be undertaken at very reduced speeds using either the shoulder or passing bays. In such cases adequate sight distances should be provided for safe stopping. These manoeuvres can be performed without hazard, and the overall loss in efficiency brought about by the reduced speeds will be small, as only a few such manoeuvres will be involved.

A single lane road will not allow passing and overtaking to occur on the carriageway. Passing must be performed using shoulders. In such cases the width of roadway including shoulder should be enough to allow two design vehicles to pass, i.e. a minimum of 6.0 metres width, and vehicles would be expected to stop or slow to a very low speed.

In the case where shoulders are not provided, passing and overtaking manoeuvres are to be undertaken on passing bays. The increased width of road at passing bays should be enough to allow two design vehicles pass safely. In such cases it is normal that passing bays should be located every 300 to 500 metres depending on the terrain and geometric conditions.

The length of individual passing bays will vary with local conditions and the type of design vehicle but, generally, a length of 20 metres including tapers will cater for most commercial vehicles.

5.12 Cross-sections over Bridges and Culverts
The safety and operational capacity of bridges and culverts will be affected if the road cross-section is not maintained or bettered across these structures. The key points to consider with respect to cross-sections over bridges and culverts are:

- Any significant narrowing of the traffic lane or shoulder is dangerous, especially on high-speed roads;
- When roads are being upgraded and widened, the bridges and culverts shall normally need to be widened as well;
- If the shoulder is not continued across the structure, vulnerable road users will move out into the traffic lane in front of fast-moving vehicles and there will be a risk of collisions;
- On two-lane bridges the carriageway width (kerb to kerb) should be at least 1.0m wider than that of the approach roads.
- Footways are conventionally provided on structures together with parapets. Where footways are provided they shall be a minimum of 1.5 metre wide on each side of the bridge in the rural areas. In urban and built up areas the minimum width shall be 2.0 metres on each side of the bridge. The footway shall be separated from the roadway by raising it by 200-250 mm in order to better protect the users of the footway. All footways shall be provided with ramps on both approaches to cater for the physically disadvantaged groups;
- It is best to segregate the vulnerable road users from vehicles by means of a safety barrier in form of vehicle/pedestrian parapets – see Figure 5-14.
- Where, exceptionally, a single lane bridge is planned the traffic lane should be a maximum of 3.7 m wide between kerbs in order to avoid confusion over whether the bridge is for one-way or two-way traffic.
See Chapter 9 for advice on the design of bridge parapets.

5.13 Footways and Cycleways

The conventional practice is to assume that pedestrians and cyclists can use the shoulders, but it is much safer for them to be on a separate footway, or combined footway/cycleway.

At high flows there can be conflicts between cyclists and pedestrians, but these are not as dangerous as conflicts with motor vehicles. Combined footways/cycleways should be 3.0m wide (2.0m absolute minimum). It is important for footway and cycleway surfaces to be at least as smooth as the adjacent traffic lanes and shoulders.

5.13.1 Footways and Cycleways Outside Urban Areas

The footway/cycleways should be separated from the carriageway by a grass strip or similar, at least 2.0m wide, as seen on Figure 5-15. On embankments the footway/cycleway can be benched into the fore slope. The planting of shade trees can help encourage people to use the facility.

![Figure 5-14: Segregated footway on bridges](image)

![Figure 5-15: Separate foot and cycleway in built-up areas on rural roads](image)
5.13.2 Footways and Cycleways in Urban Areas

Raised, kerbed footways should be provided in urban areas and the larger built-up areas. Cycleways, where necessary, should be constructed behind the footway.

![Figure 5-16: Raised, kerbed footway in urban areas](image)

A simpler and cheaper alternative is to have the footway at the same level as the traffic lane, but separated by a barrier kerb or low wall – see Figure 5-17. This means it can function as a combined footway/cycleway. Gaps are left in the separator to allow drainage and access to roadside premises. The separators should be painted white to make them more visible at night, and care should be taken to avoid starting the separator where speeds are high or visibility is poor. If necessary, reflectors should be fitted to the end of the separator.

![Figure 5-17: Footway on physically separated shoulders](image)

At the intersections and pedestrians’ crossings, ramps must be provided where the change in level is more than 200 mm to cater for the disadvantaged.

5.14 Service Roads

In the larger trading centres and towns, it is recommended that service roads be provided. A typical service road design is illustrated below. The local access traffic is kept separate from the through traffic, and the drivers of the motor vehicles shall not be allowed to park on the service road. Stopping for unloading and/or loading may however be considered during design.
5.15 Typical Cross Sections

Typical cross sections for road design class 1 to 5 are displayed below. The roads shown are primarily meant for a rural environment.

If however, a high class road should pass through a town or a populated area, additional lanes should be considered. An outer lane on both sides of the road may be introduced in order to avoid disruption of non-stopping or passing traffic by stopping vehicles in the towns. Segregation of through traffic from parking and footways is preferable for safety.

Road Design Class 1: Multilane divided road (4 lane paved freeway with a median)
The typical dimensions are shown in Figure 5-19.

<table>
<thead>
<tr>
<th>Road design class</th>
<th>Dimension (m)</th>
<th>Slope (%)</th>
<th>Median* width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RRw</td>
<td>RWw</td>
<td>Cw</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
<td>28.0 to 31.0</td>
<td>2x7.0</td>
</tr>
</tbody>
</table>

* Note that the width of the inner shoulder is included in the width of the median. Recommended width is 0.9 m, minimum requirement is 0.75 metre.

Figure 5-19: Typical cross section for a dual carriageway, design class 1
Road Design Class 2 to 5: Two lane paved road
The typical dimensions are shown in Figure 5-20.

<table>
<thead>
<tr>
<th>Road design class</th>
<th>Dimension (m)</th>
<th>Slope (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RRw</td>
<td>RWw</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>11.5</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>11.0</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>9.5</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>8.5</td>
</tr>
</tbody>
</table>

* Note that the 3.75 metre lane width can be substituted with 3.5 metre lanes with 0.5 metre painted median

Figure 5-20: Typical cross sections for two lane paved roads, design class 2 to 5

Road Design Class 6 to 8: Low volume roads
The typical dimensions are shown in Figure 5-21.

<table>
<thead>
<tr>
<th>Road design class</th>
<th>Dimension (m)</th>
<th>Slope (%)</th>
<th>Surface type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RRw</td>
<td>RWw</td>
<td>Cw</td>
</tr>
<tr>
<td>6</td>
<td>40</td>
<td>11.5</td>
<td>7.5</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>11.0</td>
<td>7.5</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>9.5</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Figure 5-21: Typical cross sections for gravel or earth roads, design class 6 to 8
Dimensions given in figures 5-19, 5-20 and 5-21 above are for typical cross sections. Alternatives to the dimensions suggested may be appropriate for particular conditions. Careful consideration should be given to the function of the cross-sectional element before departing from the recommended values. Where a variation is local, e.g. to accommodate the use of a narrow structure because it is not economically feasible to replace or upgrade it, due attention must be paid to the provision of adequate road signs and markings warning drivers of the inconsistency in design.
Chapter 6 Alignment Design

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Chapter 6 Alignment Design

6.1 INTRODUCTION

The alignment is defined as the combination of horizontal and vertical geometric elements giving the location of the road in the terrain. Alignment design should take care of road safety, comfort, aesthetics, economics and environmental factors. During the design of roads the design control factors covered in chapter 4 should be taken on board. Furthermore the road designer should ensure consistency in the design of the horizontal and vertical alignment and the cross section and that there are no abrupt changes in the geometric standards of the roads. This is due to the fact that abrupt changes in the road design standards could defy drivers’ expectation and therefore cause serious accidents. The design aspects on cross sectional elements have been covered in chapter 5.

Coordination of the horizontal and vertical alignments is also covered to ensure a proper combination of the horizontal and vertical alignments for safety and aesthetic purposes.

The designer is required to follow these standards and at the same time exercise sound engineering judgment. Consideration on application of road signs should also be made where the standards cannot be achieved due to economic or other justifiable reasons. Particular attention should be given to sight distance considerations which are integral part of road safety.

6.2 SIGHT DISTANCES

6.2.1 General Considerations

Simply put, sight distance is the distance visible to the driver of a passenger car. For highway safety, the designer must provide sight distances of sufficient length to ensure that drivers can control the operation of their vehicles when driving on the road. They must be able to avoid striking an unexpected object on the travelled way. Two-lane highways should also have sufficient sight distances to enable drivers to occupy the opposing traffic lane for passing manoeuvres, without risk of accidents.

Two-lane rural highways should generally provide such passing sight distances at frequent intervals and for substantial portions of their length (see Table 6-1).

6.2.2 Stopping Sight Distance

The stopping sight distance on a roadway must be sufficiently long to enable a vehicle traveling at the design speed to stop before reaching a stationary object in its path. The minimum stopping sight distance is determined from the following formula, which takes into account both the driver reaction time and the distance required to stop the vehicle. The formula is:

\[
SSD = 0.278 \times t \times V + \left( \frac{V^2}{254(f+G)} \right)
\]

Where:
- SSD = stopping sight distance [m]
- t = driver reaction time, generally taken as 2.5 seconds
- V = Vehicle speed [km/h]
- f = coefficient of longitudinal friction
- G = percent grade, + for up grade and – for down grade [%/100]
Table 6-1: Sight Distances on Level Ground (G=0)

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Coefficient of Friction (f)</th>
<th>Stopping sight distances (m)</th>
<th>Passing sight distances from formulae (m)</th>
<th>Reduced passing sight distances for design (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>.40</td>
<td>30</td>
<td>217</td>
<td>75</td>
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<tr>
<td>40</td>
<td>.38</td>
<td>45</td>
<td>285</td>
<td>125</td>
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<tr>
<td>50</td>
<td>.35</td>
<td>63</td>
<td>345</td>
<td>175</td>
</tr>
<tr>
<td>60</td>
<td>.33</td>
<td>85</td>
<td>407</td>
<td>225</td>
</tr>
<tr>
<td>70</td>
<td>.31</td>
<td>110</td>
<td>482</td>
<td>275</td>
</tr>
<tr>
<td>80</td>
<td>.30</td>
<td>130</td>
<td>540</td>
<td>315</td>
</tr>
<tr>
<td>90</td>
<td>.30</td>
<td>169</td>
<td>573</td>
<td>340</td>
</tr>
<tr>
<td>100</td>
<td>.29</td>
<td>205</td>
<td>670</td>
<td>375</td>
</tr>
<tr>
<td>110</td>
<td>.28</td>
<td>247</td>
<td>728</td>
<td>399</td>
</tr>
<tr>
<td>120</td>
<td>.28</td>
<td>285</td>
<td>792</td>
<td>425</td>
</tr>
</tbody>
</table>

The values shown in the third column of table 6-1 for minimum stopping sight distance are rounded from the above formula.

If terrain or right-of-way problems result in an inability to meet these criteria, right-of-way must be obtained and/or geometrics improved to meet this important safety element.

Alternatively in rare cases it may be necessary to seek a Departure from Standard, and here a reduction would require lowering the design speed in the section and provision of proper signage.

Control of Sight Distance

A. On Crest Vertical Curves

The sight distances should be checked during design, and adjustments made to meet the minimum requirements. The following values should be used for the determination of sight lines:

- Driver’s eye height: 1.07 meters
- Object height for stopping sight distance: 0.15 meters
- Object height for passing sight distance: 1.30 meters

Figure 6-1 illustrates sight distance criteria for crest vertical curves.
B. **On Sag Vertical Curves**

![Figure 6-2: Stopping sight distance in a sag curve](image)

C. **On Horizontal Circular Curves**

On the inside of horizontal curves, it may be necessary to remove buildings, trees or other sight obstructions or widen cuts on the insides of curves to obtain the required sight distance. (See Figure 6-3).

![Figure 6-3: Sight distance for horizontal curves](image)

The sight line (L_s) for horizontal curves is a chord and is measured using the centreline of the inside lane around the curve. Relevant formulae are as follows:

**Line of sight (L_s)**

$$L_s = 2RS\sin\left(\frac{\Delta}{2}\right)$$

Where:

- R = Radius (m) to the centreline of the inside lane
- $\Delta$ is the deflection angle in degrees subtended by line of sight

**Middle ordinate (M)**

$$M = R\left(1 - \cos\left(\frac{\Delta}{2}\right)\right)$$
Where:
M = Middle ordinate
R = Radius (m) and
\( \Delta \) is the deflection angle in degrees subtended by line of sight

Example: Radius = 1000 metres, \( \Delta = 20^\circ \);

\[
L_s = 2RSin\left(\frac{\Delta}{2}\right) \\
M = R\left(1 - Cos\left(\frac{\Delta}{2}\right)\right)
\]

\[
= 2(1000)Sin\left(\frac{20^\circ}{2}\right) \\
= 1000\left(1 - Cos\left(\frac{20^\circ}{2}\right)\right)
\]

\[
= 347 \text{ metres} \\
= 15.2 \text{ metres}
\]

The available sight distance needs to be checked separately for both stopping and passing sight distance, for each direction of travel.

Height criteria do not affect design for horizontal curves to fit minimum stopping sight distance requirements except where the obstruction is a cut slope. In that case the following values should be used:

- Height of eye - 1.07 m
- Height of object - 0.15 m

A height of 0.6 m can be used to approximate the midpoint of the sight line where a cut slope on the inside of curve, obstructs the line of sight. The critical point on a cut is a point 0.6m above the road (pavement) level for stopping sight distance checking.

In order to satisfy the required stopping sight distance for any design speed, the middle ordinate calculated per the relationship above should not be less than that shown in Table 6-2.
### Table 6-2: Minimum distance (M) from the centreline of inside lane to an obstruction

<table>
<thead>
<tr>
<th>Radius (m)</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
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</thead>
<tbody>
<tr>
<td>30</td>
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<td>40</td>
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<td>4.9</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>3.7</td>
</tr>
</tbody>
</table>

#### 6.2.3 Stopping Sight Distance: Single Lane Roads

Certain classes of roads only have a single lane, with passing pull-outs. In these circumstances, a stopping sight distance is required to enable both approaching drivers to stop. This distance is the sum of the stopping sight distance for the two vehicles, plus a 30-metre safety distance. The resultant distance is that shown in Table 6-1, doubled, plus 30 metres.

Example:

As can be noted from Table 6-1, a vehicle of a speed of 50 km/h, the SSD required is 63 m. Therefore the SSD for a single lane road is:

\[
\text{SSD} = (63 \times 2) + 30 = 156 \text{ metres}
\]

#### 6.2.4 Passing Sight Distance

Passing Sight Distance is the minimum sight distance on two-way single carriageway roads that must be available to enable the driver of one vehicle to pass another vehicle safely without interfering with the speed of an oncoming vehicle travelling at the design speed.
Within the sight area the terrain should be the same level or a level lower than the roadway.

Otherwise, for horizontal curves, it may be necessary to remove obstructions and widen cuttings on the insides of curves to obtain the required sight distance. Care must be exercised in specifying passing/no-passing zones in areas where the sight distance may be obscured in the future due to vegetation growth.

The passing sight distance is generally determined by a formula with four components, as follows:

- $d_1$ = initial manoeuvre distance, including a time for perception and reaction
- $d_2$ = distance during which passing vehicle is in the opposing lane
- $d_3$ = clearance distance between vehicles at the end of the manoeuvre
- $d_4$ = distance traversed by the opposing vehicle

The formulae for these components are as indicated below:

$$d_1 = 0.278 t_1 \left( v - m + \frac{a t_1}{2} \right)$$

Where:
- $t_1$ = time of initial manoeuvre in sec
- $a$ = average acceleration, km/h/s
- $v$ = average speed of passing vehicle, km/h
- $m$ = difference in speed of passed vehicle and passing vehicle, km/h

$$d_2 = 0.278 \, v \, t_2$$

Where:
- $t_2$ = time the passing vehicle occupies right lane, s
- $v$ = average speed of passing vehicle, km/h

$d_3$ = safe clearance distance between vehicles at the end of the manoeuvre, is dependent on ambient speeds as per Table 6-3:

<table>
<thead>
<tr>
<th>Speed Group (km/h)</th>
<th>50 - 65</th>
<th>66 - 80</th>
<th>81 - 100</th>
<th>101 - 120</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_3$ (m)</td>
<td>30</td>
<td>55</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

$d_4$ = distance traversed by the opposing vehicle, which is approximately equal to $d_2$ less the portion of $d_3$ whereby the passing vehicle is entering the right lane, estimated at:

$d_4 = 2d_3/3$

The minimum Passing Sight Distance (PSD) for design is therefore:

$$PSD = d_1 + d_2 + d_3 + d_4$$

Resulting passing sight distances are included in Table 6-1.
The usual values resulting from application of the formulae are reduced in this manual, as it is deemed appropriate to address the distances covered by twice the $d_4$ distance and the clearance distance $d_3$. A driver finding that he has insufficient distance after initiating the passing manoeuvre can choose to abort the manoeuvre (see Figure 6-4). Values for Minimum Passing Sight Distance at various design speeds are given in the fifth column of Table 6-1.

### 6.2.5 Decision Sight Distance

Decision sight distance is the distance required for a driver to detect an unexpected or otherwise difficult-to-perceive information source or hazard in a roadway environment that may be visually cluttered, recognize the hazard or its potential threat, select an appropriate speed and path, and initiate and complete the required safety manoeuvre safely and efficiently. Because decision sight distance gives drivers additional margin for error and affords them sufficient length to manoeuvre their vehicles at the same or reduced speed rather than to just stop, its values are substantially greater than stopping sight distances.

### 6.3 Horizontal Alignment

#### 6.3.1 General

The design elements of a horizontal alignment are the tangent (straight section), the circular curve, the transition curve (spiral curve) and the superelevation section. These elements are presented in detail in the following text.

#### 6.3.2 Tangent Section

The tangent section is the straight section of the road before meeting the curved sections and after departing from the curved sections. The straight sections have an advantage of providing good Sight Distances for passing and stopping. However they have disadvantage of causing headlights glare and accidents due to fatigue and over speeding. It is therefore recommended that the length of straights on a road should not exceed 2 kilometres. Short straights between curves turning in the same direction could cause a “broken back” effect and therefore should be avoided.

#### 6.3.3 Circular Curve

Circular curves are introduced between the tangents to facilitate for smooth movement during change of direction. It is recommended that circular curves should be long enough to avoid kink appearance. The minimum length of circular curves shall be 150 m and where the deflection angle is less than 5
degrees, the minimum length of curves shall be 200 m. The circular curves should not be too long to avoid tracking problems especially when the radius is small. Curves which are too long also tend to cause problems to the overtaking sight distances. The desirable maximum length of circular curve is 800 m and absolute maximum length of curve shall be 1000 m. Figure 6-5 shows various features of a circular curve.

---

**Figure 6-5: Elements of a circular curve**

1. PI is the point of the intersection of the two tangents
2. T is tangent length, \( T = R \tan(\Delta/2) \)
3. \( \Delta \) is the deflection angle formed by the intersection of the two tangents at the PI
4. \( L \) is the length of the arc (curve) between the BC and EC, \( L = \Delta \times R \times \frac{2\pi}{360} \)
5. LC is the long chord length between the BC and the EC, \( LC = 2R \sin(\Delta/2) \)
6. E is the external distance from the PI to the centre of the arc, \( E = R \sec(\Delta/2) - 1 \)
7. M is the Middle ordinate, the distance from the middle of the arc to the midpoint of the Long Chord, \( M = R(1 - \cos(\Delta/2)) \)
8. BC is the beginning of curve, also known as Point of Curvature (PC), and is the point where the tangent ends and the curve begins, \( BC = PI - T \)
9. EC is end of curve, also known as Point of Tangency (PT), and is the point where the curve ends, and the tangent starts, \( EC = BC + L \)
10. R is the radius. It is the distance from the centre of the circle (O) to any point on the circumference
### 6.3.4 Minimum Curve Radii

When vehicles pass around a horizontal curve they experience centrifugal forces which tend to pull them away from the centre of the road. These are counteracted by superelevation and side friction forces between the tyres and the road. Design speed is a very important control factor which affects alignment design including determination of minimum curve radius. The minimum radius for design of Tanzanian roads is obtained from the formula which relates design speed and superelevation rate as below.

\[ R_{\text{min}} = \frac{V_D^2}{127(e + f)} \]

Where:
- \( R_{\text{min}} \) = Minimum Radius for Road Curves (m)
- \( V_D \) = Design Speed (km/h)
- \( e \) = Cross fall of road or the maximum superelevation (\%/100). The value of \( e \) may represent the simple removal of adverse cross fall or include superelevation (\( e \) = positive for cross slopes sloping down towards the inside of the curve and otherwise negative).
- \( f \) = Coefficient of side friction force developed between the vehicle’s tires and road pavement (Table 6-4 Indicates the side friction factors used to determine the minimum radiiuses for different design speeds).

Table 6-5 summarizes the values for minimum Radii which shall be applied to curves in geometric design. The absolute minimum radii are the mandatory radii which should be applied to design roads. The desirable minimum radii are provided to give the best, where the terrain and economy permits. Where isolated curves are to be designed the radius of the curves should not be less than 1.5 times the values indicated in Table 6-5. Isolated curves are curves introduced after long stretches of straights say after 2 km. The increase of the minimum radius in such stretches is due to the fact that it is not easy for a driver to notice a curve after driving for a long straight stretch.

#### Table 6-4: Side friction factors for different design speeds

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Limiting value of f</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.17</td>
</tr>
<tr>
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<td>110</td>
<td>0.11</td>
</tr>
<tr>
<td>120</td>
<td>0.09</td>
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</tbody>
</table>

Source: UGDM
6.3.5 Superelevation

Vehicles passing around circular curves are forced out of the curves by centrifugal forces. Superelevation is the raising of the edges of a road towards the centre of a horizontal curve in order to counteract centrifugal forces.

A. Guidelines for application of Superelevation

The maximum rate of superelevation for bituminous roads shall be 0.08 (8%) for flat, rolling and hilly terrain and 0.06 (6%) for mountainous terrain. For gravel roads the maximum rate of superelevation shall not exceed 0.06 (6%). In urban areas where traffic congestion or extensive marginal development acts to curb top speeds, it is common practice to utilize a low maximum rate of superelevation, usually 4%. Similarly, either a low maximum rate of superelevation or no superelevation is employed within important intersection areas or where there is a tendency to drive slowly because of turning and crossing movements, warning devices, and signals. Superelevation is a requirement for all standards of roads.

Guidance for application of superelevation for bituminous roads is provided in Tables 6-6 to 6-8.

Note from the Tables: NC=Normal Crown, RC=Remove Adverse Crown.
<table>
<thead>
<tr>
<th>R(m)</th>
<th>Vd=40 km/h e(%)</th>
<th>Vd=50 km/h e(%)</th>
<th>Vd=60 km/h e(%)</th>
<th>Vd=70 km/h e(%)</th>
<th>Vd=80 km/h e(%)</th>
<th>Vd=90 km/h e(%)</th>
<th>Vd=100 km/h e(%)</th>
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Table 6-7: Superelevation rates and other values for design elements related to design speed and horizontal curve (emax=6%, NC=2.5%)

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Table 6-8: Superelevation rates and other values for design elements related to design speed and horizontal curve (emax=8%, NC=2.5%)

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<td>4.5%</td>
<td>5.4%</td>
<td>6.3%</td>
<td>7.2%</td>
<td>8.1%</td>
<td>8.9%</td>
<td>9.5%</td>
<td>10.0%</td>
</tr>
<tr>
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<td>RC</td>
<td>4.0%</td>
<td>5.1%</td>
<td>6.2%</td>
<td>7.1%</td>
<td>7.9%</td>
<td>8.8%</td>
<td>9.5%</td>
<td>10.0%</td>
<td>10.4%</td>
</tr>
<tr>
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<td>6.7%</td>
<td>7.6%</td>
<td>8.5%</td>
<td>9.3%</td>
<td>10.0%</td>
<td>10.5%</td>
<td>11.0%</td>
</tr>
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<td>8.4%</td>
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<td>Rmin</td>
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<td>120</td>
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<td>7.4%</td>
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</tr>
<tr>
<td>119</td>
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<td>6.3%</td>
<td>7.6%</td>
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<td>Rmin</td>
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<tr>
<td>80</td>
<td>5.5%</td>
<td>7.2%</td>
<td>8.0%</td>
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</tr>
<tr>
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<td>Rmin</td>
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<td>Rmin</td>
<td>Rmin</td>
<td>Rmin</td>
<td>Rmin</td>
<td>Rmin</td>
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<tr>
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<td>6.9%</td>
<td>8.0%</td>
<td>Rmin</td>
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<td>Rmin</td>
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<td>30</td>
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<td>Rmin</td>
<td>Rmin</td>
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<td>Rmin</td>
<td>Rmin</td>
<td>Rmin</td>
<td>Rmin</td>
<td>Rmin</td>
</tr>
</tbody>
</table>
B. **Guidelines for application of Superelevation on Gravel Roads**

The maximum rates for super elevation to be applied on gravel roads shall be calculated using the following relationship:

\[
e = \frac{V_D^2}{260R}
\]

Where:
- \(e\) = super elevation rate (decimals)
- \(V_D\) = design speed (km/h)
- \(R\) = radius of curve (m)

- The values of superelevation to be applied shall be rounded – off to the nearest 0.001 or 0.1%.
- The maximum rate of superelevation for gravel roads shall be 0.06 (6%) irrespective of terrain classification.

Below is guidance for application of superelevation where the value of \(e\) computed by the formula above is less than 0.03;

- For \(0.03 \geq e > 0.002\) remove adverse crown only
- For \(e < 0.002\) use normal camber

C. **Distribution of superelevation within the horizontal alignment**

Superelevation within a curve is applied by rotating the road lanes from the normal camber until the road attains full superelevation. The rotation is divided in two stages which are called Tangent Runoff and Superelevation runoff. This rotation can be done around the road centreline, the edge of the inner lane or the edge of the outer lane. For the purpose of design of the roads in Tanzania the rotation shall be done around the road centreline.

Tangent Runoff (TR) is the length of the road whereby the normal camber on the outside of the curve is rotated until adverse crown is removed from the outer half of the road carriageway.

Superelevation Runoff (SR) is the length of the road from the point with adverse crown removed up to the point where the road has attained the maximum superelevation.

For circular curves without transition curves 2/3 of the superelevation runoff shall be within the tangent while 1/3 shall be applied within the circular curve. Figure 6-6 illustrates application of superelevation on circular curves without transition curves.

For curves with transition curves, full superelevation shall be applied within the transition curves. In this case the length of superelevation runoff is the spiral length beginning with the tangent to spiral (TS) and ending with Spiral to Circular Curve (SC). The change in cross slope begins by removing of the adverse crown from the lane or lanes on the outside of the curve on tangent runoff just before TS and rotating the road cross section until reaching full superelevation at SC. Figure 6-7 illustrates application of superelevation on transition curves.

The length of superelevation run-off is given by the formula:
Where:
\[ L_r = \left( \frac{w n_1}{a} \right) e_d (b_w) \Delta s \]

- \( L_r \) = Length of superelevation runoff;
- \( e_d \) = Value of design superelevation in percent;
- \( \Delta s \) = Rate of change of superelevation (relative gradient) in percentage as given in Table 6-9;
- \( w \) = Width of one traffic lane, m
- \( n_1 \) = Number of lanes rotated,
- \( b_w \) = Adjustment factor for number of lanes rotated (Table 6-10)

### Table 6-9: Maximum and Minimum rate of Change of Superelevation

<table>
<thead>
<tr>
<th>Design Speed Km/h</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. ( \Delta s ) (%)</td>
<td>0.75</td>
<td>0.7</td>
<td>0.65</td>
<td>0.6</td>
<td>0.55</td>
<td>0.5</td>
<td>0.47</td>
<td>0.44</td>
<td>0.41</td>
<td>0.38</td>
</tr>
<tr>
<td>Min. ( \Delta s ) (%)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

### Table 6-10: Adjustment Factors for Number of Lanes Rotated

<table>
<thead>
<tr>
<th>Number of lanes Rotated</th>
<th>Adjustment Factor</th>
<th>Length Increase Relative to One-Lane Rotated (=n,b_w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>1.0</td>
</tr>
<tr>
<td>1.5</td>
<td>0.83</td>
<td>1.25</td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>1.5</td>
</tr>
<tr>
<td>2.5</td>
<td>0.70</td>
<td>1.75</td>
</tr>
<tr>
<td>3</td>
<td>0.67</td>
<td>2.0</td>
</tr>
<tr>
<td>3.5</td>
<td>0.64</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Figure 6-6: Application of superelevation on circular curves
The minimum length of tangent runout is calculated by the formula below:

\[ L_t = \frac{e_0}{e_d} \cdot L_r \]

Where:
- \( L_t \) = minimum length of tangent runout, m;
- \( L_r \) = Length of superelevation runoff;
- \( e_d \) = Value of design superelevation in percent, %;
- \( e_0 \) = Normal Cross Slope in percent, %;

### 6.3.6 Rotation of Shoulders during superelevation application

Shoulder slopes that drain away from the paved surface on the outside of well-superelevated sections due to drainage problems should be designed to avoid too great a cross-slope break. The algebraic difference of the travel way and shoulder grades at a high edge-of-travel way should be not more than nine percent (see Figure 6-8). It is desirable that all paved shoulders should be sloped upward at the same rate as the travel way.

Figure 6-8 provides guidance on rotation of the shoulders during application of superelevation to carriageway.
6.3.7 Widening on Curves

The required width of the road convenient for vehicles to be able to manoeuvre safely depends on the speed at which the vehicle is moving. The minimum carriage width for roads is provided in Table 4.4 of chapter 4.7.1.
Widening of the road width on sections with curves can be implemented in order to allow for manoeuvre when vehicles are moving at high speeds, allow for sweeping area for trucks and to provide for psychological feeling of safety when the road is passing on embankment with high fills. Where transition curves are provided, widening may be placed on the inside or divided equally between the outside and inside of the circular curve. On curves which have no transition, the widening should be applied on the inside edge of the pavement only. Regardless of how widening is effected; the final centreline markings should be placed midway between the edges of the widened pavement.

Table 6-11: Widening needed for a road with a carriageway of 6.5m

<table>
<thead>
<tr>
<th>Curve Radius (m)</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>100 *)</th>
<th>110 *)</th>
<th>120 *)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>40</td>
<td>2.75</td>
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<td></td>
</tr>
<tr>
<td>50</td>
<td>2.25</td>
<td>2.25</td>
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</tr>
<tr>
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<td>2.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>1.75</td>
<td>1.75</td>
<td>1.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1.25</td>
<td>1.25</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>200</td>
<td>0.50</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td></td>
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<tr>
<td>250</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>0.50</td>
<td>0.50</td>
<td>0.75</td>
<td>0.75</td>
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<td>0.50</td>
<td>0.50</td>
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<tr>
<td>400</td>
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<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.50</td>
<td>0.50</td>
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<td>0.40</td>
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<td>600</td>
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<td>0.50</td>
<td>0.50</td>
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<tr>
<td>800</td>
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<td>0.50</td>
</tr>
<tr>
<td>1000</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.50</td>
</tr>
</tbody>
</table>

*) Lanes ought to be 3.5 m wide at ADT=1500 in the design year

Note:
The values given are for a 6.50 m carriageway, for other widths the following modification shall be made:
6.00 m carriageway: 0.50 m has to be added to the values in the Table, while for 7.00 m carriageway: 0.50 m has to be subtracted from the values in the Table and for 7.5 m carriageway 1.00 m shall be subtracted.

Where negative values of curve widening are obtained, it means that there will be no curve widening but the designed carriageway width shall be adopted throughout the road.

### 6.3.8 Transition Curves

Transition curves are provided to ensure a smooth transition between tangents and circular curve. They start at the tangents with radius equal to infinity and join the circular curves with radius equal to that of the circular curve.

The advantages of transition curves are to enable smooth turning movement of vehicles between tangents and circular curves, provide basis for application of superelevation and for aesthetic purposes. Transition curves are spirals, parabolic or cubic parabola. For the purpose of design of Tanzanian
roads the spirals (clothoidal) transition curves should be applied. Figure 6-9 illustrates application of superelevation to circular curves with transition curves.

Transition curves shall be applied to circular curves under the following condition:

\[ R < \frac{V_D^3}{432} \]

Where:
- \( R \) = Radius of the circular curve (m)
- \( V_D \) = Design Speed in km/h

**Transition curve lengths**

The length of the clothoid transition curves is computed by the following equation:

\[ L = \frac{A^2}{R} \]

Where:
- \( L \) = Length of the transition curve (clothoid).
- \( A \) = Clothoid parameter
- \( R \) = radius of circular curve

To estimate the length of transition curve needed, three criteria are to be used and the higher value shall be adopted. These criteria are driver’s comfort, application of superelevation and Aesthetics as described below:

(a) **Drivers Comfort**

For comfort to the driver and the people in vehicles passing around a transition curve, the rate of the change of centripetal acceleration should be 0.5 m/sec\(^3\) and 0.6 m/sec\(^3\) for design speeds greater and equal or less than 50 km/h respectively. To meet this criterion the transition length (\( L \)) should be:

\[ L = \frac{V_D^3}{28R} \] for design speeds less than 50 km/h

\[ L = \frac{V_D^3}{23.3R} \] for design speeds greater than 50 km/h

Where:
- \( V_D \) = Design Speed (km/h)
- \( R \) = Radius for the circular curve (m)

(b) **Superelevation run-off to be contained within the transition**

The length of the transition curve should be at least equal to the required superelevation run-off length. To meet this criterion, the length of the transition (\( L \)) for a two lane road should be:
Where:
\[ e_0 = \text{cross slope} -2.5\% \]
\[ \Delta S = \text{rate of change of superelevation} \]
\[ C = \text{Carriageway width (m)} \]
\[ e = \text{maximum superelevation for the curve} \]

(c) **Aesthetics**
In order for the clothoid to display good aesthetic characteristics, it should subtend an angle of at least 3°. This condition is met if the length of the transition (L) is:

\[ L = \frac{R}{9} \]

Where:
\[ L = \text{Length of transition curve} \]
\[ R = \text{Radius of the Circular curve} \]
The three criteria described above are normally used to estimate minimum length of transition curves, however there are some cases where the computed value will be greater than what can practically be accommodated in the circular curves. In that case the maximum value of transition curve indicated in the equation below shall be considered.

\[ L_{s\text{max}} = \sqrt{\frac{24R}{V_o^2}} \]

Where:
- \( L_{s\text{max}} \) = maximum length of transition curve (m)
- \( R \) = Curve radius (m)

Furthermore it should be noted that the criteria on aesthetics can bring very big transition curve lengths in case of radiiuses greater than 1000 m and therefore engineering judgement should be exercised to ensure that such curves can be accommodated within the circular curves, otherwise the remaining two criteria can be considered.

### 6.3.9 Successive Curves

Three cases of successive curves are considered in this manual as shown in Figure 6-10. These are:

1. Circular Curves followed by circular curves in opposite direction known as Reverse Curves.
2. Circular Curves followed by circular curves each with different tangents in the same direction known as Broken Back or Flat Back Curves
3. Circular Curves followed by circular curves sharing the same tangents in the same direction known as Compound Curves
A. **Reverse Curves**

When applying a reverse curve abrupt change of alignment should be avoided. There should be a connecting tangent or a section of equal lengths including spirals as shown in Figures 6-11 to allow for change of superelevation between the curves. The clothoidal parameters should not be very different. In case of difference $A_1$ should fulfil the condition $A_1 \leq 1.5 \ A_2$:

\[
\text{Where } A_1 \text{ and } A_2 \text{ are the clothoidal parameters of the larger and the smaller clothoids respectively.}
\]

The relationship means that the radius of the larger curve shall not exceed fifty percent more than the radius of the smaller curve.
B. Broken Back curves

Broken back curves are not recommended due to the fact that drivers do not normally expect successive curves bending in the same direction (see Figure 6-12). However where a need arises the circular curves shall be separated by a tangent of a length not less than 150m. Where the curves bending in the same direction are separated by a tangent of more than 500m they are not considered as broken back curves.
C. Compound Curves

Compound curves are adjacent curves bending in the same direction connected with tangent lines intersecting at a common point of intersection and therefore there is no straight in-between the curves. It is recommended that the radii of the adjoining curves should not be very different. In order to make sure that the drivers do not experience much difference as they pass through the two adjoining curves the larger radius $R_1$ should not be greater than 1.5 times the smaller radius $R_2$ or mathematically $R_1 \leq 1.5R_2$:

Where $R_1$ and $R_2$ are the larger and the smaller radiuses respectively.

Figure 6-10 shows a compound curve as one type of successive curves. In case of a transition curve between compound curves the clothoidal parameter $A$ should be between $\frac{1}{2}$ and 1 times the smaller radius. Therefore it should fulfil the relationship.

$$\frac{1}{2} R_2 < A < R_2$$

Where:

$R_2$ is the smaller radius and $A$ is the clothoidal parameter.

6.3.10 Hairpin Curves

The designer is sometimes forced to apply curves with very small radii in mountainous terrain and escarpments. In that case the designer is required to provide hairpin curves also known as switch back curves, which will allow design vehicles to be able to pass around the curve safely (see Figure 6-13). During design of hairpin curves it is important to ensure that $R_1$ and $R_2$ satisfy the minimum inner and out radii of the design vehicles shown in Figure 4.1 and 4.2 of chapter 4.

Figure 6-13: Hairpin curve
**6.4 Vertical Alignment**

Vertical alignment consist of gradients (straights) connected to vertical curves which are normally parabolic. During the design of the vertical alignment, safety, comfort and aesthetic factors need to be considered.

### 6.4.1 Gradients

During the design of the vertical alignment it is important to ensure that the gradients provided comply with maximum gradients for the design speed. The designer shall also ensure that the length of the grades do not exceed the critical lengths as shown in Table 6-13.

#### (a) Limiting grades

Recommended maximum grades are given in Table 6-12. For low volume rural roads with short lengths of grades (less than 150m) the value in the Table can be increased by 1%

Minimum grades on cut sections shall usually be 0.5% unless special drainage treatments are provided.

<table>
<thead>
<tr>
<th>Terrain</th>
<th>Design Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Flat</td>
<td>5</td>
</tr>
<tr>
<td>Rolling</td>
<td>8</td>
</tr>
<tr>
<td>Hilly/ Mountainous</td>
<td>10</td>
</tr>
</tbody>
</table>

#### (b) Critical Length of grades

Critical Length of grade is the maximum length of the designated up-grade on which a loaded truck can operate without unreasonable reduction in speed. As such the length of all grades shall be limited to the values given in Table 6-13 for a 20 km/h reduction in speeds of trucks (from the average running speed).

<table>
<thead>
<tr>
<th>Gradient</th>
<th>Length of grade at design speed of 60 km/h</th>
<th>Length of grade at design speed of 80 km/h</th>
<th>Length of grade at design speed of 100 km/h</th>
<th>Length of grade at design speed of 120 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%</td>
<td>NA</td>
<td>≥ 900 m</td>
<td>≥ 175 m</td>
<td>0</td>
</tr>
<tr>
<td>4%</td>
<td>≥ 1200 m</td>
<td>≥ 550 m</td>
<td>≥ 125 m</td>
<td>0</td>
</tr>
<tr>
<td>5%</td>
<td>≥ 800 m</td>
<td>≥ 400 m</td>
<td>≥ 110 m</td>
<td>0</td>
</tr>
<tr>
<td>6%</td>
<td>≥ 600 m</td>
<td>≥ 350 m</td>
<td>≥ 90 m</td>
<td>0</td>
</tr>
<tr>
<td>7%</td>
<td>≥ 500 m</td>
<td>≥ 300 m</td>
<td>≥ 75 m</td>
<td>0</td>
</tr>
<tr>
<td>8%</td>
<td>≥ 400 m</td>
<td>≥ 200 m</td>
<td>≥ 40 m</td>
<td>0</td>
</tr>
</tbody>
</table>

If the algebraic difference is appreciable, one quarter (1/4) of the vertical curve length may be considered as part of the critical length of grade.
(c) Climbing Lanes
Where the critical lengths of gradients cannot be achieved consideration needs to be given to application of climbing lanes. A climbing lane is an auxiliary lane provided to remove the slow moving trucks from the traffic stream climbing a gradient in order to improve safety and the Level of Service.

Warrant for climbing lanes
Once the critical lengths of gradients shown in Table 6-13 are exceeded the designer should consider the traffic, terrain and economic factors before deciding on whether to introduce a climbing lane or not. A traffic volume of ADT ≥ 1500 shall warrant for introduction of climbing lane when the critical length of gradients is exceeded.

Design of climbing lanes
It is recommended that the width of the climbing lanes be the same as the width of the adjacent lane. Shoulders should be tapered (see fig 6-16) to allow for escape of merging vehicle in case of hindrance to merging to the main lane due to presence of traffic in the lane. Care should be taken to ensure that climbing lanes do not merge in curves wherever possible. Figures 6-14 to 6-16 provide guidance on design of climbing lanes.
Figure 6-15 Climbing lane entrance

Figure 6-16 Climbing lane terminal
Guidance on determination of start and end points of climbing lanes

By following the steps below, the start and end points of the climbing lanes can be determined. The distances from the beginning of the upgrade to points A and B as well as the distances form the crest to points D and E as shown in Figure 6-14 shall be determined during the design. These distances are referred to as $L_A$, $L_B$, $L_D$, and $L_E$ respectively. See illustration below.
Determine:

1) The first gradient, $g_1$ [\%], and the second gradient, $g_2$ [\%].

2) The speed at the beginning of the grade, $V_1$ [km/h], and the allowable speed reduction, $V_{RDC}$ [km/h] (for the purpose of this manual= 20 km/h). Calculate the climbing lane entrance speed, $V_2$ [km/h], by using the formula:

$$V_2 = V_1 - V_{RDC}$$

$V_2$ is the speed of the slow moving vehicle entering the climbing lane at point B as shown in Figure 6-14.

3) From Figure 6-17, determine lengths $L_1$ [m] and $L_2$ [m];

$L_1$ is read from where $V_1$ intersects the $g_1$ deceleration curve,

$L_2$ is read from where $V_2$ intersects the $g_1$ deceleration curve.

$L_1$ and $L_2$ express the critical lengths over which a vehicle is able to maintain the given speeds ($V_1$ and $V_2$ respectively) while moving up the grade at a given constant gradient.

4) Determine the distance from the start of the grade to point B, $L_B$ [m]. The distance is calculated as:

$$L_B = L_2 - L_1$$

Choose climbing lane entrance taper length, $L_{T1}$ [m] (minimum =100 m) and calculate the distance from the start of the grade to point A, $L_A$ [m], as:

$$L_A = L_B - L_{T1}$$
Next, the placement of the climbing lane terminal follows.

5) From Figure 6-17, read the lowest speed, $V_{\text{LOW}}$ [km/h], from where the $L_1 + L_{\text{GRADE}}$ intersects the $g_1$ deceleration curve.

$V_{\text{LOW}}$ is the speed reached after travelling the length of the grade when reaching point C. Over longer grades, the speed of a vehicle will eventually reach a constant level. This can be seen obtained from the deceleration asymptotes in Figure 6-17.

6) From Figure 6-17, determine lengths $L_3$ [m] and $L_4$ [m];

$L_3$ is read from where $V_{\text{LOW}}$ intersects the $g_2$ acceleration curve,

$L_4$ is read from where $V_2$ intersects the $g_2$ acceleration curve.

$L_3$ and $L_4$ express the critical lengths over which a vehicle is able to accelerate to a given speed while moving downhill, straight or less uphill at a given gradient.

7) The distance from the crest to point D, $L_D$ [m], is calculated as:

$$L_D = L_4 - L_3$$

By choosing the length of the terminal taper which again should be at least 100 m, the distance from the crest to point E can be simply be calculated.

Choose terminal taper length, $L_{T2}$ [m] (minimum length is 100 m), and calculate the distance $L_E$ [m] as:

$$L_E = L_D + L_{T2}.$$ 

Example of use of Figure 6-17:

A truck has a speed of 80 km/h at the beginning of a grade of a gradient of 5%. Reading the length at 80 km/h and 60 km/h, (80 km/h - 20 km/h = 60 km/h) at $s = 5\%$, one get lengths of 150 m and 450 m respectively. The difference is 300 m and this implies that after 300 m a climbing lane with full width has to be established at point B in Figure 6-14. The climbing-lane has to be continued until the truck is gaining a speed of 60 km/h. This length can also be found in Figure 6-17. The lowest speed a truck at 5% is 32 km/h assuming the length of the grade is long enough for a truck to achieve this speed. The grade is followed by a downhill of 2% and hence the length computed to the crest as shown in Figure 6-17. Taking the acceleration line -2% and reading the length at 30 km/h and 60 km/h respectively, gives 0 m and 240 m which signify that the lane has to be extended to 240 m past the crest. In addition the taper has to be added.
Example

Figure 6-19: Computation of grade to the crest
6.4.2 Vertical Curves

Figure 6-20 (a): Vertical Curves in roads
G₁ and G₂, Tangent grades in percent
A, Algebraic difference between the gradients (G₂ - G₁)
L, Length of vertical curve

PVC, Point of Vertical Curvature
PVI, Point of Vertical Intersection
PVT, Point of Vertical Tangency

Figure 6-20 (b): Crest Vertical Curves

G₁ and G₂, Tangent grades in percent
A, Algebraic difference between the gradients (G₂ - G₁)
L, Length of vertical curve

PVC, Point of Vertical Curvature
PVI, Point of Vertical Intersection
PVT, Point of Vertical Tangency

Figure 6-20 (c): Sag vertical curves

Figures 6-20 indicates the vertical curves for roads and associated parameters. Vertical curves in highways are usually parabolic and the levels are computed using the formula.

\[ LEV_x = LEV_{BVC} + G_1x + \frac{(G_2 - G_1)x^2}{2L_{VC}} \]

Where;
LEVₓ = Level at a point, x metres from the beginning of vertical curve
LEV_BVC = Level at the beginning of vertical curve
G₁ = slope of the first tangent in percentage
G₂ = slope of the second tangent in percentage
x = distance from the beginning of the vertical curve
L_VC = length of vertical curve.

Sight distances:
Minimum stopping and passing sight distances are provided in Table 6-1. It should be noted that the minimum sight distances are for both horizontal and vertical alignment (curves).

Vertical curves are specified in terms of rate of curvature K and the Algebraic difference between gradients. The vertical curves lengths are related to K by the formula:

\[ L = KA \]
6.34 Chapter 6
Alignment Design

Where:
\[ L = \text{Length of vertical curve} \]
\[ K = \text{Rate of vertical Curvature (the required length of crest/ sag curve to a 1\% change in gradients)} \]
\[ A = \text{Algebraic difference between the gradients (g2-g1)} \]

Recommended minimum rate of curvature (K) for vertical curves are given in Table 6-14. Where the K-value is greater than 51 a special attention should be given to drainage design. Where kerbs are used it may be necessary to remove them so as to provide adequate transverse drainage. Where the algebraic difference between the gradients is 0.5\% or less the computed length of the vertical curves from the K-values and A may be so small such that an impression of a kink can be observed in the vertical alignment. Engineering judgement shall be exercised to obtain reasonable lengths of curves and at the same time providing solution to drainage challenges. It is practically very expensive to construct a vertical alignment meeting the conditions for passing Sight Distance due to the fact that such a construction will need a lot of cuts and fills. It is therefore recommended to adhere to stopping sight distances during road design. The K values for passing Sight Distance can be used to indicate whether overtaking should be permitted during road marking and provision of traffic signs or not.

<table>
<thead>
<tr>
<th>Design Speed km/h</th>
<th>K-Values to Satisfy stopping sight distances (m / % of g)</th>
<th>K-Values to satisfy passing sight distances (m / % of g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crest</td>
<td>Sag</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>40</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>60</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>70</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>80</td>
<td>49</td>
<td>32</td>
</tr>
<tr>
<td>90</td>
<td>71</td>
<td>41</td>
</tr>
<tr>
<td>100</td>
<td>105</td>
<td>51</td>
</tr>
<tr>
<td>110</td>
<td>151</td>
<td>62</td>
</tr>
<tr>
<td>120</td>
<td>201</td>
<td>74</td>
</tr>
</tbody>
</table>

6.5 Coordination Of Horizontal and Vertical Alignment

Phasing of the vertical and horizontal alignment elements of a road implies their coordination so that the line of the road appears to a driver to flow smoothly avoiding the creation of hazards and visual defects. A superior design which ensures a proper combination between the horizontal and vertical alignments increases safety, encourage uniform speed and improve appearance without significant additional cost.

Alignment coordination should start at the preliminary design stage. This can be done by printing both the horizontal and vertical alignment in the same rolls of sheets and study how they match together. This visualisation can also be done by design software. Some major points on alignment coordination which need to be considered during road design are described below:
1. The best alignment is obtained when the horizontal and vertical curves are separated in design. However due to the fact that it is practically difficult to separate the horizontal and vertical curves, a satisfactory alignment can be obtained when the intersection points of vertical and horizontal curves nearly coincide or are within about 10% of the horizontal curve length. The start of the horizontal curve is then clearly visible to the driver.

2. A larger number of horizontal intersection points than vertical points is undesirable. And where the horizontal alignment is straight, a sequence of closely spaced crest and sag curves must be avoided as it may appear as horizontal but may hide oncoming traffic.

3. The beginning of a horizontal curve shall always fall within the available sight distance. Thus, a horizontal curve should never be introduced near the top or end of a sharp crest curve. The same applies for sharp horizontal curves at the bottom of steep grades.

4. On dual carriageways, variations in the width of the median and the use of separate horizontal and vertical alignment should be considered to derive the design and operational advantage of one-way roads. Another advantage is a possible reduction of construction cost by being able to fit each section separately to the terrain.

5. Sharp horizontal curves should not be placed near low points of vertical curves. This violates driver expectations as operating speeds are higher on bottom of the curve.

6. Flatten both Vertical and Horizontal curves near intersections to enhance sight distances.

6.5.1 The Elements

Six basic forms for the space curves can be defined. There are a number of long-established rules on how to combine these elements in different terrain situations. Some of these are summarized in Figure 6-21.
6.5.2 Principles of Alignment Coordination

A clothoid gives a form that facilitates the driver to choose his lateral position in the lane in the curve reducing short-cutting. It also gives a smoother alignment. The narrower the road the more important is the use of transition curves to create lane designs used by the driver and to create a harmonic road design adapted to the surroundings.
It is important that deviations between the elements of the alignment are large enough. The minor the change in direction the larger is the arc needed to avoid kinks in the alignment.

It is also important that vertical elements arc lengths are large enough to avoid kinks, especially for concave vertical curves (sags). The illustration in Figure 6-24 shows a comparison of transitions from –2 % to +3 % with a 210 m long vertical curve with radius \( R = 4000 \) m and a 900 m long vertical curve with radius \( R = 18000 \) m.
Two consecutive arcs bending in the same direction connected with a short straight should be avoided vertically as well as horizontally as illustrated in Figure 6-25. The highway designers should also avoid consecutive curves with diminishing radii because they are dangerous.

As shown in Figure 6-26, the S-curve may need particular attention. The ratio between the horizontal radius Rh and the vertical radius Rv should be as small as possible, at least with Rh / Rv < 1/5 to 1/10. Moreover, the changeover should be vertically and horizontally reasonably coordinated. The vertical curves should be small or large to facilitate the best passing sight distance conditions as illustrated in the Figure 6-26.
6.5.3 Examples of Mis-Coordination and Corresponding Corrective Action

When the horizontal and vertical curves are adequately separated or when they are coincident, no phasing problem occurs and no corrective action is required. Where defects occur, phasing may be achieved either by separating the curves or by adjusting their lengths such that vertical and horizontal curves begin at a common station and end at a common station. In some cases, depending on the curvature, it is sufficient if only one end of each of the curves is at a common station.

Cases of mis-phasing fall into several types. These are described below together with the necessary corrective action for each type.

- **Vertical Curve Overlaps One End of the Horizontal Curve**
  If a vertical curve overlaps either the beginning or the end of a horizontal curve, a driver’s perception of the change of direction at the start of the horizontal curve may be delayed because his sight distance is reduced by the vertical curve. This defect is hazardous. The position of the crest is important because the vehicles tend to increase speed on the down gradient following the highest point of the crest curve, and the danger due to an unexpected change of direction is consequently greater.

  If a vertical sag curve overlaps a horizontal curve, an apparent kink may be produced, as indicated in Figures 6-27b and c.
The defect may be corrected in both cases by completely separating the curves. If this is uneconomic, the curves must be adjusted so that they are coincident at both ends, if the horizontal curve is of short radius, or they need be coincident at only one end, if the horizontal curve is of longer radius.

- **Insufficient Separation between the Curves**
  If there is insufficient separation between the ends of the horizontal and vertical curves, a false reverse curve may appear on the outside edge-line at the beginning of the horizontal curve. This is a visual defect, illustrated in Figure 6-27d.

  Corrective action consists of increasing the separation between the curves, or making the curves concurrent, as in Figure 6-27a.

- **Both Ends of the Vertical Curve Lie on the Horizontal Curve**
  If both ends of a crest curve lie on a sharp horizontal curve, the radius of the horizontal curve may appear to the driver to decrease abruptly over the length of the crest curve.

  If the vertical curve is a sag curve, the radius of the horizontal curve may appear to increase. An example of such a visual defect is shown in Figure 6-27e.

  The corrective action is to make both ends of the curves coincident as in Figure 6-27a, or to separate them.

- **Vertical Curve Overlaps Both Ends of a Horizontal Curve**
  If a vertical crest curve overlaps both ends of a sharp horizontal curve, a hazard may be created because a vehicle has to undergo a sudden change of direction during the passage of the vertical curve while sight distance is reduced.

  The corrective action is to make both ends of the curves coincident. If the horizontal curve is less sharp, a hazard may still be created if the crest occurs off the horizontal curve. This is because the change of direction at the beginning of the horizontal curve will then occur on a downgrade (for traffic in one direction) where vehicles may be increasing speed.

  The corrective action is to make the curves coincident at one end so as to bring the crest on to the horizontal curve.

  No action is necessary if a vertical curve that has no crest is combined with a gentle horizontal curve.

  If the vertical curve is a sag curve, an illusory crest or dip, depending on the “hand” of the horizontal curve will appear in the road alignment.

  The corrective action is to make both ends of the curves coincident or to separate them.

- **Other Mis-Coordination**
  Other types of mis-phasing are also indicated in Figure 6-27:
A sag curve occurs between two horizontal curves in the same direction in Figure 6-27g. This illustrates the need to avoid broken back curves in design.

A double sag curve occurs at one horizontal curve in Figure 6-27h. This illustrates the effect in this case of a broken back vertical alignment on design.

Figure 6-27i shows a lack of phasing of horizontal and vertical curves. In this case, the vertical alignment has been allowed to be more curvilinear than the horizontal alignment.

Figure 6-27: Coordination of horizontal and vertical curves
6.5.4 Economic Consequences of Alignment Coordination

The phasing of vertical curves restricts their fitting to the ground so that the designer is prevented from obtaining the lowest cost design. Therefore, phasing is usually bought at the cost of extra earthworks and the designer must decide at what point it becomes uneconomic. He/she will normally accept curves that have to be phased for reasons of safety. In cases when the advantage due to phasing is aesthetic, the designer will have to balance the additional costs against their aesthetic contribution.
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Chapter 7 At Grade Intersections

7.1 General

An intersection, or junction, is the general area where two or more roads join, or cross, within which are included the carriageway(s) and roadside facilities for traffic movement in that area.

An intersection is a critical part of a road because the efficiency, safety, speed, cost of roads operation, and capacity of the road depend on the intersection design. The main objective of intersection design is to reduce the severity of potential conflicts between vehicles, bicycles, and pedestrians. In addition, the intersection design should facilitate the convenience, ease, and comfort of people travelling through the intersection and, at the same time, assure ease of drivers in making the necessary manoeuvres.

Although each intersection may have unique physical characteristics that distinguish from another intersection, Designers should adhere to uniform standards presented here in so as to avoid violation of driver expectancy.

Most of the intersection-accidents occur at the very lightly trafficked at-grade intersections and from a traffic-safety aspect these lightly trafficked intersections require as much attention as do those intersections where heavier conflicting traffic movements occur. Good intersection design should allow transition from one route to another or through movement on the main route and intersecting route with minimum delay and maximum safety. The layout and operation of the intersection should be obvious to the driver, with good visibility between conflicting movements. Crests, gradients and curves should be avoided and if absolutely inevitable, T-intersections on the outside of a curve will have much better visibility than those that are located on the inside of a curve. Furthermore, the number of intersections should be kept as low as possible consistent with traffic demands and their spacing should be as big as possible.

Intersections should not be located where it is difficult or expensive to provide adequate visibility or driving comfort. Locations which should be avoided are for example where earthworks are heavy, near bridges, on small radius curves, on the outside of super-elevated curves, on high embankments, steep grades (>3%) or on crests.

This chapter describes the design of basic types of at-grade intersections and the various criteria that should be considered. Grade separated intersections are described in chapter 8.

7.2 Intersection Types

Different at-grade intersection types will be appropriate under different circumstances depending on traffic flows, speeds, and site limitations.

The three basic types of at-grade intersections are the T intersection (with variations in the angle of approach), the four-leg intersection, and the multi-leg intersection. In each particular case the type is determined by the number of legs, the topography, the character of the intersecting roads, the traffic patterns and speeds, and the desired type of operation. Multi-leg intersection should be avoided whenever practical.
7.2.1 An Access

An access shall be defined as the intersection of an unclassified road with a classified road and shall generally be provided within the road reserve boundary of the classified road. An access, for instance to a private house, shall have entry and exit radii of between 6 and 15 metres, see Figure 7.1, depending upon the turning characteristics of the expected traffic with no left or right turning lanes, left turn merging lane or traffic islands. The minimum width shall be 4m. The approach to the main road along the access road should be level with the surface of the main road for the last 5-10 metres. The layout and location of the access must satisfy the visibility requirement for “stop” conditions given in Figure 7-12. A drainage culvert shall be placed as required.

However in certain locations, the constant daily vehicular movement or heavy peak hour flows at an access may justify its design to junction standards. This may occur, for example, at an entrance to an industrial development or factory site.

![Figure 7-1: Typical Access](image)

7.2.2 Junctions

For the purpose of this Manual, a junction shall be defined as the intersection of two or more classified roads on the same surface at grade and the design procedures and standards in this manual shall be applied to such intersections.

7.2.3 Classification of At-Grade Intersections

At grade intersections can be classified into two main intersection categories based on the type of control used. For each category, there are a number of different intersection types.

These types of at-grade intersection are shown in the table below:
Table 7-1: Types of at-grade Intersections

<table>
<thead>
<tr>
<th>Intersection category</th>
<th>Traffic control Major road</th>
<th>Traffic control Minor road</th>
<th>Intersection types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority intersection</td>
<td>Priority</td>
<td>Stop or give a sign</td>
<td>A Unchannelised T-intersection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B Partly Channelised T-intersection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C Channelised T-intersection</td>
</tr>
<tr>
<td>Control intersection</td>
<td>Traffic signals or give a sign</td>
<td></td>
<td>D Roundabout</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>E Signalised intersection</td>
</tr>
</tbody>
</table>

7.2.3.1 Priority Intersections

Priority intersections will be adequate in most rural situations. Three types of T intersections are given below:

- **Unchannelised T-intersection (Type A)**
  The unchannelised design is suitable for intersections where there is a very small amount of turning traffic. It is the simplest design and has no traffic islands.

- **Partly Channelised T-intersection (Type B)**
  The partly channelised design is for intersections with a moderate volume of turning traffic. It has a traffic island in the minor road arm. In urban areas, the traffic island would normally be kerbed in order to provide a refuge for pedestrians crossing the road.

- **Channelised T-intersection (Type C)**
  The fully channelised design is for intersections with a high volume of turning traffic or high speeds. It has traffic islands in both the minor road and the main road.

Typical priority intersections in rural areas are shown in Figure 7-2.

![Unchannelised T-intersection](image1)

![Partly channelised T-intersection](image2)

![Channelised T-intersection](image3)

Figure 7-2: Typical T-intersections
The crossroads form of priority intersection is not recommended to be used. It has a very high number of conflict points, and has a much higher accident risk than any other kind of intersection. Existing crossroads should, where possible, be converted to a staggered intersection, or roundabout, or be controlled by traffic signals.

### 7.2.3.2 Control Intersections

Control intersections are mostly used in towns and trading centres. However, roundabouts can be used in rural areas in intersections between major roads or other intersections with high traffic volumes. A basic requirement for all controlled intersections is that drivers must see the control device soon enough to perform the action it indicates.

There are two types of control intersections:

- **Roundabout (Type D)**
  Roundabouts are controlled by the rule that all entry traffic must give way to circulating traffic. The ratio of minor road incoming traffic to the total incoming traffic should preferably be at least 10 to 15%. Roundabouts can be of normal size, i.e. with central island radius 10m or more, or small size, i.e. with central island radius less than 10 m.

- **Signalised intersection (Type E)**
  Signalised intersections have conflicts separated by traffic signals. No conflicts are allowed between straight through traffic movements.

Typical layouts of control intersections are shown in Figure 7.3.

![Roundabout and Signalised intersection](image)

**Figure 7-3: Typical layouts for control intersections**

### 7.2.4 Intersection Manoeuvres

Three basic movements or manoeuvres occur at intersections, namely merging, cutting and diverging. These manoeuvres are illustrated below.
7.2.5 Intersection Design Speed

The Intersection Design Speed, which is the principal design parameter upon which the geometrical layout and capacity of an intersection is based, is the design speed of the major road in the vicinity of the intersection. This design speed will not necessarily be the same as the average major road design speed but may be higher or lower. Therefore, the designer must give careful consideration to the selection of the appropriate Intersection Design Speed as this will greatly affect both the safety and efficiency of the intersection and the construction cost.

For reasons of economy, the Intersection Design Speed shall not be more than 20 km/h higher than the average design speed of the major road.

For safety reasons, the Intersection Design Speed should never be less than 20 km/h lower than the average design speed for the major road.

7.2.6 The Major Road

At T-intersections, the through road, which will usually be carrying the higher traffic volume, shall be considered the major road.

At four, or more, leg intersections, the major road shall be the road with the higher sectional characteristics as determined by:

(a) Right of way regulations on adjoining junctions
(b) Vehicle operating speeds
(c) Traffic volumes

The longer the section of road with continuous priority, higher vehicle operating speeds and/or traffic volumes, the higher rated the sectional characteristics shall be, regardless of the administrative classification of the road.
7.3 Design Requirements

The design of at-grade intersections must take account of the following basic requirements:
• safety;
• operational comfort for the users;
• capacity; and,
• economy.

7.3.1 Safety and Operational Comfort

An intersection is considered safe when it is perceptible, comprehensible and manoeuvrable. These three requirements can generally be met by complying with the following guidelines.

(a) Perception
(i) The intersection should be sited so that the major road approaches are readily visible.
(ii) Early widening of the intersection approaches.
(iii) The use of traffic islands in the minor road to emphasize a “yield” or “stop” requirement.
(iv) The use of early and eye-catching traffic signs.
(v) Optical guidance by landscaping and the use of road furniture, especially where an intersection must be located on a crest curve.
(vi) The provision of visibility splays which ensure unobstructed sight lines to the left and right along the major road.
(vii) The angle of intersection of the major and minor roads should be between 70 and 110 degrees.
(viii) The use of single lane approaches is preferred on the minor road in order to avoid mutual sight obstruction from two vehicles waiting next to each other to turn or cross the major road.

(b) Comprehension
(i) The right of way should follow naturally and logically from the intersection layout.
(ii) The types of intersections used throughout the whole road network should be as much as possible similar.
(iii) The provision of optical guidance by the use of clearly visible kerbs, traffic islands, road markings, road signs and other road furniture.

(c) Manoeuvrability
(i) All traffic lanes should be of adequate width for the appropriate vehicle turning characteristics. To accommodate truck traffic, turning radii shall be at least 15 metres.
(ii) The edges of traffic lanes should be clearly indicated by road markings.
(iii) Traffic islands and kerbs should not conflict with the natural vehicle paths.

7.3.2 Capacity

The operation of uncontrolled intersections depends principally upon the frequency of gaps which naturally occur between vehicles in the main road flow. These gaps should be of sufficient duration to permit vehicles from the minor road to merge with, or cross, the major road flow. In consequence intersections are limited in capacity, but this capacity may be optimized by, for example, channelisation or the separation of manoeuvres.
Adequate capacity shall be a primary design requirement for controlled intersections. Designers shall use acceptable procedures such as those published by HCM to estimate capacity.

7.3.3 Economy
An economical intersection design generally results from minimization of the construction, maintenance and operational costs.

Delay can be an important operational factor and the saving in time otherwise lost may justify a more expensive and even grade separated intersection.

Loss of lives, personal injuries and damage to vehicles caused by intersection-accidents are considered as operational “costs” and should be taken into account.

The optimum economic return may often be obtained by a phased construction, for example by constructing initially an at-grade intersection which may later be grade separated.

7.4 Selection of Intersection Type
7.4.1 General
This sub-chapter mainly deals with traffic safety and capacity related to intersection types. Other important impacts such as road user costs, environmental issues, investment and maintenance costs should also be taken into consideration.

Intersection type is first determined before appropriate geometric design is developed.

The safety requirement for intersections can be defined as an interval where the expected number of accidents should not exceed a tolerable level and must not exceed a maximum level. If the expected number of accidents does not exceed the tolerable level, a priority intersection should be selected. If the number exceeds the maximum level, a control intersection should be selected. Between the two defined levels, a control intersection should be considered. The traffic flow threshold values presented in figures 7.5 and 7.7 are based on this concept using general European traffic safety research results on the relationship between speed and incoming traffic flows on the major and minor roads. The diagrams are judged reasonable to be used in Tanzania until sufficient local research is available.

The selection is divided into two steps; selection of intersection category (priority or control) and selection of intersection type. It is based on the following assumptions:

- Priority intersections can be safe and give sufficient capacity for certain traffic volumes and speed limits;
- If a priority intersection is not sufficient for safety and capacity, the major road traffic must also be controlled; and,
- Depending on location, traffic conditions and speed limits, different types of priority or control intersection should be selected.

7.4.2 Selection of Intersection Category
Safety
The selection of intersection category should mainly be based on safety. The selection can be made by using diagrams with the relationships between the safety levels and the average annual daily
approaching traffic volumes (AADT in veh/day) based on accident statistics. The diagrams shown in Figure 7-5 are for T-intersections on 2-lane roads with 50, 80 and 100 km/h design speed.

![Diagrams of intersection capacity based on safety for T-intersections]

**Figure 7-5: Selection of intersection category as to safety for T-intersections**

*Source: UGDM*

**Capacity**

The selection of intersection category based on safety should be checked for capacity. It can be made by using diagrams with the relationships between the capacity and the approaching traffic volumes during the design hour (DHV in pcu/design hour). The diagrams shown in Figure 7-6 are for T-intersections on 2-lane roads with 50, 80 and 100 km/h speed limit.

The desired level refers to a degree of saturation (actual traffic flow/capacity) of 0.5. The acceptable level refers to a degree of saturation of 0.7.
The diagrams are based on Swedish capacity studies with findings similar to other European countries. It is judged reasonable to be used in Tanzania until sufficient Tanzanian research is available. Capacity could be checked more in detail using standard capacity software.

Figure 7-6: Selection of intersection category as to capacity for T-intersections
Source: UGDM
7.4.3 Selection of intersection Type

Priority intersections

The selection of priority intersection type should mainly be based on safety. The selection can be made by using diagrams with the relationships between the safety levels and the average annual daily approaching traffic volumes (AADT in veh/day) based on accident statistics. The diagrams shown in Figure 7-7 are for T-intersections on 2-lane roads with 50, 80 and 100 km/h design speed. Crossroads should be avoided. The number of right turners should obviously also impact the decision.

The diagrams are based on general European findings on safety effects of right turn lanes. Note however they are only a starting point for determining the most appropriate form of intersection.

![Selection of priority intersection type as to safety for T-intersections](Source: UGDM)
Partly channelised T-intersection should normally be used if needed to facilitate pedestrian crossings and also if the minor road island is needed to improve the visibility of the intersection.

**Control intersections**
Roundabouts are suitable for almost all situations, provided there is enough space. Roundabouts have been found to be safer than signalised intersections, and are suitable for both low and medium traffic flows. At very high traffic volumes they tend to become blocked due to drivers failing to obey the priority rules. Well-designed roundabouts slow traffic down, which can be useful at the entry to a built-up area, or where there is a significant change in road standard, such as the change from a dual carriageway to a single carriageway.

Traffic signals are the favoured option in the larger urban areas. Co-ordinated networks of signals (Area Traffic Control) can bring major improvements in traffic flow and a significant reduction in delays and stoppages. However, they must be demand-responsive, in order to get the maximum capacity from each intersection.

For some traffic distributions, for example high traffic volumes on the major road, the total delay can be shorter in a signalised intersection than in a roundabout. The diagram in Figure 7-8 shows the traffic conditions for which signalised intersections are most suited, based on Kenyan and UK experience.

![Diagram showing traffic conditions for signalised and roundabout intersections](https://example.com/figure7-8.png)

*Figure 7-8: Selection of control intersection type*
Source: UGDM

If a signalised intersection is considered based on planning conditions or traffic volumes, capacity analysis and economic analysis should be made. This should include road construction and maintenance costs, accident costs, travel time costs, vehicle operating costs and environmental costs.

### 7.5 Intersection Design Procedure

The design procedure should be used for new intersections as well as for upgrading of existing intersections. Intersection design is normally done in two stages i.e. preliminary design and detailed design.

The objective with the preliminary design is to select the intersection type and location and to make a draft intersection drawing and traffic control plan. The objective with the detailed design is to do
the geometric design and to make a detailed intersection drawing and traffic control plan. As with all road projects, it is required that a safety audit be done before the scheme is finalised and built. The procedure to be used for intersection design involves four basic steps which are as follows:

(i) Data collection (see Sub-chapter 7.5.1).
(ii) Define the major road (Sub-chapter 7.2.6) and determine the intersection design speed (Sub-chapter 7.2.5).
(iii) Select intersection category and type and check that it offers adequate safety and capacity for the predicted traffic manoeuvres (Sub-chapter 7.4).
(iv) Refine and modify the basic intersection layout to meet the safety and operational requirements outlined in Sub-chapter 7.3.1. This is done by applying the principles of intersection design which are described in detail in Sub-chapter 7.6 under the following headings:

(a) Distance between adjoining intersections
(b) Visibility splays
(c) Turning lanes
(d) Major Road Cross Section
(e) Central reserves
(f) Traffic islands and minor road widening
(g) Alignment and Widening of the major road

7.5.1 Data Collection
The following data will be required to ensure that a safe, economic and geometrically satisfactory design is produced:

(a) A plan to a scale of at least 1:500, showing all topographical details.
(b) Characteristics of the crossing or joining roads, i.e. horizontal and vertical alignments, distances to adjoining intersections, cross-sectional data, vehicle operating speeds, etc.
(c) Characteristics of the predicted volumes and compositions of the various traffic streams.
(d) Other factors affecting the design, such as topographical or geotechnical peculiarities, locations of public utilities, pedestrian movements, adjacent land usage, etc.
(e) Traffic accident data, especially where the reconstruction of an existing intersection is involved.

7.5.2 Basic Intersection Layout
The basic junction layout (intersection type) for both single and dual carriageway roads is the T-junction with the major road traffic having priority over the minor road traffic. Crossroads, although not recommended, may also be used but only on single carriageway roads where traffic flows are very low and where site conditions will not permit the use of staggered T-junctions. Selection of intersection category and type is to be carried out as outlined in Sub-chapter 7.4.

Where staggered T-junctions are used to replace a crossroads, the right-left stagger as indicated in Figure 7-9 is preferred to the left-right stagger and the minimum stagger should be 50m. On traffic grounds this is because in the latter case opposing queues of right turning vehicles from the major road will have to wait side by side with the consequent possibility of the whole junction locking.
In a left/right staggered intersection the minimum distance should be at least 100 metres and should be longer in order to allow the provision of right turn lanes in the major road. The length of right turn lane depends on the junction design speed and traffic turning right in pcu/h.

Where there is a lot of cross traffic (from one minor road to the other) the right/left stagger is preferable. This is because, once the driver has turned into the main road, he can proceed to the exit without impeding other traffic. The left/right stagger involves vehicles turning right out of the main road across the path of oncoming traffic, and this is a particularly hazardous manoeuvre.

Figure 7-9: Right/Left and Left/Right staggered intersections and their respective minimum distances

Where more complex junction layouts involving the intersection of four or more roads are encountered, these should be simplified by realigning the approaches, to safer, more comprehensible and manoeuvrable layouts. For safety and economic reasons, intersection roads shall meet at or nearly 90 degrees. Examples of such simplifications are given in Figure 7-10.
7.6 Principles of Intersection Design

The basic principles of good intersection design are:

- minimize the number of conflict points, and thus the risk of accidents;
- give priority to major traffic movements, through alignment, signing and traffic control;
- separate conflicts in space or time;
- control the angle of conflict; crossing streams of traffic should intersect at a right angle or near right angle;
- define and minimise conflict areas;
- define vehicle paths;
- ensure adequate sight distances;
- control approach speeds using alignment, lane width, traffic control or speed limits;
- provide clear indication of right-of-way requirements;
- minimise roadside hazards;
- provide for all vehicular and non-vehicular traffic likely to use the intersection, including goods vehicles, public service vehicles, pedestrians and other vulnerable road users;
- simplify the driving task, so that road users have to make only one decision at a time; and,
- minimise road user delay.

Having selected the basic junction layout and checked that it offers sufficient capacity, it is necessary to adapt this basic layout in accordance with the following principles to ensure that a safe, economic and geometrically satisfactory design will be produced.
7.6.1 Distance Between Adjoining Intersections

The minimum distance between consecutive intersections shall preferably be equal to \((10 \times VD)\) metres; where \(VD\) is the major road design speed in km/h. Where it is impossible to provide this minimum spacing, then the design shall incorporate either, or both, of the following:

(i) A distance between minor road centrelines equal to the passing sight distance appropriate for the Junction Design Speed plus half the length of the widened major road sections at each junction, or

(ii) A grouping of minor road junctions into pairs to form staggered T-junctions and a distance between pairs as in (i) above.

7.6.2 Visibility Splays

At major/minor priority junctions visibility splays to the standards described below should be provided at all new junctions and should be aimed at for existing junctions.

The visibility splays for both the “Approach Conditions” (Figure 7-11) and the “Stop Conditions” (Figure 7-12) should be provided.

![Figure 7-11: Visibility Splays for “Approach” or “Yield” Conditions](image)

![Figure 7-12: Visibility Splays for “Stop” Conditions](image)
On the minor road, particularly where the approach to the junction is on a horizontal curve, the visibility of traffic signs is essential and a visibility splay in accordance with Figure 7-13 must be provided.

![Figure 7-13: Minor Road Approach Visibility Requirements](image)

Where site conditions make it impossible to improve an existing junction to these standards, at least the visibility splays for the “Stop Condition” must always be provided.

### 7.6.3 Turning Lanes

Left and right turning lanes are of particular value on the higher speed roads when a vehicle slowing down to turn and leave the major road and may impede following vehicles.

(i) **Left Turn Lanes**

Left turn lanes, comprising diverging sections and deceleration sections, shall be provided under any of the following conditions:

(a) On dual carriageway roads.
(b) When the Junction Design Speed is 100 km/h or greater and the AADT on the major road in Design Year 10 is greater than 2,000 pcu.
(c) When the AADT of the left turning traffic in Design Year 10 is greater than 800 pcu.
(d) Where junctions are sited on left-hand bends and perception of the junction for major road traffic would be greatly improved by its inclusion.
(e) On four or more lane undivided highways.

Figure 7-14 shows the recommended layout for a left turn lane.

![Figure 7-14: Layout for Left Turn Lane](image)

Note: For details of traffic islands and carriageway edges to minor road, see Sub-chapter 7.6.6
The minimum lengths for diverging sections are given in Table 7.2 and shall be formed by direct tapers. However, very long tapers should be avoided as through drivers tend to use them as through lane especially on a horizontal curve.

**Table 7-2: Minimum Length of Diverging Section \( L_{ds} \)**

<table>
<thead>
<tr>
<th>Junction design speed (km/h)</th>
<th>120</th>
<th>100</th>
<th>80</th>
<th>≤ 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of diverging section (m)</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
</tr>
</tbody>
</table>

The minimum lengths for deceleration sections are dependent upon the Junction Design Speed, the exit radius from the major road into the minor road and the approach gradient of the major road. Where left turn lanes are required, the exit radius shall be 25 metres and the minimum length of deceleration sections shown in Table 7-3 shall be used.

The lengths given in Table 7-3 apply for approach gradients of -2% to +2%; where approach gradients greater than 2% are encountered the lengths from Table 7-3 shall be multiplied by the adjustment factor given in Table 7-4 but the adopted lengths must never be less than 30 metres.

The width of the deceleration lane shall be the same as the major road approach lane.

**Table 7-3: Minimum Lengths for Left Turn Deceleration \( L_{ld} \) (for approach gradient of -2% to 2%)**

<table>
<thead>
<tr>
<th>Junction design speed (km/h)</th>
<th>120</th>
<th>100</th>
<th>80</th>
<th>≤ 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of deceleration section (m)</td>
<td>110</td>
<td>70</td>
<td>50</td>
<td>30</td>
</tr>
</tbody>
</table>

Note: Where vehicles are required to stop before entering the minor road, the deceleration section length should be equal to that used for a right turn lane as given in Table 7-5.

**Table 7-4: Adjustment Factors for Approach Gradient Greater Than 2%**

<table>
<thead>
<tr>
<th>% Downgrade</th>
<th>% Upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Stacking section or area \( L_s \) is normally 10 metres long.

Stacking/storage length may be based on the number of vehicles likely to arrive in an average of 2 minutes during peak hour. The stacking area shall accommodate at least two cars or one car and a truck under excessive heavy vehicle volumes conditions.

ii) Right Turn Lanes

A separate lane for right turning traffic (i.e. traffic turning right from the major road into the minor road) shall be provided under any of the following conditions:

(a) On dual carriageway roads.

(b) When the Junction Design Speed is 100 km/h or greater and the A.A.D.T, on the major road in Design Year 10 is greater than 1500 p.c.u.

(c) When the ratio of the major road flow being cut to the right turning flow exceeds the values given on Figure 7-15.

(d) On four, or more lane undivided roads.
Figure 7-15: Criteria for Determining the Provision of Right Turn Lanes
A right turn lane will consist of a diverging (taper) section, a deceleration section and a storage section.

The minimum lengths for diverging sections are as for left turn lanes and are given in Table 7-2 and shall be formed by direct tapers.

The minimum lengths for deceleration sections for approach gradients of -2% to +2% are given in Table 7-5. For approach gradients greater than 2% the adjustment factors given in Table 7-4 for left turn lanes shall be applied but the adopted lengths shall never be less than 30 metres.

### Table 7-5: Minimum Length for Right Turn Deceleration Section (for approach gradients of -2% to 2%)

<table>
<thead>
<tr>
<th>Junction design speed (km/h)</th>
<th>120</th>
<th>100</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of deceleration section (m)</td>
<td>160</td>
<td>105</td>
<td>85</td>
<td>75</td>
<td>70</td>
<td>50</td>
<td>30</td>
</tr>
</tbody>
</table>

The lengths of storage sections for right turning traffic are given in Table 7-6.

### Table 7-6: Length of Storage Section for Right Turning Traffic

<table>
<thead>
<tr>
<th>Traffic Turning Right (pcu/h)</th>
<th>Length of Storage Section (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 150</td>
<td>20</td>
</tr>
<tr>
<td>151 - 300</td>
<td>40</td>
</tr>
<tr>
<td>over 300</td>
<td>N x 9.75 (where N is number of pcu turning right per two minutes) (Factor must be checked).</td>
</tr>
</tbody>
</table>

The width of the deceleration and storage sections shall be 3.0 metres. For details of carriageway widening to accommodate right turning lanes, see Sub-chapter 7.6.7.

On single carriageway roads where a right turn lane is to be provided, a painted channelising island shall be used to separate the lane from the opposing traffic.

Figures 7-16 (a) and (b) show typical layouts for right turn lanes to single and dual carriageway roads respectively.

Notes:
1. Central reserve to be formed by Road markings (see Sub-chapter 7.6.5)
2. For details of minor road widening and traffic islands (see Sub-chapter 7.6.6)
3. For details of major road alignment and widening (see Sub-chapter 7.6.7)

Where: 
- \( L_C \) = Length of divering section
- \( L_D \) = Length of deceleration section
- \( L_S \) = Length of storage section
- \( W_L \) = Width of through carriageway
Notes:

1. Edges of central reserve may be kerbed in the vicinity of junction (Sub-chapter 7.6.5).
   If raised kerbs are used, they must be set back 0.25m from lane edges (Sub-chapter 7.6.6).

2. For details of minor road widening and Traffic islands (see Sub-chapter 7.6.6).

7.6.4 Major Road Cross Section

Excessive intersection widths should be avoided in order to discourage high speeds and overtaking. If section of major road is made across the full width of right turn lane it will have the view shown in Figure 7-17.

The maximum cross-section width is:

\[ W = W_{SI} + W_{L1} + W_R + W_T + W_{L2} + W_{S2} \]

- through lanes width, \( W_{L1} \) and \( W_{L2} \), should normally be unchanged through the intersection. However, if they are \( \geq 3.5 \) m on the approaches to the intersection, they could be slightly narrowed to discourage high speeds and overtaking, otherwise the width should be kept.
- the right turning lane width, \( W_R \), should normally be 3.0 m.
- the traffic island width, \( W_T \), depends on island type:
island created with road markings: normally 0.35 m for double centre line
kerbed island: space needed for:
  • pass left side only traffic sign, 0.4 to 0.9 m
  • lateral clearances, minimum 0.3 m
  • an inner hard shoulder, if needed, in the opposite direction, 0.25 to 0.5 m for an edge line

The total width will vary from minimum 1.2 m to 2.0 m.

paved shoulder widths, $W_{s1}$ and $W_{s2}$, are as per the design class of road, should be narrowed in two lane roads to 0.5 m in order to discourage overtaking in the intersection. Separate footways should be provided for pedestrians so that they do not have to walk on the shoulder.

Where there are many long vehicles turning right into the main road consider widening the central reserve so that it provides them with some protection if the driver decides to make the turn in two stages (i.e. crosses one major road traffic direction at a time).

### 7.6.5 Central Reserves

The widening of the central reserve of a dual carriageway in the vicinity of a junction may be required to allow more space for crossing vehicles to wait in safety. A width of 10 metres will normally provide the appropriate balance between safety and cost.

To ensure that vehicles can turn right without difficulty to, or from, a major road, the gap in the central reserve should extend beyond the continuation of both kerb lines of the minor road to the edge of the major road. Normally an extension of 3.0 metres will be sufficient but each layout should be checked. The ends of the central reserve should be curved to ease the paths of turning vehicles.

On single carriageway roads where a right turn lane is to be provided, a hatched central reserve shall always be used unless lighting is provided, in which case the central reserve may be kerbed.

On dual carriageway roads the central reserve in the vicinity of junctions should be edged with flush kerbs unless lighting is provided, in which case raised kerbs may be used.

### 7.6.6 Traffic Islands and Minor Road Widening

Traffic islands should be provided where necessary, at major/minor priority junctions, for the following reasons:

(i) To assist traffic streams to intersect or merge at suitable angles.
(ii) To control vehicle speeds.
(iii) To provide shelter for vehicles waiting to carry out certain manoeuvres such as turning right.
(iv) To assist pedestrians to cross.

Islands are either elongated or triangular in shape and are situated in areas not normally used as vehicle paths, the dimensions depending upon the particular junction or bus layout. Traffic islands bordered by raised kerbs should not be used in the major road unless lighting is provided but can be used without lighting in the minor road. To enable raised islands to be clearly seen they should have an area
of at least 4.5 square metres and where necessary additional guidance should be given by carriageway markings in advance of the nose supplemented, if necessary, by speed humps.

The layout of an island is determined by the edges of the through traffic lanes, turning vehicles and the lateral clearance to the island sides. The edges of all raised islands parallel to traffic lanes must be set back from the traffic lane edges by a minimum of 0.25 metres.

Generally two basic layouts for traffic islands and minor road widening will be used but each junction should be carefully checked to ensure that adequate clearance is given for the types of vehicles expected to use the junction; see Chapter 3 for details of design vehicle turning characteristics.

Intersection Layout Type C (channelised intersection), as shown on Figure 7-18, is to be used whenever a separate right turn lane is required in accordance with the requirements of Sub-chapter 7.6.3 (ii). It should be noted that this layout also makes provision for a left turn lane. However, the left turn lane may be omitted if the conditions described in Sub-chapter 7.6.3 (i) for its provision are not met; in such cases the exit radius should be amended to comply with the triple radius exit curve shown for Intersection Layout Type B and the triangular island omitted.

Intersection Layout Type B (partly channelised intersection), as shown on Figure 7-19, is to be used whenever a separate right turn lane is not required. The layout shown on Figure 7-19 does not include a left turn lane but such a lane may be included if the conditions for its provision, as described in Sub-chapter 7.6.3 (i), are met; in such cases the triple radius exit curve should be replaced by the 25 metre exit radius and an additional traffic island as shown for Intersection Layout Type C.
Notes:
1. $R_c$ = Central radius dependent upon vehicle turning characteristics (minimum turning radius) recommended value: 15 m.
2. The ratio $R_1:R_2:R_3$ to be 2:1:3 and the recommended value for $R_2$ is 12.0 m.
3. $W_1$ shall equal minor road lane width but shall not be less than 3.0m.
4. $W_2$ shall equal 5.5 m (Excluding offsets to raise kerbs)
5. For detail of major road widening, see Sub-chapter 7.6.7.

Figure 7-18: Intersection Layout Type C
Notes:

1. $R_c$ = Central radius dependent upon vehicle turning characteristics.
2. The ratio $R_1:R_2:R_3$ to be 2:1:3 and $R_2$ will be dependant of vehicles turning characteristics and proportion of large vehicles, recommended range for $R_2$ is 8.0-12.0 m.
3. $W_1$ shall equal minor road lane width.
4. $W_2$ shall be dependant upon vehicle turning characteristics.

Figure 7-19: Intersection Layout Type B
7.6.7 **Alignment and Widening of the Major Road**

In order to accommodate a right turn lane on a single carriageway road the carriageway has to be widened to provide the required width. The width of the through lanes at the junction shall be the same as the approach lanes.

The widening shall be designed so that the through lanes are given smooth and optically pleasing alignments.

On straight alignments, the widening shall be provided by the deviation of the through lane opposite the minor road. This deviation shall be effected so as to avoid the appearance of an unsightly “bulge” in the horizontal alignment. This shall be achieved by introducing radii of 7,500m at the beginning and end of the widening, 1 in 45 tapers and a radius of between 5,000 and 10,000 metres as shown diagrammatically on Figure 7-20 (a).

On curved alignments, a smooth alignment for the through lanes can be achieved by widening on the inside of the curve. This is done by introducing transition curves which approximate to 1 in 45 tapers as shown on Figure 7-20 (b).

It is advisable to lengthen the island, if the intersection is located on a crest or in a horizontal curve, as this will make the intersection more visible to approaching traffic.
Figure 7-20: Application of Widening to the Major Road
### 7.6.8 Checklist for Intersection Design

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Will the intersection be able to carry the expected/future traffic levels without becoming overloaded and congested?</td>
</tr>
<tr>
<td>2</td>
<td>Have the traffic and safety performance of alternative intersection designs been considered?</td>
</tr>
<tr>
<td>3</td>
<td>Is the route through the intersection as simple and clear to all users as possible?</td>
</tr>
<tr>
<td>4</td>
<td>Is the presence of the intersection clearly evident at a safe distance to approaching vehicles for all directions?</td>
</tr>
<tr>
<td>5</td>
<td>Are warning and information signs placed sufficiently in advance of the intersection for a driver to take appropriate and safe action given the design speeds on the road?</td>
</tr>
<tr>
<td>6</td>
<td>On the approach to the intersection, is the driver clearly aware of the actions necessary to negotiate the intersection safely?</td>
</tr>
<tr>
<td>7</td>
<td>Are turning movements segregated as required for the design standard?</td>
</tr>
<tr>
<td>8</td>
<td>Are drainage features sufficient to avoid the presence of standing water?</td>
</tr>
<tr>
<td>9</td>
<td>Is the level of lighting adequate for the intersection, location, pedestrians, and the design standard?</td>
</tr>
<tr>
<td>10</td>
<td>Are the warning signs and markings sufficient, particularly at night?</td>
</tr>
<tr>
<td>11</td>
<td>Have the needs of pedestrian and non-motorized vehicles been met?</td>
</tr>
<tr>
<td>12</td>
<td>Are sight lines sufficient and clear of obstructions including parked and stopped vehicles?</td>
</tr>
<tr>
<td>13</td>
<td>Are accesses prohibited a safe distance away from the intersection?</td>
</tr>
<tr>
<td>14</td>
<td>Have adequate facilities such as footpaths, refuges, and crossings, been provided for pedestrians?</td>
</tr>
<tr>
<td>15</td>
<td>Does the design, road marking and signing clearly identify rights of way and priorities?</td>
</tr>
<tr>
<td>16</td>
<td>Is the design of the intersection consistent with road types and adjacent intersection?</td>
</tr>
<tr>
<td>17</td>
<td>Are the turning lanes and tapers where required of sufficient length for speeds and storage?</td>
</tr>
</tbody>
</table>

Date: ............................................................................
Designer........................................................................

### 7.7 Design of Roundabouts

The following design items concerning roundabouts are covered in this section:

1. The use of roundabouts;
2. General requirements;
3. Design principles;
4. Sight distances;
5. Central island and circulating carriageway;
6. Entries;
7. Exits;
8. Combination of entries and exits; and
9. Pedestrian and cycle crossings.
7.7.1 The Use of Roundabouts

Generally, roundabouts should not be introduced on roads along rural areas. However, close to built-up areas where the through road may be crossed by local roads carrying high traffic volume, the use of roundabouts may be considered.

The following factors will influence the choice of providing a roundabout or some other form of control:

a) Safety
Roundabouts should not be introduced on roads along rural areas where the design speeds of adjacent sections are 80 km/h or greater.

Roundabouts may be introduced if the design speeds of the adjacent sections are:

i) less than 60km/h, or
ii) less than 80 km/h and the roundabout and approach roads are provided with overhead lighting.

b) Traffic flow
High proportions of turning movements favour roundabouts. Roundabouts should generally be used if the major road flow is less than 3 times the minor road flow. Roundabouts are an advantage where peak flows are greater than 1.5 times the average flows due high capacity.

c) Site conditions
Roundabouts generally take more land than fully channelised junctions. The additional land acquisition costs for roundabouts should be balanced with the increased capacity offered and less maintenance cost.

d) Driver behaviour
Roundabouts regulate traffic flow and should reduce accidents as well as increase capacity.

7.7.2 General Requirements

The following features are generally considered necessary for a roundabout to perform safely and efficiently:

• it must be easily seen and identified when drivers are approaching it;
• the design must encourage drivers to enter the intersection slowly (<50 km/h) and keep a low speed throughout – this is crucial to safety;
• the layout must be simple and easy to understand;
• it must be clearly signed and marked and where possible, lighting should be considered for safety.
• adequate, but not excessive sight distance, must be provided at all entry points to enable the driver to observe the movements of conflicting vehicles, pedestrians and cyclists.
7.7.3 Design Principles

Speed control
Approaching vehicles must be slowed down to 50km/h or less and this can be achieved in various ways including the use of a large centre island, offsetting the entry roads, and deflecting the entry roads sharply to the left as they join the circulatory carriageway. In practice all roundabouts must be designed with some entry deflection.

To keep the speed down to 50 km/h or less, the roundabout should be designed so that it is not possible to drive through it on a path (see Figure 7.31) with an exit radius not exceeding 100 m.

Number and alignment of entry roads
Roundabouts work best with four arms or entries, but they can also be used where there are three or five entries. More than five legs should not be considered.

Ideally, the entry roads should be equally-spaced around the perimeter with a minimum angle of 60 degrees between them.

In three arm intersections, the angles between the entry roads can be adjusted by displacement of the central island from the intersection point of the centrelines of the connecting roads or by deflection of the road alignments.

In five arm intersections, the space for the extra connection can be created by making the central island elliptical or by increasing the radius of the central island to at least 20 m. However, elliptical central islands can be confusing.

![Figure 7-21: Three and five arm roundabout](image)

7.7.4 Visibility and Sight Distances

Roundabouts should be located where; approaching drivers can have a good overview of the roundabout with its entries, exits and circulating carriageway. Stopping sight distances must be provided at every point within the roundabout and on all approaches.

The visibility splays shown in Figure 7.22 must be provided to allow drivers to judge whether it is safe to enter the roundabout. It must be possible to see vehicles at the preceding entry and the following exit as well as the nearest parts of the circulating carriageway. However, drivers should not be able to see the preceding entry from more than 15m before the “give way” line, as this might encourage excessive approach speeds.
7.30 Chapter 7
At Grade Intersections

Figure 7-22: Required visibility for entering a roundabout
Source: UGDM

Note: The darker shade in figure (b), from the same entry point as figure (a), is required visibility forward, the lighter grey shade is identical to required visibility on figure (a) plus visibility-triangle in the centre island to show the limit of the area where shrubs can be planted.

Once in the roundabout drivers must be able to see the area shown in Figure 7.23. Signs and landscaping on the centre island should be designed and located so that they do not obstruct the view more than absolutely necessary as illustrated to the right above.

Figure 7-23: Required visibility for drivers within a roundabout
Source: UGDM

7.7.5 Centre Island and Circulating Carriageway
The dimensions of roundabouts are defined by the following radii and widths shown in Figure 7.24:

- Edge of carriageway radius, Re
- Central island radius, Rc
- Inner central island radius, Ri
- Circulating carriageway width, B and,
- Traversable area (small roundabouts only).
Figure 7-24: Roundabout radii and widths

(a) Normal roundabouts
These are roundabouts with the edge of carriageway radius which is at least 18 m and the central island radius which is at least 10 metres.

Central island radius
The central island radius should normally be between 10 metres and 25 metres. It is difficult to control speeds if the roundabout is larger than this, and this would mean that cyclists and other vulnerable road users would be at risk. In most cases the size of the site will determine the size of the roundabout.

Width of the circulating carriageway
The width of the circulating carriageway depends on whether it is to be one lane or two-lane. Normally, one lane roundabouts are designed for an articulated vehicle and two lane roundabouts are designed for an articulated vehicle and a passenger car. Figure 7.25 below shows the minimum width of circulating carriageway after determination of design vehicle and inscribe diameter (outer diameter).
For normal (central island radius 10 metres or greater) one lane roundabouts and two-lane roundabouts, the central island radius, the edge of carriageway radius and the width of the circulating carriageway are determined by the diagram in Figure 7.26.

The designer should check that the circulating carriageway is no more than about 1.2 x the maximum entry width. Very wide carriageways encourage unsafe speeds.

(b) Small roundabouts
These are roundabouts whose edge of carriageway is less than 18 metres.

Where space is limited, such as in built-up areas, a slightly different design of roundabout is needed in order to accommodate long trucks without sacrificing speed controlling features.
Island radius
Small roundabouts shall have an inner central island radius of at least 2 metres.

Width of the circulating carriageway
The problem with small roundabouts is that it is difficult to control car speeds because the circulating carriageway has to be very wide in order to accommodate semi-trailers and long vehicles. The solution is to build a centre island with an outer fringe which is traversable by long vehicles – see Figure 7.24. The traversable area should be a maximum of 40 mm high, have a rough surface (to discourage light vehicles), and be edged with a mountable kerb. The intention is that light vehicles will go around the outside of the traversable area, thus forcing the drivers to travel slowly. Drivers of long vehicles will be able to negotiate the roundabout by letting the rear wheels cross the traversable area.

Guidance on selection of central island radii and traversable area are given in Figure 7.27.

![Figure 7-27: Roundabout radii in small roundabouts](image)

7.7.6 Entries
Number of entry lanes
One lane roundabouts are preferred from a safety viewpoint. For higher traffic volumes, a 2-lane circulating roadway may be necessary. The diagram Figure 7.28 shows the need for two lanes.
The need for two lanes must be checked for each entry’s entering and circulating flows during the design hour. If two lanes are necessary for one entry, the whole roundabout should be designed with two lanes. An alternative design to increase the capacity for one entry can be to use a separate left turn lane as shown in Figure 7.29. With this arrangement, care must be taken to ensure good visibility and signing at the merge – otherwise cyclists and other vulnerable road users could be put at risk.

Approach alignment
As previously stated, entry deflection is essential in order to reduce the speed of approaching vehicles to 50 km/h or less. The size of the deflection is dependent on the alignment of the entry and should normally be at least one lane wide (3.5 m). Figure 7.30 shows one way of achieving entry deflection. The designer should avoid making the deflection too sharp as this could cause vehicles to overturn or overshoot (i.e. driver unable to stop at the “give way” line).

The entry road must be level with the circulating carriageway for a distance of at least 15 m before the “give way” line.
Entry Radius
The entry radius should normally be in the range 15 – 20 m. It should never be less than 10 m. Large entry radii will result in inadequate entry deflection and must not be used.

Entry width
The entry width is depending on the main entry radius. The entry widths in Table 7.7 should normally be used for one and two lanes roundabouts respectively. The transition to normal lane width should be at least 30 metres long.

<table>
<thead>
<tr>
<th>Number of lanes</th>
<th>Design vehicle(s)</th>
<th>Entry width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Entry radius ≤ 15 m</td>
</tr>
<tr>
<td>1</td>
<td>Semi-trailer</td>
<td>6.5 m</td>
</tr>
<tr>
<td>2</td>
<td>Semi-trailer + passenger car</td>
<td>10.0 m</td>
</tr>
</tbody>
</table>

7.7.7 Exits

Number of exit lanes
The number of exit lanes can be decided according to Table 7.8.

<table>
<thead>
<tr>
<th>Exiting traffic veh/Dh</th>
<th>Number of lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 750</td>
<td>One</td>
</tr>
<tr>
<td>750 - 1050</td>
<td>Consider two</td>
</tr>
<tr>
<td>1050 - 1500</td>
<td>Two</td>
</tr>
</tbody>
</table>

Exit curve
The exit should be designed to give smooth traffic flow. The main radius in the exit curve should be between 50 and 100 metres for a normal roundabout. If there is a pedestrian crossing on the exit the radius should be 50 m or smaller, in order to control speeds.
Exit width
The exit widths in Table 7.9 should normally be used for one and two lanes roundabouts. The transition to normal lane width should be 75 - 100 metres long.

Table 7.9: Exit Widths

<table>
<thead>
<tr>
<th>Number of lanes</th>
<th>Design vehicle(s)</th>
<th>Exit width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Semi-trailer</td>
<td>6.0 m</td>
</tr>
<tr>
<td>2</td>
<td>Semi-trailer + passenger car</td>
<td>8.0 m</td>
</tr>
</tbody>
</table>

7.7.8 Combination of Exit and Entry Curves

Driving paths
The alignment of the connecting roads can make it necessary to adjust the exit and entry curve radii. If larger radii than normal are used, the designer must check that all possible 2 metres wide driving paths for passenger cars fulfil the requirement $R_1 \leq R_2 \leq R_3 \leq 100$ metres to achieve speed control, see Figure 7.31.

![Figure 7-31: Driving paths for passenger cars](image)

7.7.9 Alignment between Entry and Exit
It is preferable to avoid reverse curvature between the entry and the following exit - see Figure 7.32. For roundabouts with big central islands or long distances between entry and exit, this can be difficult to avoid. If possible, the alignment of the connecting roads should be adjusted.

![Figure 7.32: Alignment between entry and exit](image)
7.7.10 Pedestrian and Cycle Crossings

Pedestrian/cycle crossings are normally placed according to one of the two alternatives shown in Figure 7.33.

In Alt 1 the give way line is placed after and in Alt 2 before the pedestrian crossing. The advantages and disadvantages associated with the Alt 1 compared to Alt 2 are mainly the following:

With a distance between the crossing and the give way line, vehicles can yield for the pedestrian crossing and the roundabout separately. This improves capacity. The traffic safety effects are questioned. Some traffic safety researchers claim Alt 2 to be superior.

With the pedestrian crossing at a distance from the roundabout, an exiting vehicle can give way to a pedestrian without blocking the roundabout with obvious capacity advantages.

A disadvantage is that the traffic island may have to be extended and widened to accommodate pedestrians and cyclists. Another disadvantage is that pedestrians have to make an extra detour.

7.7.11 Capacity of Roundabouts

The capacity of a roundabout is governed by the capacity of each individual weaving section.

The capacity of a weaving section between entries, when designed in accordance with the foregoing principles, is calculated from the formula:

\[
Q_p = \frac{240w(1 + \frac{e}{w})}{1 + \frac{w}{L}}
\]

where:

- \(Q_p\) is the practical capacity [pcu/hour];
- \(w\) is the width of weaving section (the difference between edge of carriageway (Re) and central island radius (Rc) [m];
- \(e\) is the average width of entries to the weaving section [m]; and,
- \(L\) is the length of weaving section [m].

The actual design capacity of the weaving section should not exceed 85% of the practical capacity, \(Q_p\).
The following steps may be followed in laying out a trial geometry for a roundabout:

1. Select the general design criteria to be used;
2. Select the appropriate design vehicle for the site;
3. Adopt a minimum design vehicle turning radius;
4. Determine from traffic flows the number of lanes required on entry, exit and circulation;
5. Identify the needs of pedestrians;
6. Identify the location of controls such as right-of-way boundaries, utilities, access requirements, and establish the space available;
7. Select a trial central island diameter and determine the width needed of the circulating carriageway;
8. Draw the roundabout;
9. Check that the size and shape is adequate to accommodate all intersecting legs with sufficient separations for satisfactory traffic operations;
10. Lay out the entrance/exit islands;
11. Check the achievement of adequate deflection (Figure 7-30). Adjust as required;
12. Check site distances at approaches and exits;
13. Layout lane and pavement markings;
14. Layout lighting plan; and,
15. Layout sign plan.
7.8 Design of Signalised Intersections

7.8.1 Introduction

This section deals with geometric layout of signalised intersections and connections to the signal control strategy. Close co-operation is necessary with the signal control and electrical engineers throughout the design process, especially in the early stages, to optimize and coordinate geometric layout and signal control strategy.

Signal control at an intersection, properly designed, can enhance traffic safety and efficiency by reducing congestion and conflicts between different vehicle movements. The major advantages compared to priority-controlled intersections are:

- the maximum waiting time is fixed and known (if capacity is not reached);
- the available capacity is distributed fairly between approaches; and,
- the driver on the minor road does not have to make a judgment on when it is safe to proceed.

Most of the safety problems that arise with signalised intersections are related to drivers passing the signal at red, and rear-end collisions at signal changes from green to red. This has implications for signal visibility and timings.

![Figure 7-35: Criteria for traffic signalization of intersection](image)

Primary conflicts between motor vehicles must be separated in a signalised intersection, see Figure 7.36 below. Motor vehicles passing a steady green signal or green arrow signal must not encounter any primary conflicts, but lower order conflicts, i.e. with turning vehicles, may be acceptable in some circumstances.
The control strategy of a signalised intersection is called the phases or the stage sequence. An example of a stage sequence for a T-intersection with a protected right turn (controlled by a green arrow) - is shown in Figure 7.37.

The control strategy can work on fixed timings or be vehicle-actuated - adapting to traffic conditions by detectors. Vehicle actuated (demand-responsive) signals are much more efficient, and because of this drivers are more likely to comply with them. Each stage has a minimum and maximum green time. There should always be an inter-green period between conflicting stages to allow for safe stage changes. The length of the inter-green depends mainly on the size of the intersection, speed limit and whether pedestrians and cyclists are involved. The time period between two consecutive starts of the same stage is the cycle time.

**7.8.2 Control Strategy and Layout**

Signalised intersections should normally be restricted to roads with a speed limit 50 km/h. Where signals are needed on roads with speeds higher than 50 km/h additional equipment is needed to ensure safety like overhead mounted signal on each high-speed approach. For more information, see A Guide to Traffic Signing, Ministry of Infrastructure Development, 2009. Signals should never be installed on roads where the speed limit is higher than 70 km/h.
Protected right turns are preferable from a safety viewpoint. They give positive control and are easy to understand. The disadvantage is that they use up significant intersection capacity, so waiting times are longer.

Pedestrian crossing signals may be provided at signalised intersections. They should have their own stage, during which there should be no conflicts with vehicle movements. Figure 7-38 shows the criteria to be met for installing pedestrian crossing signals.

<table>
<thead>
<tr>
<th>Speed limit</th>
<th>85%-fractile (km/h)</th>
<th>Traffic volume (ADT)</th>
<th>Pedestrians/cyclists (no./max. hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>-</td>
<td>5000 - 8000</td>
<td>&gt;30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;8000</td>
<td>&gt;20</td>
</tr>
<tr>
<td>40</td>
<td>-</td>
<td>5000 - 8000</td>
<td>&gt;20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;8000</td>
<td>&gt;10</td>
</tr>
<tr>
<td>50</td>
<td>-</td>
<td>5000 - 8000</td>
<td>&gt;20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;8000</td>
<td>&gt;10</td>
</tr>
<tr>
<td>60</td>
<td>&lt;65*</td>
<td>&gt;2000</td>
<td>&gt;20</td>
</tr>
<tr>
<td>70</td>
<td>&lt;65*</td>
<td>&gt;1500</td>
<td>&gt;20</td>
</tr>
</tbody>
</table>

*) When speed levels exceed 65 km/h, flashing yellow beacon should be installed ahead of the traffic signals

Figure 7-38: Criteria for traffic signalization of cross walks

The number of traffic lanes with permitted traffic directions and signal control type with stages and location of signal heads should be decided due to capacity, traffic safety, road user costs, environmental and other impacts and investment and maintenance costs. The capacity analysis should be based on expected traffic volumes during the design hour, normally both morning and evening peaks.

The following safety requirements must be coordinated with the geometric layout:

- Protected right turns (i.e. without conflicts) must have right turn lanes
Permissive right turns (i.e. with conflict with opposing straight forward traffic) can have separate lanes.

**7.8.3 Visibility**

Each traffic lane shall have clear vision of at least one primary signal head associated with its particular movement from the desirable stopping sight distance, 70 m at 50 km/h and 110 m at 70 km/h speed limit. It is also important that the desirable stopping sight distance is available to all possible queue tails given by the capacity calculation. The warning sign for traffic signals must be used where the visibility is marginal.
The intersection inter-visibility zone is defined as the area bounded by measurements from a distance of 2.5 m behind the stop-line extending the full carriageway width for each arm, as indicated in Figure 7.42. Designers should aim to achieve the greatest level of inter-visibility within this zone to permit manoeuvres to be completed safely once drivers, cyclists and pedestrians have entered the zone.

Visibility along the intersecting road must be at least equal to the standards for “STOP” signs, as set out in Figure 7.12. This is to ensure a minimum level of safety when the signals are out of order.

Minor obstructions to visibility caused by slender projections such as lighting columns, sign supports, signal posts, controller cabinet and guardrails may be unavoidable. When placing signs, street furniture and planting, consideration should be given to ensure that their obstructive effect is minimised.

![Figure 7-42: Inter-visibility zone without pedestrian crossing](source: UGDM)

### 7.8.4 Lane design

Traffic lanes should normally be 3.0 to 3.5 m wide. Nearside (kerb) lanes that are well-used by cyclists should be widened to 4 m if possible. The lane width can be narrowed to 2.75 m, if space is very limited, but only if there are few trucks or buses.

The required lane lengths depend on estimated queue lengths to be decided based on the capacity analysis.

Entry lanes for right turners are needed, as already stated, if protected right turns are to be used. Additional entry lanes for through traffic will improve capacity and level-of-service, but the larger intersection area can result in the need to set longer inter-green periods.

The entry taper Li of a kerbed entry lane should be minimum 30 m (taper 1:10) to allow a design semi-trailer to cope with it. Tapers can be narrowed to 1:5 to allow more queuing space within the same total length, see Figure 7-43.
Minimum design measurements for a right turn with a ghost island are shown in Figure 7.44.

Opposing right turns, especially permissive right turns (i.e. with opposing traffic) on the main road, should be aligned opposite each other to improve visibility to meeting vehicles, to avoid, if possible, safety problems as shown in Figure 7.45.

The number of straight ahead entry and exit lanes should be balanced in order to reduce conflicts caused by traffic merging or diverging within the intersection visibility zone. Lane drops should take place beyond the visibility zone over a distance of at least 100 m for a single lane reduction. The lane drop may be carried out on either the nearside or offside dependant on traffic condition.
Slip lanes (for left turners, see Figure 7-47) can be signalised or uncontrolled (“give way” signs and markings). They can be used when left turn manoeuvres for large vehicles have to be facilitated, see Figure 7-47. Uncontrolled slip lanes improve the efficiency of the traffic signal control, as inter-greens can be decreased, especially at high left turn volumes. Uncontrolled traffic should be separated with a triangular separation island.

If left turn slip lanes are used, a consistent design approach should be adopted for ease of understanding. Uncontrolled slip lanes can be confusing for pedestrians. Uncontrolled and controlled pedestrian crossings should not be mixed within the same intersection.

### 7.8.5 Swept Paths and Corner Curves

Corner curves and channel width design depend on what design vehicle and design level-of-service is chosen, see Chapter 4.

Signalised intersections with very low volumes of large trucks and buses could have simple 6 m corner radiiuses to minimise the intersection area and optimise the signal control strategy. The radius should be increased to 10 m if 12 m rigid trucks or buses are common. The following combinations of tapers and corner radii can be used in urban areas to accommodate semi trailers, see Figure 7-48.
It is essential to ensure that adequate turning radii are provided for the swept paths of all types of vehicles using the intersection as shown in Figure 7-47. Swept paths must be checked for all permitted turning movements to control locations of traffic islands, signals etc, see examples below. The example on the left indicates that there is an unnecessary taper; the example on the right indicates that the stop-line must be set back.

Simple swept path templates, if available in correct scale, is usable for checking whether semi trailers can negotiate intersections, but the use of specialist computer software (such as AUTOTURN) gives a more accurate simulation.

Nosings of central reserves and pedestrian refuges should be set back a minimum of 1.5 m, measured from a line extended from the edge of the intersecting roads. Minimum clearances should be provided, see Chapter 6, and must be controlled if the superelevation is over 2.5%.
7.8.6 Signals

There should be at least two signals visible from each approach, see Figure 7-50 and stop-line usually comprising a primary and a secondary signal (see also the Traffic Signs Manual, Volume 1). Where separate signalling of turning movements is used this advice applies to the approach lane(s) associated with each turning movement. One signal post can then display information for more than one turning movement.

The primary signal should be located to the left of the approach a minimum of 1 m beyond the stop line and in advance of crossing marks for pedestrians if any. The secondary signal should be located within a 30 degree angle on a maximum distance of 50 m with priorities as shown in Figure 7-50.

![Figure 7-50: Signal location advice](image)

The primary signal should preferably be located 0.8 to 1.0 metre from the edge of the carriageway with 0.3 and 2.0 m as minimum and maximum. Recommended locations in relation to the stop-line and a pedestrian crossing are shown in Figure 7-51.

![Figure 7-51: Primary signal location advice](image)

The following alternative designs may be used where there are approaches with three or more traffic lanes and protected right turns. The primary right turn arrow is mounted on the exit separation island, Alt 1, or on an extra separation island in the approach, Alt 2, being more expensive.
The standard traffic signal head width is 300 mm (with 450 mm as oversize), which results in island width requirements, including clearances, of 0.3 to 0.6 m or from 0.9 m to 1.65 m. Wider islands can be needed if they are also to serve as pedestrian refuges.

**7.8.7 Spacing of Signalized Intersections**

Designers seldom have influence on the spacing of roadways in a network as it is largely predicated by the original or developed land use. Nevertheless, the spacing of any type of intersection impact significantly on the operation, level of service and capacity of a roadway. It then follows that intersection spacing should, inter alia, be based on road function and traffic volume. Road Agency should therefore play a role in the determination of the location of individual intersections. This is of particular concern when the provision of a new intersection on an existing road is being considered. Along signalized roads, intersection spacing should be consistent with the running speed and signal cycle lengths, which are variables in themselves. If the spacing of the intersections is based on acceptable running speeds and cycle lengths, signal progression and an efficient use of the roadway can be achieved. All these variable are combined in a chart given in Figure 7-53, allowing the selection of suitable spacing between signalized intersection.

From figure 7-53 it can be seen that the minimum spacing is 400 m. Where spacing closer than this minimum exists, a number of alternative actions can be considered. Among these alternatives are two-way flows can be converted to one-way operation or minor connecting roads can be closed or diverted, and channelisation can be used to restrict turning movements.
7.8.8 Pedestrian and Cyclist Facilities

Pedestrian crossings should be perpendicular to the edge of the carriageway to assist inter-visibility and to benefit visually impaired people. The footway should have a dropped kerb, see Figure 9-1.

Minimum measures for pedestrian refuges for pedestrian crossings timed to permit crossing in one movement is shown below. The normal width should be 2.5 m, with 1.5 m as the absolute minimum.

![Diagram of pedestrian and cyclist facilities](image)

Figure 7-54: Traffic signal island and pedestrian refuge

Source: UGDM
Pedestrian phases should preferably not have conflicts with turning traffic. This could be arranged with staggered pedestrian crossings as illustrated below.

Figure 7-55: Example of a signal-controlled intersection with a staggered pedestrian crossing

Source: UGDM

7.9 Design of Highway–Railway Grade Crossing

7.9.1 General

This section provides general information on highway-railway grade crossings; characteristics of the crossing environment and users; and the physical and operational improvements that can be made at highway-railway grade crossings to enhance the safety and operation of both highway and railway traffic (motorised and non motorised) over crossing intersections. A highway-railway crossing, like any highway-highway intersection, involves either a grade separated or at grade crossing.

7.9.2 Design Requirements

The geometric design of a highway-railway grade crossing involves the elements of alignment, profile, sight distance, and cross section. The horizontal and vertical geometrics of a highway approaching an at-grade railway crossing should be constructed in a manner that does not necessitate a driver to divert attention to roadway conditions.

Crossings should not be located on either highway or railway curves. Roadway curvature inhibits a driver’s view of a crossing ahead and a driver’s attention may be directed towards negotiating the curve rather than looking for a train. Railway curvature may inhibit a driver’s view down the tracks from both a stopped position at the crossing and on the approach to the crossings.

The appropriate design may vary with the type of warning device used. Where signs and pavement markings are the only means of warning, the highway should cross the railway at or nearly at right
angles. Where this is not possible, the angle of skew shall be not greater than 45 degrees (see Figure 7-56). Even when flashing lights or automatic gates are used, small intersection angles should be avoided.

![Figure 7-56: Railway Crossing Details with Rumble Strips](Source: EGDM)

Where highways that are parallel with main railway’s tracks intersect highways that cross the tracks, there should be sufficient distance between the tracks and the highway intersections to enable highway traffic in all directions to move expeditiously and safely.

Regardless of the type of control, the roadway gradient should be level at and adjacent to the railway crossings to permit vehicles to stop, when necessary, and then proceed across the tracks without difficulty (see Figure 7-57). Vertical curves should be of sufficient length to ensure an adequate view of the crossing, and crest and sag curves are the same as for the roadway design.

![Figure 7-57: Railway Crossing Details on Vertical Curve](Source: EGDM)

Sight distance is a primary consideration at crossings without train-activated device. As in the case of a highway intersection, there are several events that can occur at a railroad - highway grade intersection without a train activated warning devices. Two of these events related to determining the sight distance are:

- The vehicle driver can observe the approaching train in a sight line that will allow the vehicle to pass through the grade crossing prior to the train arrival at crossing.
- The vehicle driver can observe the approaching train in a sight line that will permit the vehicle to be brought to a stop prior to encroachment in the crossing area.
Both of these manoeuvres are shown on Table 7-10; the sight triangle consists of the two major legs (i.e. the sight distance $d_H$ along the highway and the distance $d_T$ along the railway tracks). Case A of Table 7-10 indicates values of the sight distances for various speeds of the vehicle and the train.

Table 7-10: Required Design Sight Distance for Combination of Highway and Train Vehicle Speeds; 20-m Truck Crossing a Single Set of Tracks at 90 Degrees

<table>
<thead>
<tr>
<th>Metric</th>
<th>Case B Departure from stop (km/h)</th>
<th>Case A Moving vehicle (Vehicle speed (km/h))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance along railroad from crossing, $d_T$ (m)</td>
<td>10</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>181</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>227</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>272</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>317</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>362</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>408</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>453</td>
</tr>
<tr>
<td></td>
<td>110</td>
<td>498</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>544</td>
</tr>
<tr>
<td></td>
<td>130</td>
<td>599</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>634</td>
</tr>
<tr>
<td>Distance along highway from crossing, $d_H$ (m)</td>
<td>15</td>
<td>25</td>
</tr>
</tbody>
</table>

Source: HCM

Figure 7-58: Case A: Moving Vehicle to safely Cross or Stop at Railway Crossing

Key:
- $T$ = Train
- $V$ = Vehicle
\[ d_H = \text{sight distance leg along the highway that allows a vehicle proceeding to speed } V_V \text{ to cross tracks even though a train is observed at a distance } d_T \text{ from the crossing or to stop the vehicle without encroachment of the crossing area (m)}. \]

\[ d_T = \text{sight distance leg along the railroad tracks to permit the manoeuvres described as for } d_H \text{ (m)} \]

\[ V_V = \text{speed of the vehicle (km/h)} \]

\[ V_T = \text{speed of the train (km/h)} \]

\[ D = \text{distance from the stop line or front of the vehicle to the nearest rail, which is assumed to be 4.5 m} \]

\[ L = \text{length of vehicle, which is assumed to be 19.5 m} \]

\[ W = \text{distance between outer rails (for a single track, this value is 1.5 m)} \]

Adjustments must be made for skewed crossings.
Assumed flat highway grades adjacent to and at crossings.

Figure 7-59: Case B: Departure of Vehicle from Stopped Position to Cross Single Railway Track

Key:

\[ d_T = \text{sight distance along railroad tracks to allow a stopped vehicle to depart and safely cross the railroad tracks} \]

\[ D = \text{distance from the stop line to the nearest rail (assumed to be 4.5 m)} \]

\[ L = \text{length of vehicle (assumed to be 19.5 m)} \]

\[ W = \text{distance between outer rails (for a single track, this value is 1.5 m)} \]

Adjustments must be made for skewed crossings.
Assumed flat highway grades adjacent to and at crossings.

To ensure safety at crossings, all highway - railway grade crossings should be equipped with signage and traffic control devices for both motorist and non motorist as provided in the manual “A Guide to Traffic Signing Ministry of Infrastructure Development 2009”.
# Chapter 8 Grade Separated Intersections

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Chapter 8 Grade Separated Intersections

8.1 INTRODUCTION

8.1.1 General

The principal difference between grade separated intersection (interchanges) and other forms of intersection is that, in grade separated intersection, crossing movements are separated in space whereas, in the latter case, they are separated in time. At-grade intersections accommodate turning movements either within the limitations of the crossing roadway widths or through the application of turning roadways whereas the turning movements at interchanges are accommodated on ramps. The ramps replace the slow turn through an angle of skew that is approximately equal to 90 degrees by high-speed merging and diverging manoeuvres at relatively flat angles.

The first interchange built was for driving on the right and provided loops for all left turns and outer connectors for all right turns thus creating the Cloverleaf Interchange.

The various types of interchange configuration are illustrated in Chapter 8.7. Each basic form can be divided into sub-types. For example, the Diamond Interchange is represented by the simple diamond, the single point diamond and the split diamond. The most recent development in the Diamond interchange form is the Single Point Diamond Interchange. This form is also referred to as the Urban Interchange.

Historically, the type of interchange to be applied at a particular site would be selected as an input into the design process. In fact, like the cross-section, the interchange is the aggregation of various elements. A more sensible approach is thus to select the elements appropriate to a particular site in terms of the topography, local land usage and traffic movements and then to aggregate them into some or other type of interchange.

8.1.2 Design Principles

Manoeuvres in an interchange area occur at high speeds close to the freeway and over relatively short distances. It is therefore important that drivers should experience no difficulty in recognising their route through the interchange irrespective of whether that route traverses the interchange on the freeway or diverts to depart from the freeway to a destination that may be to the left or the right of the freeway. In following their selected route, drivers should be disturbed as little as possible by other traffic. These requirements can be met through the application of the basic principles of interchange design.

The driver has a number of tasks to execute successfully to avoid being a hazard to other traffic. It is necessary to:

- select a suitable speed and accelerate or decelerate to the selected speed within the available distance;
- select the appropriate lane and carry out the necessary weaving manoeuvres to effect lane changes if necessary; and
- diverge towards an off-ramp or merge from an on-ramp with the through traffic.
To maintain safety in carrying out these tasks, the driver must be able to understand the operation of the interchange and should not be surprised or misled by an unusual design characteristic. Understanding is best promoted by consistency and uniformity in the selection of types and in the design of particular features of the interchange.

Interchange exits and entrances should always be located on the left. Right-hand side entrances and exits are counter to driver expectancy and also have the effect of mixing high-speed through traffic with lower-speed turning vehicles. The problem of extracting turning vehicles from the median island and providing sufficient vertical clearance either over or under the opposing freeway through lanes is not trivial. The application of right-hand entrances and exits should only be considered under extremely limiting circumstances. Even in the case of a major fork where two freeways are diverging, the lesser movement should, for preference, be on the left.

Route continuity substantially simplifies the navigational aspects of the driving task. For example, if a driver simply wishes to travel on a freeway network through a city from one end to the other it should not be necessary to deviate from one route to another.

Uniformity of signing practice is an important aspect of consistent design and reference should be made to The Guide on Traffic Signing, Ministry of Infrastructure Development (2009).

Ideally, an interchange should have only a single exit for each direction of flow with this being located in advance of the interchange structure. The directing of traffic to alternative destinations on either side of the freeway should take place clear of the freeway itself. In this manner, drivers will be required to take two binary decisions, (Yes/No) followed by (Left/Right), as opposed to a single compound decision. This spreads the workload and simplifies the decision process, hence improving the operational efficiency of the entire facility. Closely spaced successive off-ramps could be a source of confusion to the driver leading to erratic responses and manoeuvres.

Single entrances are to be preferred, also in support of operational efficiency of the interchange. Merging manoeuvres by entering vehicles are an interruption of the free flow of traffic in the left lane of the freeway. Closely spaced entrances exacerbate the problem and the resulting turbulence could influence the adjacent lanes as well.

From the standpoint of convenience and safety, in particular prevention of wrong-way movements, interchanges should provide ramps to serve all turning movements. If, for any reason, this is not possible or desirable, it is nevertheless to be preferred that, for any travel movement from one road to another within an interchange, the return movement should also be provided.

Provision of a spatial separation between two crossing streams of traffic raises the problem of which to take over the top - the perennial Over versus Under debate. The choice of whether the crossing road should be taken over or under the freeway depends on a number of factors, especially the terrain and construction costs. There are, however, a number of advantages in carrying the crossing road over the freeway. These are:

- Exit ramps on up-grades assist deceleration and entrance ramps on downgrades assist acceleration and have a beneficial effect on truck noise;
- Rising exit ramps are highly visible to drivers who may wish to exit from the freeway;
The structure has target value, i.e. it provides advance warning of the possibility of an interchange ahead necessitating a decision from the driver whether to stay on the freeway or perhaps to change lanes with a view to the impending departure from the freeway;

- Dropping the freeway into cut reduces noise levels to surrounding communities and also reduces visual intrusion;

- For the long-distance driver on a rural freeway, a crossing road on a structure may represent an interesting change of view; and,

- The crossing road ramp terminals may include right and left turn lanes, traffic signals and other traffic control devices. Not being obstructed by bridge piers and the like, these would be rendered more visible by taking the crossing road over the freeway.

The other design principles, being continuity of basic lanes, lane balance and lane drops are discussed in Sub-chapter 8.5 as matters of detailed design.

### 8.2 Interchange Warrants

#### 8.2.1 Traffic Volumes

With increasing traffic volumes, a point will be reached where all the options of temporal separation of conflicting movements at an at-grade intersection have been exhausted. One of the possible solutions to the problem is to provide an interchange.

The elimination of bottlenecks by means of interchanges can be applied to any intersection at which demand exceeds capacity and is not necessarily limited to arterials. Under these circumstances, it is necessary to weigh up the economic benefits of increased safety, reduced delay and reduced operating and maintenance cost of vehicles against the cost of provision of the interchange. The latter includes the cost of land acquisition, which could be high, and the cost of construction. As the construction site would be heavily constricted by the need to accommodate traffic flows that were sufficiently heavy to justify the interchange in the first instance, the cost of construction could be significantly higher than on the equivalent green field site.

#### 8.2.2 Freeways

The outstanding feature of freeways is the limitation of access that is brought to bear on their operation as freeways are designed with full access control. Access is permitted only at designated points and only to vehicles travelling at or near freeway speeds. As such, access by means of intersections is precluded and the only permitted access is by way of interchanges. Crossing roads are normally those that are high in the functional road hierarchy, e.g. arterials, although, if these are very widely spaced, it may be necessary to provide an interchange serving a lower order road, for example a collector.

It follows that the connection between two freeways would also be by means of an interchange, in which case reference is to a systems interchange as opposed to an access interchange.

#### 8.2.3 Safety

Some at-grade intersections exhibit high crash rates that cannot be lowered by improvements to the geometry of the intersections or through the application of control devices. Such situations are often found at heavily travelled urban intersections. Crash rates also tend to be high at the intersections on heavily travelled rural arterials where there is a proliferation of ribbon development.
A third area of high crash rates is at intersections on lightly travelled low volume rural locations where speeds tend to be high. In these cases, low-cost interchanges such as the Jug-handle layout, Figure 8-11, may be an adequate solution to the problem.

### 8.2.4 Topography

The topography may force a vertical separation between crossing roads at the logical intersection location. As an illustration, the through road may be on a crest curve in cut with the crossing road at or above ground level. If it is not possible to relocate the intersection, a simple Jug-handle type of interchange as illustrated in Figure 8-11 may be an adequate solution to the problem.

### 8.3 Weaving

The Highway Capacity Manual (2000) defines weaving as the crossing of two or more traffic streams travelling in the same general direction without the aid of traffic control devices but then goes to address the merge-diverge as a separate issue. However, the merge-diverge operation, associated with successive single-lane on-and off-ramps where there is no auxiliary lane, does have two streams that, in fact, are crossing. Reference to weaving should thus include the merge-diverge.

Three types of weave are illustrated in Figures 8-1, 8-2 and 8-3. A Type A weave requires all weaving vehicles to execute one lane change. Type B weaving occurs when one of the weaving streams does not have to change lanes but the other has to undertake at most one lane change. Type C weaving allows one stream to weave without making a lane change, whereas the other stream has to undertake two or more lane changes.

![Type A weaves](image)

(a) ramp-weave  
(b) major weave with crown line

**Figure 8-1: Type A weaves**
Figure 8-2: Type B weaves:

(a) major weave with lane balance at exit
(b) major weave with merging at entrance
(c) major weave with merging at entrance and lane balance at exit

Figure 8-3: Type C weaves:

(a) major weave without lane balance
(b) two-sided weave

The Type B weave is, in essence, a Type A weave but with the auxiliary lane extending either up- or downstream of the weaving area and with an additional lane being provided either to the on- or to the off-ramp. It follows that a Type A weaving section can be easily converted into a Type B weave. At any site at which a Type A weave appears, it would thus be prudent to check the operation at the site for both types of weave.
8.4 **Location and Spacing of Interchanges**

The location of interchanges is based primarily on service to adjacent land. On rural freeways bypassing small communities, the provision of a single interchange may be adequate, with larger communities requiring more. The precise location of interchanges would depend on the particular needs of the community but, as a general guide, would be on roads recognised as being major components of the local system.

Rural interchanges are typically spaced at distances of eight kilometres apart or more. This distance is measured from centreline to centreline of crossing roads.

The generous spacing applied to rural interchanges would not be able to serve intensively developed urban areas adequately. As an illustration of context sensitive design, trip lengths are shorter and speeds lower on urban freeways than on rural freeways. It should be noted that Context Sensitive Design (CSD) is an approach of planning and designing a road project based on active and early participation of the communities.

At spacings appropriate to the urban environment, reference to a centreline-to-centreline distance is too coarse to be practical. The point at issue is that weaving takes place between interchanges and the available distance is a function of the layout of successive interchanges. For a common centreline-to-centreline spacing, the weaving length available between two diamond interchanges is significantly different from that between a Par-Clo-A followed by a Par-Clo-B. Weaving distance is defined in the Highway Capacity Manual and other sources as the distance between the point at which the separation between the ramp and the adjacent lane is 0.5 metres to the point at the following off-ramp at which the distance between ramp and lane is 3.7 m as illustrated in Figure 8-4.

Three criteria for the spacing of interchanges can be considered. In the first instance, the distance required for adequate signage should ideally dictate spacing of successive interchanges. If it is not possible to achieve these distances, consideration can be given to a relaxation based on achieving Level Of Service (LOS) D conditions on the freeway. The third criterion is that of turbulence, which is applied to the merge-diverge situation.

![Figure 8-4: Weaving distance](image)

(1) The distance required to provide adequate sign posting which, in turn, influences the safe operation of the freeway, is used to define the minimum distance between ramps. In Table 8-1 an access interchange is like a simple diamond interchange with a single exit. In systems interchanges, turning movements are catered for by individual ramps, hence there will be a minimum of two exits.
Table 8-1: Interchange Spacing in terms of Signage Requirements

<table>
<thead>
<tr>
<th>Type of freeway</th>
<th>Distance between access interchanges</th>
<th>Distance between an access- and a systems-interchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeways in rural areas</td>
<td>≥ 5.0 km, 3.6 km</td>
<td>≥ 5.0 km, 3.8 km</td>
</tr>
<tr>
<td>Freeways in built up areas</td>
<td>≥ 3.0 km, 2.4 km</td>
<td>≥ 3.8 km, 3.6 km</td>
</tr>
</tbody>
</table>

Source: SATCC + UGDM

(2) In exceptional cases, where it is not possible to meet the above requirements, relaxation of these may be considered. It is, however, necessary to ensure that densities in the freeway left hand lane are not so high that the flow of traffic breaks down. Densities associated with LOS E would make it difficult, if not actually impossible, for drivers to be able to change lanes. Formulae according to which densities can be estimated are provided in the Highway Capacity Manual.

(3) In the case of the merge-diverge manoeuvre, turbulence caused on the left lane of the freeway by a close succession of entering and exiting vehicles becomes an issue. According to some studies this turbulence manifests itself over a distance of roughly 450 metres upstream of an off-ramp and downstream of an on-ramp. A spacing of 900 metres would suggest that the entire length of freeway between interchanges would be subject to turbulent flow. The likelihood of breakdown in the traffic flow would thus be high and the designer should ensure that space is available for one area of turbulence to subside before onset of the next interchange.

(4) In off-peak periods, vehicles would be moving between interchanges at the speed limit or higher. The geometry of the on- and off-ramps should be such that they can accommodate manoeuvres at these speeds. Increasing the taper rates or reducing the length of the speed change lanes purely to achieve some or other hypothetically acceptable Yellow Line Break Point distance does not constitute good design.

(5) The spacing between successive interchanges will have an impact on traffic operations on the crossing roads and vice versa. If the crossing road can deliver vehicles to the freeway faster than they can carry out the merge, stacking of vehicles will occur on the on-ramp with the queue possibly backing up on to the crossing road itself. Stacking can also occur on an off-ramp if the crossing road ramp terminal cannot accommodate the rate of flow arriving from the freeway. The queue could conceivably back up onto the freeway, which would create an extremely hazardous situation. The design should always be such that the possible queuing should take place on the secondary road system, not the freeway.

It should be realised that relaxations below the distances recommended under (1) above will result in an increase in the driver workload. Failure to accommodate acceptable levels of driver workload in relation to reaction times can be expected to result in higher than average crash rates. Some studies demonstrate that, at spacings between noses of greater than 2,500 metres, the crash rate is fairly constant, i.e. the presence of the following interchange is not a factor in the crash rate. At spacings of less than 2,500 metres between noses, the crash rate increases until, at about 500 m between noses, the crash rate is nearly double that of the 2,500 m spacing. This is illustrated in Figure 8.5 below.

The question that must be addressed is the benefit that the community can expect to derive in exchange for the cost of the higher accident rate. By virtue of the fact that freeway speeds tend to be high, there is a high probability that many of the accidents would be fatal. It is therefore suggested that the decision to reduce the interchange spacing below those listed in Table 8-1 should not be taken lightly.
It would be necessary to undertake a full-scale engineering analysis of the situation that would include:

- estimation of future traffic volumes at a twenty year time horizon, comprising weaving and through volumes in the design year;
- calculation of traffic densities;
- assessment of the local geometry in terms of sight distances, and horizontal and vertical alignment;
- configuration consistent appropriate interchange type and with the surroundings;
- development of a sign sequence; and
- a form of benefit/cost analysis relating community benefits to the decrease in traffic safety.

Density offers some indication of the level of exposure to risk and, for want of any better measure, it is suggested that a density higher than 22 vehicles/kilometre/lane, corresponding to LOS D, would not result in acceptable design. It would be necessary to pay attention to remedial actions to prevent interchange constraints, such as inadequate ramp capacity, signalling or crossroad volumes, causing back up onto the freeway.

### 8.5 Basic Lanes and Lane Balance

Basic lanes are those that are maintained over an extended length of a route, irrespective of local changes in traffic volumes and requirements for lane balance. Alternatively stated, the basic number of lanes is a constant number of lanes assigned to a route, exclusive of auxiliary lanes.

The number of basic lanes changes only when there is a significant change in the general level of traffic volumes on the route. Short sections of the route may thus have insufficient capacity, this problem can be overcome by the use of auxiliary lanes. In the case of spare capacity, reduction in the number of lanes is not recommended because this area could, at some future time, become a bottleneck.

The basic number of lanes is derived from consideration of the design traffic volumes and capacity analyses. To promote smooth flow of traffic there should be a proper balance of lanes at points where merging or diverging manoeuvres occur.
At merges, the number of lanes downstream of the merge should be one less than the number of lanes upstream of the merge. This is typified by a one-lane ramp merging with a two-lane carriageway that, after the merge, continues as a two-lane carriageway as is the case on a typical Diamond Interchange layout. This rule precludes a two-lane ramp immediately merging with the carriageway without the addition of an auxiliary lane.

At diverges, the number of lanes downstream of the diverge should be one more than the number upstream of the diverge. The only exception to this rule is on short weaving sections, such as at Cloverleaf Interchanges, where a condition of this exception is that there is an auxiliary lane through the weaving section.

When two lanes diverge from the freeway, the above rule indicates that the number of freeway lanes beyond the diverge is reduced by one.

This can be used to drop a basic lane to match anticipated flows beyond the diverge. Alternatively, it can be an auxiliary lane that is dropped.

Basic lanes and lane balance are brought into harmony with each other by building on the basic lanes, adding or removing auxiliary lanes as required. The principle of lane balance should always be applied in the use of auxiliary lanes. Operational problems on existing roadways can be directly attributed to a lack of lane balance and failure to maintain route continuity.

The application of lane balance and coordination with basic number of lanes is illustrated in Figure 8-6.

### 8.6 Auxiliary Lanes

As in the case of the two-lane two-way road cross-section with its climbing and passing lanes, and the intersection with its right- and left-turning lanes, the auxiliary lane also has its role to play in the freeway cross-section and the interchange. In a sense, the application of the auxiliary lane in the freeway environment is identical to its application elsewhere. It is added to address a local operational issue and, as soon as the need for the auxiliary lane is past, it is dropped. Important features to consider in the application and design of the auxiliary lane are thus:

- The need for an auxiliary lane;
- The terminals; and
- Driver information.
8.6.1 The Need for an Auxiliary Lane

Auxiliary lanes are normally required on freeways either as:

- climbing lanes; or
- to support weaving; or
- to support lane balance.

The climbing lane application is similar to that discussed in Chapter 6 in respect of two-lane two-way roads whereas the weaving and lane balance applications are unique to the freeway situation.
Climbing lanes
Ideally, maximum gradients on freeways are in the range of three to four per cent ensuring that most vehicles can maintain a high and fairly constant speed. However, in heavily rolling country it is not always possible to achieve this ideal without incurring excessive costs in terms of earthworks construction. Because of the heavy volumes of traffic that necessitate the provision of a freeway, lane changing to overtake a slow-moving vehicle is not always easy and, under peak flow conditions, may actually be impossible. Speed differentials in the traffic stream are thus not only extremely disruptive but may also be potentially dangerous. Both conditions, i.e. disruption and reduction in safety, require consideration.

If a gradient on a freeway is four per cent or steeper, an operational analysis should be carried out to establish the impact of the gradient on the Level of Service. A drop through one level, e.g. from LOS B through LOS C to LOS D, would normally suggest a need for a climbing lane.

Crash rates increase exponentially with increasing speed differential. For this reason, international warrants for climbing lanes normally include a speed differential in the range of 15 to 20 km/h. A truck speed reduction of 20 km/h is taken to warrant for climbing lanes. If, on an existing freeway, the measured truck speed reduction in the outermost lane is thus 20 km/h or higher, the provision of a climbing lane should be considered. In the case of a new design, it will be necessary to construct a speed profile of the truck traffic to evaluate the need for a climbing lane.

Weaving
In the urban environment, interchanges are fairly closely spaced and local drivers are very inclined to use freeways as part of the local circulation system where the higher order road is bypassed through the use of local residential streets as long-distance urban routes. To ensure that the freeway is not unduly congested because of this practice, an auxiliary lane can be provided between adjacent interchanges resulting in the type of weaving described in Sub-chapter 8.3.

If a large number of vehicles are entering at the upstream interchange, it may be necessary to provide a two-lane entrance ramp. Some of these vehicles may exit at the following interchange but those wishing to travel further will have to weave across traffic from still further upstream that intends exiting at the following interchange and then merge with through traffic on the freeway. The auxiliary lane is then extended beyond the downstream interchange to allow a separation between the two manoeuvres. Similarly, a large volume of exiting vehicles may necessitate a two-lane exit, in which case the auxiliary lane should be extended upstream. Type B weaving thus comes into being. The desired length of the extension of the auxiliary lane beyond the two interchanges is normally assessed in terms of the probability of merging vehicles locating an acceptable gap in the opposing traffic flow.

Lane balance
As discussed in Sub-chapter 8.5, lane balance requires that:

- In the case of an exit, the number of lanes downstream of the diverge should be one less than the number upstream; and,
- In the case of an entrance, the number of lanes downstream of the merge should be one more than the number upstream
- Lane-drops should be done on tangent sections of horizontal alignments and approach sides of crest curves
This is illustrated in Figure 8-6.

Single-lane on- and off-ramps do not require auxiliary lanes to achieve lane balance in terms of the above definition. It should be noted that, unless two-lane on- and off-ramps are provided, the Type A weave is actually a violation of the principles of lane balance.

To achieve lane balance at an exit, three lanes upstream of the diverge should be followed by a two-lane off-ramp in combination with two basic lanes on the freeway. The continuity of basic lanes requires that the outermost of the three upstream lanes should be an auxiliary lane.

If all three upstream lanes are basic lanes, it is possible that traffic volumes beyond the off-ramp may have reduced to the point where three basic lanes are no longer necessary. Provision of a two-lane exit would thus be a convenient device to achieve a lane drop while simultaneously maintaining lane balance.

### 8.6.2 Auxiliary Lane Terminals

An auxiliary lane is intended to match a particular situation such as, for example, an unacceptably high speed differential in the traffic stream. It follows that the full width of auxiliary lane must be provided over the entire distance in which the situation prevails. The terminals are thus required to be provided outside the area of need and not as part of the length of the auxiliary lane.

Entering and exiting from auxiliary lanes require a reverse curve path to be followed. It is thus suggested that the taper rates discussed in Chapter 6 be employed rather than those normally applied to on- and off-ramps. The entrance taper should thus be about 200 metres long and the exit taper should be a minimum of 100 metres long except for climbing lanes.

### 8.6.3 Driver Information

The informational needs of drivers relate specifically to needs with regard to the exit from the auxiliary lane and include an indication of:

- the presence of a lane drop;
- the location of the lane drop; and
- the appropriate action to be undertaken.

### 8.7 Interchanges Types

#### 8.7.1 General

There is a wide variety of types of interchanges that can be employed under the various circumstances that warrant the application of interchanges. The major determinants of the type of interchange to be employed at any particular site are the traffic composition, access control, classification and characteristics of the intersecting road. Intersecting roads are typically freeways but may also be collectors.

In the case of freeways as intersecting roads, reference is made to systems interchanges. Systems interchanges exclusively serve vehicles that are already on the freeway system.

Access to the freeway system from the surrounding area is via interchanges on roads other than freeways, for which reason these interchanges are known as access interchanges. Service areas, providing opportunities to buy fuel, or food or simply to relax for a while are typically accessed via an
interchange. In some instances, the services are duplicated on either side of the freeway, in which access is via a left-in/left-out configuration. The requirements in terms of deflection angle, length of ramp and spacing that apply to interchange ramps apply equally to left-in/left-out ramps. In effect, this situation could be described as being an interchange without a crossing road.

The primary difference between systems and access/service interchanges is that the ramps on systems interchanges have free-flowing terminals at both ends, whereas the intersecting road ramp terminals on an access interchange are typically in the form of at-grade intersections.

Interchanges can also be between non-freeway roads, for example between two heavily trafficked collectors. In very rare instances there may even be an application for an interchange between a major and a local road, as suggested above in the case where local topography may force a grade separation between the two roads.

In addition to the classification and nature of the intersecting road, there are a number of controls guiding the selection of the most appropriate interchange form for any particular situation. In the sense of context sensitive design, these include:

- Safety;
- Adjacent land use;
- Design speed of both the freeway and the intersecting road;
- Traffic volumes of the through and turning movements;
- Traffic composition;
- Number of required legs;
- Road reserve and spatial requirements;
- Topography;
- Service to adjacent communities;
- Environmental considerations;
- Economics, and,
- Stakeholders.

The relative importance of these controls may vary from interchange to interchange. For any particular site, each of the controls will have to be examined and its relative importance assessed. Only after this process will it be possible to study alternative interchange types and configurations to determine the most suitable in terms of the more important controls.

While the selection of the most appropriate type and configuration of interchange may vary between sites, it is important to provide consistent operating conditions in order to match driver expectations.

**8.7.2 Systems Interchanges**

As stated above, at-grade intersections are inappropriate to systems interchanges and their avoidance is mandatory. For this reason, hybrid interchanges, in which an access interchange is contained within a systems interchange, are to be avoided.

Hybrid interchanges inevitably lead to an unsafe mix of high and low speed traffic. Furthermore, signposting anything up to six possible destinations within a very short distance is, at best, difficult. Selecting the appropriate response generates an enormous workload for the
driver so that the probability of error is substantial. Past experience suggests that these interchange configurations are rarely successful.

Directional interchanges provide high-speed connections to left and to right provided that the ramp exits and entrances are on the left of the through lanes. Where turning volumes are low or space is limited, provision of loops for right turning traffic can be considered. Directional interchanges that include one or more loops are referred to as being partially-directional. If all right turns are required to take place on loops, the cloverleaf configuration emerges. Various forms of systems interchanges are illustrated below.

**Four-legged interchanges**

The fully directional interchange illustrated in Figure 8-7 (i) provides single exits from all four directions and directional ramps for all eight turning movements. The through roads and ramps are separated vertically on four levels. Partially directional interchanges allow the number of levels to be reduced. The Single Loop Partially-directional Interchange, illustrated in Figure 8-7 (ii), and the Two Loop arrangement, illustrated in Figure 8-7 (iii) and (iv), require three levels.

The difference between Figures 8-7 (iii) and (iv) is that, in the former case, the freeways cross and, in the latter, route continuity dictates a change in alignment. Loop ramps are normally only used for lighter volumes of right-turning traffic. A three-loop arrangement is, in effect, a cloverleaf configuration, with one of the loops being replaced by a directional ramp and is not likely to occur in practice, largely because of the problem of weaving discussed below.

The principal benefit of the cloverleaf (figure 8-7 (v)) is that it requires only a simple one-level structure, in contrast to the complex and correspondingly costly structures necessary for the directional and partially directional configurations. The major weakness of the cloverleaf is that it requires weaving over very short distances. Provided weaving volumes are not high and sufficient space is available to accommodate the interchange, the cloverleaf can, however, be considered to be an option. If weaving is required to take place on the main carriageways, the turbulence so created has a serious effect on the flow of traffic through the interchange area. The cloverleaf also has the characteristic of confronting the driver with two exits from the freeway in quick succession (figure v (a)). Both these problems can be resolved by providing collector-distributor roads adjacent to the through carriageways (figure v (b)).
Three-legged interchanges:

Various fully-directional and partially-directional three legged interchanges are illustrated in Figure 8-8. In Figure 8-8 (i), one single structure providing a three-level separation is required. Figure 8-8 (ii) also requires three levels of roadway but spread across two structures hence reducing the complexity of the structural design.

It is also possible with this layout to slightly reduce the height through which vehicles have to climb. Figure 8-8 (iii) illustrates a fully-directional interchange that requires only two but widely separated structures. If North is assumed as being at the top of the page, vehicles turning from West to South have a slightly longer path imposed on them so that this should, ideally be the lesser turning volume.
Figures 8-8 (iv) and (v) show semi-directional interchanges. Their names stem from the loop ramp located within the directional ramp creating the appearance of the bell of a trumpet. The letters “A” and “B” refer to the loop being in Advance of the structure or Beyond it. The smaller of the turning movements should ideally be on the loop ramp but the availability of space may not always make this possible.

### 8.7.3 Access and Service Interchanges

In the case of the systems interchange, all traffic enters the interchange area at freeway speeds. At access and service interchanges, vehicles entering from the crossing road may be doing so from a stopped condition, so that it is necessary to provide acceleration lanes to ensure that they enter the freeway at or near freeway speeds. Similarly, exiting vehicles should be provided with deceleration lanes to accommodate the possibility of a stop at the crossing road, see Tables 8-7 and 8-8.

As previously discussed, there is distinct merit in the crossing road being taken over the freeway as opposed to under it. One of the advantages of the crossing road being over the freeway is that the positive and negative gradients respectively support the required deceleration and acceleration to and from the crossing road. The final decision on the location of the crossing road is, however, also dependent on other controls such as topography and cost.
Access interchanges normally provide for all turning movements. If, for any reason, it is deemed necessary to eliminate some of the turning movements, the return movement, for any movement that is provided, should also be provided. Movements excluded from a particular interchange should, desirably, be provided at the next interchange upstream or downstream as, without this provision, the community served loses amenity.

There are only two basic interchange types that are appropriate to access and service interchanges. These are the Diamond and the Par-Clo interchanges (a partial cloverleaf interchange) interchanges. Each has a variety of possible configurations.

Trumpet interchanges used to be considered suitable in cases where access was to provided to one side only, for example to a bypass of a town or village. In practice, however, once a bypass has been built it does not take long before development starts taking place on the other side of the bypass. The three-legged interchange then has to be converted into a four-legged interchange. Conversion to a Par-Clo can be achieved at relatively low cost. Other than in the case of the Par-Clo AB, one of the major movements is forced onto a loop ramp. The resulting configuration is thus not appropriate to the circumstances. In practice, the interchange should be planned as a Diamond in the first instance, even though the crossing road, at the time of construction, stops immediately beyond the interchange.

**Diamond Interchanges**

There are three basic forms of Diamond:

- The Simple Diamond;
- The Split Diamond; and the,
- Single Point Diamond.

The Simple Diamond is easy for the driver to understand and is economical in its use of space. The major problem with this configuration is that the right turn on to the crossing road can cause queuing on the exit ramp. In extreme cases, these queues can extend back onto the freeway, creating a hazardous situation. Where the traffic on the right turn is very heavy, it may be necessary to consider placing it on a loop ramp. This is the reverse of the situation on systems interchanges where it is the lesser volumes that are located on loop ramps. It has the advantage that the right turn is converted into a left-turn at the crossing road ramp terminal. By the provision of auxiliary lanes, this turn can operate continuously without being impeded by traffic signals.

The Simple Diamond can take one of two configurations: the Narrow Diamond and the Wide Diamond.

The Narrow Diamond is the form customarily applied. In this configuration, the crossing road ramp terminals are very close in plan to the freeway shoulders to the extent that, where space is heavily constricted; retaining walls are located just outside the freeway shoulder breakpoints. Apart from the problem of the right turn referred to above, it can also suffer from a lack of intersection sight distance at the crossing road ramp terminals. This problem arises when the crossing road is taken over the freeway and is on a minimum value crest curve on the structure. In addition, the bridge balustrades can also inhibit sight distance. In the case where the crossing road ramp terminal is signalised, this is less of a problem, although a vehicle accidentally or by intent running the red signal could create a dangerous situation.
The Wide Diamond was originally intended as a form of stage construction, leading up to conversion to a full Cloverleaf Interchange. The time span between construction of the Diamond and the intended conversion was, however, usually so great that, by the time the upgrade became necessary, standards had increased to the level whereby the loop ramps could not be accommodated in the available space. The decline in the popularity of the Cloverleaf has led to the Wide Diamond also falling out of favour.

The Wide Diamond has the problem of imposing a long travel distance on right-turning vehicles but is not without its advantages. The crossing road ramp terminals are located at the start of the approach fill to the structure. To achieve this condition, the ramps have to be fairly long so that queues backing up onto the freeway are less likely than on the Narrow Diamond. The crossing road ramp terminals are also at ground level, which is a safer alternative than having the intersections on a high fill. Finally, because the ramp terminals are remote from the structure, intersection sight distance is usually not a problem.

The Split Diamond can also take one of two forms: the conventional Split and the transposed Split. This configuration is normally used when the crossing road takes the form of a one-way pair. The problems of sight distance and queues backing up are not normally experienced on Split Diamonds and the most significant drawback is that right-turning vehicles have to traverse three intersections before being clear of the interchange. It is also necessary to construct frontage roads linking the two one-way streets to provide a clear route for right-turning vehicles.

The transposed Split has the ramps between the two structures. This results in a very short distance between the entrance and succeeding exit ramps, with significant problems of weaving on the freeway. Scissor ramps are the extreme example of the transposed Split. These require either signalisation of the crossing of the two ramps or a grade separation. The transposed Split has little to recommend it and has fallen into disuse, being discussed here only for completeness of the record.

The Single Point Interchange brings the four ramps together at a point over the freeway. This interchange is required where space is at a premium or where the volume of right-turning traffic is very high. The principal operating difference between the Single Point and the Simple Diamond is that, in the former case, the right turns take place outside each other and in the latter they are “hooking” movements. The capacity of the Single Point Interchange is thus higher than that of the Simple Diamond. It does, however, require a three-phase signal plan and also presents pedestrians with wide unprotected crossings.

The various configurations of the Diamond Interchange are illustrated in Figure 8.9 including the use of roundabouts at the crossing road terminals.

**Par-Clo interchanges**

Par-Clo interchanges derive their name as a contraction of PARtial CLOverleaf, mainly because of their appearance, but also because they were frequently a first stage development of a Cloverleaf Interchange. These interchanges are preferred where there are difficulties to obtain land in some quadrants of interchanges i.e. Diamonds cannot be used.

Three configurations of Par-Clo Interchange are possible: the Par-Clo A, the Par-Clo B and the Par-Clo AB. As in the case of the Trumpet Interchange, the letters have the significance of the loops being in advance of or beyond the structure. The Par-Clo AB configuration has the loop in advance of the structure for the one direction of travel and beyond the structure for the other. In all cases, the
loops are on opposite sides of the freeway. Both the Par-Clo A and the Par-Clo B have alternative configurations: the A2 and A4 and the B2 and B4.

These configurations refer to two quadrants only being occupied or alternatively to all four quadrants having ramps.

The various layouts are illustrated in Figures 8-10, 8-11 and 8-12.

Internationally, the Par-Clo A4 is generally regarded as being the preferred option for an interchange between a freeway and a heavily trafficked arterial. In the first instance, the loops serve vehicles entering the freeway whereas, in the case of the Par-Clo B, the high-speed vehicles exiting the freeway are confronted by the loop. This tends to surprise many drivers and loops carrying exiting traffic have higher accident rates than the alternative layout. Secondly, the left turn from the crossing road is remote from the intersections on the crossing road and the only conflict is between right-turning vehicles exiting from the freeway and through traffic on the crossing road. This makes two-phase signal control possible.
The Par-Clo AB is particularly useful in the situation where there are property or environmental restrictions in two adjacent quadrants on the same side of the crossing road.

The Rotary Interchange illustrated in Figure 8-12 has the benefit of eliminating intersections on the crossing road, and replacing them by short weaving sections. Traffic exiting from the freeway may experience difficulty in adjusting speed and merging with traffic on the rotary.

Rotaries have also been used in the United Kingdom as systems interchanges. In this configuration, a two-level structure is employed.

One freeway is located at ground level and the other freeway on the upper level of the structure with the rotary sandwiched between them. This is the so-called “Island in the Sky” concept.
8.7.4 Interchanges on Non-Freeway Roads

The application of interchanges where a non-freeway is a major route would arise where traffic flows are so heavy that a signalised intersection cannot provide sufficient capacity. In this case, the crossing road terminals would be provided on the road with the lower traffic volume. As a general rule, a simple and relatively low standard Simple Diamond or a Par-Clo Interchange should suffice.
An intersection with a particularly poor accident history may also require upgrading to an interchange. The accident history would provide some indication of the required type of interchange.

Where the need for the interchange derives purely from topographic restraints, i.e. where traffic volumes are low, a Jug Handle Interchange, illustrated in Figure 8-13, would be adequate. This layout, also known as a Quarter Link, provides a two-lane-two-way connection between the intersecting roads located in whatever quadrant entails the minimum construction and property acquisition cost.

Drivers would not expect to find an interchange on a two-lane two-way road and, in terms of driver expectancy, it may therefore be advisable to introduce a short section of dual carriageway at the site of the interchange.

### 8.8 Ramp Design

#### 8.8.1 General

A ramp is defined as a roadway, usually one-way, connecting two grade-separated through roads. It comprises an entrance terminal, a midsection and an exit terminal.

![Figure 8-13: Jug Handle interchange/One Quadrant Interchange](image)

The general configuration of a ramp is often determined prior to the interchange type being selected. The specifics of its configuration, being the horizontal and vertical alignment and cross-section, are influenced by a number of considerations such as traffic volume and composition, the geometric and operational characteristics of the roads which it connects, the local topography, traffic control devices and driver expectations.

A variety of ramp configurations can be used. These include:

- The outer connector, which serves the left turn and has free-flowing terminals at either end;
- The diamond ramp, serving both the left-and right-turns with a free-flowing terminal on the freeway and a stop-condition terminal on the cross-road;
- The Par-Clo ramp, which serves the right turn and has a free-flowing terminal on the freeway and a stop-condition terminal on the crossing road, with a 180 degrees loop between them;
- The loop ramp, serving the right turn and which has free-flowing terminals at both ends and a 270 degrees loop between them;
• The directional ramp also serving the right turn, with a curve only slightly in excess of 90 degrees and free-flowing terminals at either end, and,
• The collector-distributor road intended to remove the weaving manoeuvre from the freeway.

8.8.2 Design Speed

The design speed of a ramp should be related to the design speed of the through and intersecting roads, and should preferably not be less than the operating speed of the through road. Ramp design speed can, however, gradually be reduced to half that of the through road under restricted circumstances.

In general, a design speed of 40 km/h is adequate for loops as the advantages of a higher design speed will very often be nullified by the additional distance of travel resulting from the correspondingly larger radii required. As the free-flowing ramp terminal is designed to the speed of the through road, it may be necessary to achieve the minimum radius by compounding it with larger radii as discussed in Sub-chapter 8.8.4.

A semi-directional layout is selected for a given ramp when a high volume of turning traffic is expected. Free-flowing terminals at both ends of the ramp will accommodate traffic entering and leaving the ramp at speeds close to the operating speeds of the through and intersecting roads. A low design speed on the mid-section of the ramp will clearly have a restrictive effect on the capacity of the ramp and is therefore not acceptable. The minimum design speed of a semi-directional ramp should not be less than the speed suggested in Table 8-2.

<table>
<thead>
<tr>
<th>Through roads (km/h)</th>
<th>Ramp (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>120</td>
<td>90</td>
</tr>
</tbody>
</table>

Source: SATCC

Direct connections, such as the outer connectors of a cloverleaf interchange, should also be designed for the speeds suggested in the table.

Diamond ramps always and Par-Clo ramps usually, have a free-flowing terminal at one end and a stop-condition terminal at the other. The free-flowing terminal and the section of ramp immediately following should have a design speed equivalent to the operating speed of the through road, and the design speed should not be less than 80 km/h. After that the design speed may become progressively lower, but must be at least 40 km/h at the stop-condition terminal. As in the case of the loop, the Par-Clo ramp may also have a minimum radius appropriate to a design speed of 40 km/h.

8.8.3 Sight Distance on Ramps

It is necessary for the driver to be able to see the road markings defining the start of the taper on exit ramps and the end of the entrance taper. At the crossing road ramp terminal, lanes are often specifically allocated to the turning movements with these lanes being developed in advance of the terminal. The driver has to position the vehicle in the lane appropriate to the desired turn. It is therefore desirable that decision sight distance be provided on the approaches to the ramp as well as across its length.
Appropriate values of decision sight distance are given in Chapter 6.

8.8.4 Horizontal Alignment

Minimum radii of horizontal curvature on ramps should comply with that given in Chapter 6 (Table 6.4) for various values of $e_{\text{max}}$. In general, the higher values of $e_{\text{max}}$ are used in highways design and the selected value should also be applied to the ramps.

It is generally accepted that changes in design speed should not be too marked, so that these changes should occur in increments not exceeding 10 km/h. The two lowest speeds in Table 6-4 apply to the design of stop-condition terminals, and the others to the design of the ramp itself.

The ratio between succeeding radii is generally about 1:1.5. When a compound curve of above-minimum radii is being determined, this ratio can be employed to advantage. Drivers are reluctant to brake sharply on a curve, and deceleration along a compound curve would take place under conditions of no, or at most gentle, braking. The successive curves forming the compound curve should thus each be long enough to allow the driver to match his speed to that judged appropriate to the following section of curve without sharp braking. This condition is achieved if the length of the arc is approximately a third of its radius.

8.8.5 Superelevation on Ramps

The selection of a superelevation rate of 8 per cent as the maximum for open road conditions is based on the likelihood of there being vehicles in the traffic stream that will be travelling at speeds considerably different from the design speed. As ramp design speeds are lower than those on the through and intersecting roads of an interchange, it is reasonable to expect that vehicle speeds on ramps will more closely match the selected design speed, so that higher rates of super-elevation can be adopted. Higher rates of superelevation would, however, require greater lengths for superelevation development and, because the necessary length would probably not be available, the maximum rate of 8 per cent is also applied to ramps.

The development of superelevation on a ramp takes into account the comfort of the occupants of a vehicle traversing the ramp. Under the less restricted circumstances of the open road the length of development can be extended to enhance the appearance of the curve. It is convenient to express the rate of development in terms of the change in superelevation rate per unit length, as shown in Table 8-3.

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Rate of Change per m (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0.195</td>
</tr>
<tr>
<td>50</td>
<td>0.185</td>
</tr>
<tr>
<td>60</td>
<td>0.175</td>
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<tr>
<td>70</td>
<td>0.165</td>
</tr>
<tr>
<td>80</td>
<td>0.155</td>
</tr>
<tr>
<td>90</td>
<td>0.145</td>
</tr>
<tr>
<td>100</td>
<td>0.135</td>
</tr>
</tbody>
</table>

Source: SATCC
Ramps are relatively short and the radii of curves on ramps often approach the minimum for the selected design speed. Furthermore, if there is more than one curve on a ramp, the distance between the successive curves will be short. Under these restrictive conditions, transition curves should be considered.

Ramps are seldom, if ever, cambered and superelevation typically involves rotation around one of the lane edges. Drivers tend to position their vehicles relative to the inside edge of any curve being traversed, i.e. they steer towards the inside of the curve rather than away from the outside. For aesthetic reasons, the inside edge should thus present a smoothly flowing three-dimensional alignment with the outside edge rising and falling to provide the superelevation. Where a ramp has an S- or reverse curve alignment, it follows that first one edge and then the other will be the centre of rotation, with the changeover taking place at the point of zero crossfall.

### 8.8.6 Crossover Crown

A crossover crown line is a longitudinal line at which an instantaneous change of slope across the pavement occurs. The only difference between this and the normal crown of the road is that it may occur at any position across the pavement other than the centre of the road. The principal application of the crossover crown is at ramp tapers, where it can be used to begin the super-elevation of the first ramp curve earlier than would otherwise be the case. The crossover crown may pose a problem to the driver, particularly of a vehicle with a high load, because the vehicle will sway as it crosses over the crown line, and, in extreme cases, may be difficult to control. For this reason, maximum algebraic difference in slope across the crossover crown line is as indicated in the Table 8-4 below:

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Algebraic difference in slope (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 and 30</td>
<td>5 to 8</td>
</tr>
<tr>
<td>40 amd 50</td>
<td>5 to 6</td>
</tr>
<tr>
<td>60 and over</td>
<td>4 to 6</td>
</tr>
</tbody>
</table>

Source: SATCC

In view of the restricted distances within which superelevation has to be developed, the crossover crown line is a useful device towards rapid development. The crossover crown could, for example, be located along the yellow line defining the edge of the left lane of the freeway, thus enabling initiation of superelevation for the first curve on the ramp earlier than would otherwise be the case.

### 8.8.7 Vertical Alignment of Ramps

#### Gradients

The profile of a ramp typically comprises a midsection with an appreciable gradient coupled with terminals where the gradient is controlled by the adjacent road. If the crossing road is over the freeway, the positive gradient on the off-ramps will assist a rapid but comfortable deceleration and the negative gradient on the on-ramp will support acceleration to highway speeds. In theory, thus, the higher the value of gradient, the better. Values of gradient up to eight per cent can be considered but, for preference, gradients should not exceed six per cent. Diamond ramps are usually fairly short, possibly having as little as 120 to 360 metres between the nose and the crossing road. The effect of the midsection gradient, while possibly helpful, is thus restricted. However, a steep gradient (8 per cent) in conjunction with a high value of superelevation (10 per cent) would have a resultant of 12.8 per cent
at an angle of 53 degrees to the centreline of the ramp. This would not contribute to drivers’ sense of safety. In addition, the drivers of slow-moving trucks would have to steer outwards to a marked extent to maintain their path within the limits of the ramp width. This could create some difficulty for them. It is suggested that designers seek a combination of superelevation and gradient such that the gradient of the resultant is less than ten per cent. Table 8-5 provides an indication of the gradients of the resultants of combinations of superelevation and longitudinal gradient.

### Table 8-5: Maximum Resultant Gradients

<table>
<thead>
<tr>
<th>Superelevation (%)</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
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<tr>
<td>4</td>
<td>4.5</td>
<td>5.7</td>
<td>7.2</td>
<td>8.9</td>
</tr>
<tr>
<td>6</td>
<td>6.3</td>
<td>7.2</td>
<td>8.5</td>
<td>10.0</td>
</tr>
<tr>
<td>8</td>
<td>8.3</td>
<td>8.9</td>
<td>10.0</td>
<td>11.3</td>
</tr>
<tr>
<td>10</td>
<td>10.2</td>
<td>10.7</td>
<td>11.6</td>
<td>12.8</td>
</tr>
</tbody>
</table>

Source: UGDM

The combinations of gradient and superelevation shown in lighter colour in Table 8-5 should be avoided.

**Vertical Curves**

It is essential that the driver should be able to see the road markings on the ramp. The suggested sight distance on ramps should be the normal stopping sight distance, but measured from an eye height of 1.05 m to the road surface. The vertical curvature required for this is given in Table 8-6.

### Table 8-6: Minimum values of k for vertical curves on ramps

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Crest curves</th>
<th>Sag curves</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>50</td>
<td>20</td>
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</tr>
<tr>
<td>60</td>
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<td>25</td>
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<td>70</td>
<td>43</td>
<td>32</td>
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<td>80</td>
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<td>90</td>
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<td>110</td>
<td>154</td>
<td>75</td>
</tr>
<tr>
<td>120</td>
<td>210</td>
<td>91</td>
</tr>
</tbody>
</table>

(Source: SATCC)

### 8.8.8 Ramp Cross-Section

If a stalled vehicle blocks an off-ramp, the line of stopped vehicles will soon extend back to the freeway creating a hazardous situation and also affecting the quality of traffic flow on the freeway. The blocking of an on-ramp will lead to the blocking of the stop-condition terminal, impeding the flow of traffic along the crossing road. An overall ramp width of 8.0 m, comprising two shoulders 2.0 m wide and a lane 4.0 m wide, would be adequate for this situation and also allow for future conversion of the single lane into two narrower lanes.

In the case of a loop ramp, the radius could be as low as 50 metres. At this radius, a semi trailer would require a lane width of 5.07 metres. It is necessary for the designer to consider the type of vehicle
selected for design purposes and to check whether the four metre nominal width is adequate. If semi trailers are infrequent users of the ramp, encroachment on the shoulders could be considered.

**8.8.9 Ramp Terminals**

Bellmouths are used in the design of the terminal where the ramp joins the intersecting road and traffic enters the intersecting road at angles near to 90 degrees. Tapers are used for vehicles entering or exiting from the through road at angles close to parallel to the through road. The ramp terminal of the intersecting road should be designed in accordance with the guidelines given in Figures 8.14 – 8.18. Through road ramp terminals are discussed below.

The spacing of successive terminals should be such that the manoeuvres carried out by a driver entering at one terminal are not hampered by vehicles entering at the next terminal downstream. The distance between an entrance and the following exit should allow for weaving between the two terminals. An exit followed by another exit does not cause any driving problems, and if this were the only criterion, successive exits could be closely spaced. It is necessary however, for the driver to be able to differentiate clearly between the destinations served by two successive exits, and adequate space should be allowed for effective signing. A distance of 300 m between successive terminals is adequate for terminals located on the highway itself. If successive terminals are on a collector-distributor road, or on the ramps of a systems interchange, the distance between terminals can be reduced to 240 m. If the ramps on which successive terminals occur form part of an access interchange, the distance between terminals can be further reduced to 180 m. The distances suggested correspond to decision sight distance for the different design speeds that are likely to apply to the various circumstances.

In this section, two types of free-flowing ramp terminal are discussed, namely the parallel terminal and the taper. The parallel terminal involves a combination of a taper with a length of auxiliary lane and is used when, because of steep gradients, an additional length is required for either acceleration or deceleration and when the necessary distance cannot be obtained by other means. The length of the auxiliary lane would normally be 600 to 1 000 m. These auxiliary lanes could also be introduced for the purpose of achieving lane balance at a terminal. The distance of 600 m corresponds to a travel time of 20 seconds, which is double the reaction time required for complex decisions.

Two different criteria apply to the selection of taper rate, depending on whether the ramp is an exit or an entrance. If the ramp is an exit, the only task required of the driver is to negotiate a change of direction without encroaching on either the adjacent lane or the shoulder. It is customary to indicate the start of the taper clearly by introducing it as an instantaneous change of direction rather than as a gentle curve. If a crossover crown is not used, the cross-fall across the taper will be the same as that on the through lane, i.e. two per cent. This corresponds to the super-elevation applied to a curve of radius 2 500 m to 3 000 m at a speed of 100 km/h. A vehicle can be contained within the width of travelled way available to it while negotiating a curve of this radius if the taper rate is in the region of 1:15. Higher design speeds and hence higher operating speeds require flatter tapers, whereas lower design speeds would make it possible to consider sharper tapers. At an entrance taper, in addition to negotiating a change of direction, the driver must merge with through traffic in the outside lane of the through road. A rate of convergence of about 1:50 provides an adequate merging length. Tapers that can be used for single and two-lane entrances and exits are illustrated in Figures 8-14 to 8-18. The dimensions shown on these figures are also appropriate for major forks and merges. The main difference between forks, merges and ramps is that the first two are a continuation of through roads. In the case of forks and merges, through road speeds would be used in design and the restriction on exiting or entering from the right would not apply.
NOTE: For 50m advance of the merging end, the ramp should not be more than 0.75m lower than the freeway.

Dimensions in metres

Figure 8-14: Single-lane entrance
NOTE: Sight distance of 300m measured from an eye height of 1.05m to the road surface should be provided in the area in advance of the nose.

Figure 8-15: Single-lane exit
NOTE: For 50m advance of the merging end, the ramp should not be more than 0.75m lower than the freeway.

Figure 8-16: Two-lane entrance (with one lane added)
NOTE: Sight distance of 300m measured from an eye height of 1.05 to the road surface should be provided in the area in advance of the nose.

1:15 taper

Dimensions in metres

Figure 8-17: Two-lane exit (with one lane dropped)
Research has shown that deceleration rates applied to off-ramps are a function of the freeway design speed and the ramp control speed. As both speeds increase, so does the deceleration rate, which varies between 1.0 m/s² and 2.0 m/s². For convenience, the deceleration rate used to develop Table 8.7 has been set at 2.0 m/s².

<table>
<thead>
<tr>
<th>Freeway design speed (km/h)</th>
<th>Ramp control speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LT (m) 0 40 50 60 70 80 90 100</td>
</tr>
<tr>
<td>60</td>
<td>66 70 60 21</td>
</tr>
<tr>
<td>70</td>
<td>75 95 85 45 25</td>
</tr>
<tr>
<td>80</td>
<td>75 125 115 75 55 30</td>
</tr>
<tr>
<td>90</td>
<td>85 115 150 110 85 60 30</td>
</tr>
<tr>
<td>100</td>
<td>91 190 185 145 125 100 70 35</td>
</tr>
<tr>
<td>110</td>
<td>101 235 225 185 165 140 110 75 40</td>
</tr>
<tr>
<td>120</td>
<td>107 280 270 230 210 180 155 120 85</td>
</tr>
<tr>
<td>130</td>
<td>111 325 320 275 225 230 200 170 135</td>
</tr>
</tbody>
</table>

Source: UGDM

The acceleration rate can, according to American literature, be taken as 0.7 m/s². The length of the acceleration lane is thus as shown in Table 8.8.

The lengths of the deceleration and acceleration lanes shown in Tables 8-7 and 8-8 apply to gradients of between -3 per cent and +3 per cent. Acceleration lanes will have to be longer on upgrades and may be made shorter on downgrades, with the reverse applying to deceleration lanes.
Table 8-8: Length of Acceleration Lanes (m)

<table>
<thead>
<tr>
<th>Freeway design speed (km/h)</th>
<th>LT (m)</th>
<th>0</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>45</td>
<td>200</td>
<td>110</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>54</td>
<td>270</td>
<td>180</td>
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<td>460</td>
<td>415</td>
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<td>200</td>
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<td>130</td>
<td>90</td>
<td>930</td>
<td>840</td>
<td>797</td>
<td>730</td>
<td>660</td>
<td>580</td>
<td>485</td>
<td>380</td>
</tr>
</tbody>
</table>

Source: UGDM

8.9 Collector - Distributor Roads

A collector-distributor road, often abbreviated as C-D road, is a one-way road next to a freeway that is used for some or all of the ramps that would otherwise merge into or split from the main lanes of the freeway.

Collector-distributor roads are typically applied to the situation where weaving manoeuvres would be disruptive if allowed to occur on the freeway. Their most common application, therefore, is at Cloverleaf interchanges where vehicles are entering and leaving simultaneously on adjacent loop ramps. The exit and entrance tapers are identical to those applied to any other ramps. The major difference between Cloverleaf interchange C-D roads and other ramps is that they involve two exits and two entrances in quick succession. The C-D road has the dual function of operating as a deceleration/acceleration lane and as a weaving area.

The C-D road should be separated from the freeway so weaving manoeuvres are not made in the through lanes of the main carriageway.

A collector-distributor road may be warranted within an interchange, through two adjacent interchanges or continuous for some distance along the freeway through several interchanges if the spacing between successive interchanges is less than 800 m. Collector-distributor roads should be provided at all cloverleaf interchanges and particularly at such interchanges on controlled access facilities. A collector-distributor road should be designed to meet the following goals:

- transfer weaving from the main lanes
- provide single-point exits from the main lanes
- provide exit from the main lanes in advance of cross roads.

The distance between the successive exits should be based on signing requirements so as to afford drivers adequate time to establish whether they have to turn to the right or to the left to reach their destination. Nine seconds is generally considered adequate for this purpose and seeing that vehicles may be travelling at the design speed of the freeway as they pass the nose of the first exit, the distance between the noses should desirably be based on this speed.
The distance between successive entrances is based on the length required for the acceleration lane length quoted in Table 8-8.

### 8.10 Other Interchange Design Features

#### 8.10.1 Ramp Metering

Ramp metering consists of traffic signals installed on entrance ramps in advance of the entrance terminal to control the number of vehicles entering the freeway. The traffic signals may be pre-timed or traffic-actuated to release the entering vehicles individually or in convoys. It is applied to restrict the number of vehicles that are allowed to enter a freeway in order to ensure an acceptable level of service on the freeway or to ensure that the capacity of the freeway is not exceeded. The need for ramp metering may arise owing to factors such as:

- Recurring congestion because traffic demand exceeds the provision of road infrastructure in an area;
- Sporadic congestion on isolated sections of a freeway because of short term traffic loads from special events;
- As part of an incident management system to assist in situations where an accident downstream of the entrance ramp causes a temporary drop in the capacity of the freeway; and,
- Optimising traffic flow on freeways.

Ramp metering also supports local transportation management objectives such as:

- Priority treatments with higher levels of service for High Occupancy Vehicles; and,
- Redistribution of access demand to other on-ramps.

It is important to realise that ramp metering should be considered a last resort rather than as a first option in securing an adequate level of service on the freeway. Prior to its implementation, all alternate means of improving the capacity of the freeway or its operating characteristics or reducing the traffic demand on the freeway should be explored. The application of ramp metering should be preceded by an engineering analysis of the physical and traffic conditions on the freeway facilities likely to be affected. These facilities include the ramps, the ramp terminals and the local streets likely to be affected by metering as well as the freeway section involved.

The stop line should be placed sufficiently in advance of the point, at which ramp traffic will enter the freeway, to allow vehicles to accelerate to approximately the operating speed of the freeway, as would normally be required for the design of ramps. It will also be necessary to ensure that the ramp has sufficient storage to accommodate the vehicles queuing upstream of the traffic signal.

The above requirement will almost certainly lead to a need for reconstruction of any ramp that is to be metered. The length of on-ramps is typically determined by the distance required to enable a vehicle to accelerate to freeway speeds. Without reconstruction, this could result in the ramp metering actually being installed at the crossing-road ramp terminal.
8.10.2 HOV Preferential Lane

Ramp meter installations should operate in conjunction with, and complement other transportation management system elements and transportation modes. As such, ramp meter installations should include preferential treatment of carpools and transit riders. Specific treatment(s) must be tailored to the unique conditions at each ramp location. However, the standard or base treatment upon which other strategies are designed is the High Occupancy Vehicle (HOV) preferential lane.

An HOV preferential lane shall be provided at all ramp meter locations.

In general, the vehicle occupancy requirement for ramp meter HOV preferential lanes will be two or more persons per vehicle. At some locations, a higher vehicle occupancy requirement may be necessary. The occupancy should be based on the HOV demand and coordination with other HOV facilities in the vicinity.

A preferential lane should typically be placed on the right, however demand and operational characteristics at the ramp entrance may dictate otherwise. The Road Authority responsible for ramp metering shall determine which side of the ramp they shall be placed, and whether or not the HOV lane will be metered.

Signing for an HOV preferential lane should be placed to clearly indicate which lane is designated for HOVs. Real-time signing at the ramp entrance, such as an overhead extinguishable message sign, may be necessary at some locations if pavement delineation and normal signing do not provide drivers with adequate lane usage information. To avoid trapping Single Occupancy Vehicles (SOVs) in an HOV preferential lane, pavement delineation at the ramp entrance should lead drivers into the SOV lane.

8.10.3 Express-Collector Systems

Express-collector systems are used where traffic volumes dictate a freeway width greater than four lanes in each direction. The purpose of the express-collector is to eliminate weaving on the mainline lanes by limiting the number of entrance and exit points while satisfying the demand for access to the freeway system.

An express-collector system could, for example, be started upstream of one interchange and run through it and the following, possibly closely spaced, interchange, terminating downstream of the second. The terminals at either end of the express-collector system would have the same standards as applied to conventional on- and off-ramps. The interchange ramps are connected to the express-collector system and not directly to the freeway mainline lanes.

Traffic volumes and speeds on the express-collector roads are typically much lower than those found on the mainline lanes, allowing for lower standards being applied to the ramp geometry of the intervening interchanges.

The minimum configuration for an express-collector system is to have a two-lane C-D road on either side of a freeway with two lanes in each direction. The usual configuration has more than two mainline lanes in each direction.
## Chapter 9 Road Furniture and other Facilities

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Chapter 9 Road Furniture and other Facilities

9.1 General

This chapter deals with road furniture and other facilities related to the road. It represents a collection of elements intended to improve the road user’s safety and driver’s perception and comprehension of the continually changing appearance of the road. Elements addressed herein include pedestrian and cycle facilities, traffic signs, road markings, marker posts, traffic signals, and lighting.

Traffic signs provide essential information to drivers for their safe and efficient manoeuvring on the road. Traffic signs, road markings and traffic signals including signing at road works shall conform to the Guide to Traffic Signing, Ministry of Infrastructure Development (2009).

Pedestrian facilities include pedestrian routes and crossing facilities while cycle facilities include provision of cycle ways or adequate shoulder widths for cyclists’ use.

Traffic islands, kerbs and road markings delineate the pavement edges and thereby clarify the paths that vehicles are to follow. Safety fences prevent cars from leaving the road at locations where this would have the most severe consequences.

Fences and gates along the road reserve are a means of controlling access.

Marker posts assist in a timely perception of the alignment ahead and, when equipped with reflectors, provide good optical guidance at night. Kilometre posts show the road user distances to the destination and from the origin at specified locations along the road. Road reserve markers provide proper demarcation of the border of the road reserve to limit unauthorized access and development within the road reserve area.

Lighting provides an effective means of reducing accidents especially at major junctions. The lighting poles will be considered as road furniture as are all other fixed objects along the carriageway which may form a traffic hazard.

9.2 Traffic Signs and Roads Markings

Traffic signs (also called road signs) are devices mounted on a fixed or portable support, whereby a specific message is conveyed by means of symbols or words officially erected for the purpose of warning or guiding the road users.

Road markings are traffic control devices in form of lines, symbols, words and patterns painted or otherwise applied on the surface of the road for the control, warning, guidance or information to the road users. They may be used to supplement kerbside or overhead signs or they may be used independently.

Signs and markings are not ordinarily needed to confirm basic rules of the road but they are essential where special regulations apply at specific places or at specific times only, where hazards are not self-evident, and to furnish information.
Signs and markings are also needed to give road users information concerning routes, directions and points of interest.

Signs and markings should only be used where they are warranted and justified by the application of engineering principles and factual studies. An adequate number of signs and markings must be used to inform properly the road users.

For details regarding the design, location and application of traffic signs, road markings and traffic signals including signing at road works, reference should be made to the Guide to Traffic Signing (2009) by Ministry of Infrastructure Development.

### 9.3 Pedestrian Facilities

Pedestrians have as much right to use the road as motorists, and roads must be designed with their needs in mind. The first step is to identify major pedestrian generators (markets, shops, schools, etc.) and determine which are the most important pedestrian routes. The aim should be to develop a network of pedestrian routes and crossing facilities that is convenient to use and avoids conflicts with vehicular traffic.

The risk of dying from injuries increases greatly with the speed of the vehicle hitting a pedestrian as shown in Figure 9-1.

![Figure 9-1: Risk of death from injuries at different vehicle speeds](image)

Source: NPRA
9.3.1 Shoulders and Footways

The conventional view is that pedestrians in rural areas can walk on the road shoulders. The shoulder should be at least 1.5 m wide. The surface must be well drained and as smooth as the traffic lanes – if not, pedestrians may prefer to walk in the traffic lane. The implication of this is that low-cost chip seal shoulders may not be a good investment. Letting pedestrians use the shoulders is not entirely satisfactory, as there is nothing to protect the pedestrian from speeding traffic. This is of particular concern on high-speed and / or high traffic volume roads. In these situations a separate footway should be provided several metres beyond the edge of the shoulder – and separated from it by a grass strip (see also Chapter 5 – Cross-Section Design). Some criteria for the provision of footways are given in Table 9-1 below but these should be used with caution – in some circumstances footways can be justified at lower pedestrian flows.

<table>
<thead>
<tr>
<th>Location of footway</th>
<th>Average daily vehicle traffic</th>
<th>Pedestrian flow per day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speed limit of 60 - 80 km/h</td>
<td>Speed limit of 80 - 100 km/h</td>
</tr>
<tr>
<td>One side only</td>
<td>400 to 1,400</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>&gt; 1,400</td>
<td>200</td>
</tr>
<tr>
<td>Both sides</td>
<td>700 to 1,400</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>&gt; 1,400</td>
<td>600</td>
</tr>
</tbody>
</table>

Table 9-1: Criteria for provision of footways

Source: UGDM

Standard footway widths are:

- Absolute minimum: 1 m (two persons cannot pass each other)
- Desirable minimum: 1.5 m (two persons can pass each other closely)
- Light volume: 2.0 m (two persons can pass each other comfortably)
- Heavy volume: 3.5 m+ (space for three persons)

When the road passes urban areas the footways are normally raised, and edged with barrier kerbs. Barrier kerbs should normally be 150 – 200 mm high. Higher kerbs (250 mm) are sometimes used in order to deter vehicles from parking on the footway, but these are not recommended for general use, because they are too high for most pedestrians – who will prefer to walk in the traffic lane. The kerb should be lowered at all pedestrian crossings, and where private entrances, footpaths, and cycle tracks enter the carriageway. The “dropped kerb” (Figure 9-2) is particularly helpful to physically disadvantaged persons.

![Figure 9-2: Dropped kerb](image-url)
9.3.2 Pedestrian Crossing Facilities

Pedestrian crossings are provided to improve road safety for pedestrians when crossing a road. Factors to take into account for the provision of pedestrian crossing facilities include:

- the volume of pedestrians crossing the road;
- the speed of the traffic;
- the width of the road;
- whether there are a lot of children crossing; and
- whether there are significant numbers of disabled pedestrians.

There are many things that can be done to help pedestrians cross the road, including:

- Formal crossings;
  - uncontrolled (zebra) crossings; and
  - controlled (signal-controlled) crossings.
- Humped pedestrian crossings;
- Build-outs;
- Refuge islands;
- Medians;
- Pedestrian bridges (see next sub-section); and,
- Underpasses (see next sub-section).

The uncontrolled (zebra) and signal-controlled crossings should be used where there are high volumes of pedestrians trying to cross wide and / or busy roads. The safety benefits of zebra crossings depend on the discipline amongst drivers. Where discipline exists and all drivers stopped for pedestrians, this can lead to severe congestion at busier crossings. Signal-controlled crossings, though more expensive to install and maintain, are likely to perform better.

Various requirements have to be met when placing pedestrian crossing facilities. They should be located well away from conflict points at uncontrolled road junctions. Signal-controlled crossings on major roads should be located as shown in figure 9.3, a minimum of 20 metres from the nearest kerb of the side-road. Pedestrian fences may be provided at the intersections to ensure the pedestrians cross the road at the specified locations.

![Figure 9-3: Placing of pedestrian crossing facilities](image-url)
For zebra crossing without signal-control, the distance should be a minimum of 5 metres away.

Crossings should not be placed adjacent to bus stops. If this is unavoidable, bus stops should always be beyond the crossing.

Zebra crossings can be made to work better if the crossing is marked on top of a plateau road hump. The hump forces approaching vehicles to slow down and this gives the pedestrian a chance to step onto the crossing and claim priority.

Crossing the road can be made a lot safer by means of simple, informal measures, such as build-outs, refuge islands and medians. Figure 9-4 shows the use of build-outs and refuge islands with a zebra crossing, but they can also be used on their own.

Build-outs are useful on wide roads where there is roadside parking, because they extend the footway further into the road thus improving inter-visibility between pedestrians and drivers.

Refuge islands in the centre of the road enable pedestrians to cross the road in two stages, which makes it much easier and safer. However, kerbed refuge islands are at risk of being hit by speeding vehicles, so they must be well signed – with R103, “Keep left” signs. Alternatively, refuges can be created out of road markings (RM5 traffic island marking) and rumble strips provided within them. Refuge islands should be at least 1.5 m wide (preferably 2.0 m). The designer should make sure that there is sufficient width of carriageway left to enable traffic to flow freely. A width of 3.0 – 3.5 m is normally enough for one lane of traffic.

When considering the provision of crossing facilities at a site, the inter-visibility between pedestrians and drivers should always be checked. It shall be at least equal to the stopping sight distance as detailed in Chapter 6 of this manual.

![Figure 9-4: Pedestrian crossing facilities](image)

Refer to Chapter 5 Cross-Section Design for advice on pedestrian facilities on bridges.
Criteria for provision of pedestrian crossing are as follows:

**Speed limit of 30 km/h**
Normally a zebra crossing is not established at speed limit of 30 km/h. If a crossing is needed for some reason, the 85%-percentile has to be 35 km/h or less. Otherwise a speed-reducing measure should be considered.

**Speed limit of 40 km/h**
Normally a zebra crossing will be considered when more than 20 pedestrians/bicycles cross during the max-hour and ADT is ≥ 2,000.

**Speed limit of 50 km/h**
Normally a zebra crossing will be considered when more than 20 pedestrians/bicycles cross during the max-hour and ADT is ≥ 2,000.

**Speed limit of 60 km/h**
Normally a zebra crossing should not be considered at speed limit of 60 km/h and never if ADT is ≥ 4,000. A grade separated crossing must be considered independent of number of pedestrians/bicycles crossing.

**Speed limit of 80 km/h**
Roads with ADT ≤ 4,000 and number of pedestrians ≥ 50, grade separated crossing for pedestrians/bicycles must be established.
With ADT ≥ 4,000, a grade separated crossing must then be established independent of number of pedestrians/bicycles crossing.

### 9.3.3 Pedestrian Bridges and Underpasses
Considerations to be taken into account in the provision of grade-separated crossings over freeways/highways are:

- The persistent tendency of pedestrians to cross the freeways/highways at-grade at specific points.
- The distance from other freeways/highways crossing facilities.
- Pedestrian-related accidents on freeways/highways.
- Physical characteristics, e.g. topography, which facilitate convenient crossing facilities.

Underpasses are preferable to pedestrian bridges because the height difference is less, but they are much more costly, and the security and maintenance problems can be worse. Whenever possible the pedestrian bridge or underpass should be in line with the normal path that pedestrians take when crossing the road. If pedestrians have to diverge from their direct route they will be discouraged from using the facility. Pedestrian barriers can be used to try and force pedestrians to use the facility, but local people can destroy them if they feel that the detour is unreasonable. When designing pedestrian bridges and underpasses, the designer should make sure that they are easy to access (special attention to be made to children, elderly and disabled) and as pleasant and safe to use as possible. Pedestrian fences may be provided at the pedestrian bridges/underpasses to ensure the pedestrians use the facilities. Underpasses should be designed so that the pedestrian can see from one end to the other and can thus choose not to enter if there is a potentially threatening situation. Recommended minimum dimensions for underpasses are given in Table 9-2.
Table 9-2: Minimum underpass dimensions

<table>
<thead>
<tr>
<th>Type of underpass (m)</th>
<th>Width (m)</th>
<th>Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short (i.e. &lt; 15 m)</td>
<td>2.3</td>
<td>2.5</td>
</tr>
<tr>
<td>Long (i.e. &gt; 15 m)</td>
<td>3.3</td>
<td>3.0</td>
</tr>
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</table>

The designer shall provide an underpass width based on the anticipated number of pedestrians to use the underpass but should never be less than the values shown in Table 9-2 above.

Ideally, there should be a choice of stairs or ramps. Ramps should not normally be steeper than 10% and should have a non-slip surface.

Recommended standards for stairs are:

- Flights of stairs (between landings) should be limited to 12 steps;
- Stair landing should be a minimum of 1.8 m;
- Steps should be of equal heights throughout the underpass or pedestrian bridge;
- Optimum dimensions for stairs are 300 mm tread (horizontal) and 150 mm rise (vertical); and,
- Handrails (1 m above the floor) should be provided on both sides of stairs and ramps central handrails may be advisable where the width of the stairs or ramps exceeds 3 m.

The desirable clearance required for pedestrian bridges above the carriageway surface is 5.5 m and the absolute minimum 5.2 m. This headroom must be attained over the full width of the carriageway, including the tip of the cross-fall.

9.4 **Bus Bays**

Bus bays are recommended for new and upgraded roads, other than low-volume roads. They enable buses to slow down and stop outside the traffic lane, and this greatly reduces the risk of following traffic colliding with them or having to overtake in a panic. At bus stops the waiting passengers sometimes stand in the bus bay and so prevent the buses from fully entering the bus bay, in this case pedestrian barrier can be installed to prevent this.

To be fully effective, bus bays should incorporate:

a) a deceleration lane or taper to permit easy entrance to the loading area. It must be long enough to enable the bus to leave the through traffic lanes at approximately the average running speed of the highway without undue inertial discomfort or sideways to passengers; Due to higher entry speeds, more clear space for lateral movement is required on the approach to a bus stop than on the departure side;

b) a standing space sufficiently long to accommodate the maximum number of buses expected to occupy the space at one time and far enough from the carriageway edge to eliminate sight distance problems; and,

c) a merging lane to enable easy re-entry into the through-traffic lanes. The length of acceleration lanes from bus bays, unlike deceleration lanes, should be well above the normal minimum values as the buses start from a standing position and the loaded bus has a lower acceleration capability than passenger cars.
The standard design for a bus bay is shown in Figure 9-5, but the dimensions can be adjusted to suit local traffic situations.

Bus bays should be at least 3.25 m wide and should be placed adjacent to the paved or gravel shoulder so that buses can stop clear of the carriageway. The length of a bus bay in rural areas should be not less than 15 m. Where multiple bus bays are provided - such as when the road passes urban areas - the length of the individual bus bays should not be less than 15 m. On heavily trafficked roads, a channelizing island 1.0 m wide may be provided along the road edge line to direct bus drivers to stop clear of the road shoulder.

Bus bays should preferably be located on straight, level sections of road with good visibility (at least Stopping Sight Distance). They should be sited after intersections, to avoid stopped vehicles from interfering with the view of drivers who want to enter the main road from the minor road [see Figure 9-6 (a)]. They should be sited after pedestrian crossings, for similar reasons. Bus bays shall not be sited opposite each other, because this can cause safety problems due to road blockage if both buses set off at exactly the same time. Bus bays must be staggered tail to tail so that departing buses move away from each other [Figure 9-6 (b)].
Figure 9-6: Recommended location for bus bays

At heavily used bus bays the dripping of oil and diesel onto the road surface may result in early failure of the pavement. In these situations use of concrete pavement should be considered. A loading area should provide 15 m of length for one bus and the length shall be increased depending on the anticipated number of buses that can frequently, simultaneously use the bus bay.

When siting bus bays, the designer should bear in mind that the existing bus stops will generally be located where they are most convenient for the passengers, and it is usually very difficult to persuade passengers and bus drivers to move to new stops, especially if they are more than 50m away. The provision of a bus shelter to protect the waiting passengers against the sun and rain will encourage passengers to use the bus stop. Such shelters should be robust enough to be difficult to vandalise and should have a depth of at least 1.6 metres as shown in figure 9.7 below. Also they should have a minimum width of 2.0 metres.

Figure 9-7: Typical bus shelter

The shelter should be provided with sitting facility, route information and trash receptacles. The designer should ensure that pedestrian access is easy and convenient at bus bays. It is important to consider the need to provide passengers with a convenient and safe path to and from the bus stop.
9.5 **Vehicle Parking Facilities and Rest Areas**

Vehicle parking facilities are constructed to provide a convenient area for travellers to park the vehicles in an organised manner. Rest areas are off-road designated locations provided for drivers and passengers to take rest breaks and overcome fatigue. Normally, rest areas and vehicle parking facilities are conveniently constructed at the same location.

9.5.1 **Vehicle parking facilities**

Vehicle Parking Facilities are provided at terminal or along the roadway allowing travellers to safely and efficiently park and rest in an organised manner. These facilities usually take into consideration particular modes of vehicles to address safety aspects. This sub-chapter addresses parking facilities for travellers along the roadway, which include parking in rest areas and Emergency Lay Bys.

Each parking facility shall generally contain a minimum area of 1,000 square metres which does not include manoeuvring and access. The actual area shall be determined based on the anticipated users.

Provision of a combined light vehicle and trucks parking in the rest area is recommended wherever possible. The light vehicles and truck parking areas shall be segregated to avoid internal conflicts, and to minimise disturbance between the two types of vehicle groups.

All parking areas must be surfaced with durable and dustless material capable of supporting wheel load of at least 5 tonnes per axle weight. Parking areas must be constructed utilising an approved bituminous mixture, concrete, interlocking paving blocks or other water sealed surface and should be provided with adequate drainage. The pavement layers should follow the requirements of the Pavement and Materials Design Manual, Ministry of Works (1999).

9.5.2 **Rest Areas**

Fatigue is a significant issue for those travelling long distances in the rural road environment. It is estimated that fatigue is the main contributing factor in approximately 25% of road crashes involving serious injury.

The provision of rest opportunities through rest areas represents a management tool in addressing fatigue-related crashes. A major challenge to realise the potential benefits of rest areas is to increase backing by those road users travelling long distances.

9.5.2.1 **Types of Rest Areas**

The main different types of rest areas are:

- Major Rest Areas
- Minor Rest Areas
- Truck Parking Areas

Each type of rest area will include a basic level of facility including the provision of a shelter with picnic table and seats, and in most cases bins. The key difference between the types of rest areas is in terms of capacity or size. In most cases each type of rest area will be accessible to all road users, with the main exception being a small number of minor rest areas where heavy vehicle access is not possible due to physical constraints of the site.
Major Rest Areas
These rest areas are intended to cater for long distance travellers in all user groups, including drivers of heavy vehicles, regular passenger vehicles and camper vans. Where possible major rest areas will define separate areas for heavy and light vehicle users. It is expected that Major Rest Areas will be utilised as long stay rest opportunities for long distance travellers.

Major rest areas will have the following facilities:

a) Adequate shelter with facilities, separated from vehicle carriageways and easily accessible (including access for physically disadvantaged groups);
b) Accommodation facilities for long rest stay;
c) Bins for rubbish collection;
d) Sufficient number of Toilets;
e) Lighting;
f) Fencing of the rest area – to contain rubbish movement, and protect surrounding native vegetation;
g) An unsealed all weather pavement for parking of vehicles (high volume routes or rest areas with significant usage may have sealed pavement);
h) A sealed carriageway through the rest area.

Where possible, Major Rest Areas shall be given a unique name. The name should be chosen to reflect the geographical location of the Major Rest Area. The naming of rest areas enables clear identification of rest opportunities, particularly in planning to manage rest areas.

Minor Rest Areas
Minor Rest Areas are primarily designated to cater for short term rest breaks by all road users including passengers of commuter buses, and therefore include basic facility, in particular sufficient number of toilets.

Minor rest Areas subjected to high usage should be considered for providing additional facilities, such as lighting, shelters, tables and seats. However, this will be determined on a case by as case basis.

Some minor rest areas may have local constraining factors that limit the suitability for safe access for heavy vehicles. In these instances the rest areas will be signed as not suitable for trucks.

Truck Parking Areas
These rest areas provide the same facilities as the minor rest area; however the capacity is limited. Whilst recognised as truck parking bays in terms of spacing and capacity, for all intents and purposes they are a rest area for all road users and will be signed accordingly.

For truck parking area, a parking facility is recommended to accommodate parking spaces for at least 10 long vehicles. These truck parking areas shall be located outside the road reserve and shall be accessed through deceleration and acceleration lanes.

An example of a layout of a truck parking facility has been shown in Figure 9.8 below.
Rest areas should be designed to encourage road users to take rest breaks or overcome fatigue. If rest areas are overly noisy, unattractive or poorly serviced, they will not fulfil their purpose. Therefore, the planning and design of rest areas is crucial to its attractiveness and intended purpose. Good planning and design requires an integration of the strategic planning and the detailed design aspects of rest areas. An integrated approach in the planning and design of rest areas includes the following:

### 9.5.2.2 Strategic Planning of Rest Areas

The selection of locations for rest areas is often difficult due to the large number of factors that need to be considered. Locations for rest areas should not be simply selected out of convenience from available unused sites. Poor placement of rest areas may discourage rest area use by general public. The initial planning of rest areas should use an integrated approach along a route long term rather than focussing on microscopic details of individual rest areas.

In assessing the long term needs of a route, consideration must be given to natural traffic growth and redirected traffic from other sources as route improvements are provided. Consideration should be given to reserving or acquiring necessary land to allow the flexibility of upgrading existing or new rest areas in the future. Factors that need to be taken into consideration in relation to spacing of rest areas include:

- Location of existing stopping opportunities and commercial service centres.
- Annual Average Daily Traffic (AADT).
- Composition of traffic.
- Future construction works.

The designer should carry out a rest areas demand study in order to calculate the spacing of the rest areas and the number of vehicle spaces required for each rest area. The recommended typical spacings for rest areas are:

- Major Rest Areas every 100 - 120 km – intended for long stays;
- Minor Rest Areas every 50 - 60 km – intended for short breaks; and
- Truck Parking Bays every 30 - 40 km. – intended for short breaks/load check.

Rest areas may be located at closer distances where existing rest areas are unable to satisfy demand, and cannot be expanded due to local conditions. Rest areas in towns along the roads including those provided by commercial operators should be taken into account when assessing rest area spacing.

The spacing of rest areas should also consider the directional benefits and safety of locating the rest areas on both directions on dual carriageways with high traffic volume.
The size of the rest area relates to the demand for parking spaces. The designer should carry out demand estimation to estimate the number of vehicle spaces required in rest areas. For this data input such as traffic volume on an hourly basis, proportion of vehicles using a facility and assumed ratios for the local or regional conditions shall be required.

9.5.2.3 Site Location

Potential rest area locations can be identified based on preferences of rest area features that the sites naturally provide such as grade, natural shade, good views of the surrounding area, availability of utilities, and by considering the geometric and environmental constraints of the sites. The following lists some factors that assist in identifying preferable rest area locations.

a) Rest areas should be located within close access to the route and outside the Road Reserve.
b) Better utilisation can be expected from sites with clear early visibility of facilities.
c) Straight sections prior to downgrades, with good sight distance are preferred. This will enable all vehicles, in particular heavy vehicles, improved outlet when leaving or re-entering traffic flow.
d) Flat areas are important for truck parking in rest areas.
e) Areas that provide shade and scenic value are desirable for rest areas. Good views and an attractive setting will encourage road users to stop. Shade is particularly important for truck drivers.
f) Close proximity to public utilities such as water, sewerage connections, and electricity is desirable, as this reduces the cost of building and operating the rest area, as well as improving the quality.

Potential locations for rest areas should undertake environmental assessment to ensure environmental impacts are minimised. For example, a visual impact assessment will help to provide guidance on the best possible location for good views. Good views at rest areas encourage people to stop, relax and take their mind off the journey.

9.5.2.4 Site Design

There are many factors that need to be addressed in the development of a successful rest area. In order to ensure these are covered and integrated into a coherent approach, it is important that an overall concept is prepared.

Access into and outlet from rest areas are important design aspects for rest areas. Access and outlet must provide an adequate level of safety for vehicles entering or leaving the rest area and re-entering the traffic flow. Uphill exits are very undesirable for trucks and may lead to trucks stopping on the road shoulder nearby, instead of using the rest area.

Chapter 7 Design of at Grade Intersections should apply to roadside rest area access points. Sight distance, design vehicle turning paths and interference to through traffic by decelerating and accelerating vehicles should be considered at each site.

a) Access arrangement - On dual carriageway roads, left in/left out rest area access is always recommended for both light vehicles and heavy vehicles. This means that rest area facilities must be duplicated (one rest area on each side of the road). Such pairs of rest areas do not have to be opposite each other. (they may be staggered down the road).
b) Acceleration and deceleration lanes – Adequate acceleration and deceleration lanes shall be provided at the exit and entrance of rest areas respectively. Acceleration lanes are provide to enable entering traffic to accelerate to the design speed of the through carriageway. Locating rest areas at the top of crests also assist vehicles to decelerate and accelerate when entering and leaving the rest area and reduces the length of acceleration and deceleration lanes.

c) Turning radii - Access into and out of the rest area should consider the turning radii of light and heavy vehicles.

d) Sealed pavement - Access into the rest area should be sealed to enable safe entry and exit.

e) Special consideration for the disadvantaged – Adequate facilities for the physically disadvantaged groups shall be provided in all aspects of the rest areas.

A consistent approach should be adopted in the provision of rest area facilities. Based on survey responses from rest area users; toilets, shade, picnic tables and chairs, and rubbish bins are considered the most desirable features at rest areas. In order to minimise life cycle cost, rest area facilities should be durable, low maintenance, vandal resistant and not portable.

The following figures show examples of vehicle parking and rest area layout. Major rest areas are shown in Figures 9-9 and 9-10. Typical Emergency Lay-bys are shown in Figure 9-11.

Figure 9-9: Rest area lay-out design with truck and car parking – front to rear parking design

Figure 9-10: Rest area lay-out design with truck and car parking – angle parking design

9.5.3 Emergency Lay-bys

The purpose of a lay-by is to provide a convenient area for short period stops so the road user can undertake tasks which would otherwise be considered unsafe whilst driving or pulled up on the side of the road. These would include tasks such as answering a mobile phone, changing driver, changing a flat fire or some other form of emergency stop.

When the width of shoulders is not more than two metres, the available space is not sufficient to warrant emergency parking and therefore in such circumstances, emergency lay bays should be provided. In rural areas, the desirable frequency is for lay-bys to be provided at intervals of about 5 km.
The lay-bys on the two lane two way road should be staggered and need not be close to or opposite each other. This will reduce the likelihood of pedestrians crossing the road which is a safety hazard.

Demand estimation shall be used to determine the length of the emergency lay bay. The demand is affected by factors such as traffic flow, lay-by spacing, proximity to junctions and proximity to other facilities. A minimum parking length (L2) of 30 m is recommended to accommodate at least two long vehicles. Shorter parking spaces normally encourage drivers to park along tapers which is undesirable.

\[ L1 = \text{Entrance taper length equal to at least } 35 \text{ m} \]
\[ L2 = \text{Parking length equal to at least } 30 \text{ m} \]
\[ L3 = \text{Exit taper length equal to at least } 20 \text{ m} \]
\[ D = \text{Width of the bay equal to at least } 4.5 \text{ m} \]

Figure 9-11: Typical Emergency Lay-bys
9.6 **Cycle Facilities**

Design of cycling facilities requires an understanding of the patterns and habits of potential users of the facility. The first step when planning highway programmes or projects is therefore to assess the demand and get some idea of journey patterns and volumes. Getting the design right the first time saves expense in the long run. Installing cycling facilities that are too narrow can often lead to require widening in the future, which might be difficult and expensive. A design approach that allows for future expansion may be required.

The conventional view is that cyclists in rural areas can use the shoulders, and this is acceptable provided that the combined volume of pedestrians and cyclists is low (< 400 per day) and the shoulder is at least 1.5 m wide. But, with heavier flows, and especially if there is high-speed traffic and/or a high proportion of heavy goods vehicles, it will be better to provide a separate cycleway or a combined cycleway and footway. Figure 9-12 shows the basic dimensions of a cyclist, and Table 9-3 gives recommended cycleway widths. Cycleways need to have a smooth surface with good skid resistance.

![Figure 9-12: Cyclist dimensions](source: NPRA)

<table>
<thead>
<tr>
<th>Type</th>
<th>Minimum width (m)</th>
<th>Standard width (m)</th>
<th>Width for heavy usage (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycleway (separate from carriageway)</td>
<td>2.0</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Combined cycleway and footway</td>
<td>2.0</td>
<td>3.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Cycle lane (one way)</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Source: NPRA
### Table 9-4: Recommended Clearances

<table>
<thead>
<tr>
<th>Type</th>
<th>Recommended Clearance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum overhead clearance</td>
<td>0.50</td>
</tr>
<tr>
<td>Clearance to wall, fence, barrier, or other fixed object</td>
<td>0.50</td>
</tr>
<tr>
<td>Clearance to unfenced drop-off, e.g. embankment, river, wall</td>
<td>1.0</td>
</tr>
<tr>
<td>Minimum clearance to edge of traffic lane for speed limit of:</td>
<td></td>
</tr>
<tr>
<td>50 km/h</td>
<td>0.50</td>
</tr>
<tr>
<td>80 km/h</td>
<td>1.00</td>
</tr>
<tr>
<td>100 km/h</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Source: NPRA

Speed calming measures in trading centres and other built-up areas will help cyclists by reducing motor vehicle speeds, but the needs of cyclists must be considered from the beginning. Otherwise features such as gates and narrowings could increase the dangers to cyclists. If there are a lot of cyclists it may be worth providing a short by-pass (1 m wide) which will enable cyclists to avoid the speed reduction measures.

### 9.7 Safety Barriers

#### 9.7.1 General

In order to improve and maintain highway safety, road safety barriers are necessary. The safety barriers are designated to redirect errant vehicles with a specified performance level and provide guidance for pedestrians or other road users.

The purpose of roadside barrier is:
1) To reduce/eliminate run-off-road potential;
2) To provide opportunity of run-off-road driver to return to the road; and
3) To reduce severity of accidents.

When a roadside hazard is identified, the best solution is to remove the hazard. Where the hazard is a drop, it will be worth considering whether the slope can be flattened to make it less hazardous. If this cannot be done there may be a case for shielding the hazard with a barrier.

Traffic safety barrier can be classified as:
1) Longitudinal barrier:
   o Flexible steel beam guardrail with posts made of steel or timber
   o Wire rope barrier
   o Concrete barrier.
2) Terminals:
   o Redirective
   o Non-redirective.
3) Transitions.
4) Crash cushions.

Ideally, the safety barrier will:
a) prevent the vehicle from passing through the barrier (the vehicle will be contained);
b) absorb (cushion) the impact of the vehicle without injuring the occupants (no severe deceleration);
c) re-direct the vehicle along the road parallel to the other traffic; and,
d) enable the driver to retain control of the vehicle (no spinning or overturning of the vehicle).

9.7.2 Design Principles

It is the designer’s responsibility to determine where a barrier is needed, its length and performance standard.

In addition, the designer should understand that safety barrier technology is still evolving. Thus, the designer should be ready to monitor the technology regularly for new developments and techniques. They are used to prevent vehicles from hitting or falling into a hazard - such as falling down a steep slope, or falling into a river, hitting an obstruction in the clear zone, or crossing a median into the path of traffic on the other carriageway. These events happen when a driver has lost control of the vehicle due to excessive speed, lack of concentration or being sleepy, tyre failure, collision, etc.

The specification, installation and maintenance of safety barriers are a highly technical subject, and this Manual can only give a brief introduction to the subject. The designer should always seek advice from experts, as safety barrier can be useless and even dangerous if not properly designed and installed. The components of safety barrier should always be purchased from a specialist manufacturer and their advice obtained. If possible, arrangements should be made for them to install it, or supervise the installation.

9.7.3 Alternative solutions to safety barriers

All elements of risk along the roads as obstacles, steep side slopes, bridges and underpasses might cause serious personal injuries in case of a vehicle accident. The road users have to be protected against such elements of risks. This can be done in six different ways:

1. Remove risk elements.
2. Make risk elements harmless.
3. Relocate risk elements.
4. Replace risk elements.
5. Protect risk elements.
6. Delineate risk elements.

A safety barrier is also an element of risk in its own and should only be used when it is more dangerous to drive off the road than to hit a safety barrier.

9.7.4 Containment requirements for safety barriers

The containment levels for safety barriers and bridge parapets in Tanzania are shown in Table 9-5.

Normally, safety barriers are designed to redirect errant passenger vehicles as shown under containment level N1 and N2, below. However, at places where the consequences of the barrier not withstanding a probable impact are great, barriers designed for heavy vehicles should be selected, i.e. containment level H2 or H4.
### Table 9-5 Requirement for containment level related to road/bridge conditions

<table>
<thead>
<tr>
<th>Containment level</th>
<th>Roads type/condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>Roads with speed limits ≤ 60 km/h and AADT ≤ 12,000</td>
</tr>
<tr>
<td></td>
<td>Roads with speed limits ≥ 70 km/h and AADT ≤ 1,500</td>
</tr>
<tr>
<td>N2</td>
<td>Roads with speed limit ≤ 60 km/h and AADT &gt; 12.00</td>
</tr>
<tr>
<td></td>
<td>Roads with speed limits ≥ 70 km/h and AADT &gt; 1,500</td>
</tr>
<tr>
<td></td>
<td>Freeway carrying high traffic volumes</td>
</tr>
<tr>
<td>H2</td>
<td>Bridges and large culverts</td>
</tr>
<tr>
<td></td>
<td>Retaining walls with drop &gt; 4 m</td>
</tr>
<tr>
<td></td>
<td>Cliff or a rock face with a drop of more than 4 metres and a slope steeper than 1:1.5*</td>
</tr>
<tr>
<td></td>
<td>Narrow medians (&lt; 2 m) in freeways with design speed &gt; 80 km/h and a high portion of HGV (&gt; 20 %)</td>
</tr>
<tr>
<td></td>
<td>Sensitive locations where errant vehicles may cause substantial damage e.g. at railways, drinking water reservoirs, etc.</td>
</tr>
<tr>
<td>H4</td>
<td>On and under bridges where an accident can cause bridge collapse</td>
</tr>
</tbody>
</table>

* On condition of satisfactory deformation space and fastening of the post

Source: NPRA

### 9.7.5 Performance criteria (Design criteria)

The manufacturer shall demonstrate or document by calculation that the performance criteria shown below is fulfilled.

The performance criteria are shown in Table 9-6 below. With this impact criterion, the errant vehicle shall be redirected safely to the road without crossing the line to the opposite direction of traffic. The vehicle shall remain in upright position after the test to assure that the driver can control the vehicle. The safety barrier, or the bridge parapet, shall not be fractured into pieces which can harm pedestrians close to the vehicle.

<table>
<thead>
<tr>
<th>Containment level</th>
<th>Impact speed (km/h)</th>
<th>Impact angle (degree)</th>
<th>Total mass kg</th>
<th>Type of vehicle</th>
<th>Theoretical kinetic energy KNm</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>80</td>
<td>20</td>
<td>1500</td>
<td>Car</td>
<td>43.3</td>
</tr>
<tr>
<td>N2</td>
<td>110</td>
<td>20</td>
<td>1500</td>
<td>Car</td>
<td>81.9</td>
</tr>
<tr>
<td>H2</td>
<td>70</td>
<td>20</td>
<td>13000</td>
<td>Bus</td>
<td>287.5</td>
</tr>
<tr>
<td>H4</td>
<td>65</td>
<td>20</td>
<td>30000</td>
<td>Rigid HGV</td>
<td>572.0</td>
</tr>
</tbody>
</table>

Source: NPRA

### Deformation of the safety barriers

When a safety barrier is hit by a vehicle, it will deform. The deformation of safety barriers during impact tests is characterised by the working width. The barrier’s working width (W) is the maximum horizontal distance between the front edge of the barrier before deformation and the rear edge after. If the vehicle body deforms around the road safety barrier, so that the latter cannot be used for the purpose of measuring the working width, the maximum lateral position of any part of the vehicle shall be taken as an alternative.
The barrier’s dynamic deformation or width of deformation, D, is the horizontal distance between the front edge of the barrier before deformation and after.

![Diagram showing width of deformation](image)

**Figure 9-13: Deformation of safety barriers**
Source: NPRA

**Safety barrier including parapet behaviour**
The safety barrier including parapet shall contain the vehicle without complete breakage of any of its principal longitudinal elements. Elements of the safety barrier including parapets shall not penetrate the passenger compartment of the vehicle. Deformations of the passenger compartment that can cause serious injuries shall not be permitted.

**Test vehicle behaviour**
The vehicle shall not spin and/or roll over (including rollover of the vehicle onto its side) during or after impact.

### 9.7.6 Requirement for safety barrier

On existing roads, the main consideration will be the accident history. If collisions with the hazard are occurring repeatedly there may be justification for safety barrier – assuming the hazard cannot be removed. Cost-benefit analysis can help determine whether it is worthwhile installing barrier.

SATCC has developed general criteria for installation of guardrails. These appear in Figure 9-14 and have to be used as a general guideline and starting point for determining need.
In addition to installing safety barriers when the fill is high and the side slopes are steep, there are a substantial risk caused by obstacles within the clear zone area. Such obstacles include:

- Bridge piers, abutments and culverts walls
- None yielding light columns, gantries and trees with diameter > 18 cm
- Concrete bumpers, solid concrete elements, culvert outlets, end of retaining walls,
- Solid stones or rock outcrops which have a top more than 20 cm above the terrain or steep rock slopes where protruding parts should be less than 30 cm.
- Solid installations

Such dangerous roadside obstacles should be removed, replaced with yielding road furniture or protected with a safety barrier. If, however, a back slope is built in front of the obstacles in the clear zone, safety barriers are not necessary if the criteria shown in Figure 9-15 are satisfied, i.e.:

- When the gradient of the back slope is 1:2, the height of the slope measured from the adjacent road surface shall be minimum 1.8 m.
- When the gradient of the back slope is 1:1.5 the height of the slope measured from the adjacent road surface can be reduced to 1.4 m.

![Figure 9-14: Guardrail – guide for determination of need](image)

In some cases there is a rock outcrop along the road. If it is too expensive to remove the rock, the use of a back slope from the ditch will normally be preferred to a safety barrier as shown in Figure 9-16.

![Figure 9-15: Roadside layout which functions as a safety barrier](image)
When the gradient of the back slope is 1:2 the height of the slope measured from the adjacent road surface shall be at least 1.4 m. When the gradient of the back slope is 1:1.5 the height of the slope measured from the adjacent road surface can be reduced to 1.0 m.

![Diagram showing the dimensions with * are variable.](image)

**Figure 9-16: Back slope to prevent vehicles impacting a rock outcrop**

### 9.7.7 Required Length of a Safety Barrier

Steel beam safety barrier is often installed in lengths that are too short to be effective. This is done to keep costs down, but the resulting installation may be completely useless. Generally, at least 30 m of steel beam strong post guardrail are needed for it to perform satisfactorily. Figure 9-17 gives guidance on determining the length of need. Note that on a two-way single carriageway road, both directions of travel have to be considered - it cannot be assumed that vehicles will not hit the downstream end of a barrier. One of the common faults on hazardous bends is to stop the barrier at the point where the bend meets the tangent. Experience shows that some of the vehicles that fail to negotiate the bend will run off the road just beyond the tangent point. Any gaps through which vehicles may fall should always be closed.

The set-back shall normally be 50 cm beyond the edge line of the road to the face of the barrier. With roads having annual average daily traffic volume (AADT) of 12,000 and above and speed limit greater than 80km/h, the set-back shall be 75 cm.

![Diagram showing how to determine the required length of the guardrail.](image)

**Figure 9-17: Determining the required length of the guardrail**

(Source: Australian guidelines)


### 9.7.8 Steel Beam Strong Post Guardrail

Steel beam strong post guardrail is the most common type of safety barrier used in Tanzania (refer to Figure 9-18). The precise design varies in detail, but the basic characteristics are:

- Steel beams with a W-shape (this is the part that comes into contact with the vehicle);
- The beams are 4130 mm long;
- The beams are mounted on steel posts that are set either 1905 mm or 3810 mm apart;
- The beams are mounted so that the centre of the beam is 600 mm above the height of the road surface; and,
- There is a steel spacer block between the post and the beam to prevent the vehicle from hitting (“snagging”) on the post (“snagging” will usually result in the vehicle spinning out of control).

When an out-of-control vehicle hits the barrier the beam flattens, the posts are pushed backwards, and the tension in the beam builds up to slow the vehicle and redirect it back onto the road. That is if it performs successfully. The speed, mass and angle of the vehicle is critical to success. With heavy vehicles, high angles of impact and very high speeds the barrier may be torn apart or crushed. The containment capability can however be increased by using two beams, one mounted above the other.

![Figure 9-18: Steel beam strong post guardrail - typical details](image-url)


9.7.8.1 Installation of Steel Beam Strong Post Guardrail

- The beams must be overlapped in the direction of travel, so that if they come apart in an impact there is not an end that can spear the vehicle;
- The beams must be bolted together with eight bolts and the whole structure must be rigid;
- The beam centre must be 600 mm ± 5 mm above the adjacent road surface - if it is lower, vehicles may ride over it; if it is higher, vehicles may go under it;
- The spacer block must be fitted to the post with two bolts, otherwise it may rotate in a collision;
- There must be two layers of beam at each spacer block, so at the intermediate posts (i.e. those where there is no beam splice) insert a short section of beam between the main beam and the spacer block - this is often called a backup plate and it helps to prevent the beam hinging or tearing at this point;
- If the posts and spacer blocks are made of steel channel they must be installed so that the flat side faces the traffic - this reduces the risk of injury if they are hit by a person who has fallen from a vehicle;
- There must be a space of at least 1000 mm between the back of the post and any rigid obstacle - this can be reduced to 500 mm if the barrier is stiffened by putting in extra posts (at 952 mm centres), putting two beams together (one nested inside the other) and using extra large concrete foundations;
- When installed on top of an embankment there must be at least 600 mm between the back of the post and the break of slope in order to have sufficient ground support for the post - where this is not possible, much longer posts must be used;
- The guardrail should not be installed behind a kerb, because when a vehicle hits the kerb it will be pushed upwards and so will hit the guardrail too high - with a risk that the vehicle will go over the guardrail; and,
- The guardrail shall be set back from the shoulder edge (or carriageway edge if there is no shoulder) by at least 600 mm - putting it at the edge of the shoulder reduces the effective width of the shoulder and increases the risk of minor damage.

9.7.9 Concrete barriers

Concrete barriers are strong enough to stop most out-of-control vehicles, and being rigid there is no deflection on impact. This makes them suitable for use on narrow medians and where it is essential to keep vehicles on the road, such as at bridges. Small angle impacts usually result in little damage to the vehicle. However, large angle impacts tend to result in major damage to the vehicle, and severe injuries to the occupants. Research has shown that the conventional profile (commonly called New Jersey Barrier) tends to cause small vehicles to over turn, and the preferred shape is now a vertical or near-vertical wall (see Figure 9-20). Concrete barrier generally requires very little routine maintenance except after very severe impacts.

The ends of concrete barriers are very hazardous, so every effort should be made to terminate the barrier where speeds are low. The end of the barrier should be ramped down. If approach speeds are unavoidably high the end of the barrier should be protected by fitting a section (of at least 20 m) of semi-rigid guardrail (see 9.7.12).
9.7.10 Median barriers

In general, median barriers should be provided on high speed dual carriageway roads i.e. with speed limit exceeding 80 km/h, having AADT greater than 8,000.

High-speed dual carriageway roads with medians less than 1.5 x Minimum Clear Zone width may need to have median barriers to reduce the risk of cross-over accidents and/or to provide protection against collision with obstacles (e.g. lighting columns). Median barriers should not normally be used on urban dual carriageways with speed limits of less than 80 km/h. If such roads have a cross-over problem it should be tackled through speed calming measures.

If the median is less than 9 m it shall have a safety barrier or a soil embankment when the design speed is greater or equal to 90 km/h or with speed limits greater or equal to 70 km/h. In principle, there are four types of safety barriers that can be used as median barrier (see Figure 9-19).

- One-sided steel beam/pipe barrier (One at each side of the median)
- Double-sided steel beam/pipe barrier (placed as below)
- Concrete barrier - either cast in situ or built by connecting pre-cast sections
- Or soil embankment.

![Figure 9-19: Different systems for median barrier](image)

$$h_r = \text{Height of rail (750 – 800 mm depending on the barrier type)}$$

Median barriers should not normally be used on urban dual carriageways with speed limits of less than 70 km/h. If such roads have a cross-over problem it should be tackled through speed reduction measures.

Median barriers often take the form of two guardrail beams mounted back to back on one post – see Figure 9-19. They are not suitable where the median is narrower than 2.0 m because they deflect too much on impact. A mono rail barrier with a box rail on top of the posts can sometimes be a good solution.

Concrete can be preferred in situation where higher performance is needed (see Figure 9-20). Concrete barrier can be made in situ casted or by elements mounted together so it acts as a continuous barrier.

As always with safety barriers it is a problem to terminate it safely. If possible the barrier should be terminated at points where speeds are low, such as at roundabouts. Failing this, the guardrail beams should be flared and ramped down, or at least be capped with a protective end-piece (bull-nose end treatment). Concrete barriers should be ramped down.
During provision of the Median Barriers, the following shall be observed:

- Kerbs should never be used when median barriers are installed;
- The consequences of no barrier are greater than barrier installations; and
- The clear zone problems relating to rigid objects and ditches in the median.

### 9.7.11 Terminals

The approach and departure ends of a steel beam guardrail are its most dangerous features, the former being more so than the latter and thus, they shall be constructed with leading and trailing terminal sections. Short (< 80m) gaps should not be left in guardrail - instead they should be made continuous.

There is no wholly safe way of terminating guardrail but the general advice is to:

- stiffen the end section by installing the posts at 1905 mm spacing, and
- flare the end section of the guardrail away from the edge of the shoulder until it is offset by at least 1m - use a flare rate of at least 1 in 10 - this reduces the risk of a direct impact; and
- use a special impact-absorbing terminal piece or ramp the beam down sharply into the ground.

With both treatments the post spacing is halved over the first three to five lengths, as shown in Figure 9-21 below.

On a two-way road both the upstream and downstream ends of the guardrail will need to be terminated in the above way. One of the problems of ramped ends is that they can launch out-of-control vehicles into the air, with disastrous consequences. Try and avoid this by ramping the beam down sharply. Flaring is an effective way of reducing the risk of impact but this can be difficult to achieve in some situations, such as on narrow embankments.
One of the main functions of the terminals is to anchor the longitudinal barriers.

Terminals shall be designed to be crashworthy - i.e. to be able to provide deceleration forces within survivability limits - especially if they are within clear zones.

**Figure 9-21: Guardrail end treatment - typical details**

Source: SATCC
9.7.12 Transition from Guardrail to Bridge Parapets and Concrete Barriers

Collisions with the ends of bridge parapets and concrete barriers are usually very severe. It is essential that these obstacles be shielded so that out-of-control vehicles will be redirected along the face of the parapet or concrete barrier. This is best done by installing a semi-rigid steel beam guardrail on the approach - normally at least 30 m long. It must line up with the face of the parapet/barrier and be strongly connected to it. The guardrail must be progressively stiffened so that deflection is reduced to zero as the parapet/barrier is reached. This is called a transition section. The stiffening is achieved by putting in extra posts, putting two beams together (one nested inside the other) and using extra large concrete foundations. See Figure 9-22. A steel connecting piece is used to bolt the end of the guardrail to the parapet or barrier - the design of this will vary to suit the design of the parapet/barrier.

![Figure 9-22: Typical transition (W-beam guardrail to rigid object)](image)

9.7.13 Bridge Parapets

A parapet is a protective fence or wall at the edge of a bridge or similar structure. Parapets shall be placed on all bridges. Some different types of parapets are illustrated in Figure 9-23 below.

![Figure 9-23: Bridge Parapets](image)

Note: In urban and built-up areas, the minimum footway width shall be 2.0 m.
There are three broad types of parapets:

2. **Vehicle / pedestrian parapets**: These are designed to contain vehicles and safeguard pedestrians. They are usually made either of steel or reinforced concrete. Vehicle / pedestrian parapets must be designed to contain out-of-control vehicles on the bridge and to deflect them back into the traffic lanes without severe deceleration or spinning. The design should normally satisfy containment level H2 and in some cases H4. The parapet height should not be less than 1.2 m.
3. **Vehicle parapets**: These are designed for vehicles only without any pedestrian traffic. They have normally horizontal elements and have bigger space between the elements.

The bridge can also have an inner barrier to separate the vehicle and pedestrian traffic. The intention is to protect the pedestrian against vehicle than by an accident came in wrong field. The separation barriers do not need to be higher than an ordinary safety barrier when the bridge has a 1.2 m outer barrier.

**Requirement for bridge parapets**
The design of bridge parapets shall satisfy these requirements:

- Parapets should present an uninterrupted continuous face to the traffic and should have a solid connection with the approach guardrails;
- Steel parapets should be designed with horizontal rails set in front of posts, so that vehicles brush against the rails and do not snag on the posts;
- As far as possible the horizontal rails on steel parapets should be continuous – if joints are unavoidable they must be strengthened so that there is no risk of them coming loose on impact and exposing free ends (like a spear);
- The ends of the bridge rail must continue in a safety barrier with a transition in between. If it is not necessary to continue with a safety barrier, the end must be linked with a strong connecting piece so that there are no exposed ends to spear a vehicle. It is important to close off with safety barrier any gaps or ‘open windows’ between the end of the parapet and a back slope, especially where the approach to the bridge is on a bend.
- Where kerbs are located in front of parapets, the height of the parapet should be increased to take account of dynamic jump effects.
- Parapets shall be designed in such a way that they will not prevent visibility standards from being met.

Reinforced concrete parapets should take the form of solid, continuous walls with no openings. A steel hand rail is often fitted along the top of the wall in order to improve the visual appearance.

In most cases there will be a need to provide guardrails at both the approach and departure ends of the parapet in order to prevent out-of-control vehicles hitting the end of the parapet. This is particularly important with reinforced concrete parapets, because of their rigidity. The guardrail can also prevent out-of-control vehicles from entering on the wrong side of the parapet and dropping into a river/ railway / etc. This is a common incident at bridges where the approach is on a bend. The guardrail should be at least 20 m long and should continue the line of the traffic face of the parapet.
It is possible to design a steel parapet that incorporates w-beam guardrail, and this has the advantage that the guardrail can be extended off the bridge to protect vehicles on the approach sections. The containment capability can be increased by using two beams, one above the other.

9.7.14 Pedestrian Barriers and Parapets

Uncontrolled pedestrian movements are a significant factor in urban traffic and safety problems. Pedestrian barrier can bring big improvements by segregating pedestrians from vehicular traffic and channelling them to safe crossing points. At intersections, barrier can:

- reduce conflicts by channelling pedestrians to crossing points on the approaches;
- discourage buses, minibuses and cyclists from stopping and parking within the intersection;
- discourage delivery vehicles from loading or unloading within the intersection; and,
- discourage roadside vendors from occupying the road space in the intersection

Other applications include:

- Schools – barrier can be used to prevent children from running into the road from the school gate;
- Bus parks, cinemas, stadiums, etc – barrier can channel pedestrian flows at areas of heavy pedestrian movement;
- Pedestrian crossings, underpasses’, footbridges – barrier helps channel pedestrians to the crossing facility; and,
- Medians – barrier can be used to deter pedestrians from using the median to cross the road, though barriers on the footways are more likely to be effective.

Figure 9-24: Vehicle/pedestrian parapet - typical details
Ideally, pedestrian barrier should:

- be effective;
- be strong and easily maintained;
- cause no serious damage to vehicles and the occupants when hit;
- not be hazardous to pedestrians, including the disabled;
- not interfere with visibility; and,
- look acceptable.

Pedestrian parapets are designed to safeguard pedestrians but are not intended to contain vehicles. These are used where there is a safety barrier between the vehicle lanes and the footway. Figure 9-24 shows a typical design for a lightweight steel parapet.

The requirements are:

- The minimum height for parapets is 1.2 m, but this should be increased to 1400 mm for cycleway, and 1500 mm for bridges over railways and other bridges where containment is essential;
- Metal parapets should have no openings wider than 100 mm. If necessary the parapet should be faced with wire mesh panels. When the bridge has no facilities for pedestrians, the openings could be increased to 300 mm.

The choice is between steel railings and brick or concrete walls. Steel railings should be designed with a minimum number of horizontal elements. They have to be very well fasten to posts to prevent fracturing and penetrating the vehicle when it impact the parapet. Brick or concrete walls are likely to be cheaper and easier to maintain but they take up more space. All barriers should be set back (normally 500 mm) from the traffic face of the kerb to give adequate clearance for passing vehicles. Ends of pedestrian barrier may need to be fitted with reflectors to make them less of a hazard at night.

Parapets should be designed so that they are difficult to climb, i.e. no footholds or flat tops.

Finally, since nobody likes walking further than they have to, they should not be forced to make unreasonably long detours. People may break down the pedestrian barrier if they consider it to be too much of an obstacle to movement.

### 9.7.15 Crash Cushions

Crash cushions are protective systems that prevent errant vehicles from impacting fixed and rigid roadside obstacles by decelerating the vehicle to a safe stop when hit head-on or redirecting it away from the obstacle minimising the potential injury level of the vehicle occupants.

Site preparation is important in using crash cushions design. Inappropriate site conditions may compromise cushion effectiveness. Crash cushions should be located on a level area free from kerbs or physical obstructions. Where appropriate, the design of new highway facilities should as much as possible consider other alternatives than the use of crash cushions. Due to its cost crash cushions should only be used where all other safety facilities are inappropriate. Where site conditions do not allow use of safety barriers, crash cushions can be considered in order to minimise impacts against rigid objects such as bridge piers, overhead sign supports, abutments, and retaining wall ends. Crash
cushions can also be used where safety terminals for road side and median barriers are not available or cannot be used. Figure 9-25 below shows an example of crash cushion.

![Figure 9-25: An example of crash cushion](image)

Attention is drawn to the fact that the acceptance of a crash cushion will require the successful completion of a series of vehicle impact tests as well as compliance with the full EN-1317-3 standard.

Note: Currently, EN-1317-3 tests are only for light/medium vehicles (max. 1,500 kg). Therefore, crash cushions are not designed for absorbing the impact of a heavy vehicle.

### 9.8 Runaway Vehicle Facilities

#### 9.8.1 General

Where long steep grades occur it is desirable to provide emergency escape ramps at appropriate locations to slow and/or stop an out-of-control vehicle away from the main traffic stream. Out-of-control vehicles result from drivers losing control of the vehicle because of loss of brakes through overheating or mechanical failure or because the driver failed to change down gears at the appropriate time. Experience with the installation and operation of emergency escape ramps has led to the guidelines described in the following paragraphs for such ramps.
9.8.2 Types of Escape Ramps

Figure 9-26 below, illustrates four types of escape ramps.

![Figure 9-26: Types of vehicle escape ramps](image)

**Sand Pile Type**
The sand pile types are composed of loose sand and are usually not more than 130 m in length. The influence of gravity is dependent on the slope of the surface and the sand pile. The increase of rolling resistance to reduce overall lengths is supplied by loose sand. This type is suitable where space is limited.

**Ramp Type**
The ramp types are applicable to particular situations where emergency escape ramps are desirable and must be compatible with the location and topography.

The most effective escape ramp is an ascending ramp with an arrester bed. An arrester bed is an area provided with special material designed to stop a runaway vehicle. Arrester beds are used on roads where traffic volume is more than 1000 vehicles per day. Where traffic volume is less than approximately 1000 vehicles per day, clear runoff areas without arrester beds are acceptable.

9.8.3 Location of Runaway Vehicle Facilities

For safety ramps to be effective their location is critical. They should be located prior to or at the start of the smaller radius curves along the alignment. For example, an escape ramp after the tightest
curves will be of little benefit if trucks are unable to negotiate the curves leading up to it. Since brake temperature is a function of the length of the grade, escape ramps are generally best located within the bottom half of the steeper section of the alignment.

Due to terrain, lack of suitable sites for the installation of ascending type ramps may necessitate the installation of horizontal or descending arrester beds. Suitable sites for horizontal or descending arrester beds can also be limited particularly if the downward direction is on outside or fill side of the roadway formation.

Runaway-vehicle facilities should not be constructed where an out-of-control vehicle would need to cross oncoming traffic.

### 9.8.4 Design of Arrester Beds

An arrester bed is a safe and efficient facility used to deliberately decelerate and stop vehicles by transferring their kinetic energy through the displacement of aggregate in a gravel bed. The bed should be provided with predominately rounded single size particles of gravel of size ranging between 12 mm and 20 mm.

A gradual or staged increase of depth of the bed should be provided over the 50 m of the entry ramp. This is to ensure a gradual rate of deceleration. The first 100 m of the bed after the entry ramp should be 350 mm deep. The bed depth should then increase over the next 25 m to 450 mm and remain at that depth for the rest of the bed. The designer shall determine the total length of the ramp depending on the gradient of the facility, estimated entering velocity and the surface material (specific to the site). A typical section along the length of the bed is shown in Figure 9-27 below.

![Figure 9-27: Typical Emergency Escape Ramp and Arrester Bed Layout](image-url)


9.8.5 Design Considerations for Escape Ramps

The criteria for location of escape ramps are based primarily on engineering judgment. Each mountainous/hilly road section presents a unique set of design requirements, depending on the following factors:

- Nature of terrain along the section;
- Degree of slope and roadway alignment;
- Availability of sights adjacent to the road;
- Environmental impact;
- Logical site distance below the summit;
- Maximum potential speed of runaway trucks;
- Etc.

The following is a summary of minimum design considerations:

a) The length of the escape ramp must be sufficient to dissipate the kinetic energy of the vehicle.

b) The alignment of the ramp should be straight or of very gentle curvature to relieve the driver of undue vehicle control problems.

c) The arrester bed material should be clean, not easily compacted and have a high coefficient of rolling resistance.

d) The full depth of the arrester bed should be achieved in the first 50 m of the entry to the bed using a tapering depth from 50 mm at the start to full depth at 50 m.

e) The bed must be properly drained and a positive means of effecting the drainage must be used.

f) The entrance to the ramp must be designed so that a vehicle travelling at high speed can enter it safely. A 5 degrees angle of departure or less is required, and as much sight distance as possible should be provided. The start of the arrester bed must be normal to the direction of travel to ensure that the two front wheels of the vehicle enter the bed simultaneously.

g) Comprehensive signing is required to alert the driver to the presence of the escape ramp.

h) Vehicles that enter the ramp will have to be retrieved, as it is likely that they will not be able to retrieve themselves from the arrester bed. An appropriate service road adjacent to the ramp is required to effect retrieval.
9.9 **Kerbs**

9.9.1 **Function**

Kerbs have a number of useful functions:

- they define the edge of traffic lanes, traffic islands and footways – during both day and night (they reflect vehicle headlights);
- they support pavements and island structures so that edge break-up is avoided;
- they protect adjacent areas from encroachment by vehicles; and,
- they assist in drainage of the carriageway.

9.9.2 **Types of Kerbs and their Application**

The main types of kerbs and their applications are listed below: (see also Figure 9-28).
9.9.2.1 Barrier Kerbs
The barrier kerbs are used to provide protection to footways, traffic islands, pedestrian guardrail, traffic signs, etc. Kerbs on footways should have a height of 150 – 200 mm above road level. If they are higher than this, pedestrians may prefer to walk in the road. Barrier kerbs should not normally be used on roads with vehicle speeds in excess of 70 km/h.

9.9.2.2 Semi-Mountable Kerbs
These kerbs can be used in rural situations where high speeds would make the use of barrier kerbs risky. They are useful in defining and protecting the edges of the carriageway and traffic islands at intersections.

9.9.2.3 Mountable Kerbs
These kerbs are used to define traffic islands and road edges in urban and rural situations where there is a high risk of the kerbs being hit by vehicles.

9.9.2.4 Kerbs with Integral Drain
This is a neat and effective way of providing proper drainage in urban areas, and it reduces the risk of water penetration into the edge of the pavement. Other types of kerbs can be designed with integral drains.

9.9.2.5 Flush Kerbs
These kerbs are used to protect and define an edge which can be crossed by vehicles.

9.10 Traffic Islands
A traffic island is a defined area between traffic lanes for the control of vehicle movements and which may also be used as a pedestrian refuge. Traffic islands may take the form of an area delineated by barrier kerbs or pavement area marked by paint or a combination of these.

9.10.1 Function
Traffic islands are a key element in the design of safe, efficient intersections. They can be used to:

- separate conflicting traffic streams;
- control the path of vehicles and reduce unnecessary areas of carriageway;
- provide segregated lanes for some vehicle types or some traffic movements;
- warn drivers that they are approaching an intersection;
- provide shelter to vehicles that are waiting to make a manoeuvre;
- slow vehicles down by deflecting them from a straight ahead path;
- assist pedestrians to cross the road; and,
- locate traffic signs and signals where they will be at least risk of being hit.

9.10.2 Design Requirements
Traffic islands must help drivers to recognise and follow a safe path through the intersection. This calls for care in location, alignment, sizing and construction details. The key requirements are:
a) of sufficient size to be easily seen (min. 4.5 square metres);

b) shape should take into consideration the wheel tracks of turning vehicles, the radii of left and right turns, island nose radii, etc (use vehicle turning circle templates or computerised swept path analysis);

c) where islands are needed on high-speed rural roads consideration should be given to creating them with road markings – driver compliance can be encouraged by infilling them with rumble strips;

d) where kerbed islands are to be provided on high-speed rural roads the kerbs should preferably be of the mountable or semi-mountable type;

e) kerbed islands shall be made more visible by painting the kerbs black and white (500 mm sections);

f) pedestrian refuges should normally have barrier kerbs and be 1.5 m wide (1.2 m absolute minimum);

g) traffic signs (typically sign no. R103 “Keep Left”) should be used on kerbed islands, and they should be positioned so that there is at least 300 mm clearance between the edge of the sign and the traffic face of the kerb;

h) the nose at the approach end of an island should have a minimum radius of 0.6 m – at other corners the radius can be as small as 300 mm;

i) on high-speed roads it is advisable to offset the edges of islands from the edge of the through traffic lane by 0.6 m – 0.9 m, to reduce the risk of collisions; and,

j) road markings (typically sign no. RM5.2 “Channelising Island”) should be used to guide drivers safely past the island.

9.11 Speed Calming Measures

Major traffic safety problems arise when main roads pass through trading centres and towns. This is because of the mix of long-distance high-speed motor vehicles with local access traffic, parking and vulnerable road users. The safest solution and by far the most expensive is to build a by-pass. If this is not possible, the use of speed limit signs and speed calming measures like gates and road humps is recommended.

Through roads with heavy traffic can also be provided with a median to improve traffic safety. U-turns should then preferably be achieved by use of roundabouts, which maybe false, i.e. no connecting roads.

This sub-chapter focuses on speed control measures in built-up areas. However, some of the measures described may have uses in other situations, such as before hazardous bends or bridges.

Through roads in trading centres and towns speed shall be limited to 50 km/h or less. The entrance to the built up area should be clearly indicated by the necessary road signs. The cross-section within part of and sometimes all the 50 km/h area should normally have separate footways. Major trading centres and towns should also have service roads. Advice on footways, cycleways and service roads is given in other parts of this manual.

Details of the recommended speed calming measures are given below.
9.10.1 Gates

The design of gates is as shown in figure 9-29 below:

<table>
<thead>
<tr>
<th>Entry Speed Controlled Gate</th>
<th>Entry and Exit Speed Controlled Gate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth Design</td>
<td>Smooth Design</td>
</tr>
<tr>
<td>Taper Design</td>
<td>Taper Design</td>
</tr>
</tbody>
</table>

![Figure 9-29: The design of gates](image)

Drivers should be clearly informed that they are entering a section, typically a village, where they are required to drive more slowly and carefully, and this can best be done by installing a gate or gateway at the point where the built-up area begins. The gateway sign shall be double-sided and combines the speed limit sign with a panel showing the place name.

Gates can be created using signs, but they must be very conspicuous. A combination of the R201 Speed Limit sign and the GL3 Village Name sign mounted together on a high visibility backing plate, and installed at both sides of the road, is particularly effective. Gates are likely to achieve greater speed reductions if they incorporate traffic islands that prevent the driver from continuing straight ahead - some typical designs are shown in Figure 9-29. However, to avoid the islands becoming a hazard, especially at night, they must be very clearly marked with reflective markings and road studs - and they should be designed so that, if errant vehicles hit them, the consequences are not severe.

The gate should preferably be designed such that the toughest vehicle path for a passenger car, through the gate or portal should have an entry radius R1 below 100 m for 50 km/h speed control and 50 m for 30 km/h speed control. Curves that follow (R2, R3) should have a radius greater than or equal to the entry radius. The gate could be one-sided with speed control only in the entry direction or two-sided with speed control also in the exit direction. The design can be tapered or smoothed with curves as shown in figure 9-29.

The narrowing of the carriageway through the gate can put pedestrians and cyclists at risk of being squeezed by motor vehicles. It is recommended that short footway / cycle by-passes be built around the gates.

9.11.2 Road Humps

A road hump is a device for controlling the speed of vehicles, consisting of a raised area across the roadway.

There are two main types of road humps i.e. circular, which are intended for traffic speed reduction only and flat-topped humps, which are intended for speed reduction and for use as a pedestrian crossing.
A road hump is differentiated from a road bump as shown in Figure 9-30 below.

![Figure 9-30: Difference between a Road Bump and a Circular Road Hump](image)

Road bumps are 75 - 100 mm high and 300 – 900 mm long and are typically used in parking lots and on private roads. To pass over road bumps without doing damage to the vehicle or causing discomfort, the driver must slow down almost to a complete stop. They are acceptable only in residential areas and are not recommended to be used on other roads.

Road humps are 75 - 100 mm high and 4.0 – 9.5 m long. They may be used on roads where proven to be absolutely necessary.

### 9.11.2.1 Circular Road Humps

The circular road hump shall have a circular profile with a short run-on fillet at both ends to smoothen the passage of vehicles. The circular road hump and its details are shown in Figure 9-31 below.
Standard circular road humps in Tanzania are 100 mm high with standard lengths of 4.0 m and 9.5 m for speed limits of 30 and 50 km/h respectively. However, other sizes may be adopted depending on site conditions as indicated in Table 9-7 below:

**Table 9-7: Design of circular road humps**

<table>
<thead>
<tr>
<th>Car (truck) speed level</th>
<th>Radius (m)</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 (15)</td>
<td>20</td>
<td>4.0</td>
</tr>
<tr>
<td>35 (20)</td>
<td>31</td>
<td>5.0</td>
</tr>
<tr>
<td>40 (25)</td>
<td>53</td>
<td>6.5</td>
</tr>
<tr>
<td>45 (30)</td>
<td>80</td>
<td>8.0</td>
</tr>
<tr>
<td>50 (35)</td>
<td>113</td>
<td>9.5</td>
</tr>
<tr>
<td>(40)</td>
<td>180</td>
<td>12.0</td>
</tr>
</tbody>
</table>

Source: Danish guidelines
9.11.2.2 Flat-Topped Road Humps

Flat-topped road humps are an alternative to the circular road humps but are longer and with a flattened top, used to give pedestrians a level crossing between footways. They can especially be useful where there are a lot of pedestrians.

Normally, pedestrian (zebra) crossings should only be installed at busy crossing points. Where it is necessary to use traffic calming measures to reduce speed, the most suitable arrangement is to install circular road humps a short distance from the pedestrian crossing. If it is necessary to provide a hump at the crossing, a flat-topped hump should be used, which is easier for pedestrians. It should however be noted that flat-topped humps cause more discomfort to bus passengers, so they should not be installed on busy bus routes.

The standard flat-topped road hump and its dimensions are shown in Figure 9-32 below.

Figure 9-32: Standard Flat-topped Road Hump

The standard size in Tanzania is normally 8.4 m long and 100 mm high as shown in Figure 9-32. However, other sizes may be adopted depending on site conditions as indicated in Table 9-8 below:

<table>
<thead>
<tr>
<th>Car (truck) speed level</th>
<th>Ramp length r (m)</th>
<th>Grade i (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 (10)</td>
<td>1.0</td>
<td>10</td>
</tr>
<tr>
<td>35 (15)</td>
<td>1.3</td>
<td>7.5</td>
</tr>
<tr>
<td>40 (20)</td>
<td>1.7</td>
<td>6</td>
</tr>
<tr>
<td>45 (25)</td>
<td>2.0</td>
<td>5</td>
</tr>
<tr>
<td>50 (30)</td>
<td>2.5</td>
<td>4</td>
</tr>
<tr>
<td>(35)</td>
<td>3.3</td>
<td>3</td>
</tr>
<tr>
<td>(40)</td>
<td>4.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Source: Danish guidelines
9.11.2.3 Rumble Strips

Rumble strips are transverse strips across the road used to alert and warn drivers with a vibratory and audible effect before a hazard ahead such as a sharp bend, an intersection or a big change in the speed limit. They shall have a rounded profile, a maximum height of 15 mm, and installed in groups of four. They shall extend across the full width of the carriageway, including the shoulders but be terminated so that they do not interfere with the road drainage system. Each strip shall be marked with yellow thermoplastic lines across the top for better visibility. They are not intended to reduce speed and hence their dimensions shall never be changed by increasing the height with the aim of reducing speed as such move will change the rumble strips to road bumps.

The standard layout comprises three groups of strips, the first pair 90 m apart and the second pair 60 m apart. Where approach speeds are less than 80 km/h, the number of groups can be reduced to two or one. The last group should be 25 – 50 m in advance of the hazard. Rumble strips shall not be used on bends with a radius of less than 1,000 m as they could be a hazard to motorcyclists.

![Figure 9-33: Rumble Strips Details](image)

Rumble strips can be used for example in the following situations:

- before a local speed limit sign
- at an approach to a dangerous intersection
- before a sharp bend
- before a hump.

9.11.2.4 Technical Requirements for Road Humps

Effectiveness of road humps decreases as spacing increases. It is recommended that road humps should not be closer than 20 m apart. The maximum spacing between road humps will influence the mean “between hump” speeds. Spacing in excess of 200 m may increase the “between hump” speeds significantly. Figure 9-34 below shows a typical arrangement of road humps, rumble strips and signs at the approach to villages and towns on the main road.

![Figure 9-34: Typical Arrangement of Humps, Rumble Strips and Signs](image)

Each road hump or series of humps must have accompanying warning signs in accordance with the Guide to Traffic Signing (2009) by Ministry of Infrastructure Development. In addition, each road hump should be provided with a marker post as shown on the plan of Figure 9-31 and as detailed in Figure 9-35 below.
All road humps must be painted with a pattern that makes them visible to drivers and provide a safe and reasonable sight distance. (See Figures 9-31 and 9-32).

Road humps should not be placed on sharp curves (either vertical or horizontal). If the curves are too sharp, it can result in lateral and/or vertical forces on the vehicle when traversing the road hump. Road humps should not be placed on a vertical curve with less than the safe stopping sight distance. Placing humps on horizontal curves increase the risk of losing control of a vehicle because it will not be approaching perpendicular to the hump.

Road humps should be constructed on both the carriageway and the shoulders. However, the designer should provide space for cyclists’ passage along the shoulders in which 400 mm high rigid posts spaced 750 mm apart may be provided to demarcate the cyclists’ passage and prevent use of the passage by motor vehicles trying to avoid the road hump.

The designer should consider whether the hump will interfere with road drainage. On roads with kerbed footways, the hump may have to stop 100 – 150 mm before the kerb to create a drain.

Standard road humps for speed limit of 30 km/h are 4.0 m long which is longer than the average wheel base length for cars (3 m). This allows the car to maintain control while passing over the hump and omits “bottoming out”. Vehicles with a wheel base longer than 4.0 m will experience the same effect as a road bump (jolting of cargo and passengers). If traffic volumes consist of more than 5% long
wheel base vehicles, such standard road humps should not be installed. Since the wheel base length of most buses is greater than 4.0 m, the 4.0 m long road humps are not recommended on transit routes and instead only 9.5 m long road humps may be considered.

9.12 Marker Posts

Marker posts are intended to make drivers aware of potential hazards such as abrupt changes in shoulder width, abrupt changes in the alignment, approaches to structures etc. Generally, horizontal curves can be outlined sufficiently by marker posts positioned only on the outside of a curve. Reflecterised surfaces or buttons on marker posts greatly improve their visibility at night, when most needed. Marker posts are not intended to resist impact.

Marker posts should be constructed in the most economical way, in material which is not likely to be removed for alternative uses by the local population. Marker posts should be sited 0.25 m outside the edge of the shoulder.

Installation details of the marker posts are given in Figure 9-37 below. For retro-reflective sheeting or buttons, see Figure 9-35.

![Figure 9-37: Marker posts details](image-url)
9.13 **Kilometre Posts**

Kilometre posts are blocks or pillars of concrete set up beside major roads to show distances from that point to town capitals or major settlements along the road.

The kilometre posts shall show both the distance to the destination and that of the origin placed in such a way that the road user will only immediately see the distance to the destination.

The kilometre posts shall be set up and maintained along the whole road at distance intervals of 5 kilometres from each other, with shortened names and distance in kilometres inscribed thereon. The kilometre posts shall be placed in stagger thus forming a 10 km interval on each side of the road.

The stated distance is measured from a defined point of origin, usually a regional capital or important junction. This ‘zero’ point may be marked by a ‘zero’ post but quite often there is no marker at ‘zero’ point.

During reconstruction or rehabilitation of roads, improvement of the geometrics might shorten the road. The kilometre posts shall be recalibrated along the new alignment.

Details of the kilometre posts are given in Figure 9-38 below.

![Figure 9-38: Kilometre post details](image_url)

Note: High tensile reinforcements of the same sizes may also be used depending on availability.
9.14 Road Reserve Marker Posts

Often, numerous unauthorized accesses tend to develop within the road reserve area. This unwanted development can be limited by providing proper demarcation of the border of the road reserve.

Road reserve marker posts shall be erected on both sides of the road at intervals of 100 m from each other when traversing inhabited areas and 300 m on other areas. Whenever new villages are formed along the roads, additional road reserve marker posts shall be erected to meet the 100 m intervals.

Details of the road reserve marker post are given in Figure 9-39 below.

![Figure 9-39: Road reserve marker post details](image)

9.15 Lighting

Lighting is provided to improve the safety of a road and improves personal security. Priority in the provision of lighting should be given to areas with a high proportion of night-time pedestrian accidents, such as bus terminals, pedestrian crossings and entertainment centres. Lighting should be provided on all main roads passing urban areas, where there are concentrations of pedestrians and junctions in order to reduce accidents. Statistics indicate that the night-time accident rate is higher than during daylight hours, which, to a large degree, may be attributed to impaired visibility. Lighting of rural highways is seldom justified except at junctions, intersections, and railway level crossings, narrow or long bridges, tunnels, sharp curves, and areas where there is activity adjacent to the road (e.g. markets).

To minimize the effect of glare and to provide the most economical lighting installation, luminaries should be mounted at a height of at least 9 metres. High mounted luminaries provide greater uniformity of lighting and mounting heights of 10 to 15 metres are frequently used to illuminate large areas such as intersections. This type of lighting gives a uniform distribution of light over the whole area and thus illuminates the layout of the intersection.

Lighting columns can be a hazard to out-of-control vehicles. The lighting scheme should aim to minimize the number of lighting columns and ensure that the poles are not located in vulnerable
positions. Standards for lateral clearance, clear zones, etc. must be respected. Lighting columns (poles) should be placed behind kerbs whenever practical. The appropriate distance is 0.5 m behind the kerb for roads with a design speed of 50 km/h or less, and 1.2 m or greater for roads with a design speed of 80 km/h or greater. Where poles are located within the clear zone, regardless of distances from the edge of the carriageway, they should be designed to include a frangible impact attenuation feature. However, these types of poles should not be used on roads in densely populated areas, particularly with footways. When struck, these poles may collapse and cause injury to pedestrians or damage adjacent property.

There are three types of columns (poles):

- Solid columns
- None energy absorbing columns (NE)
- High energy absorbing columns (HE)

Solid columns are fixed to a strong foundation block and cannot be moved in any way. These columns can be very dangerous to road users when impacting them and should be avoided within the clear zone.

None energy absorbing columns (NE) will take very little energy when a vehicle impact the column. The speed when impacting a NE column will be reduced very little. These NE columns can be placed within the clear zone. NE columns should be used also for sign posts. These columns can be made in such a way that they break, be detached or yield under vehicle impact.

High energy absorbing columns (HE) will take very much energy when a vehicle impact the column. The vehicle impacting a HE column will stop completely or pass through with very little speed.

On dual carriageways, lighting may be located either in the median or on the other side of each carriageway. However, with median installation, the cost is generally lower and illumination is higher on the high-speed outer lanes. On median installations, dual mast arms should be used, for which 12-15 metre mounting heights are favoured.

These should be protected with a suitable safety barrier. On narrow medians, it is preferable to place the lighting poles so that they are integral with the median barrier.

When it is intended to install road lighting in the future, the necessary conduits/ducts should be provided as part of the initial road construction can as this brings considerable savings.
Chapter 10 Improvement of Existing Roads

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Chapter 10 Improvement of Existing Roads

10.1 General
As used in this Chapter, road improvement means the rehabilitation and/or upgrading of existing roads. Road improvement is distinguished from road maintenance by the nature and extent of the work. Road improvement includes changes to road alignment, widening, significant repair/upgrade of road surfacing and replacement of drainage structures. Improvement of paved roads also reflect economics and safety relative to their design until full design criteria can be applied; i.e., reconstruction.

This Chapter presents the geometric and roadside safety design guidelines for improvement of existing roads. However, these guidelines should not be substituted for sound engineering judgment and value for money of the proposed improvement. The application of design criteria for new roads should be adhered to as indicated in this Manual unless specified otherwise.

10.2 Objective
The objective of improvement of an existing road is, within practical limits, to restore the road to its original service or to improve it to meet current/future demands. This objective applies to all aspects of the road’s serviceability, functional or/and structural requirements including:

• level of service for the traffic flow,
• geometric design,
• road safety,
• traffic control
• structural adequacy,
• drainage,
• slope and embankment stability.

10.3 Approach
The approach to the designing of the improvement of the existing road projects is to evaluate the existing condition and selectively recommend the improvements to the existing geometrics. This is summarized as follows:

10.3.1 Nature of Improvement
The designer shall identify the specific improvement intended for the road project.

• pavement rehabilitation/resurfacing/restoration,
• widening of the roadway including provision of climbing lanes,
• control of land use and access to minimise accidents,
• upgrade roadside safety,
• increase the length of one or more acceleration or deceleration lanes,
• improve a weaving area,
• widen an existing bridge as part of a bridge rehabilitation project,
• improve bridge structural adequacy,
• improve drainage adequacy and/or
10.3.2 Selecting Design Criteria

If reconstruction is required to address an identified operational or safety element, the designer will use the criteria for new construction or modified criteria if necessary.

10.3.3 Design Considerations

The designer shall identify and evaluate any design deficiencies that may be precipitated by the road improvement. For example:

- The installation of a concrete barrier may restrict horizontal sight distance.
- A pavement overlay may require the adjustment of roadside barrier heights or reduce the vertical clearance to below the allowable criteria.

10.3.4 Design Exceptions

The designer shall also discuss design exceptions that apply equally to the geometric design of the existing projects.

10.3.5 Safety Analysis

The designer shall identify geometric and roadside safety design deficiencies within the project limits. Conduct an accident analysis when determining any improvements that can be practically included without exceeding the intended project scope of work. For example, if a concrete kerb stone is constructed, it is reasonable to correct any superelevation deficiencies to full standards at the same time, because superelevation corrections in the future may require modifications to the kerb stone.

10.3.6 Project Evaluation

This includes, for example, accident data, pavement condition, geometric design consistency, and traffic control devices as applicable.

10.3.7 Reporting

The designer shall prepare the report for proper references that contains at least the following:

1. Description of Existing Conditions. Before determining the scope of the proposed improvement of the project road, an analysis of the existing conditions is necessary. The designer shall provide a fact sheet indicating project length, design and operational speed, current and future traffic (for all road users) and percentage of trucks, etc. From as-built drawings and as verified by a field survey, the following should be determined:

- existing roadway, structures, and intersections geometrics;
- general pavement distress or failure mode;
- specific areas of failure;
- presence of underdrains and pipe drain headwalls;
- provision of design elements for non-motorized transport;
- location and performance level of existing road safety appurtenances;
- locations and performance of existing shallow roadside ditches;
- accident history over the past four years.
The details of the inventory data to be collected shall be put in a table indicating all the data collected. Table 10-1 below is an example of the data collected in a road that should be used by a designer.

<table>
<thead>
<tr>
<th>ADT 2010 Total / Heavy</th>
<th>3000 / 1000</th>
<th>3000 / 1000</th>
<th>3500 / 1000</th>
<th>3500 / 1000</th>
<th>4000 / 1800</th>
<th>4000 / 1800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrians / Bicycles</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Posted speed limit (km/hr)</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Operational speed</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Accidents the last 10 years</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Roadway width (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Condition of drainage, incl. culverts</td>
<td>good</td>
<td>good</td>
<td>good</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td>Pavement</td>
<td>Surface type</td>
<td>AC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td>Environmental impacts</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td>Horizontal Curves &lt; 400 m radius</td>
<td>Ok</td>
<td>R=250 m</td>
<td>Ok</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical alignment</td>
<td>Slope &gt;5%</td>
<td>Crest curve too sharp</td>
<td>Ok</td>
<td>Ok</td>
<td>0k</td>
<td></td>
</tr>
<tr>
<td>Bridges</td>
<td>Carriageway width (m)</td>
<td>NA</td>
<td>NA</td>
<td>6.0</td>
<td>NA</td>
<td>6.0</td>
</tr>
<tr>
<td>Condition</td>
<td>NA</td>
<td>NA</td>
<td>poor</td>
<td>NA</td>
<td>poor</td>
<td>NA</td>
</tr>
<tr>
<td>Intersection</td>
<td>Classifide roads</td>
<td>None</td>
<td>Int with R32</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Private access</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other facilities</td>
<td>0 km</td>
<td>1 km</td>
<td>2 km</td>
<td>3 km</td>
<td>4 km</td>
<td>5 km</td>
</tr>
</tbody>
</table>

**Plans Drawn to scale**

2. **Proposed Scope of Improvement Work.** The designer shall provide a brief description of the proposed scope of work. This description must include at least the following items:
   - a map showing the location of the proposed improvement, the limits of the proposed work, and any omissions,
   - a typical cross section showing the proposed resurfacing thickness, shoulder widths, pavement and shoulder cross slopes, side slopes, bridge widths; and exceptions from this Manual or any other Manuals of Ministry of Works.

3. **Estimated Cost for the Proposed Improvement.**
4. Other special reports are such as:
   • justification for requests for exceptions from design Manuals,
   • discussion of high-accident locations or other over-represented accident locations
   • and proposed countermeasures,
   • proposed geometric revisions and superelevation corrections,
   • vertical clearances,
   • condition of existing structures,
   • Drainage analyses,
   • environmental and social issues and
   • any other as it will be indicated in the project Terms of References.

10.4 GEOMETRIC DESIGN

In general, the geometric design criteria for new construction/reconstruction also applies to the roads improvement projects. However, the designer must still make certain decisions, and there is some flexibility that can be applied as discussed in the following section.

10.4.1 Design for the Original Construction

A specific geometric design element on existing roads may not meet the current criteria but did meet the criteria at the time of original construction. In these cases, the design criteria used for horizontal and vertical alignment and carriageway; shoulder and median width can remain in place if they meet the current design criteria.

10.4.2 Design Speed

The existing posted speed limit will be acceptable as the minimum design speed for the improvement project. However, the designer should determine if the existing posted speed limit is likely to change after project completion.

There are two methods that can be used to select the design speed for improvement projects. These may be used alone or in combination.

• Select an overall design speed greater than or equal to the posted regulatory or prima facie speed on the section being improved.
• Determine the 85th percentile speed for the feature being designed, such as horizontal curves or vertical curves etc.

10.4.3 Design Traffic Volume

The AADT shall be used during design processes. The designer shall consider the use of the forecasted traffic for 10 years beyond the date of completion for the improvement project.

It should be noted that the design traffic volume for a given road feature should match the average traffic anticipated over the expected performance period of that feature.

10.4.4 Horizontal Curve

Unless there have been serious safety problems, existing horizontal curves with a design speed 0-25 km/h less than the posted speed, may be retained without approval of the Road Authority. However, the operation and safety should be improved to the extent feasible through such elements as superelevation modifications, removing crown, and removal of sight obstructions to improve
stopping sight distance. When the horizontal alignment does not meet the posted speed, applicable traffic control devices should be installed.

A decision not to reconstruct an existing horizontal curve where, the curve design speed is more than 25 km/h below the posted speed shall be supported with a design exception.

Mainline horizontal curves should have minimum superelevation rates equal to those allowed to remain in. If the required minimum superelevation rates are not met, the designer should provide additional resurfacing thickness or milling to correct the superelevation to the rate for the required comfortable operating speed.

Where the curve occurs beneath an existing overhead structure, the additional thickness may cause the vertical clearance to become less than that required, and thus appropriate adjustments will be required.

All ramp superelevation rates should be corrected to the full superelevation rates for new construction.

10.4.5 Vertical Alignment

Vertical Curves
The designer shall analyze vertical curves to determine if they meet the criteria found in Chapter 6. If not, he shall determine if operational or safety problems exist at the location. Where no operational or safety hazard is present, the curve may remain in place.

Existing vertical curves with a design speed 0-30 km/h less than the posted speed do not require a design exception. However, designers should examine the nature of potential hazards in relation to sight distance and provide warning signs when appropriate.

Vertical Clearances
The preferable vertical clearance over the travel lanes and shoulders for new or reconstructed structures is 5.5 m while the absolute minimum is 5.2m. Projects that do not meet the proper vertical clearances as discussed above will require permission from the Ministry of Works before they can be implemented.

10.4.6 Bridges

Bridge Condition Reports
A Bridge Condition Report and a proposed remedial works drawings are required for every structure within a roadway section covered in the improvement project. This report will ensure that the bridge meets the minimum requirements for width, safety, and structural capacity.

Safety Analysis for Bridges
Narrow bridges within the project limits must first be analyzed to determine if widening is necessary to address a road safety experience or other operational problems. This analysis will include a review of accident data for the previous four years and, if necessary, a direct field check.

Bridge Replacement/Rehabilitation
Improvement or rehabilitation of road projects may include bridge replacements or bridge rehabilitation work and, in some cases, this may be the entire project scope of work. The following will apply to the geometric design of these projects:
1. **Horizontal and Vertical Alignment:** An existing bridge may have an alignment that does not meet the current criteria. For bridge replacement projects, the designer should evaluate the practicality of realigning the bridge to meet the applicable alignment criteria for new construction/reconstruction. For bridge rehabilitation projects, it is unlikely to be cost effective to realign the bridge in order to correct any alignment deficiencies.

2. **Width:** When the Bridge Condition Report indicates deck replacement is necessary, the designer should consider widening the superstructure to the extent possible without requiring substructure additions. In no case shall the structure be made narrower than the existing width. The bridge width should be wider than the full approach carriageway width by one metre. Capacity analyses could determine the need for auxiliary lanes and/or the need for wider walkways. Because bridges represent major economic investments with longer design lives, it may be warranted to provide the wider widths as part of a bridge replacement or rehabilitation project.

3. **Safety:** It is important to check whether the parapet and any approach safety barrier meets current containment and other safety standards.

### 10.4.7 Road Safety

**General**

The designer should consider site specific conditions to determine the appropriateness for making improvements to side slopes and/or clear zones. Considerations include an evaluation of the costs as well as the impacts of improvement alterations. Therefore, the objective should be to use the available funds to provide the most cost-effective design. This objective will require the designer to identify hazardous features and to determine:

- which hazards should be redesigned to be made traversable,
- which hazards should be removed or relocated,
- which hazards should be shielded with an appropriate barrier, and
- which hazards are not cost effective to redesign and therefore should remain untreated.

Recurring accident locations or over-represented accidents shall be identified early in the preliminary stages of plan preparation and appropriate action included in the plans to ameliorate the cause of these accidents.

Any item identified as requiring treatment by the designer may remain untreated if that item is shielded by a roadside barrier required for some other hazard. In addition, some hazards may be allowed to remain just inside the clear zone when there are other similar hazards just outside the clear zone that do not require treatment and if the accident experience for the facility does not indicate a problem with the type of hazard involved.

**Side Slopes**

Side slopes should be flattened as much as cost considerations and conditions permit. The designer shall review accident history for improvement needs. Special consideration should be given to the following:

- Where run-off road accidents are likely to occur (i.e., outside of sharp horizontal curves), side slopes steeper than 1:3 within existing road reserve should be flattened as much as conditions permit.
Retain the current rate of side slopes when widening lanes and/or shoulders, unless steeper slopes are warranted by special circumstances. This often requires new ditches, however, the fore-slopes should not be steepened beyond the existing fore-slope rate (existing rates flatter than 1:4, may be steepened to 1:4).

Cross-Slopes and Superelevation

- Improvement road projects that include resurfacing pavement, cross-slopes should be restored to new construction standards.
- The maximum cross-slope can vary if supported by sub-chapter 5.5 of this Manual based on roadway surface type.
- Superelevation rates on horizontal curves should be increased if necessary, to the appropriate rate for new construction for the design speed.

Clear Zone

A uniform clear zone (i.e., a uniform distance from the edge of carriageway to the tree line, utility poles, etc.) is desirable for the project length. Special consideration should be given to the following:

- Removing, relocating, and/or shielding isolated roadside obstacles on the fore-slope or roadside ditches, particularly in target areas and non-recoverable fore-slopes.
- Removing, relocating and/or shielding roadside obstacles with recorded accident concentrations.
- If run-off road accidents are not concentrated in any location, but there is a significant number distributed throughout the project, the designer should consider widening the average clear zone for the length of the project.

Tree Removal

Tree removal will be selective and will generally “fit” conditions within the existing road reserve and character of the road. National Environment Management Council (NEMC) guidelines present size of trees to be removed within the clear zone without permission. However, the removal is not always practical in some towns. Consequently, trees within the clear zone should be considered for removal subject to the following criteria:

- Accident Frequency - Where there is evidence of vehicle-tree crashes either from actual accident reports or scarring of the trees.
- Outside of Horizontal Curves - Trees in target position on the outside of curves with a radius of 900 metres or less.
- Intersections and Railroads Crossings - Trees that are obstructing adequate sight distance or are particularly vulnerable to being hit.
- Volunteer Tree Growth - Consider removal of volunteer trees within the originally intended tree line. Volunteer trees are those that have naturally occurred since original construction of the road.
- Maintain Consistent Tree Line - Where a generally established tree line exists, consider removing trees that break the continuity of this line within the clear zone.

Roadside Obstacles

Roadside improvements should be considered to enhance safety. Improvements may include removal, relocation, redesign, or shielding of obstacles such as culvert headwalls, utility poles, and bridge supports that are within the clear zone as referenced in sub-chapter 5.8 of this Manual.
A review of accident history will provide guidance for possible treatments. However, treatment of some obstacles, such as large culverts, can add significantly, perhaps prohibitively, to the cost of a project. This means that in most instances only those obstacles that can be cited as specifically related to accidents or can be improved at low-cost should be included in the project. Ends of culverts that are within the clear zone should be considered for blending into the slope.

**Guardrails**

An analysis (including an onsite inspection of the height, length and overall condition) should be made of all existing guardrail installations to determine if continued existence or removal is appropriate. Evaluation of Guardrails and Bridge Rails should include and not limited to the following:

- An onsite inspection of height, length, and overall condition should be done to determine guardrail upgrading needs
- Blunt ends and turned down endings shall be upgraded to current standard terminals.
- Unconnected guardrails to bridge rail transitions shall be connected or upgraded to current standards.
- Existing bridge rail may remain in place if it meets static load requirements as indicated in chapter 9. Otherwise, the bridge rail shall be replaced.

Special consideration should be made to fill sections. Clear zone is not free of obstacles and slopes are non-recoverable with hazards at the landing zone, or at any location that requires guardrail based on the traffic accident history analysis.

**Intersection Design**

Designers should evaluate existing intersections when design traffic volumes on either roadway exceed 1,500 vehicles per day or there is evidence of accident related to existing conditions. Such intersections should be reviewed during design and safety improvements and should be included in the project where practical and feasible. All available accident data should be utilized in the field review of the intersection.

Safety measures, as discussed in the Supplemental Safety Measures herein, can be utilized to mitigate safety concerns at intersections. Warning panels/signs should be installed where appropriate.

**Traffic Control Devices**

Signs, pavement markings, and traffic signal controls shall be installed in accordance with The Guide on Traffic Signing, Ministry of Infrastructure Development (2009), supplemented by current SADC Road Traffic Signs Manual.

**Signing**

Consideration should be given to upgrading sign reflectivity, supports, and locations.

**Supplemental Safety Measures**

The design of roads provides a range of supplemental measures that can be utilized alone or in combination with others to mitigate deficiencies in controlling elements to provide for safer roadways. Where reconstruction of a roadway feature, such as a horizontal curve, vertical curve, intersection or bridge, is not feasible or prudent because of economic, social or environmental concerns, alternative safety measures should be considered. Some of these are:
## Table 10-2: Safety Measures for Different Geometric Problems

<table>
<thead>
<tr>
<th>Geometric Problem</th>
<th>Supplemental Safety Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow lanes and shoulders</td>
<td>Pavement edge lines, Paved shoulders, Permanent pavement markers, Post delineators, Warning signs</td>
</tr>
<tr>
<td>Steep side slopes; roadside obstacles</td>
<td>Warning signs, Slope flattening, Round ditches, Obstacle removal, Breakaway hardware, Post delineators, Install guardrail</td>
</tr>
<tr>
<td>Narrow bridge</td>
<td>Traffic control devices, Approach guardrail, Pavement markings, Warning signs</td>
</tr>
<tr>
<td>Poor sight distance at hill crest</td>
<td>Traffic control devices, Shoulder widening, Driveway relocation, Warning signs</td>
</tr>
<tr>
<td>Sharp horizontal curve</td>
<td>Traffic control devices, Shoulder widening, Appropriate superelevation, Advisory signs and speed signs, Slope flattening, Obstacle removal, Pavement anti-skid treatment, Post delineators, Permanent pavement markers, safety barrier</td>
</tr>
<tr>
<td>Problem intersections</td>
<td>Traffic control devices, Traffic signalization, Fixed lighting, Speed controls, Advisory signs, Rumble strips, Pavement anti-skid treatment, channelisation using traffic islands</td>
</tr>
</tbody>
</table>

### Safety Reviews

It is not possible to include all hazards in any one set of guidelines. Therefore, a safety or “plan in-hand” field review is important.
Chapter 11 Drawings Requirements

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Chapter 11 Drawings Requirements

11.1 INTRODUCTION

The aim of this chapter is to provide the designers with a brief guidance on the contents and presentation of the design drawings. The chapter presents standard numbering for drawings, drawing presentation, units of measurements and symbols.

The designer shall prepare drawings which are clear, accurate and with enough details to meet the intended purposes. Depending on their purpose the drawings can be classified as Preliminary Design Drawings for feasibility studies, Detailed Engineering Drawings for tendering and construction purposes and As-built Drawings for archive purposes. This chapter provides guidance on standards of preparing drawings for different purposes. The designer should adhere to the requirements of this manual and the Terms of Reference for the project.

Intermediate drawings submitted as Preliminary Drawings and Draft Final Drawings in the Detailed Engineering Design Projects shall be stamped as shown below to indicate that they are yet not ready for implementation stages.

![DRAFT DRAWINGS](image1.png)

**Figure 11-1: Stamp on Draft Drawings**

In case the submitted drawing is part of a preliminary design which has been approved for further stages it should be stamped as shown below.

![APPROVED FINAL PRELIMINARY DESIGN DRAWINGS](image2.png)

**Figure 11-2: Stamp on Approved Final Preliminary Design Drawings**

After approval is granted in the submitted Final Design Drawings they shall be stamped as shown below to show that they are ready for tendering and construction stage.
11.2 Standard Numbering of Drawings

For the purpose of easy identification and storage, the drawings should be provided with standard numbering. The numbering shall start with the number of the road, followed by dash then a letter representing the category of the drawing and then the number of the drawing with three digits followed by dash and then the stage for the drawings. All Roads in Tanzania have unique numbers allocated to them such as T1 is for TANZAM Highway, T2 is for Chalinze – Segera – Arusha-Namanga road, R101 is for Murongo - Bugene road etc. In assignments whereby the respective roads have no numbers the designer shall consult the client for agreement on a number to be utilised. An example is shown below:

T1/DS/C 001

The road number, T1 stands for the TANZAM Highway. When it comes to the topic shown on the drawing, each topic is identified by a letter.

The letters following the road number represents the status of the drawings as shown below:

DS shall be used to indicate Detail Engineering Design;
PR shall represent Preliminary Design and;
AB shall represent As-Built Drawings.
The final letter in the numbering system represents the topic shown in the drawing. For example topic C stands for a Typical Cross Section. Finally the number 001 stands for the first drawing under the topic C. The following is a list of letters associated with different categories of drawings.

A List of Drawings - List of drawings including their drawing numbers
B Overview - Map or Aerial aerial photograph or orthophoto showing the overall location of the road/bridge, including a longitudinal profile.
C Typical Cross Sections
D Plans and Profiles of the primary road
E Plans and Profiles of the secondary roads
F Intersections and access
G Longitudinal Drainage
H Utilities (water, sewerage, electric cables, communication cables, etc)
J Road furniture including kerbstones, noise barriers and guardrails, road markings and road signs.
K Structures including bridges, culverts, retaining walls, etc.
L Traffic signals, street lighting and any electrical / electronics works related to the roads.
M Landscaping
N Pictorial or three dimensional presentation of important road features.
P Soils and Geological maps and details
Q Land Acquisitions
R This should not be used for drawing numbers. In Tanzania letter R is used for classification of Regional Roads.
S Environmental Protection Measures
T This should not be used for drawing numbers. In Tanzania letter T is used for classification of Trunk Roads.
U Plans for different construction phasing. To provide details on planned construction stages within the project.
V Hazardous Works.
W Quantities, Mass Haul diagrams etc.
X Cross section drawings at a given interval (Always bound separately).
Y Standard Drawings e.g. Consultant’s office and accommodation, weighbridge stations, pits, guard fencing etc.
Z Drawings indicating conflict areas between different activities or facilities. (These drawings are filed to document quality control)
11.3 **Title Block**

All drawings title blocks shall clearly show: - Designed by, approved by, with the name and signature of the responsible engineer and the date clearly displayed. Initials alone instead of names shall not be used in the drawings. The Approved Final Detailed Engineering Drawings shall be signed by Authorized person responsible for design of roads at a provision to be provided in the title block.

The drawings should have the emblem for the responsible Road Authority and should have the following text “THIS DRAWING IS THE PROPERTY OF (RESPECTIVE ROAD AUTHORITY) AND THEREFORE COPYING OF THIS DRAWING IS NOT ALLOWED UNLESS AUTHORISED IN WRITING BY THE (RESPECTIVE ROAD AUTHORITY)”.

After completion of construction the As Built drawings shall be recorded in the Road Authority Headquarters and the Respective Regional Index System. Figure 11-5 indicates a sample of a title block.
Figure 11-5: A Sample Title Block
11.4 Presentation

The final drawings must be well detailed, clear, readable, concise, unambiguous and consistent to serve the intended purposes.

The drawings shall include legends which shall define the lines and symbols used to represent different features to ensure uniform interpretation of the information depicted in the drawings.

All the drawings such as drawings for landscaping, land acquisition, utilities etc. should be prepared in a scale sufficient to show all the important features for the intended purposes. For drawings prepared to show the location of related facilities, the plan (D and E drawings) can appear as a background and shown as faint lines while the intended information is drawn using more visible lines. This can be applicable to longitudinal drainage, utilities, road accessories, structures, traffic signs and traffic signals, landscaping, land acquisitions, etc.

The following is the list of drawing types to be included in projects drawings; however what shall be included in projects depends on the size and complexity of the projects:

**Document Cover Sheet**
The document cover sheet has no drawing number. The Document Cover Sheet provides an easily identifiable cover that helps protect the document contents. The details contained on the Document Cover Sheet should enable a reader to identify the job, without the need to open the document set.

**Drawings A: List of Drawings**
The List of Drawing is a summary index listing all relevant final drawings included in a contract. The List of Drawings is used as an easy guide to referencing a particular final plan of interest to a relevant sheet number.

The List of Drawings contains a listing of all final plans in sequential order of sheet number followed by drawing number and description can be divided into various drawing types.

**Drawings B: Overview**
The Purpose of overview plan is to show the site of the proposed road in relation to the surrounding area and geographical features. The scale of the plan is variable depending on the size and complexity of the project.

The Overview drawing shall consist of maps/aerial photographs or ortho-photo maps.

**Drawings C: Typical Cross Sections**
The Typical Cross Section drawing illustrates the structural elements of the roadway, lateral distance, cross falls, batter slopes and subsurface drains. The Pavement Detail drawing provides the pavement structural thickness and materials, and may include the location of kerb and channel, subsurface and surface drainage.

The Pavement Detail drawings are not usually drawn to any nominal scale, but should be visually proportional with the drawing scale being specified as ‘Not to Scale’. Where there is a need to provide more than one typical cross section a constant nominal scale should be adopted for visual consistency between drawings.
Typical Cross Sections should be provided at locations where the road formation is consistent and applies over a reasonable length. Specific Typical Sections whose application is restricted to a limited and specific area may be shown when the section is relevant.

**Drawings D and E: Plan and Profiles**

For practical reason, two letters have been assigned for these drawings. The D-drawings are meant to be used for the main road to be built, whereas the E drawings are meant for the secondary roads related to the main road such as service roads, ramps, separate roads for pedestrians/non motorised traffic, etc.

The plans and profiles constitute the basis for virtually all other drawings related to the project. The drawings consist of geometrical plans and vertical profile.

Geometric plans are used to establish a baseline (datum) for the location and setting out of construction works. It is also used to establish the relationship between the design line and other design lines and/or traverse lines.

The longitudinal sections are used to obtain the vertical geometry of the roadway. Longitudinal details combined with the cross fall information are used by the surveyors and contractors in various programs to obtain cut and fill values for both earthworks and pavement construction.

The following scales shall be applied for the plans of detailed engineering design unless otherwise stated in the terms of reference:

<table>
<thead>
<tr>
<th>Table 11-1: Scales for Plans for Preliminary Design Drawings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drawing type</strong></td>
</tr>
<tr>
<td>Rural type environment, with sparse details and straight forward alignment</td>
</tr>
<tr>
<td>Rural or urban environment with construction constraints and straight forward alignment</td>
</tr>
<tr>
<td>Urban type alignment with complex alignment and important details</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 11-2: Scales for Plans for Detailed Engineering Design Drawings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drawing type</strong></td>
</tr>
<tr>
<td>Rural type environment, with sparse details and straight forward alignment</td>
</tr>
<tr>
<td>Rural or urban environment with construction constraints and straight forward alignment</td>
</tr>
<tr>
<td>Urban type alignment with complex alignment and important details</td>
</tr>
</tbody>
</table>

For Profile or longitudinal section drawings the following scales shall be applied unless otherwise stated.

<table>
<thead>
<tr>
<th>Table 11-3: Scales for Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drawing type</strong></td>
</tr>
<tr>
<td>Detailed Engineering drawings for Highways, main roads, access roads, ramps for interchanges and other uses</td>
</tr>
<tr>
<td>Preliminary Design drawings for Highways, main roads, access roads, ramps for interchanges and other uses</td>
</tr>
</tbody>
</table>
Labelling of the chainages of the plans and profile shall be done at the end of every 100m and at the salient points. The drawings should have tables summarising all the important parameters required for setting out of the curves including the chainages and coordinates of beginning and end of circular curves and spirals, the points of intersection for tangents, the deflection angles for tangents, the radii of the curves. **Grids with Easting and Northing coordinates** at convenient interval should be provided as backgrounds to the plans to facilitate easy interpretation of the drawings. The orientation for each of the plan drawings should be in such a way that the chainages starts from the left towards the right direction irrespective of the orientation of the North direction.

The profile drawings should provide existing ground level and finished road levels at intervals of 25m or any interval indicated in the Terms of reference. The important profile parameters such as the beginnings and ends of vertical curves, the gradients and the K-values should be indicated in the drawings. The values of maximum superelevation and the superelevation diagram for each curve should be indicated in the profiles.

The designers shall use the standard symbols and parameters indicated in this manual to ensure uniform and standard interpretation of the drawings. The following symbols shall be used in the drawings.

- TS: Tangent to Spiral
- SC: Spiral to Curve
- CS: Curve to Spiral
- ST: Spiral to Tangent
- TC: Tangent to Curve
- CT: Curve to Tangent
- PI: Point of Intersection
- PVC: Point of Vertical Curvature
- PVI: Point of Vertical Intersection
- PVT: Point of Vertical Tangent
- K: Rate of Vertical Curvature (For uniformity of presentation Equivalent Radius of Vertical Curve RV shall not be used on drawings).

The chainages shall be presented using kilometres with a + sign in between to separate the kilometre and the metres. For example 53+250 means chainage at 53 kilometres and 250 metres from the start point.

For the Detailed Engineering Drawings the Alignment drawing including the road widening, climbing and deceleration and acceleration lanes shall provide the necessary information to allow for construction.

**Drawings F: Intersections, roundabouts and accesses**

The location of intersections, roundabouts, accesses, rest areas, lay byes for buses, etc. shall be shown on the D and E drawings. However, the details of these facilities shall be shown on separate drawings, namely the F-drawings. The F-drawings will include details of different intersection found in a particular project and typical standardised solutions to accesses, lay byes for buses, etc.
**Drawings G: Longitudinal Drainage**

The G-drainage shall show all drainage facilities along the road. Drainage longitudinal profile is often drawn with a scale exaggeration of 5:1. Often the normal scale is horizontal 1:1000 and vertical 1:200. Drainage details are included in the G-drawings.

**Drawings H: Utilities**

Existing water, sewerage, electric cables, communication cables, etc. shall be shown, superimposed on the plans and profiles. Existing features that are to be retained must be identified together with features that require special construction treatment or to be replaced or new features to be constructed.

**Drawings J: Road Furniture including road signs, kerbstones, noise barriers and guardrails.**

These drawings shall include but not limited to necessary information for construction of road accessories including road marking, kerbstones, road signs, kerbstones, noise barriers, and guardrails.

Signs shall be referred to by their type numbers (as given in the Guide on Traffic Signing, Ministry of Infrastructure Development (2009)), together with a small-scale illustration of the sign face. Road markings shall be designated by their respective numbers from the MoID’s Guide to Traffic Signing (2009).

**Drawings K: Structures including bridges, culverts, retaining walls, etc.**

The drawings for drainage structures and facilities such as bridges should be clear and sufficient to allow for their construction. A schedule of bridges and cross drainage structures should be provided to indicate, the existing and the proposed structures and their location and characteristics. Invert levels for side drains, culverts, and other drainage structures should be provided to allow for smooth construction works.

Information on existing bridges should include their bridge numbers which are used in the Bridge Maintenance Management Systems.

The structural drawings should include the followings:

**A: Bridge**

Final drawings for a bridge should consist of a site plan, a plan and elevation drawing, foundation plan, substructure drawings, superstructure drawings, deck elevation plan and tabulation, and boring logs. They should be assembled in that general order. The deck elevation plan shall show finished deck elevations along the centrelines of longitudinal beams or girders, gutter lines, breaks in roadway cross slope, and on tops of parapets. The Bar Bending Schedules for all reinforcements to be used in the bridge shall be provided in the Bridge drawings.

**B: Culvert**

Final drawings for a culvert should consist of a site plan, a plan and elevation drawing, culvert cross-section, wing wall cross sections, detail drawings, roadway surface elevation plan and tabulation (if top of culvert is roadway surface), and boring logs. It must also show any inlet and outlet protection measures proposed.
C. **Retaining Wall**

Final drawings for a retaining wall should consist of a site plan, the necessary number of plan and elevation sheets, detail drawings, and boring logs.

Drafting shall conform to the following general principles:
- Plan and elevation shall be drawn to the same scale
- The scales shall be appropriate for the drawing sheet size
- Only the lifework necessary to reflect drawing intent shall be shown
- Increasing chainages shall read from left to right
- Sections should be taken through elevations
- Sections shall be viewed from left to right
- Show objects below natural surface or fill using dashed line work

**Numbers for Structural Drawings**

Drawing numbers for structural drawings shall start with K followed by a number indicating type of structural element. The common abbreviations and numbering of bridge structural elements should be as follows:

<table>
<thead>
<tr>
<th>Common abbreviations</th>
<th>Structural Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1</td>
<td>List of Drawings/List of Bridges included in the project</td>
</tr>
<tr>
<td>K2</td>
<td>General Arrangement</td>
</tr>
<tr>
<td>K3</td>
<td>Foundation Layout</td>
</tr>
<tr>
<td>K4</td>
<td>Reinforced Concrete Pile</td>
</tr>
<tr>
<td>K5</td>
<td>Abutment and Pier Reinforcement</td>
</tr>
<tr>
<td>K6</td>
<td>Superstructure</td>
</tr>
<tr>
<td>K7</td>
<td>Details for Bearing, Expansion Joint, Drain Pipes, Approach Slab, Railing, etc</td>
</tr>
<tr>
<td>K8</td>
<td>Overlay</td>
</tr>
<tr>
<td>K9</td>
<td>Design and Construction Standards</td>
</tr>
<tr>
<td>K10</td>
<td>Bar Bending Schedule</td>
</tr>
</tbody>
</table>

**Table 11-4: Scales for Structural Drawings**

<table>
<thead>
<tr>
<th>Drawing type</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Arrangement and Foundation Layout</td>
<td>1:100 / 1:500</td>
</tr>
<tr>
<td>Reinforced Concrete Pile, Abutment and Pier Reinforcement, Superstructure</td>
<td>1:50</td>
</tr>
<tr>
<td>Details for Bearing, Expansion Joint, Drain Pipes, Approach Slab, Railing etc.</td>
<td>1:50</td>
</tr>
</tbody>
</table>

**Drawings L: Traffic signals, street lighting and electrical / electronics works**

The drawings that provide all details required by a contractor to construct and erect traffic signals, street lighting and all other electrical works required of the project road.

The drawings scale are normally variable depending to the amount of details required. However, the drawings should be visually proportional and legible.

**Drawings M: Landscaping**

The landscaping drawings are used to show the planned roadside beatification to be implemented. Such drawings will normally show:
• Existing trees or vegetation which shall be protected during the construction period
• Which areas shall undergo a special landscape beautification and a specification of the details of the beautification measures?

The scale of the drawings is normally variable depending to the amount of details required.

**Drawings N: Pictorial or three dimensional presentations of road features**
Sometimes it might be necessary to provide a visual impression of the road or other facilities to the stakeholders. This could be to provide illustrations on how the road will fit with the environment where there is an environmental or road safety concern or to attract financiers/investors on the project. Where a need arises for the drawing, it is important that the drawing is clear and visible with the scale indicated. If no scale has been used the designer shall show in the drawing that it is not to scale or abbreviation NTS.

**Drawings P: Soils and Geological maps and details**
Soil and Geological maps/drawings assist the contractor to identify designed homogenous sections of subgrade of the road project. It also enables contractors to identify the locations for good construction materials.

The drawings shall also include drawings that indicate positions and details obtained during geotechnical investigations activity at bridge location and at any other location that will be considered geotechnical investigations are necessary.

The drawings scale are normally variable depending to the amount of details required.

**Drawings Q: Land Acquisitions**
The bases for the drawings showing new land to be acquired are the D and E drawings. The boundary of the land needed for the project may be shown as a blue dotted line. Existing property boundaries must be shown together with an identification of the owner together with the plot number. Land to be purchased can for example be shown in yellow.

The drawing should also show a list containing all plots that are shown on the drawing together with the name and address of the owners. The same list shall also show the area to be acquired. Special agreements that may affect the construction of the road shall also be clearly identified and referred to in the above mentioned table.

**Drawings S: Environmental Protection Measures**
These drawings comprise issues related to the environment, including natural resources and cultural sites. Which topics, if any, shall be shown must be decided on basis of the local conditions. The topics may include:

• Areas with high noise exposure and possible noise protection measures
• Cultural sites
• Graveyards
• Recreational sites
• Agricultural areas of high value

The bases for the P-drawings are, as above, the D and E drawings.
Drawings U: Construction Phasing
The need for construction phasing may depend on the complexity of the project and the amount of traffic that needs to be accommodated through the area of construction. Therefore drawings of this category are mainly used in urban or built up areas. The drawings may include:

- Areas where the construction shall be concentrated in each phase.
- Permitted accesses to be used by the construction vehicles and equipment.
- Construction of temporary roads that will ensure an acceptable traffic flow during simple mentionation.
- Facilities that will accommodate pedestrians and non motorised traffic.
- Information boards prior to the construction site informing the road users about the works.

Also in this case the bases for the Q-drawings are the D and E drawings.

Drawings V: Hazardous Works
The purpose of these drawings is to identify works that may involve risk to the contractor or others that may be involved in the project. These may include:

- Areas with poor soils conditions
- Low hanging high voltage cables
- High cuts with steep slopes

The drawing shall show protection measures to be implemented.

Drawings W: Quantities, Mass Haul diagrams etc.
These are drawings which incorporate the quantities of different materials for different sections of the road and also mass haul diagrams which are prepared in order to show the balance of cuts and fills and how the construction materials shall be utilised from different borrow pits. Provision of this information will depend on what is stipulated in the terms of reference or where the designer finds it to be important to facilitate smooth construction of the road.

Drawings X: Cross Sections
Cross sections drawings are useful for the purpose of computation of volumes and for the purpose of setting out of the roads. For the detailed design, the designer will be required to provide cross sections at an interval of 25m unless otherwise specified in the Terms of Reference. Cross sections shall also be provided at location of culverts for the purpose of providing the invert levels. For preliminary design purposes cross-sections may not be needed in some cases, however if there is a need the intervals shall be as stipulated in the terms of reference. The cross section drawings shall indicate all the necessary information for the road embankments and cuttings and drainage structures. The information to be provided includes the offsets and levels for road centrelines, ends of carriageways and shoulders, inverts for ditches and culvers and edges and toes for embankments and cuttings. Each cross section drawings shall be associated with areas for cut and fill.

Drawings Y: Standard Drawings
These are standard drawings and information which are already available to the road authority and are required to be included in the design drawings e.g. Consultant’s office and accommodation, weighbridge stations, pits, guard fencing etc.
**Drawings Z: Conflict areas**

These are drawings indicating conflict areas between different activities or facilities. These drawings help the designers and clients to visualise possible conflict interaction between different facilities in the construction areas and plan construction on the best way to minimise overlapping of activities and facilities to enable smooth construction of roads with minimum effect to facilities and activities.
### Bibliography
