Midland Highway Projects
Vertical Alignment Design Considerations

Contents

Definitions:

GRD1:	Austroads Guide to Road Design – Part 1: Introduction to Road Design
GRD2:	Austroads Guide to Road Design – Part 2: Design Considerations
GRD3:	Austroads Guide to Road Design – Part 3: Geometric Design
NDD:	Normal Design Domain
EDD:	Extended Design Domain
SSD:	Stopping Sight Distance

Objective:

To provide guidance in selecting appropriate vertical alignment parameters to enable designers to deliver value for money projects at brownfield sites on the Midland Highway.

This paper did not consider horizontal alignments specifically, however it is generally assumed that horizontal design parameters match or exceed the vertical design parameters.

Discussion:

In general terms, vertical curve improvements are costly and disruptive. Improvements to vertical alignments are likely to be most value for money where there are minimal physical constraints from a cost perspective (i.e. not in severe rock cuts) or where there are isolated crests on straight alignments (example of Conara to Perth). Additional shoulder width to allow for manoeuvrability could be considered in lieu of improving vertical curvature.

A key objective of the Midland Highway Improvements Program is to improve the AusRAP star rating to a minimum of “3”. Another key objective is to provide a consistent environment, and by extrapolation, a consistent operating speed to at least the posted limit (110km/h).

Projects also need to be designed so they provide value for money, and take considered risk (from TIS Vision). At the same time, ***Safety in Design*** has to be considered, ignorance of existing conditions is not easily defensible in a court of law.

1. For the Midland Hwy in particular, achieving a value for money project has to consider developing “Context Sensitive” designs by taking considered risks or adopting a blanket design speed approach (120km/h, which is OK for Greenfield sites).
2. State Growth needs to provide enough direction for Consultants to be able to deliver value for money projects with enough certainty that they are not exposing the Government or themselves to excessive risk.
3. State Growth, as a client needs to communicate its “appetite for risk” to Consultants and designers; and thus needs to be informed in communicating its acceptable parameters before communicating “appetite for risk”.
4. To provide guidance and understand the risk appetite, the following parameters need to be carefully considered in preparing a final [vertical] design.
   - Sight Distance & Reaction Time
   - Horizontal Curvature and Superelevation
   - Vertical Alignment – Road Type & Reaction Time
5. Recommending what is considered acceptable in terms of Stopping Sight Distance (SSD) sight distance acceptance but acknowledging that there might be localised and minor departures.
   - Communicates “risk appetite” to Consultants / Designers in a technical sense.
   - Nominates what specific reporting and analysis of design is required in preparing design & therefore nominates parameters where departures from standards or guidelines should be reported.
6. Allowing the use of EDD parameters at specific locations where there are significant constraints:
   - Use of EDD must be approved in writing by the Authority (could be done on a project by project basis).
   - Understanding that if EDD is used in vertical alignment design, that there needs to be a concession to another design element. This is usually in the form of additional shoulder width, or perhaps median width to allow for manoeuvrability at the location where the EDD parameter is invoked.

Key Design Consideration Points:

- Determination of Operating Speed
  - 85th percentile from traffic counters
  - Assessment using Austroads Operating Speeds Model
  - Austroads guideline **in absence of the above is 10km/h above the posted speed limit**.
- Determining the Design Domain for coefficient of deceleration
  - This determines whether SSD and K values are for *most rural road types* or *major highways and freeways*.
- Determining the appropriate reaction time to be adopted
  - un alerted = 2.5s
  - alerted = 2.0s
- This could allow development of a "Context Sensitive" design by allowing design elements to be reduced below a 120km/h blanket design speed.

Other issues that Consultants / designers need to factor in to design and report, particularly for 2+1 projects include:

- **Drainage**: Wide pavements transitioning between reverse curves in a dip can lead to ponding / aquaplaning.
- **Stopping Sight Distance**: Reduction in SSD due on single lane sections with a central barrier, particularly at right hand bends over crests. *Design to be checked and reported.*
- **Stopping Sight Distance:** Reduction in SSD due to earthworks etc. due to un-coordinated horizontal and vertical alignments using minimum design parameters.

Early detection of these issues can allow suitable solutions to be factored into design, rather than in the construction phase.

Recommendations to Be Considered:

Highlighted lines are the recommendation to be considered.
Underlined lines indicate the conditions recommendation satisfies.
Italic lines indicated additional condition recommendation satisfies.

For 2+1, the aim would be for Normal Design Domain (NDD) and isolated elements might be reduced to comply with EDD but only in writing. Any new alignments / deviations should seek to comply with NDD.

1 - Minimum sight distance parameters to be achieved (refer T5.4 GD3).

1. **Absolute Minimum SSD of 209m**
   {Maximum rate of deceleration (most rural road types), un-alerted reaction time @ 110km/h}
   {Comfortable rate of deceleration (major highways), alerted reaction time @ 100km/h is 207m}

2. **Desirable Minimum SSD of 260m**
   {Comfortable rate of deceleration (major highways), un-alerted reaction time @ 110km/h}
   {Maximum rate of deceleration (most rural road types), un-alerted reaction time @ 120km/h is 241m}
   {Comfortable rate of deceleration (major highways), un-alerted reaction time @ 100km/ is 221m}
   OR
   Desirable Minimum SSD of 244m
   {Comfortable rate of deceleration (major highways), alerted reaction time @ 110km/h}
   {Maximum rate of deceleration (most rural road types), un-alerted reaction time @ 120km/ is 241m}
   {Comfortable rate of deceleration (major highways), un-alerted reaction time @ 100km/ is 221m}
   OR
   Desirable Minimum SSD of 285m *[CURRENTLY PROPOSED AT WHITE LAGOON]*
   {Comfortable rate of deceleration, un-alerted reaction time @ 110km/h}
   {Comfortable rate of deceleration (major highways), un-alerted reaction time @ 110km/h, is 260m}
   {Maximum rate of deceleration (most rural road types), un-alerted reaction time @ 120km/ is 241m }

2 - Corresponding crest K values to be used to enable sight distance parameters to be achieved (refer T8.7 GRD3)

1. **Absolute Minimum Stopping Sight Distance: K = 97.3**

2. **Desirable Minimum SSD: K = 150.6**
   OR
   Desirable Minimum SSD: K = 133.4
   OR
   Desirable Minimum SSD: K = 181.1

3 - Vertical Curve Design should also consider minimum lengths of crest

Both 110km/h & 120km/h recommend between 100m to 150m.

4 – Sag Vertical Curves need similar consideration; though "traditionally" are based on comfort criteria.

K Values between 51 – 112 could be considered acceptable, as these cater for various lengths of headlight sight distance.

5 – Reporting and Acceptance

1. Designers / Consultants should perform SSD checks that consider the effects of barrier.
2. Locations where SSD falls below the recommended Desirable Minimum should be reported, both in terms of the achievable SSD and identify the length of where desirable SSD is not reached.
3. Locations where SSD falls below the recommended Absolute Minimum should be reported in the same terms, suggest an alternate remediation; i.e. EDD parameter and should also invoke the Departure from Standards.

Extracts from Austroads Guides to Road Design:

GRD1

- 3.2 Road Design Guidelines: introduces concept of 'context sensitive design' where intention is to allow flexibility in applying critical judgement. For example, "by choosing design values outside of normally accepted limits when prevailing constraints require … be able to produce strong defensible evidence"
- 3.2.2 Application of Guidelines: discusses that guidelines provide a range of values for the parameter "In considering results of a design process, it is important to step back and provide a reality check … should be satisfied that finished product is likely to best meet the various needs of the project…"
- 3.3 Context Sensitive Design: is a concept that "emphasises the development of an appropriate and cost-effective design for the particular context that applies, rather than a design that simply meets specified values". Talks about a range of values suitable for elements and looking at interrelationship of elements in a holistic approach to design. Mentions lower end of design domain typically lists values that are undesirable but can still be justified in certain circumstances. Mentions adoption of lower values might be least preferred but might be necessary in certain situations, particularly *for existing roads in certain circumstances*.
- 3.4 Geometric Consistency. Talks about how consistency can be addressed in terms of cross section, operating speed and driver workload. Mentions self-explaining road that "provides confidence in expectations for driver, who then operates vehicle in accordance with these expectations, which are in turn are in tune with the nature of the road".
- Commentary H: Using values towards the lower end of the domain has particular relevance to upgrading and restoration projects.

GRD2

- 1.1 Introduction: Talks about balanced approach and that objectives be carefully considered.
- 1.4.2 Designing for Safety: All elements of design have safety implicitly included in their derivation; i.e. horizontal and vertical designs are based on sight distance and lateral acceleration considerations.
- 2. Context Sensitive design: Discussed design domain concept – which places emphasis on developing appropriate and cost-effective designs, rather than providing a design that simply meets 'standards'. ***It is in this area that State Growth can provide more guidance to out Consultants by defining (to an extent) the minimum design outcomes.***
- Table 2.2: Shows typical difference between design domains. NDD used for significant lengths of existing road reconstruction or new carriageway or a duplication. EDD Improving standards of roads in constrained situations, new carriageway of duplication in constrained situations.
  For 2+1, the aim would be for NDD and isolated elements might be reduced to comply with EDD but only in writing. Any new alignments / deviations should seek to comply with NDD.
- 2.4.3 Speed parameters: principal parameters include stopping distance, sight distance and curve radii. All parameters relate to the speed on the road. Establishment of the appropriate speed for use in design in in GRD3.
- Table 3.1 Checklist: Design speed correlates primarily to curve radii, sight distance & intersection design & provided by road authority. References to Commentary R.
- Commentary R: Design speed "is used to select design features such as alignment and cross section features. It must reflect actual operating speeds on the road to ensure the safe and efficient movement of traffic. A good design combines all geometric elements into one harmonious whole, consistent with the speed environment, so that drivers may be encouraged to maintain a reasonably uniform speed…"

GRD3:

- 1.3 Design Criteria in Part 3: General part relates to NDD. NDD to be used on Greenfield where no constraints exist to prevent NDD design values. Outlines that brownfield sites might have elements that require values outside NDD and/or EDD; however only one minimum EDD value can be applied at once. **EDD to be applied only after approved in writing from Authority or delegated representative.**

Speed Parameters

- 3.1 Speed Parameters – General:
  - Operating Speed to be adopted typically provides some margin over the posted speed limit. ***In terms of the Midland Highway, operating speed should be assumed to be at least the speed limit (can be confirmed with speed data at traffic count sites).***
  - "Where the Operating Speed cannot be determined through speed measurement … designers shall adopt an operating speed 10km/h higher than the legal (posted) speed limit. This practice is valid provided all horizontal curves are suitable for that speed".
- 3.2.1 – Operating Speed: "Operating Speed in this guide refers to the 85th percentile of cars at a time when traffic volumes are low…"
- 3.2.3 – Design Speed: "Design Speed should not be less that the intended operating speed (85th percentile speed). If operating speed varies along the road, the design speed must vary accordingly".
  Intimates that blanket design speeds are not appropriate in all cases.
- 3.2.4 – Vehicle Speeds on Roads: **High Speed is considered 90km/h or greater**.

- 3.4.1 – High Speed Rural Roads: "The standard of horizontal and vertical geometry … supports a high desired speed and permits uniform operating speeds. Consequently they should have a single design speed. Sometimes a design speed higher than the desired speed us used on rural highways to promote a higher quality of service".

Sight Distance

- 5.2.2 – Driver Reaction Time: Refer Table 5.2. For Midland Highway, considerations include the following (x) denotes no, (?) indicates uncertain. There are other factors not listed.
  - 2.5s – High speed roads with long distances between towns (?), Un alerted driving conditions due to road only having isolated geometric features to maintain interest (x), Areas with high driver workload complex decisions(?)
  -2.0s – Alerted Driving Conditions in rural areas (?), few intersections (Y); absolute minimum for these road conditions.
  - 1.5s – N/A
- 5.2.3 – Longitudinal deceleration: Shown in Table 5.3
  1. Comfortable deceleration on sealed roads; value used for deceleration turn lanes at intersections (0.26 – Desirable minimum value for major highways and freeways).
  2. About 90th percentile value for braking on wet roads; maximum value for deceleration lanes at intersections (0.36 – Desirable minimum value for most rural roads)
- 5.3 – Stopping Sight Distance SSD: **"The provision of SSD is a mandatory design condition for all roads and intersections in the Normal Design Domain. Designers should provide SSD for both cars and trucks for all roads in daytime conditions**.
- 5.3.1 – Car Stopping Sight Distance: "Car Stopping Sight Distance shall be available along all traffic lanes on all roads. … shall include grade correction factors …." Mentions that it is not always practical to provide SSD to a 0.2m high object over roadside barriers & references alternate table. As a result additional shoulder widths are recommended to provide for additional manoeuvrability.
- 5.3.2 – Truck Stopping Sight Distance: Mentions that checks for trucks should be done, as specific lateral barriers can become problematic due to increased eye height.
- 5.7 – Manoeuvre Sight Distance: Has been removed as a stand-alone model. Suggests the use of less conservative values of SSD & that when less conservative values are used that supplementary manoeuvre width is provided. Refers to table 5.6 for additional supplementary shoulder widths & manoeuvre times.

Coordination of Horizontal and Vertical Alignment

- **Where possible, horizontal and vertical geometry should be coordinated for appearance and safety**.
- 6.2 - Safety Considerations: The design speed of the road in both planes should be the same. Crest vertical curves should be contained within horizontal curves. A small movement in one direction should not be combined with a large movement in another. *This could infer maintaining a consistent design speed, but also consider the notion that a large radius curve can be designed for 140km/h, however this does not mean that a VC should also be designed at 140km/h or not fitted in to the terrain.*

Vertical Alignment

- 8.2 – Vertical Controls: Existing topography is considered a vertical control, as are existing accesses.
- 8.6 – Vertical Curves: "Sight Distance is a requirement in all situations for driver safety; Appearance is generally required in low embankment and topography situations.
- Table 8.7: Provides various K values for crests, based on sight distance requirements for various speed.
- Figure 8.7: Relates to K values for Sag Curves (similar criteria but seems to have more flexibility in choice).

Appendix A – Extended Design Domain for Geometric Design

- A1: General:
  - ***The decision to use EDD should not be taken lightly***.
  - *NDD values should be used wherever practical.*
  - **Only to be used if approved in writing be the delegated representative from the relevant road authority**.
  - EDD should only be used for only one parameter in any application and not be used in combination with any other minimum or EDD value.
  -"… the use of minimum values for several parameters at the same location does not constitute good practice and generally leads to an inferior of unsafe design".
- A3: EDD for Stopping Sight Distance:
  - Use of EDD for SSD is only appropriate when crash data indicates there are no sight distance related crashes.
  - Future arrangements / planning must be satisfied; i.e. for safety barriers.
  - Horizontal and vertical curves should not be considered in isolation. Sight distances in both planes need to be measured.
  - Particular attention must be given to truck requirements on routes with high numbers of heavy vehicles.
  - There are numerous check cases to determine if EDD is appropriate – too many to list in this paper.
  - Where check cases use object heights greater than 0.2m for cars, or 0.8m for trucks minimum shoulder/ traversable widths and minimum manoeuvre times must be applied (ref Table A12.) This could increase shoulder width to 2.5m or 3.0 depending on the vehicle type.
  - There are numerous tables to select crest K values, depending on the outcome of EDD check cases.
  - A.3.9 mentions a number of criteria mentions several requirements for EDD on horizontal curves where there is no line of sight over barriers / structures.

EDD checks could be done when the recommended Absolute Minimum SSD is not met.