FEASIBILITY OF 2+1 ROADS ON ALBERTA RURAL HIGHWAY NETWORK

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ABSTRACT

Background

Over the last twenty years, European countries have built several thousand kilometres of "2+1 roads", in which an existing or new 13 to 14 metre wide, paved two-lane road segment (8 to 20 kilometres long) is re-striped into three traffic lanes, with the centre lane used as the passing lane in alternate directions. The European 2+1 roads serve traffic volumes from 6,000 AADT to 30,000 AADT. Many are quasi-freeways with grade separated access. At-grade intersections are discouraged; where they cannot be avoided, they are, as a rule, placed in the transition zone between adjacent alternating passing lanes. From the European experience, it is evident that the 2+1 road design aids in the economic, environmental and social sustainability of roads, because it: (a) reduces fuel consumption by improving the road's Level of Service by reducing platooning and congestion; (b) helps defer or avoid the need for road twinning; and (c) reduces the rate of fatal and serious injury collisions by an average 25 percent.

Objective of the Study

The European 2+1 road design has not yet been implemented in North America. The objective of the study reported in this paper was to assess the feasibility of implementing the European 2+1 road concept on the rural Alberta highway network managed by Alberta Transportation (AT), and if found feasible, to propose a small number of segments for implementation.

Methodology

As a first step, an exhaustive literature search was conducted to gain insights regarding the European 2+1 road design standards and criteria, and improvements achieved in safety and Level of Service. AT's warrants and criteria for twinning and climbing/passing lanes were reviewed, as well as the access control and geometric standards and guidelines.

A short list of 12 Control Sections (from an initial long list of 67 Control Sections on the Alberta two-lane rural highway network) was developed for potential 2+1 road application on the basis of the following factors: traffic volumes, collision rates, and AT's warrants and planned programs for twinning and for climbing/passing lanes.

All of the 12 Control Sections were "virtually driven" using AT's digital video log. The purpose was to note the location and number of major and minor intersections, and other features such as bridges that could influence the suitability of the 2+1 road design. In the 12 Control Sections it was possible to identify 15 potential 2+1 road segments ranging in length from 7 to 24 km. Unfortunately, however, it turned out that the potential segments contained an average of 2.7 intersections per km, with a range of 0.8 to 4.1.

Conclusions

1. The European 2+1 roads concept does not appear to be suitable for general application on the Alberta rural highway network, because:

    - It would be very difficult to accommodate the large number of intersections in the 2+1 road design because of Alberta's requirements for safety performance and sight distance. Even if it were possible to accommodate these fixed-location intersections in the transition zone between adjacent passing lanes, adequate sight distances at these transition areas may not be available. In addition, the frequent presence of intersections within the 2+1 segments would increase the likelihood of collisions, thus potentially negating a main benefit of 2+1 roads.

- On the European 2+1 roads, improvements of two Levels of Service (e.g., from D to B) have been experienced. On Alberta rural highways where the Level of Service is frequently "A", it will be impossible to achieve a significant improvement in Level of Service through conversion to the 2+1 road configuration. The existing "net passing opportunity" requirement as defined in Alberta's Geometric Design Guide is relatively high, and the conversion to 2+1 configuration would result in large transition areas that must be marked as "no passing" in both directions. It is therefore unlikely that the "net passing opportunity" could be improved on Alberta rural highways by the 2+1 design.

2. The European 2+1 roads concept may be more feasible elsewhere in Canada: for example in Nova Scotia, where some sections of arterial two-lane highways are quasi-freeways with grade-separated access control.

PURPOSE AND SCOPE OF THE PAPER

Highway jurisdictions around the world routinely provide isolated, short auxiliary (passing and climbing) lanes on two-lane roads in order to reduce platooning and improve the Level of Service and safety.

The Alberta rural highway network, managed by Alberta Transportation (AT), comprises 28,624 km (2006 figures), of which 2,214 km are multi-lane divided highways. The remaining 26,410 km are two-lane undivided highways. The traffic volumes on the divided highways range from 1,900 vehicles per day to 154,000 vehicles per day Annual Average Daily Traffic (AADT); and the traffic volumes on two-lane highways range from less than 100 vehicles per day to 15,000 vehicles per day AADT. The two-lane highway network in Alberta includes 374 km of auxiliary lanes, comprising 85 km of passing lanes (44 passing lanes with an average length of 1.94 km), and 289 km of climbing lanes (152 climbing lanes with an average length of 1.90 km).

Figure 1 shows the Alberta highway network (maps of the Alberta highway system are available on AT's web site shown in Reference 1).

In the conventional passing/climbing lanes design on two-lane highways, the additional lane is provided on the right hand side of the existing lane for the slow moving vehicles so that the existing lane can be used by faster vehicles to pass. Figure 2 shows the various alternative configurations for conventional passing lanes.

Over the last twenty years, European countries have built several thousand kilometres of 2+1 roads, in which an existing or new 13 to 15 metre wide, paved two-lane road segment (6 to 20 kilometres long) is re-striped into three traffic lanes, with the centre lane used as the passing lane in alternate directions throughout the length of the segment. Figures 2, 3 and 4 show a schematic layout, the cross sections, and several examples of the European 2+1 roads.

Alberta Transportation retained the services of EBA Engineering Consultants Ltd. (EBA) in June 2007 to undertake a study to assess the feasibility of implementing the European 2+1 road concept on the rural Alberta highway network. This paper presents the results of EBA's assessment.

The scope of the study comprised the following main tasks:

1. Describe the 2+1 road design concept, summarize the practice and experience with 2+1 roads in Europe; and investigate whether the concept has been used in North America.

2. Review AT's criteria and current and future plans for twinning or passing/climbing lanes; and develop proposed criteria for potential application of 2+1 roads in Alberta.

3. Based on the proposed criteria, prepare a preliminary long list of candidate 2+1 highway Control Sections on the rural Alberta highway network that could accommodate 2+1 road segments; and cull it to a short list of candidate 2+1 highway Control Sections.

4. Evaluate the short list for feasibility on Alberta rural highways; and if determined to be feasible, recommend the top ten candidate segments for implementation.

THE 2+1 ROAD DESIGN CONCEPT AND ITS USE TO DATE

The 2+1 Road Design Was Pioneered in Europe

As mentioned above, the European 2+1 roads concept involves providing a continuous three-lane cross-section, and striping the centre lane in such a manner as to make it the passing lane in alternate directions throughout the length of the up to 20 km long segment.

Figure 3 shows a schematic, and several examples of 2+1 roads in Europe. The salient aspects of the 2+1 road design in Europe are summarized below (the information has been gleaned from "NCHRP Research Results Digest 275, Application of European 2+1 Roadway Designs" (3) and selective European reports (4, 5, 6, 7, 8, and 10).

1. The 2+1 road design has been implemented in many European countries. Finland, Germany and Sweden together have built more than a 1,000 km of 2+1 roads. France, Italy, Spain, and the United Kingdom have also experimented with 2+1 roads. In Ireland, a program is underway to build new 2+1 roads (as against re-striping existing roads) on nearly 30 percent of Ireland's 2,800 km National Primary Road network.

2. Figure 3 shows typical cross sections of 2+1 roads. The initial application of the of 2+1 road design in Europe mostly consisted of re-striping existing 13 to 14 m wide pavements to provide three lanes with less than 1 m shoulders. In some countries, a narrow central flush median is provided. On new construction, a 14 m pavement width is used (see Figure 3). Finland, Sweden and Ireland prefer a cable barrier in the narrow flush median separating the two directions of travel, but Germany considers such cable barriers undesirable.

3. The length of the continuous 2+1 road segments in Europe has ranged from 8 km to 20 km. The lengths of the passing lanes and the striped transitions between alternating passing lanes vary somewhat from country to country.

4. The main rationale for 2+1 road design in Europe is to improve the level of safety and mobility. It has been implemented on two-lane roads carrying 6,000 to 30,000 AADT with high congestion, low Level of Service and high collision experience, where four-laning was considered unjustified or prohibitively expensive. Cost comparisons between 2+1 roads and four-laning are not available, but benefit/cost ratios for implementation of 2+1 design on existing roads have been reported to be between 1 and 10.

5. The 2+1 road design does not increase the capacity of the road, but has been found to improve the operational Level of Service by at least two levels higher (e.g., from D to B) compared to a two-lane road carrying the same amount of traffic. In terms of safety improvements, experience from Germany, Finland and Sweden indicates that 2+1 roads

without a central cable barrier reduce the rate of fatal plus injury collisions by 5 to 36 percent. Reference 3 estimates an average collision reduction factor of 24 percent.

6. Although exact figures are unavailable, it appears that many of the 2+1 roads in Europe are high volume semi-motorways (semi-freeways), i.e. undivided roads, with no at-grade intersections. Major intersections are discouraged on 2+1 roads for obvious safety and operational reasons. On non-grade-separated 2+1 roads, the general European practice is to place the intersections in the transition zones (Figure 5 shows some intersection treatments on European 2+1 roads).

The 2+1 Road Design Has Not Been Implemented to Date in the USA

The NCHRP Research Results Digest 275 (3) had recommended the use of The European 2+1 roads concept in the US. However, a search of the literature and EBA's contact with the officials of the US Federal Highway Administration indicated that the European 2+1 road concept is yet to be implemented in the U.S.

The state of Arkansas appears to be the only U.S. jurisdiction that has built segments of alternating passing lanes, although not necessarily based on the exact European design. Arkansas has upgraded some two-lane highways to three-lane cross sections, and marked them for alternating passing lanes. The traffic volumes on the alternating passing lane segments range from 2,000 ADT to 9,000 ADT, with a weighted average of 5,300. A preliminary examination of the operation of the Arkansas alternating passing lanes (9) indicated a significant reduction in platooning, and lower crash rates (no comparative averages were reported) on the majority of the passing lane sections than the state-wide average for rural two-lane highways.

The 2+1 Road Design Has Not Been Implemented to Date in Canada

A search of the literature and EBA's contacts with the officials of the Transportation Association of Canada and selective provincial departments of transportation indicated that the European 2+1 road concept is yet to be implemented in Canada.

On the basis of an informal communication that Newfoundland and Labrador (NF) might have utilized the 2+1 road design on the TransCanada Highway, AT asked EBA to follow up with the NF transportation staff regarding their passing/climbing lane practice.

EBA's discussion with the NF transportation staff and a review of their passing/climbing lane standards and practices (12) indicated that NF has not and does not plan to use the European 2+1 road design. They have, of course, built numerous regular climbing/passing lanes that generally conform to the Transportation Association of Canada guidelines.

An interesting (and different than other jurisdictions) aspect of the NF design and operation of their passing/climbing lanes is the rule that the vehicles in the passing lane must yield to the traffic in the curb/right lane before the end of the passing/climbing lane. This is indicated by painting two YIELD messages in the passing/climbing lane before the end of the climbing/passing lane (see Figure 6 for details of the layout and marking scheme used in NF for this purpose).

The NF transportation staff report that this rule has been accepted well by the NF drivers; and that the scheme appears to have added safety benefits although no formal collision statistics have yet been compiled and analyzed (12).

DEVELOPMENT OF THE LIST OF 2+1 CANDIDATE SEGMENTS ON THE ALBERTA RURAL HIGHWAY SYSTEM

Introduction

This section presents the rationale, methodology, and results of the process utilized to select and analyze the candidate segments for 2+1 roads on Alberta highways.

As in other highway jurisdictions, for ease of reference each Alberta highway is divided into Control Sections of manageable length. For Alberta highways that are oriented generally east-west, the Control Section numbers run from west to east (e.g. Control Sections 1:02 to 1:22 on Highway 1 starting at the BC border); and on highways that are oriented generally north-south, the Control Section numbers run from south to north (e.g. Control Sections 2:02 to 2:62 on Highway 2 starting at the US border). Interestingly, the Control Section numbers are, with some exceptions, even numbers and usually start with :02. The longer Control Sections are sub-divided into several shorter Traffic Sections for which traffic statistics, e.g. AADT, travel kilometres, percentage of various vehicle types, equivalent axle loadings, etc. are reported.

The first step in the analysis was the selection of a 'long list' of 64 Control Sections on Alberta two-lane rural highway network, based on certain criteria as explained below. This list was circulated to AT's Regional Operations staff for comments. The comments received resulted in the addition of 3 Control Sections to the long list, increasing its size to 67 Control Sections.

In the next step, AT staff comments were utilized, along with other criteria discussed below, to arrive at a 'tentative short list' of 28 Control Sections. The remaining 39 Control Sections were deemed to not meet the criteria for the tentative short list. With the help of AT staff, a final short list of 12 Control Sections was selected.

The 12 Control Sections on the short list were further analyzed on the basis of another set of criteria with a view to selecting a short list of approximately ten segments of 8 km to 20 km in length each, which could be appropriate candidates for implementation of the 2+1 road concept.

Development of the Long List of 2+1 Candidate Control Sections

A detailed description of the selection criteria, analysis, and results, and the Excel spreadsheets utilized, are available in the study report (11). Presented below is a brief summary.

Potential for collision reduction and the AADT were considered the rationales for potential 2+1 roads in Alberta. Note that the Level of Service on most rural Alberta highways tends to be quite high (often A or B); and the Level of Service or peak hour traffic volumes were not directly considered as criteria in this analysis.

The base spreadsheet was AT's collision data summary for the years 2000 to 2004 for all Control Sections on two-lane highways with greater than 1,000 AADT. The 2+1 roads can logically be expected to reduce certain types of collisions, such as head-on collisions, more than the other types. But AT does not summarize data by detailed collision types. The non-animal collision rate per 100 MVKM (million vehicle kilometres) was the finest relevant detail available, and was considered sufficient as a suitable surrogate at this level of analysis.

Data on the following was added, for the applicable Control Sections, to the non-animal collision rate and AADT spreadsheet:

- Locations of existing climbing/passing lanes
- Top 50 locations warranted for twinning (four-laning) based on AT's warrants
- Top 50 locations warranted for climbing lanes based on AT's warrants
- Top 50 locations warranted for passing lanes based on AT's warrants

A notation was added to Control Sections that appeared to be near-urban or commuter routes (with heavy AM and PM peaking, thus not conducive to 2+1 road treatment).

Various combinations of criteria shown below were then applied, independent of each other, to determine whether a given Control Section might be a possible candidate for the 2+1 long list. These criteria were arrived through discussion with AT staff; and it was recognized that there was some arbitrariness to them.

- Control Sections that have a non-animal collision rate of greater than the provincial average and have one or more warranted locations for twinning, climbing lanes, or passing lanes.
- Control Sections that have a non-animal collision rate of greater than the provincial average and an AADT >3,000.
- Control Sections with AADT >3,000 and have one or more warranted locations for twinning, climbing lanes, or passing lanes.
- Control Sections with a very high (150% of the provincial average – an arbitrary number) non-animal collision rates per 100 MVKM and an AADT >2,000. It is interesting to note that many of the Control Sections with the highest non-animal collision rate are on highways with relatively low traffic volumes.
- Control Sections with 6 or more (an arbitrary number) existing or warranted climbing and/or passing lanes.

The long list consisted of 67 Control Sections that met one or more of the above criteria. Of course, an entire Control Section would not be a 2+1 candidate, but only appropriate segment(s) in it that were to be decided later on the basis of additional criteria and judgment and knowledge of AT staff.

Development of the Tentative Short List of 2+1 Candidate Control Sections

The long list of 67 Control Section containing all the above data was circulated to AT's Regional Operations staff for comments. A tentative short list of 28 Control Sections was then prepared utilizing AT staff comments and additional criteria, so that each of the 28 Control Sections met the majority of the following criteria:

- Traffic volume of at least 2,000 AADT (note that the vast majority have an AADT between 3,000 and 5,100);
- Greater than average non-animal collision rate;
- Six or more existing or warranted auxiliary (climbing or passing) lanes;
- Greater than 20 km length, so as to allow a reasonably long 2+1 segment.

Control Sections with near-urban or commuter characteristics were excluded.

Development of the Final Short List of 2+1 Candidate Control Sections

EBA and AT staff discussed the 28 Control Sections in detail one by one. It was decided that EBA would further examine the following 12 Control Sections with the help of AT's video log and other suitable data to select 10 locations potentially suitable for the 2+1 road configuration.

Highway 2:46	Highway 28:18
Highway 3:04	Highway 28:20
Highway 11:10	Highway 39:06
Highway 13:10	Highway 39:10
Highway 22:16	Highway 2A:14
Highway 22:30	Highway 2A:16

Selection of 2+1 Segment Locations from the Final Short List of Control Sections

The next step was to select the most suitable locations of 2+1 segments from the final short list of 12 Control Sections. To be feasible, a 2+1 road segment would require a minimum length of 6 km. In addition, a suitable 2+1 road segment should meet the majority of the following criteria:

- no bridges (to avoid the cost of bridge widening or a new bridge);
- no major intersections;
- as few as possible minor intersections;
- as few as possible very tight horizontal curves;
- locations where the existing or proposed auxiliary lanes can be rationalized into a 2+1 design; and
- no guardrails (if possible).

The first step taken to achieve this was to visit each of the 12 Control Sections using AT's digital video log available to registered users via AT's web site. The digital video log includes video footage of each Control Section and the kilometre location of any given feature, such as the above criteria, can be noted.

The digital video log for each of the 12 short listed Control Sections was virtually driven, and a detailed inventory was made of the location of bridges, intersections, guardrails, and tight curves. The types of intersection (farm and property accesses, intersections with Range and Township roads, and intersections with other highways) were noted.

Application of the above procedure resulted in the identification of 15 potential 2+1 road segments ranging in length from 6.9 to 24.2 km.

The culling process was able to exclude bridges and most major intersections from the potential 2+1 road segments. Unfortunately, it turned out that the potential segments contain an average of 2.7 minor intersections per km, with a range of 0.8 to 4.1. Only two potential segments (both on Control Section 2:46 east of Slave Lake) contain less than one minor intersection per km.

To double check on the prevalence of minor intersections, air photo mosaics for three of the 12 Control Sections (Control Sections 2:46, 22:30 and 39:06) were assembled and examined. They

confirmed the plethora of intersections with Range Roads, Township Roads, and farm and other local access points and approaches. Being a major negative for the 2+1 road concept, this among other reasons as explained below, led EBA to the conclusion that the European 2+1 road concept would not be suitable for Alberta rural highways.

CONCLUSIONS

The European 2+1 roads concept does not appear to be suitable for general application on the Alberta highway network. The main reasons for this conclusion are presented below:

1. The reduction in collisions is an important rationale for the European 2+1 road design, which heavily depends on there not being too many intersections or conflict points within the 2+1 road segments. Indeed, a large proportion of the 2+1 roads in Europe are on semi-motorways (semi-freeways) with no at-grade intersections. Where unavoidable, intersections on European 2+1 roads are generally accommodated within the transition zones between the alternating passing lanes. In Alberta, almost every kilometre of highway has several fixed location intersections with County (Township/Range) Roads and farm and other property access roads. It would be very difficult, if not impossible, to accommodate these intersections in a European 2+1 road design because of safety performance and sight distance requirements.

   In theory, it may be possible to locate some of the potential 2+1 road segments on the Alberta rural highways so that the intersections with Township/Range Roads fall within the transition zones. This would not be frequently practicable, because sight distances at these transition areas may not be available. Adequate sight distance is a necessity because motorists must not rely on signage and road markings alone to tell them they need to merge. Therefore, these transitions cannot be located on curves or over the crest of hills.

   The presence of minor approaches within the 2+1 segments may still be undesirable, as this may cause confusion to the driver, thus increasing the likelihood of collisions. AT's geometric design guidelines for passing lanes have strict requirements regarding the location of intersections vis a vis passing lanes.

   In addition, the frequent presence of intersections within the 2+1 segments would tend to increase the likelihood of collisions, thus negating a main benefit of 2+1 roads.

2. The two-lane European highways where 2+1 roads have been or are planned to be built, generally have much higher traffic volumes (up to 30,000 AADT) and a lower Level of Service than the two-lane Alberta rural highways. Therefore, the Level of Service improvements as a result of 2+1 roads are much higher (two levels of service, e.g., from E to C or D to B) in Europe than they would be on Alberta highways. On Alberta rural highways where the Level of Service is frequently A or B, it will be impossible to achieve a significant improvement in the Level of Service through the conversion to 2+1 road configuration. The existing "net passing opportunity" requirement as defined in Alberta's Geometric Design Guide is relatively high, and the conversion to 2+1 configuration would result in large transition areas that must be marked as "no passing" in both directions. It is therefore unlikely that the "net passing opportunity" could be improved on Alberta rural highways by using a 2+1 design.

3. Instead of pursuing the European 2+1 roads concept for Alberta highways, Alberta Transportation may want to investigate the potential for building more conventional auxiliary (passing/climbing) lanes, alternating if the situation and warrants permit, on selective highways.

On relatively high volume highways, this could provide a cost effective interim solution for a few years before four-laning is implemented. This non-continuous passing lane concept may be more suitable for Alberta because the planners and designers can be selective about where to locate the passing lane sections, thus avoiding the design challenges for 2+1 roads posed by the presence of intersections and steep hills.

4. The European 2+1 roads concept may be more feasible elsewhere in Canada: for example in Nova Scotia, where some sections of arterial two-lane highways are quasi-freeways with grade separated access control, which have a significant number of conventional passing/climbing lanes.

DISCLAIMER

The opinions expressed in this paper are those of the authors, and do not necessarily represent the policies or opinions of Alberta Transportation.

REFERENCES

1. Alberta Transportation website for highway maps. http://www.transportation.alberta.ca/608.htm

2. Frost, U., Morrall, J. Comparison and evaluation of the geometric design practices with passing lanes, wide-paved shoulders and extra-wide two-lane highways in Canada and Germany. International Symposium on Highway Geometric Design Practices, August 30 – September 1, 1995.

3. National Cooperative Highway Research Program (NCHRP). Application of European 2+1 Roadway Design. NCHRP Research Results Digest Number 275. Transportation research Board, Washington, DC. April 2003.

4. Berg, T., Carlsson, A. 2+1 Roads With and Without Cable Barriers: Speed Performance. Fourth International Symposium on Highway Capacity, June 2000. Published by Transportation Research Board, Washington, DC. 2000.

5. Carlsson, A. (2001). Traffic Safety on Three Continents. International Conference in Moscow, Russia, September 2001. Published by Swedish National Road and Transport Research Institute.

6. Herrstedt, L. (2001). 2+1 Roads – Danish Experiences. Dansmarks Transportforskning. http://www.trm.dk/sw9212.asp

7. Ireland National Road Authority, 2+1 Road Pilot Program, Pamphlet, 2004. http://www.nra.ie/Publications/DownloadableDocumentation/GeneralPublications/file,3509,en.PDF

8. Various Papers on 2+1 Roads in the Proceedings of the "Third International Symposium on Highway Geometric Design", June 29-July 1, 2005, Chicago. Compendium of Papers on CD_ROM available from Transportation Research Board, Washington, DC. http://pubsindex.trb.org/document/view/default.asp?record=760393

9. Gattis, J.L., R. Bave, L. Duncan. Alternating Passing Lane Lengths. Transportation Research Record No. 1961. Transportation research Board, Washington, DC. 2006.

10. Carlsson, A. Evaluation of 2+1 roads with cable barriers. VTI report 636, Swedish Road Administration. 2009 (with English summary).

11. Alberta Transportation. Feasibility of 2+1 Roads on the Alberta Rural Highway Network. Report prepared by EBA Engineering Consultants Ltd., November 2008. (unpublished)

12. Morrissey, John. Telephone and email communications with John Morrissey, Manager of Highway Design, Department of Transportation and Works, Newfoundland and Labrador, February 2008.

FIGURE 1. Alberta Provincial Highway Network (Source: Canadian Automobile Association)

FIGURE 2. Alternative Configurations for Conventional Passing Lanes (Source: Reference 2)

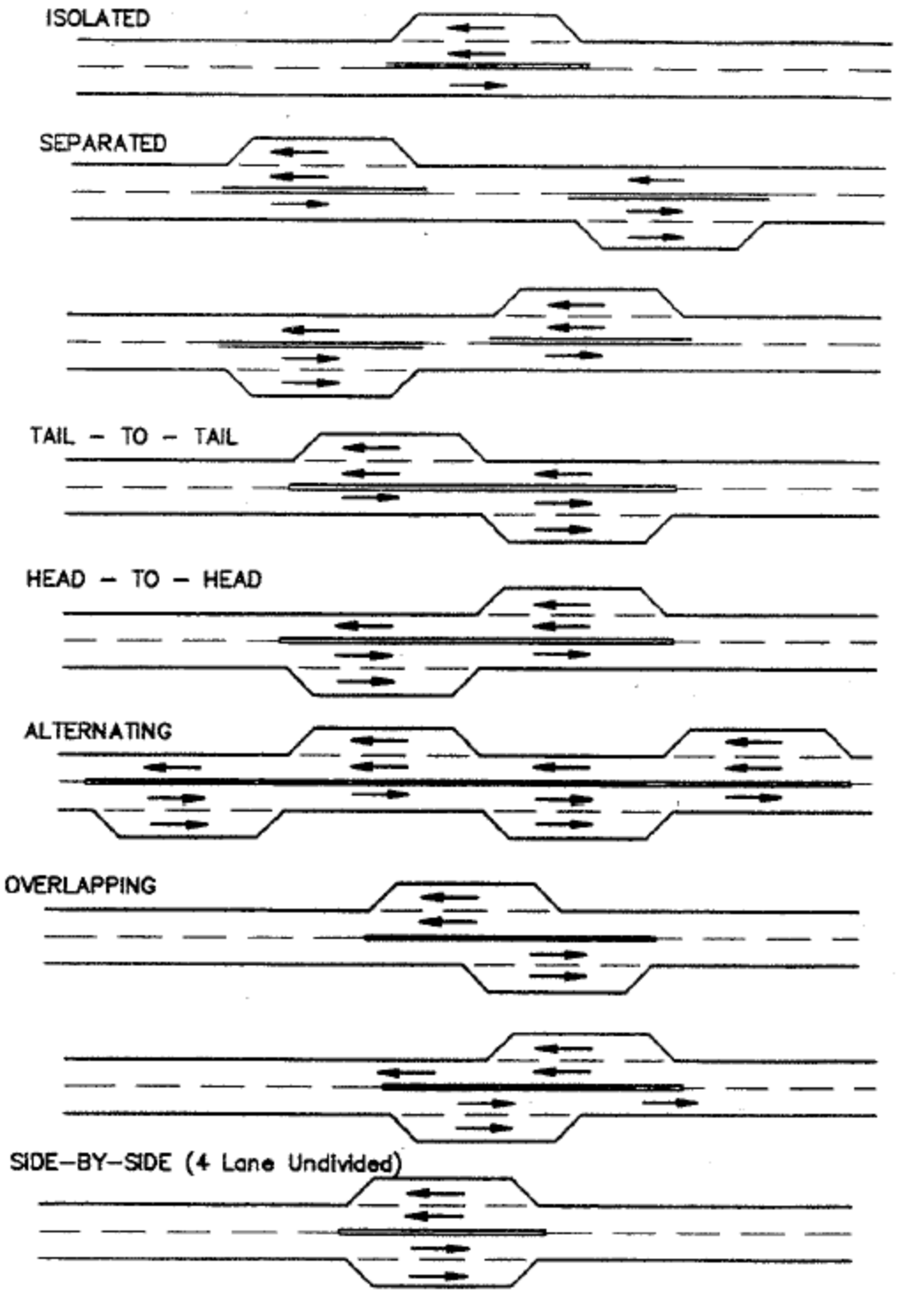


FIGURE 3. A Schematic & Examples of 2+1 Roads in Europe (Source: Reference 3)

Schematic of 2+1 roadway

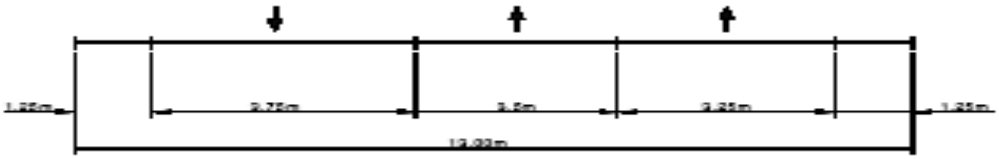
2+1 roadway in Germany

Example of lane addition transition in Finland

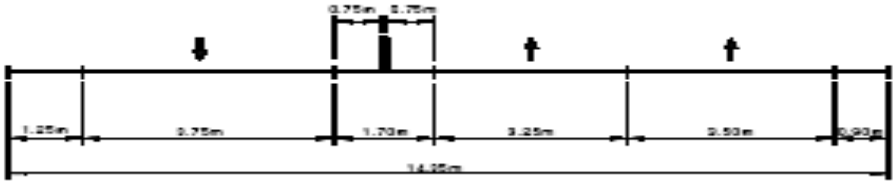
Roadway in Finland

Example of lane-drop transition in Finland

FIGURE 4. Typical Cross Sections on 2+1 Roads in Europe (Source: Reference 3)

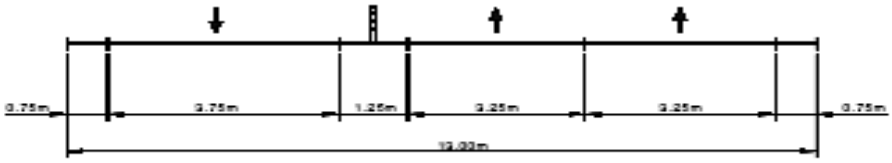


Cross section without median barrier used in Finland



Cross section with median barrier being considered for use in Finland

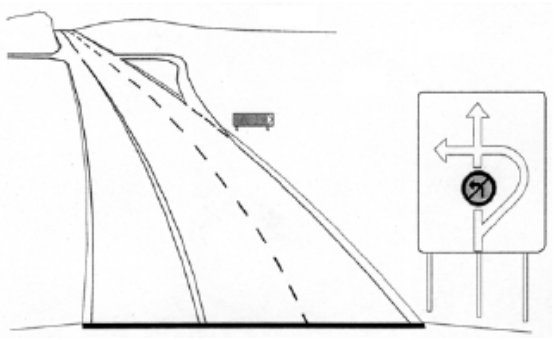
Cable barrier on a 2+1 road in Sweden



Cross section of existing 2+1 roadways with cable barrier in Sweden

FIGURE 5. Examples of Intersection Treatments on 2+1 Roads in Europe

(Source: Reference 3)



Right diverging lane loop for left turns used in Finland

Three-legged intersection on 2+1 roadway in Sweden

Four-legged intersection on 2+1 roadway in Sweden

FIGURE 6. Pavement Markings & Sign Layout for Climbing Lane on Two-Lane Highway in Newfoundland and Labrador (Source: Reference 12)