The Geometric Design Standards and the Enhanced Clear Zone Concept as Utilized on the Trans Canada Highway Project

Blake Wellner, Opus International Consultants (Canada) Ltd.

Paper prepared for presentation

At the Implications of P3 Projects on Geometric Design Session

Of the 2008 Annual Conference

of the Transportation Association of Canada

Toronto, Canada

Abstract

The selection of geometric design standards which should be utilized for a Private / Public Partnership (P3) project is a question that must always be considered by the facility's owner especially in the current era of design domains. The paper shows how the standards were developed for the 98 kilometre Trans Canada Highway project in New Brunswick.

A brief description of the Trans Canada Highway Project (TCHP) and how it fits into the overall transportation system in the province is provided. The paper describes how each geometric design feature was evaluated based on the owner's engineer having a thorough knowledge of the project to be constructed and the adjacent network in which the project was to be incorporated. It is recognised that the project standards must be consistent with this adjacent network. It also talks about how many features of this project, such as the horizontal alignment standards for the main lanes, are essentially pre-determined by the owner. This determination is the result of the owner having to select standards for preconstruction activities such as the establishment of the Right of Way (ROW). The paper also discusses how the change request process allows both the Developer and the Owner to deal with specific instances where it might be advantageous for both parties to vary from the project's standards. It also talks about the lessons learned from the project in relation to the establishment of geometric design standards.

The paper also talks about the application of an enhanced clear zone concept and how it was used on the project. This concept allowed for low cost safety improvements to be undertaken outside the traditional clear zone limits in order to add value to the project. These enhanced clear zone improvements were utilized both for the new construction and the upgrading of the adjacent existing sections.

The paper concludes that by having the owner's engineer having a thorough knowledge of both the P3 project and the adjacent network a set of geometric project standards can be developed that allow the project to be consistent with the adjacent system, without completely limiting the Developer's flexibility. It also concludes that the enhanced clear zone concept can cost-effectively add safety improvements to both the areas of new construction and on the adjacent highway system.

Introduction

The determination of what geometric design standards should be utilized for a Public/Private Partnership (P3) project is a question that must always be considered by the facility's owner especially in the era of design domains. The paper talks about how the standards were developed for the approximately 98 kilometre Trans Canada Highway project in New Brunswick.

The paper also talks about how an enhanced clear zone concept on the project was utilized. This concept allowed for low cost safety improvements to be undertaken outside the traditional clear zone limits to add value to the project.

Project Description

The Trans Canada Highway Project (TCHP) involved the design and construction of 98 kilometres of new four lane highway between Grand Falls and Woodstock, as well as upgrades to another 128 kilometres of existing roadway. This construction was completed, and the highway was opened to the public, in the fall of 2007. The Design Build (DB) portion of the project was completed on time, under budget and with no claims. Figure 1 shows the map of the project. As can be seen, the new 98 kilometre roadway is basically divided into two sections intertwined into the existing network.

Now that the project is complete, the length of the Trans Canada highway in New Brunswick from the Quebec to Nova Scotia borders is currently 516 kilometres. The TCHP was obviously a significant part of this overall total.

The TCHP contract also includes the operation, maintenance, and rehabilitation of 275km of four lane highway until 2033. The total value of the project was $1.05 billion. This was comprised of $543.8 million for design, construction, finance and approximately $500 million for operation and maintenance.

The Trans Canada Highway Project is the second large public-private-partnership Highway Project undertaken by the Province of New Brunswick. The Fredericton to Moncton Highway Project (FMHP) was a 195km design-build-operate project that runs from Longs Creek to Magnetic Hill. The final section of this project was opened to traffic in the fall of 2001.

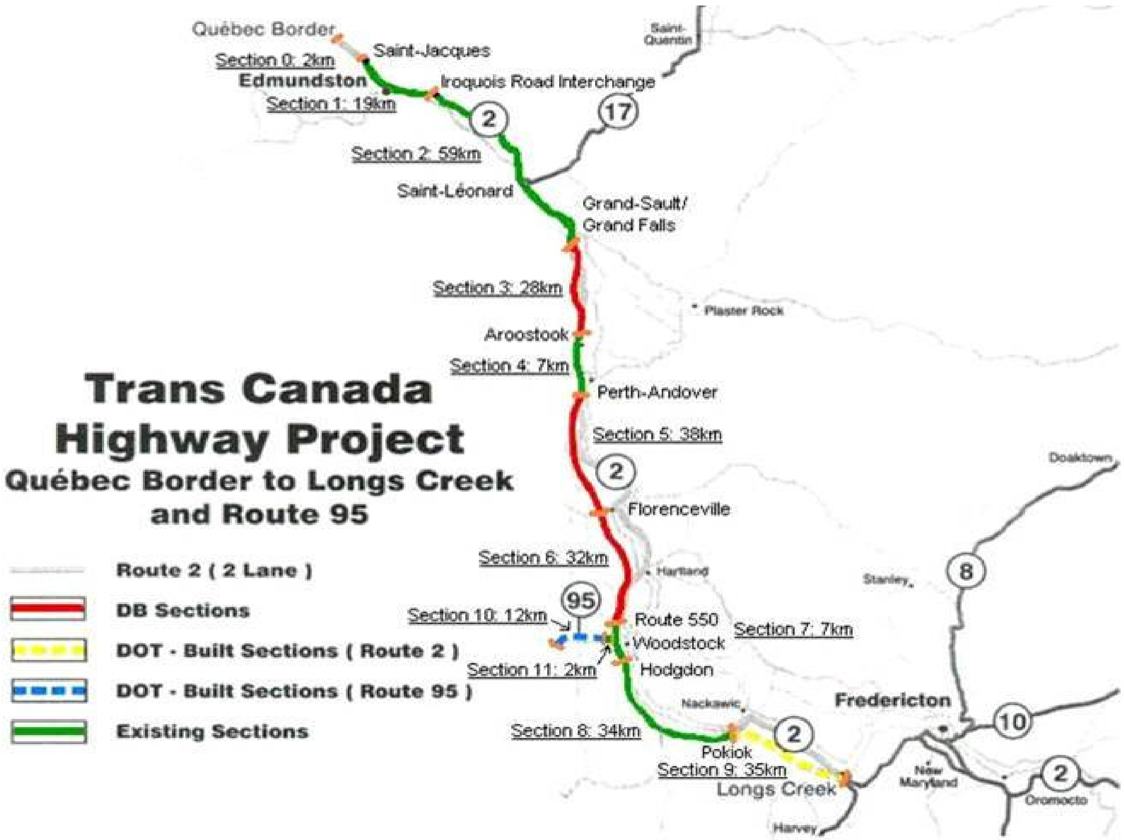

Figure 1: Project Map

Pre- RFP Activities

Because of the topography involved in the project, and the need to identify the Right of Way (ROW) limits so that the land would be available to the Developer upon the execution date, considerable work was undertaken prior to the issuance of the Request For Proposal (RFP). This information would prove useful in the determination of the geometric standards to be utilized for the project. The entire project area had been aerially mapped. A narrow centerline was also run in the field for environmental screening proposes which also allowed a centerline profile to be run. The ROW identification process required a rough grade and cross sections be generated to determine preliminary slopes stakes and hence ROW limits. This rough grade would prove valuable in later establishing the geometric standards.

Determination of Geometric Standards

The geometric design standards for Canada are contained in a publication by the Transportation Association of Canada entitled the Geometric Design Guide for Canadian Roads. This publication provides some unique challenges to P3 projects. First and foremost it is a guide, and as such, is somewhat ambiguous in many cases especially if it is to be to be a legally binding document incorporated into a Owner/ Developer P3 contract. Stating in a contract that a Developer must follow the Geometric Design Guide without some supplementary technical specifications would make the contract extremely difficult to enforce. The other difficulty utilizing the guide for P3 projects is the concept of the design domain. The design domain concept allows the designer to rationalize the selection of a particular design value based on the particular design situation from a range of values in the domain. Unfortunately, since migration to the lower end of the design domain can often lead to considerable cost savings, their unchecked use on P3 projects can result in a very minimalistic design being utilized to provide cost savings. It is also recognized that the layering of minimal design values can also lead to increased safety risk. This is where the owner and owner's engineer must become involved prior to the issuance of the P3 RFP.

The owners of proposed P3 projects need to realize that a substantive amount of work must be undertaken before the RFP is issued for a project. It is the owner's responsibility to determine the scope of the project and to ensure that, if the project is part of a larger network, it is consistent with that larger system. As was the case with the TCHP, the owner should ensure that qualified engineering team members are assigned to the project to carefully and purposely prepare the Technical Requirements. This is the where the owner specifies what they are prepared to live with in regards to the Geometric Standards and to ensure that those Technical Requirements are consistent with the larger network. As mentioned earlier, this is particularly true in the era of design domains which are now provided for many geometric design features. The owner's engineer must review each of these design domains. He must rationalize whether, based on the goals of the project, the whole of the domain is acceptable or whether some limiting technical standard must be included in the RFP documentation. Some would argue that the narrowing of the design domain limits the Developer's flexibility and increases the cost of the project. However, if the Owner's engineer has carefully considered these impacts and the result is a project that is consistent with the adjacent network, then the owner's goals will probably have been met.

A methodology does also need to exist that allows those standards to be modified in unique circumstances to the mutual benefit of both parties. The following illustrates how some of these values were determined for the TCHP.

Main Lanes

Table1 provides some of the geometric design standards for the facility main lanes.

Some of the values illustrated in the table are matters of government policy such as the highway classification, level of access control and posted speed limit. Others, such as the lane width, pavement crossfall, lane and shoulder width and maximum superelevation, although they could be seen as provincial policy, also ensure this new roadway is consistent with the adjacent network because those items were utilized in their design. Of course, specifying the design speed and the maximum superelevation establishes the minimum radius. Often on these projects since the alignment and ROW has usually been predetermined, the use of minimum radius curves on the main lanes is not an issue because it normally doesn't have a significant impact on cost. On this project, however, a secondary level of protection was added that stated that if the Developer deviated from the established alignment, the utilization of any radii less than 1500m would require a change request.

Table1
GEOMETRIC DESIGN CRITERIA FOR FACILITY MAINLINE

Highway Classification	RAD 120
Access Control	Level I
Posted Speed (km/h)	110
Minimum Crest K Value	105
Minimum Sag K Value	60
Maximum Grade (%)	5.0
Minimum Radius (m)	750
Lane Width (m)	3.70
Normal Pavement Crossfall (%)	3.0
Maximum Superelevation (%)	6.0
Outside Shoulder Width (m)	3.0 (0.8 m full strength pavement)
Inside Shoulder Width (m)	1.5 (0.8 m full strength pavement)

Sometimes the values selected come from some unlikely sources. The 5% maximum grade is the maximum grade that the federal government will fund under the National Highway funding agreement. A minimum grade of 0.5% on vertical tangents was also established to facilitate drainage as well as a structural requirement that no grades on structures less than that value would be allowed to discourage ponding on the structure.

Design domains exist for the both the crest and sag vertical curvature guidelines. There can also be significant cost savings associated with the use of minimum values. For this project, the minimum values were established by discussing with a number of the Owner’s engineers who had been involved in design of earlier parts of the network what values for these features had been utilized for minimums. Not surprisingly, their minimums tended to fall into the middle of the design domain. The design domain for crest vertical curvature for a 120km/hr design speed is a K value of between 75 and 150 with the selected minimum being 105. Similarly, for sag vertical curvature, with the same design speed and headlight control, the range is between 50 and 73. The selected minimum in this case was 60. Before these values were utilized in the Technical Specifications they were project proofed. Because preliminary grades had been established for the ROW determination these grades were quickly scrolled through to ensure that the establishment of such minimum values did not add significantly to the project cost. For example, if a sharp rock outcrop would have been spotted which in the utilization of these minimum values would have added excessively to the cost, the values would have been further reviewed and possibly a spot deviation allowed.

Some may argue that by narrowing the design domain some of the cost effectiveness of the design may be lost. However, what is being achieved here is consistency with the rest of the network which presumable through the proxy of the owner’s design engineers the public has been prepared to pay for in the past. The limits being established here are actually baseline values. If there is a case, in any particular location, where a deviation from the minimum does provide significant benefits then the Change Request process allows those benefits to be evaluated and cost shared between the Owner and Developer.

One other main lanes geometric feature that technical specifications were written for was the Centerline to Centerline spacing. This project has spacing that ranges from 22.5 metres to 82.5 metres. Recognizing the benefit of a wider tread median and the potential significant cost savings of using the narrowest values, the Developer was only allowed a 15% deviation from the established alignments.

Interchange Ramps

There were seven interchanges to be constructed as part of the project. Table 2 and the associated notes provided the technical specifications for these interchanges.

Table 2
MINIMUM GEOMETRIC DESIGN STANDARDS INTERCHANGE RAMPS

Design Element	**Directional (Non-Loop) Ramp**	**Loop Ramp** *****	**Loop Ramp**
Minimum Design Speed (km/h)	80	50	60
Minimum Radius (m)	250*	90*	130*
Minimum Radius (m) near Intersecting Highway ****	190		
Maximum Superelevation (%)	6.0	6.0	6.0
Maximum Grade (%)	8.0**	8.0**	8.0**
Minimum Crest Curve K Value	35	10	10
Minimum Sag Curve K Value	30	15	15
Minimum Sag Curve at Intersecting Highway ****	15		
Number of Ramp Lanes	1	1	1
Lane Width (m)	4.8	4.8	4.8
Normal Pavement Crossfall (%)	3.0	3.0	3.0
Right Shoulder Width (m)	2.5***	2.5***	2.5***
Left Shoulder Width (m)	1.0***	1.0***	1.0***

* controlling curvature
** for ramp downgrades terminating in a stop condition, the max. grade is 5.0%
*** 0.8 m full strength pavement structure to be provided
**** values recognize that the design speed can be reduced as a vehicle approaches a stop condition
***** applicable to WB entrance ramp at the Aroostook interchange only

Writing the technical specifications for the ramps was more time consuming because of the variable speeds that occur over their length. As can be seen from the Table 2, there was one loop ramp that required its own design criteria because of its limiting radius. Generally the same process that was used to determine the main lanes geometric features was applied to the ramps. The only exception was that, in the case of the maximum ramp grades, these were determined by reviewing the design of several interchanges in the adjacent network.

One of the most difficult areas to specify, in relation to ramps, is the connection to the intersecting roadway. Being too restrictive in the requirements can result in excessive cut in the area of the intersection. This can usually result in associated drainage issues through the interchange. In this case, grade breaks were allowed as outlined in the TAC guidelines.

The other major component of ramp design is the provision of speed change lanes (e.g. acceleration or deceleration lanes). Besides having a design domain for the overall length of the required speed change lanes, there is often some interpretation undertaken in the application of the TAC guidelines. In order to write the associated technical specifications to ensure that the new interchanges were consistent with those in the adjacent network, plans of a number of these interchanges were reviewed to determine what design elements had been used in the past. The technical specifications for the speed change lanes were based on this review. For example, deceleration lanes were first specified to be parallel single lane type. A general description of the ramp alignment as it diverges from the main lanes was provided to ensure that a minimum design speed of 96 km/h at the gore was obtained. The length of the deceleration lane was described somewhat generically because of the various ramp alignments that could have been utilized by the following statements:

- The design length for deceleration lanes shall be taken from Table 2.4.6.2 of the TAC Geometric Design Guide for Canadian Roads.

- The design speed of the turning roadway shall be the lesser of 70 km/h or the design speed of the controlling curve.

- The length of deceleration lane excluding taper shall be no less than the median value for the design domain indicated in Table 2.4.6.2 of the TAC Geometric Design Guide for Canadian Roads.

- The length shall be adjusted for grade, if required, using Table 2.4.6.3 of the TAC Geometric Design Guide for Canadian Roads.

- The length shall be measured from the start of the controlling curve. If there is no controlling curve, the length shall be measured from the gore point.

These statements were sufficient to describe the deceleration lane requirements and ensure that they would be consistent with those in the adjacent network. It is interesting to note that the median value in the design domain was again in common usage for this geometric feature. Of further note is that a minimum length of the lanes was also established. Similar requirements were also provided for the acceleration lanes on the project.

Intersecting and Ancillary Roads

There were twenty seven intersecting and twelve ancillary roadways to be constructed as part of the project. These were classified and assigned a design speed. The design criteria for these are shown in Table 3.

Table 3
GEOMETRIC DESIGN CRITERIA FOR INTERSECTING HIGHWAYS AND ANCILLARY ROADS

Design Criteria	RAU 100	RCU 90	RCU 80	RLU 80
Min. K Value (Crest)	65	45	30	30
Min. K Value (Sag)	45	35	30	30
Maximum Grade (%)	6.0	7.0	8.0	8.0
Minimum Radius (m)	440	340	250	250
Lane Width (m)	3.70	3.70	3.70	3.50
Normal Pavement Crossfall (%)	3.0	3.0	3.0	3.0
Max. Superelevation (%)	6.0	6.0	6.0	6.0
Shoulder Width (m)	3.00	2.00	1.80	1.00

The geometric features for these roadways were also determined similarly to those described earlier with the exception of the crest and sag vertical curve values which were actually determined by reviewing the grades that had been utilized to determine the ROW. Grade breaks were also allowed where the ancillary roads joined the intersecting roadways.

The next part of the paper describes how an enhanced clear zone concept was utilized to make effective low cost safety improvements to the roadway.

Enhanced Clear Zone Concept

Historically in New Brunswick, a fixed value has been utilized for the clear zone on the main lanes. A value of 10 metres was normally used regardless of the roadway slope, cost to reduce the severity, etc. More recently a more flexible range of widths have been utilized recognizing the impact of the roadway foreslope and also allowing for corrections for the curvature of the roadway. The values currently being utilized are 10 and 14 metres for 6:1 and 4:1 foreslopes respectively. It is also widely recognized that not all vehicles that leave the roadway will stop within the provided clear zone before hitting the adjacent obstacle. The number of these vehicles can be as high as 20 percent. On the TCHP, in addition to a variable clear zone width being utilized based on the slope of the foreslope and adjusted for the curvature of the roadway, the enhanced clear zone concept was introduced. This concept expands the clear zone to a width of 20 metres for obstacles that can be cost effectively treated. This concept is show graphically in Figure 2.

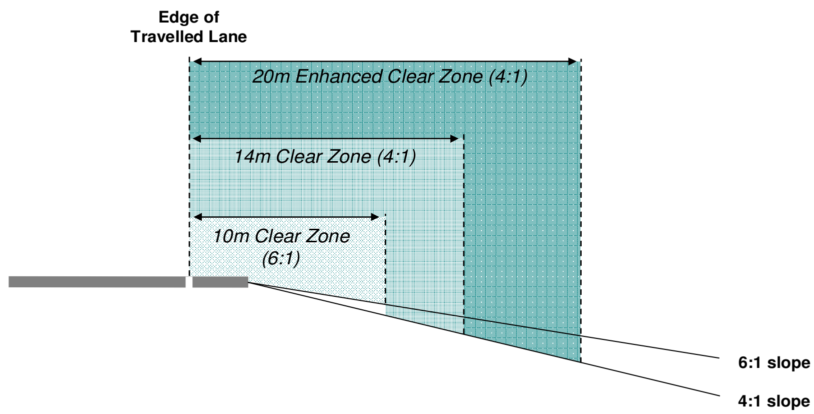

Figure 2: Enhanced Clear Zone

One example of the utilization of this concept was in regards to median crossovers. In many areas along the corridor the centerline to centerline spacing was 82.5 metres. The approach foreslope on the crossovers was set at 6:1. The question then becomes how wide laterally from the edge of the travelled lane do you build this flatter slope since the crossover is so wide. If you look at most nomographs for run of the road type collisions must vehicles stop within 20 metres on traversable main lane foreslopes. This is the value that was then utilized to define the limit of the enhanced clear zone. Obstacles along the roadway that could benefit from this enhanced clear zone concept were identified and their treatment documented in the RFP. These included the aforementioned median crossovers as well as all longitudinal pipes whether at crossovers or structures. Figure 4 shows what typically existed in one of the existing sections before improvements were made. Figure 5 shows an improved treatment after applying the enhanced clear zone concept. The foreslope to fill transitions at structures were also flattened to ensure that a vehicle off on the foreslope doesn't meet an abrupt stop at a structure fill. Since the project also included upgrades to approximately 175 kilometres of existing roadway these same improvements were also made to reflect the enhanced clear zone. In other words, the safety of the roadside for approximately 275 kilometres of Trans Canada Highway was improved at very little cost. It was estimated that the cost to flatten an existing median crossover original built at a 4:1 slope for a distance of 20 metres was approximately twenty thousand dollars each.

Figure 4: Typical Median Crossover Before Improvements

Figure 5: Typical Median Crossover After Improvements

This concept allows flexibility to have variable clear zones along the project. In relation to bridge piers, it allows an unshielded pier to be located outside of 10 metres on a 6:1 foreslope without requiring the installation of guide rail, which is arguably a hazard in itself, while still allowing treatments to be applied to other obstacles that can more cost effectively be improved.

Figure 6: Unshielded Bridge Pier

As with all projects there are lessons to be learned. The next section details some of these in relation to the establishment of the geometric standards for the project.

Lessons Learned

One of the lessons learned in relation to the geometric standards on this project was allowing for grade breaks. The TAC guidelines on this subject cover a wide range of situations where various classifications of roadways intersect. For example, it could apply to where a ramp intersects an existing roadway or an access road intersects that same roadway. Obviously, these are two very different situations and what may be an appropriate grade break for one may not be for the other. Unfortunately, by using the generic TAC guideline, this distinction was not readily identified.

The other specification that should be reviewed is in the 0.5% minimum grade requirements for structures, which is provided to enhance drainage. This requirement, while fine for a high speed main line structure, isn't necessarily appropriate for lower speed intersecting roadways where an underpass structure at the crest of a vertical curve is often utilized.

Conclusion

The Trans Canada Highway Project consists of 98 kilometres of new four lane facility intertwined with the existing network, including seven interchanges, twenty seven intersecting roadways and twelve ancillary roadways.

It has been shown that by having the owner's engineer with a thorough knowledge of both the P3 project and the adjacent network that a set of geometric project standards can be developed allowing the project to be consistent with the adjacent system, but without completely limiting the Developer's flexibility. These standards establish a baseline for the project and the Change Request process allows for any cost effective deviations to be equally cost shared between the parties. Some may consider the drafting of such technical specification to be an onerous task. However, it only took fifteen pages of technical specifications to adequately describe what the owner wanted and to ensure that the project was consistent with the adjacent network.

It was also shown that the enhanced clear zone concept can cost-effectively add safety improvements to both the areas of new construction and on the adjacent highway system to provide an overall safer roadway environment.