ROAD SAFETY AUDITS: LESSONS LEARNED FROM THE PRE-OPENING STAGE

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Abstract

This paper summarizes the lessons learned from conducting road safety audits (RSA) at the pre-opening stage. The paper is based on the experience of the authors who have conducted a wide range of RSAs throughout Canada over the past two decades including audits of large private-public partnership (P3) projects.

At the outset it is noted the pre-opening RSA stage is often the last stage in the series of RSAs which can include audits at the planning stage, functional design stage and detailed design stage (50%, 90%, 100% etc). In some cases audits are conducted at the post-construction stage after the facility has been opened to traffic. Typically P3 projects require a pre-opening audit prior to traffic availability when the operating consortium assumes liability for the agreement period (typically 30-35 years).

One of the most important lessons learned is that the pre-opening audit should be preceded by a ‘preliminary’ pre-opening RSA. This allows the contractor(s) ample lead time to attend to safety deficiencies that may take several weeks to remediate. Since most P3 projects are under tight time constraints and often subject to financial penalties for late delivery, it is particularly important for the contractor to be forewarned of safety-related deficiencies. Furthermore, auditors are often in the position of having to sign-off on the project before it can be made available for traffic so it is especially important that all issues are addressed prior to opening.

Among the lessons learned a wide range of safety issues and deviances include: missing and improper signage, grading (sideslopes, shoulder drop-offs); improper barrier installation; location of luminaires; opportunities to improve positive guidance; excessive driver workload; unprotected hazards in the clear zone (drainage features, sign structures, etc); and safety issues concerning vulnerable road users (pedestrians and cyclists) on multi-use pathways, sidewalks or bike lanes that are part of the roadway project.

1. Introduction

In recent years the development of major road infrastructure projects in Canada has increasingly been accomplished through private-public partnership (P3) models in an effort to expedite delivery of the facilities. Although the Road Safety Audit (RSA) process does not have a long history in North America, it has become a key ingredient in P3 projects to ensure that safety levels are not compromised by profit-conscious developers. The RSA process has effectively been adopted from the United Kingdom, Australia and New Zealand, however, its direct application to P3 projects requires some modification to the standard template.

This paper reflects on the experiences to date of employing the RSA process to some of the largest and most recent P3 highway projects in Canada at the Pre-Opening audit stage. This is a particularly crucial stage for P3 projects as they are often under compressed time constraints and subject to financial penalties if completion dates are not met. The authors have all served as road safety auditors on very large infrastructure projects developed under the P3 format. Their experiences are synthesized in an effort to better understand the trends evolving from the application of the RSA process to P3 projects. Common audit findings at this stage are highlighted in an attempt to streamline future applications of RSAs to P3 projects.

2. Background

Road authorities have traditionally founded road safety strategies on black-spot or collision-reduction techniques that are based on collision histories of existing road corridors or networks. Although this approach effectively highlights those locations in need of remedial treatment, it is considered reactive in that it only addresses issues following a history of events. A more proactive approach to mitigating potentially problematic road hazards was developed in the United Kingdom through the publication of the *Accident Reduction and Prevention Guidelines* by the Institution of Highways and Transportation in 1980 [1]. By 1991, the application of RSAs became mandatory for all U.K. trunk roads and motorways (freeways) following the publication of two key documents, namely, the *Guidelines for the Safety Audit of Highways* [2] and the *Road Safety Code of Good Practice* [3]. Within the U.K., an RSA is defined as “a formal procedure for assessing collision potential and safety performance in the provision of new highway schemes, and schemes for the improvement and maintenance of existing roads” [4].

Using the U.K. format as a template, Australia and New Zealand began to develop their own RSA policies in 1990 [5]. In 1993, the association of Australian and New Zealand road transport and traffic authorities (Austroads) developed the *Road Safety Audit Manual* [6]. These guidelines were revised in 2002 in response to the significant increase in experience and understanding of RSAs. This publication focused on two objectives: “to identify potential safety problems for road users and others affected by an existing road or new road project, and to ensure that measures to eliminate or reduce the problems are considered fully” [7]. Subsequently, New Zealand has written a newer version for their own use as has the European Union Road Federation [8, 9].

By 2005 the adoption of an RSA strategy had spread to more than 18 countries as reported by the PIARC Technical Committee [10]. Following an extensive review of audit practices elsewhere [11] the United States’ Federal Highway Administration sponsored the piloting of the RSA process in 13 states by 1998. The most current information indicates that approximately 17 states have now incorporated the RSA process into their procedures pending future evaluations of effectiveness [12]. The Federal Highway Administration has recently published audit guidelines and prompt lists to facilitate/standardize undertaking RSAs [13, 14].

Although an initial pilot of the RSA process was first undertaken in 1997 in British Columbia [15], it was not until the development of Highway 407 in Toronto that the need for the process came to the forefront. The 407 was developed under an innovative (at the time) P3 arrangement that saw a private consortia design, build and operate the facility under a 99 year lease while the Ontario government maintained ownership. This was essentially the first very large road project developed under a P3 model in Canada.

Prior to project opening in 1997, the Ontario Provincial Police drove the facility and publicly raised several safety concerns. Consequently, the Ontario Government and Ministry of Transportation for Ontario (MTO) commissioned the Professional Engineers of Ontario (PEO) to undertake an independent safety review of the facility. Upon completion of the study, it was determined that one of the key issues was that the project's organizational structure failed to establish which if any agency had assumed the traditional MTO role as the "guardian of public safety" [16]. It is noteworthy that several independent design firms were included in the consortium which contributed to concern over design inconsistencies between individual road sections. Perhaps the key outcome of this study was the recommendation for the inclusion of Road Safety Audits in future highway development projects. The concept of RSAs was not well understood domestically at the time. Further, it should be clear that the 407 safety review was not an RSA.

Soon after the Highway 407 study, the Province of New Brunswick undertook the development of a 196km section of the Trans Canada Highway under a P3 agreement with the Maritime Road Development Corporation in 1998. This was the first major road project in Canada to incorporate the RSA process throughout all stages of development (Planning, Preliminary Design, Detailed Design, Pre-Opening and Post-Opening). The subsequent benefits of including the RSA process are documented by Hildebrand and Gunter [17] and Hildebrand and Wilson [18].

RSAs became a more widely accepted process when the Transportation Association of Canada (TAC) published "The Canadian Road Safety Audit Guide" [15] in 2001. This was followed by the TAC publication "The Canadian Guide to In-Service Road Safety Reviews" [25], to help distinguish between RSA and the typical safety review. It has provided a general overview of the RSA process and has subsequently served as a foundation for various provincial policies developed for RSAs (e.g., BC [22], Alberta [26], Ontario and New Brunswick).

Highway projects developed under a P3 arrangement have shown several benefits including reduced cost, faster delivery (resulting in quicker realization of safety benefits and improved network efficiencies), transference of risk from government to developer, and development of innovative technologies/methodologies. Recent Canadian [19], American [20] and Australian [21] studies estimate that P3 highway projects have resulted in12-15, 6-40 and 15-30 percent cost savings, respectively, over conventional means of delivery. Seizing these benefits, some governments have been quick to adopt P3 road projects across the country. The United States Congress has recently shown increased support for using P3s to deliver major road projects [24]. Examples of current Canadian highway projects being developed under a P3 format are listed in Table 1.

Table 1: Major Canadian Private-Public Partnership Highway Projects

Province	Project	Completion	Description
BC	Port Mann/HWY 1 Gateway Project	2013	37 km of upgraded highway 4 to 10 lanes with HOV lanes and a New Port Mann toll bridge. $2.46 billion investment.
BC	Sea-to-Sky Highway	2009	$600 million upgrade
BC	Kicking Horse Canyon (Phase 2)	2009	Park Bridge $130 million. Completion was 16 months early.
BC	Golden Ears Bridge	2009	New 6-lane toll bridge across Fraser River
BC	Pitt River Bridge	2009	New bridge and interchange project.
BC	William Bennett Bridge (Lake Okanagan)	2008	New 5-lane replacement bridge.
BC	Sierra Yoyo Desan	2005	188km upgrade to resource road.
BC	Canada Line subway	2009	Rapid transit line connecting Richmond to downtown. Ahead of schedule.
AB	Anthony Henday Drive Project	2007 2011 2011	South-East Ring Road; $500 million; 11km North-West Ring Road; $1.42 billion; 21km Stony Plain/100Ave Interchange ; $170 million
AB	Calgary Ring Road (Stoney Trail)	2009 2013	21km extension of Stoney Trail from Deerfoot Trail to 17 Ave SE; $408 million 25 km of new 6 lane urban freeway. 17 Ave SE to Mcleod Trail; $770 million
ON	Windsor-Essex Parkway	Unknown	9.5km of new freeway with at least 20 interchange ramps and more than 20km of recreational trails and parallel service roads. $1.6 billion.
ON	Highway 407 East	unknown	70km Transportation Corridor
ON	Highway 407	1997+	Phase 1: 36km $930 million Final: 69km $4 billion
QC	Highway 30	Unknown	42km extension toll road ($1 billion estimate)
QC	Highway 25	2011	7.2km extension including toll bridge $207 million
NB	Route 1 Gateway	2013	55km 4-lane arterial 180km upgrade $580 million
NB	Woodstock-Grand Falls (Brunway)	2007	98km 4-lane arterial 128km upgrade $500 million
NB	Fredericton-Moncton (MRDC)	2001	193km 4-lane arterial $600 million
PEI	Confederation Bridge	1997	13km bridge linking PEI to New Brunswick $1.3 billion

3. Road Safety Audits and P3 Projects

The Road Safety Audit process is a natural fit for highway projects developed under a P3 arrangement. It effectively allocates the role, as noted in the Highway 407 review, of “guardian of public safety” [16] to the developer’s independent road safety audit team. In practice, developers have shown a tendency to just meet their contractual obligations as specified by a design-build agreement or prescribed series of design manuals/standards. While design engineers are professionals, the assurance of optimized safety is not necessarily met simply by meeting minimum design standards. Furthermore, most highway design engineers have a limited working knowledge of road safety engineering and are not experienced with the skills required to undertake safety analyses.

A key requirement for the success of an RSA in a P3 project is to explicitly set out the terms under which the audit process will operate. There are more players involved in a P3 compared with traditional delivery models and the relationships and reporting lines can become muddied as the project progresses. Some jurisdictions have very explicitly set out guidelines for the conduct of RSAs and, more importantly, how they relate to a P3 project. The British Columbia Ministry of Transportation has established the role of RSAs under the “Road Safety Audit Guidelines” [22] and explicitly stipulates the roles that the audit team, concessionaire and the Province will play within the terms of the P3 agreement. In fact, BC requires that a ‘road safety audit certificate’ be signed by all parties upon completion of the study at each design stage. Any recommendations not adopted by the concessionaire must be approved in writing by the Province.

Within the context of a P3 project, RSAs are sometimes mistaken for a compliance check for geometric design standards. This likely comes from the misconception that meeting minimum design standards (detailed in manuals or P3 Design-Build contracts) ensures an acceptable level of safety. It should be clear to all parties involved that it is not the auditors’ role to ensure compliance. This function should be the responsibility of the design team and/or the independent agent. Relying on the RSA Team for this task would be a misdirection of their skill sets.

Similarly, the audit team cannot be considered the ‘guarantors of safety’. In fact, some recent P3 projects have required that the RSA team provide a certification letter to ensure that the facility is ‘safe’ prior to opening. This is impossible given that the declaration of a ‘safe’ road implies that it is without risk. All roads carry risk. The Transportation Association of Canada notes that "it is impossible to make a road completely safe, if by "safe" we mean a road on which we can guarantee that there will never be a collision. We can, however, design a road to provide a reasonable level of safety. Just what is a reasonable level of safety, when we take into account the cost required to build it, is a matter of experience and judgment. In short, the notion of a "safe" (or collision-free) road is a myth. Design should be viewed instead as a process that can result in roads being "more safe" or "less safe" ” [23].

While it is understandable that the project owners wish to ensure that the road facility provides an optimal level of safety, guarantees of a “safe” facility of “acceptable levels of safety” are not possible.

Pre-opening audits are intended to be undertaken just before the road opens to live traffic, when all aspects of construction are complete; however, in a P3 project this is not always practical. Most P3 agreements have financial penalties associated with delayed project completion; consequently, contractors are under pressure to deliver a completed project on time. To facilitate on-time delivery, practice shows that "preliminary" Pre-opening audits are necessary in order to give the developer appropriate lead time to correct some identified problems. Rather than wait until the scheduled pre-opening audit to reveal safety-related issues that take significant time to address, it is in everyone’s interest to have these issues identified earlier in the process so that they can be addressed without delaying the opening. It is suggested that these less formal site visits be undertaken, in addition to the typical RSA process, at the expense of the developer. Furthermore, the construction foreman and a suitable representative from the design team should be present at the site visits so it is clear to the developer what issues need to be addressed in order to avoid undue delay following the formal Pre-Opening audit.

4. Pre-Opening Audit Findings for P3 Projects

An analysis of pre-opening audit findings for several recent large P3 highway projects is presented in this section. The objective is to highlight those areas where deficiencies are most prevalent with the hope that future projects can use these findings to mitigate last-minute problems that could delay project opening.

At the onset it should be noted that from a frequency perspective, the majority of audit findings are generated during the Pre-Opening stage. The data in Figure 1 represent the relative frequency of audit issues raised at the various stages that Road Safety Audits are undertaken throughout project development [18]. This is somewhat offset by the common recognition that the more profound changes generated through the RSA process tend to be made earlier in the design stages rather than later as the project nears completion.

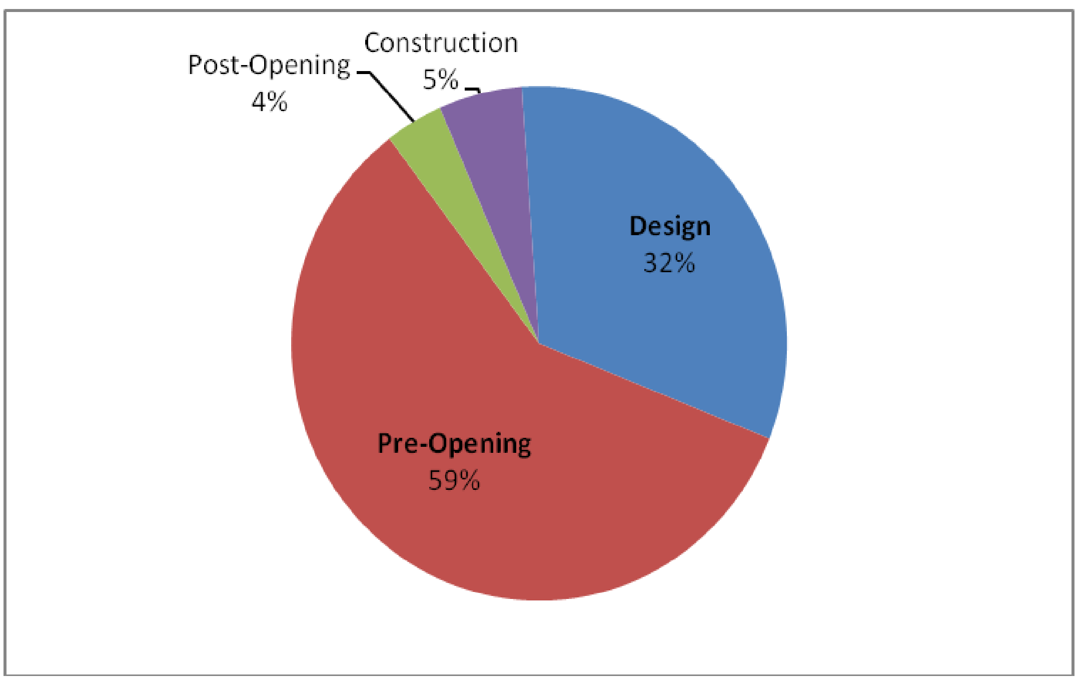

Figure 1: Audit Findings by Stage

The data presented herewith is a composite of all pre-opening audits undertaken for the highway projects listed in Table 2. The projects provide a mix of rural arterial freeways and suburban ring roads valued at nearly $2 billion.

Table 2: P3 Projects Included in Analysis of Pre-Opening Audit Findings

Project	Province	Completion	Description	Value
Fredericton-Moncton Trans-Canada Highway	NB	2001	193km 4-lane rural arterial	$600 million
Woodstock-Grand Falls Trans-Canada Highway	NB	2007	98km 4-lane rural arterial	$500 million
Anthony Henday Drive	AB	2007	11km 4-lane ring road	$500 million
Anthony Henday Drive (Stony Plain Rd/100 Ave)	AB	2011	Systems Interchange	$170 million

All of the pre-opening audits findings summarized below are a composite of the four major projects noted above. The findings include those noted during “preliminary” pre-opening audits as well as during the more traditional stage just prior to opening. It should also be noted that two of the above projects were delivered under a staged completion scheme so individual pre-opening audits were often done at different times for specific stages.

The data in Table 3 provide a synthesis of the types of pre-opening audit issues that were raised for the four projects under study. It is noted that a total of 572 safety-related issues were identified in the audit reports produced for these four projects. The majority of pre-opening audit issues are related to signing problems, while grading, pavement markings, and guiderail deficiencies are the next most frequent concerns noted in rank order. Figure 2 depicts these data to illustrate each category’s relative weight at this audit stage.

The *Other* category in Figure 2 is a catchall that includes items such as fencing, curbing, bridge joints, rumble strips, lighting, drainage structures and others.

Table 3: Pre-Opening Audit Issues

Category of Issue	Frequency of Observations
Signs	299
Grading	108
Rumble Strip	3
Pavement Markings	46
Guiderail	54
Pavement Surface	16
Lighting	4
Barrier	12
Drainage Structure	9
Fencing	4
Curb	2
Bridge Joints	3
Miscellaneous	12
Total	**572**

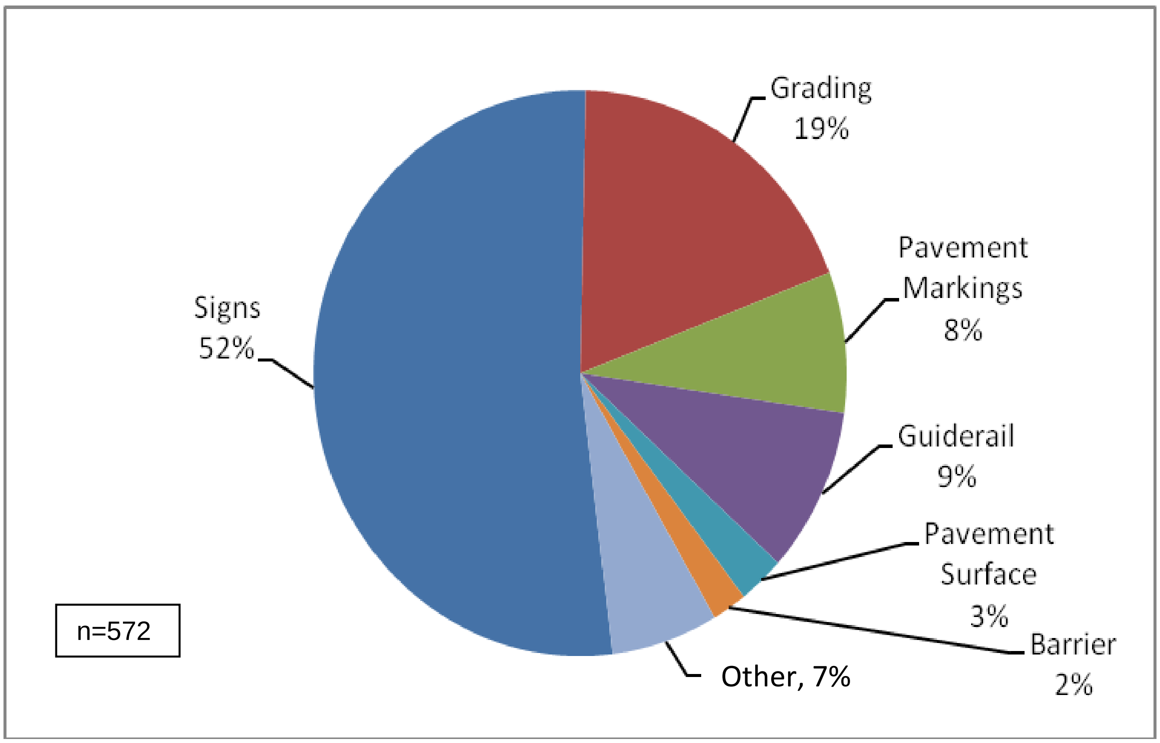

Figure 2: Pre-Opening Audit Issues

The distributions of audit issues by category were compared across all four of the highway projects. Interestingly, despite the differences in the nature and location of the projects, the distributions are relatively consistent from project to project.

4.1 Signing Issues

Signing is by far the most common category of audit issues at the pre-opening stage. This likely reflects the low priority that designers and contractors place on this aspect of the project. A recurring theme among large P3 road projects is that the task of developing signing plans is often relegated to the less experienced personnel. The impact of poor signing plans is often exacerbated by inexperience when *field-fitting* signs to locate them in the most effective position. The inclusion of an engineer experienced with traffic signing in the development of plans and field placement would alleviate many of the problems that typically arise during pre-opening reviews.

It was previously noted that 299 signing-related issues were identified during the pre-opening stage among the four projects being reviewed. A breakout of the specific types of signing issues is depicted by the data in Figure 3. The *Add Sign* category represents instances where a sign was recommended by the audit team to be installed to supplement the inventory already in the field. The additional sign may have been an oversight by the designers or an additional sign recommended by the audit team on the basis that it would enhance the level of safety afforded motorists at a particular location. For example, a request by the audit team to double-post[1] a Stop sign would fall under this category. This category represented nearly half of all sign issues.

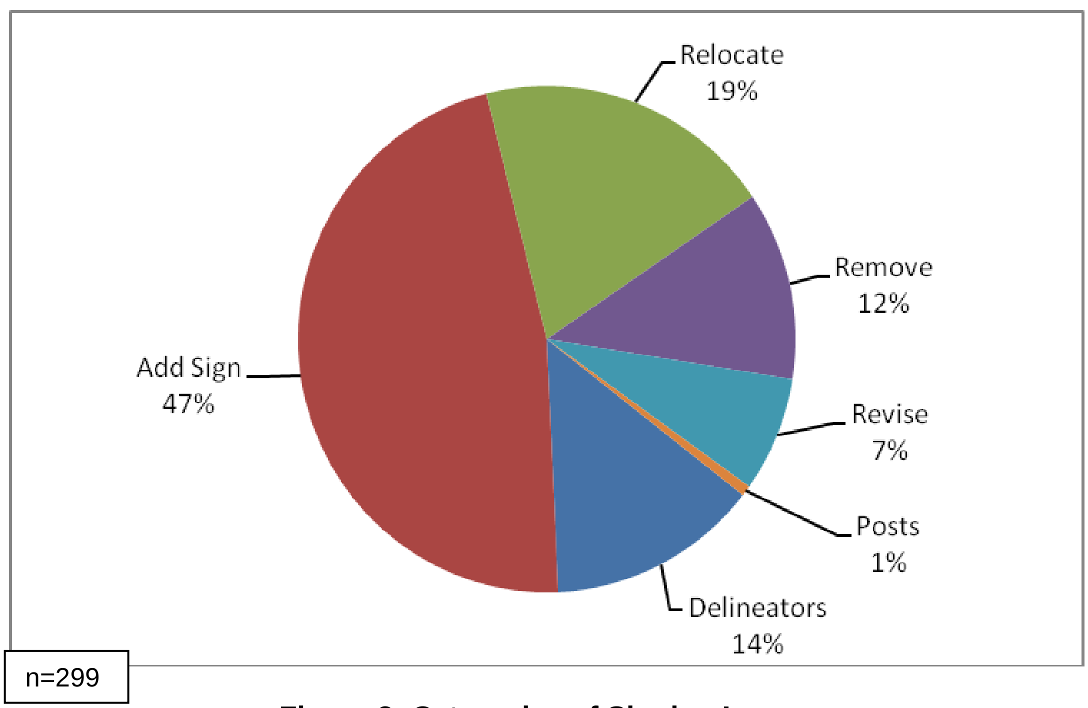

Figure 3: Categories of Signing Issues

[1] Double posting is the term used to describe posting a duplicate sign on the left-side of the road directly opposite the sign on the right-side of the road.

The signing category *Relocate* is the next most frequent issue raised and is a direct reflection of the inexperience often associated with field-fitting traffic signs to accommodate peculiarities found in the field that could not be anticipated during design. Typical issues raised under this category were to move signs longitudinally along the roadway in order to provide proper spacing between successive signs, or to locate the sign a proper distance in advance of the associated hazard. Another common issue was the lateral placement of signs – either too close to the travel lanes or too far out on the shoulder (Figure 4). Finally, signs were sometimes installed at locations where sightlines were obscured and drivers are not afforded sufficient preview time (Figure 5).

Figure 4: Example of a sign with too much lateral offset

Figure 5: Example of poor field-fitting of signs (obscured Lane Ends sign)

Interestingly, 12% of signing issues called for the removal of signs. Good signing practice avoids over-signing any location to optimize safety. There were a total of 58 instances where the audit team called for the removal of a traffic sign because either it was not warranted, was an incorrect application, or resulted in visual clutter (Figure 6).

Figure 6: Too many signs resulting in visual clutter

The signing category listed as *Revise*, incorporates all of those instances where the sign that was placed in the field was either incorrect or misleading and needed to be modified or replaced with a different sign. Figure 7 shows an Object Marker installed with the wrong orientation on the guiderail end terminal.

Figure 7: Improper orientation of Object Marker on a guiderail end terminal

The category *Delineator* refers to instances where the audit team felt that a segment of the road project would benefit from the installation of delineators to provide better positive guidance to the driver. Most instances involved a horizontal curve where the alignment change may not be readily apparent to the driver under reduced visibility conditions. Recommended treatments included post-mounted delineators, delineator tabs installed on guiderail or bridge rails, chevron alignment signs, or linear delineation systems for the vertical face of barriers.

Figure 8: Delineation treatment along shoulder and on concrete barrier

Issues related to signing posts typically related to over-sized wooden sign posts that needed to have holes drilled near their base in order make them more forgiving in the event that they are struck by an errant driver.

4.2 Grading Issues

Although *Grading* is only 18% of all findings at the pre-opening stage, this is considered to be an underestimate of the prevalence of this deficiency. This is because often a single grading comment in a pre-opening audit report relates to grading deficiencies that are present throughout a lengthy road section. In fact, inadequate and inappropriate grading may be the most common deficiency identified during pre-opening audits for major road projects. Frequent types of grading issues identified included:

- foreslopes or backslopes that were not sufficiently smooth and traversable to permit an errant vehicle to safely recover.
- foreslopes or backslopes that did not conform to design standards (Figure 9).
- presence of ditch blocks that had not been removed prior to opening.
- foreslopes that had not been properly compacted.
- grading and mounding of materials around bridge piers or light standards on the median.
- Insufficient grading of material around concrete footings for poles with frangible bases (Figure 10).

Figure 9: Improper grading resulting in non-recoverable foreslope

Figure 10: Over exposure of concrete footings

4.3 Pavement Markings Issues

Normally the application of pavement markings is a straight-forward exercise for new road projects not subject to modification outside of standard practices. Nevertheless, deficiencies related to pavement markings represented 8% of pre-opening audit findings. Most often, this category was cited as a result of work that was not complete at the time of inspection. Pavement marking tends to be one of the last items completed, and as a result is often incomplete at the time of the pre-opening audit. There were, however, numerous occasions where the audit team called for hatch-marking in gore areas to provide positive guidance for motorists (Figure 11). Another common problem found was the incorrect use of standard width lines for continuity lines.

Figure 11: Paved taper requiring hatch-marking

4.4 Guiderail Issues

The design details for guiderail installations are typically determined during the detailed design stage. Although the audit process is often engaged at this stage, many issues still tend to arise at the pre-opening stage. In fact, as noted in Figure 2, 9% of all pre-opening audit issues are related to guiderail installations. Typical kinds of problems raised include:

- the need for new guiderails due to severe hazards *just beyond* clearzone,
- incorrect lap orientation (i.e., the steel beam was lapped in the opposite direction to adjacent traffic),
- improper mounting height,
- insufficient length of need,
- improper installation of guiderail end treatment,
- small gaps between adjacent guiderail that should have been closed

Figure 12 provides an example of an energy-absorbing guiderail terminal (EAGRT) installation where the installed flare rate of 10:1 exceeded manufacturer specifications of a maximum of 25:1. Consequently, the extrusion process would not likely function properly in the event of an impact.

Figure 12: EAGRT installed with excessive flare

5. Discussion and Recommendations

This paper has provided a synthesis of lessons learned following the undertaking of several pre-opening audits for large scale P3 projects. Perhaps the most significant experience has been the requirement to engage in *preliminary* pre-opening audits in advance of final completion of work by the contractor. This has been found to be crucial in order that the contractor is afforded sufficient time to address any issues without causing a delay of project delivery.

Problems related to signing and pavement markings combined to account for 60% of all issues typically raised at the pre-opening stage. Most of these problems could have been avoided if the designers and contractors engage a traffic engineer experienced with the design/installation of traffic control devices.

Grading issues account for nearly 20% of pre-opening issues, but is likely understated as one mention of grading may be applicable to lengthy sections of road. Correcting these issues can be time-consuming, so grading is an area that contractors should pay careful attention to in order to avoid any opening delays.

Finally, it is clear from the volume of safety-related issues raised at the pre-opening stage that the RSA process is contributing to the delivery of road facilities that afford motorists with improved levels of safety.

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