CHALLENGES OF EFFECTIVE MANAGEMENT OF PAVEMENTS FOR HIGHWAY CONCESSIONS

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ABSTRACT

The number of highway concession contracts in North America is increasing rapidly with many agencies turning to the public/private/partnership model to develop and build much needed highway infrastructure. As agencies build on the PPP model, they transfer more risk to the private sector including the risks associated with the operation, maintenance and rehabilitation of the asset network. For most concessions, the pavements constitute a large percentage of the cost to maintain. To ensure public safety and acceptable levels of service, agencies specify key performance indicators and maintenance trigger values, as well as financial penalties to ensure compliance. The transfer of risk, especially cost-associated risk, permits more effective budget planning for the agency.

The challenge for the agency is to establish key performance indicator limits to maximize public benefits while minimizing PPP costs. The challenge to the concessionaire and pavement management practitioner within the PPP context is to accurately judge and predict key pavement performance indicators and maintenance/ rehabilitation actions to facilitate compliance with project specifications while minimizing the cost to complete the work an interruption to the travelling public. In addition, it is the goal of the agency to maximize the value of the assets when they are eventually turned back to the public trust.

This paper examines conflicts between the binding requirements for maintenance activities and the overall objective of effectively managing the pavement infrastructure.

INTRODUCTION

P3 projects are unique because of the detailed and binding concession agreements outlining minimum testing and performance requirements for the infrastructure assets. Each concessionaire requires a very detailed and customized solution. The requirements of concession requirements for pavements across North America vary significantly, but typically include requirements for distress ratings, smoothness, and rutting with some including other performance measures such as surface friction and structural capacity.

Numerous localized repairs may keep the concessionaire in compliance with the project specifications but a more robust overall repair of a larger area may be more desirable and longer lasting but there is no requirement for the concessionaire to do so. The concession agreement effectively forces the concessionaire to a worst first, reactionary process rather than adopting a preventive maintenance approach. Case studies from concession projects across North America are used to illustrate these issues and an alternative approach is suggested for consideration.

CONVENTIONAL PAVEMENT MANAGEMENT

Conventional pavement management systems make use of information known about the construction and condition of the pavement to develop performance models and decision matrices to assist in determining the current and future maintenance and rehabilitation needs for specific sections of pavement. The needs are prioritized in conjunction with available budgets to implement a sustainable plan to meet the needs of industry and the travelling public.

The level of complexity of traditional pavement management systems typically varies with the size of the network and available resources with State/Provincial level authorities having well designed condition evaluation procedures and robust prediction models, intervention criteria and methods. While some agencies incorporate maintenance needs in the planning needs, most separate major capital (reconstruction/rehabilitation) and maintenance activities. Maintenance actions such as crack sealing, localized patching, etc. are considered activities to maintain safety and "hold" the condition of the pavement and are not considered activities positively impact the condition rating of the pavement.

PAVEMENT MANAGEMENT FOR CONCESSION AGREEMENTS

While the purpose and needs for pavement management systems for concessions are generally similar to those used for conventionally managed infrastructure, there are difference in how information is used to manage concession projects. For very long-term concessions, of about 40 to 50 years or more, the concession agreements can be more "open" to permit the concessionaire to act more like a conventional department of transportation. The concession period is such that the infrastructure will go through at least two or more major rehabilitation cycles. The concessionaire evaluates and maintains the infrastructure by meeting overall condition goals and is free to optimize the timing and type of any intervention. For shorter term concessions of about 20 to 25 years, the concessionaire is more focused on maintenance activities to meet individual condition requirements and to defer any major rehabilitation activities as long as possible to meet the end of term requirements.

In general, many of the components of concession agreements in use across Canada are similar. For example, each specifies the minimum standard and performance of key assets. Specific concession requirements of each agency reflect the needs of the local agency, the needs of the geographical environment, and the needs of the highway users. Also with the limited experience of most agencies with these types of projects, the requirements are being developed based on the experience of previous projects and other agencies. The overall trend

is that the level of sophistication of the requirements is increasing as time passes with all parties beginning to understand both the risks and rewards.

Assets to be Evaluated

The assets to be evaluated in PPP projects are defined in the concession agreements. Most agreements include all of the major elements within the right of way including:

- Pavements (main lanes, shoulders, sideroads, pullouts)
- Structures (bridges, tunnels, retaining walls)
- Electrical systems (lighting, cameras, digital signs)
- Right of Way (landscaping, fencing, noise walls)
- Safety Appurtenances (barrier walls, pavement markings, attenuators, signs)
- Drainage

The specific maintenance and rehabilitation treatments for each asset are not specified. The concessionaire is free to select the method of treatment as long as the result meets the requirements of the asset preservation performance measure. The remainder of this paper concentrates on the management of pavement running surfaces.

Pavement Performance Criteria

The majority of PPP concession agreements include some measureable condition indicators for the pavements. These typically include pavement surface condition as measured by some form of distress manifestation or index, smoothness which is usually measured in accordance with the International Roughness Index (IRI) and wheelpath rutting. Some agreements may also include pavement surface friction. For the majority of PPP agreements in North America, the Concessionaire is required to measure the condition of the asset and take action when the condition state exceeds the maximum permitted according to the concession agreement. Examples of simple, moderate and complex asset preservation performance measures (APPMs) from several PPP projects in North America are shown in Table 1.

TABLE 1 Examples of Asset Preservation Performance Measures

APPM	Intervention Criteria	Action	Response Time	Basis of Measure
Simple				
Roughness	Where the distortion reaches a severity level of "severe"	Rehabilitation	"immediately"	Determined based on visual observation
Distress	Where the pavement condition index is less than 60 Where the severity of an individual distress reaches "severe"	The concessionaire shall establish a schedule for immediate rehabilitation	"immediately"	Condition index measured in accordance with the owners established procedures
Moderate Complexity				
Roughness	For 80 % of all sections measured, IRI, throughout 98 % of each section is less than or equal to 1.5 m/km IRI measured throughout 98 % of sections is less than or equal to 1.9 m/km	Permanent repair	Within 6 months	Measured in accordance with the owner's procedures for inertial profilers (to allow for measurement bias, an adjustment of 0.15 m/km (10 in/mile) is made for concrete pavements before assessing compliance
Distress	Pavement condition score for 80 % of sections exceeding 90 for main lanes and ramps	Permanent repair	Within 6 months	Measurements are completed using procedures, techniques and equipment consistent with owner's PMS manual

APPM	Intervention Criteria	Action	Response Time	Basis of Measure
Complex				
Roughness	Where roughness exceeds an IRI value of 2.5 m/km Where roughness over any traffic lane exceeds the cumulative distribution curve for IRI (Figure 1)	Undertake physical works to address non-compliance	12 months	IRI collected for each wheel-path per specifications and averaged
Distress	Where pavement surface deterioration over any traffic lane exceeds the cumulative distribution limits curve for pavement distress index (Figure 2)	Undertake physical works to address non-compliance	12 months	Ratings performed in accordance with the owner's procedures with PDI calculated according to the owner's pavement distress index model

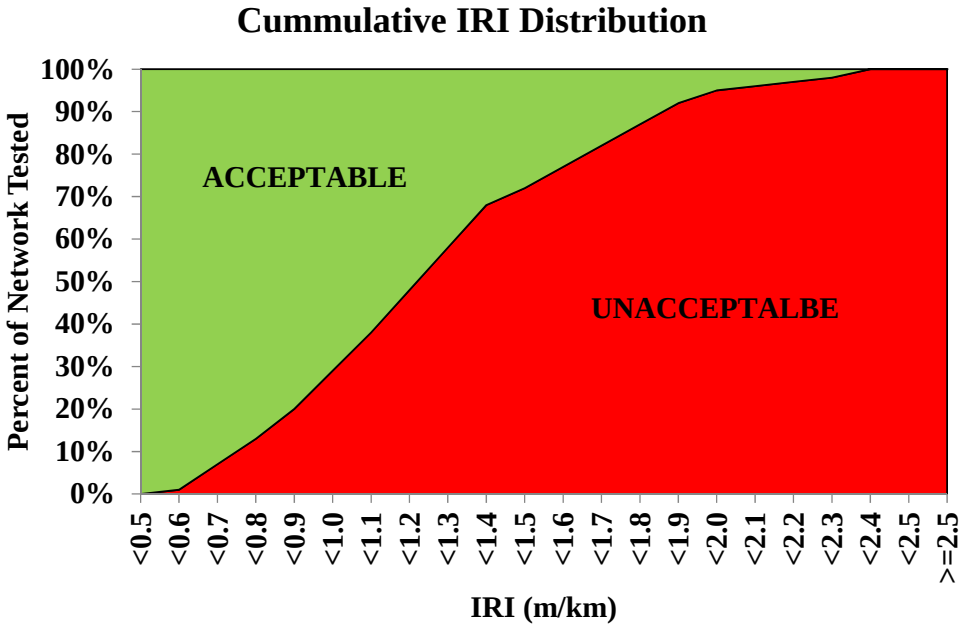

FIGURE 1 APPM Cumulative distribution curve for roughness.

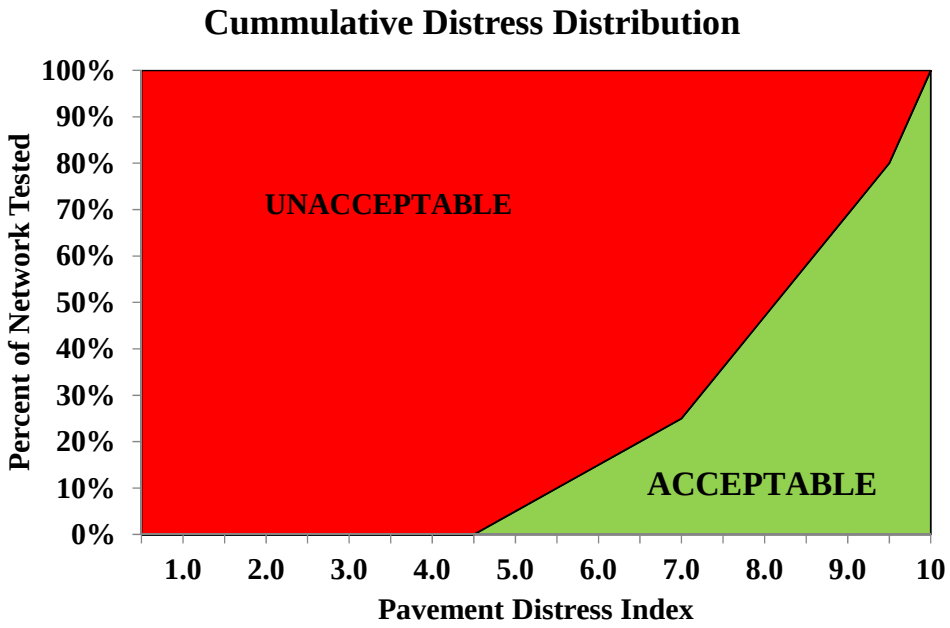

FIGURE 2 APPM Cumulative distribution curve for pavement surface distress.

COMPLEXITY OF APPM REQUIREMENTS

For the "simple" APPM requirement shown in Table 1, the concessionaire is required to manage the pavement to ensure that it has an overall condition index of more than 60 with no individual distress having a rating greater than severe [1]. The size of the section is not dictated in the concession agreement. In this particular case, the roadway under management is for the most part in an urban area and the management sections are about 2 km (1.2 miles) in length between interchanges in each direction. Localized slab replacement for exposed concrete and patch repairs for flexible pavements are the primary treatments for distresses of higher severity. This allows the concessionaire to use conventional pavement performance modelling techniques to effectively predict future pavement condition and plan rehabilitation activities long in advance.

For the "moderate" APPM requirement, the concessionaire manages the overall highway network such that the pavement surface meets the distress and smoothness condition [2]. The length of the managed sections is established in about 0.8 km (0.5 mile) lengths. The concessionaire is permitted to have a number of sections in a variety of distress and

smoothness condition with an overall lower limit for which the majority of sections (98 percent) are permitted. This type of APPM requirement permits middle term performance models to be developed for the network and permits the concessionaire some latitude in their method for maintaining the quality of the roadway surface in accordance with the concession agreement.

The "complex" APPM requirement outlined in Table 1 is the most restrictive on the actions of the concessionaire. In this method, limits on the maximum permitted level of roughness require action to improve the exceedance within a year of measurement [3]. The length of the management sections is 50 m by individual lane. The concessionaire is required to maintain the total of the individual roadway sections such that the percentage of condition of the individual management sections meets the cumulative distribution requirements for distress and roughness as shown in Figures 1 and 2.

MANAGEMENT OF PAVEMENT SMOOTHNESS

This section outlines the difficulties in using traditional pavement management tools for new concessions for which much of the pavement infrastructure is renewed prior to the turnover of the roadway surfaces to the operation and maintenance team. Due to the relatively young age of the majority of the highway running surfaces for most new PPP projects, the APPMs govern the short-term timing of localized maintenance or rehabilitation treatments.

As a part of the annual pavement condition evaluations, the pavement condition is evaluated to determine if action is required. If action is required for any areas, project level evaluation will begin to determine the most suitable treatment and the extent that it will be applied.

The type of intervention required will be evaluated based on which APPM has been triggered and the severity of the problem. Localized and isolated issues will often be addressed using preventative maintenance techniques and holding strategies whenever possible. Larger area issues will be scheduled for a more cost-effective and long-lasting rehabilitation option.

For concessions with mainly new or rehabilitated pavements, it is very difficult to develop performance models. With conventional PMS systems for a mature network, there are many sections of pavement that have differing ages, different construction and different historical maintenance and rehabilitation treatments. For new networks, with a limited number of pavement sections and only a few construction types, developing a performance model can be very difficult, if not impossible.

An evaluation of the historical trend of the currently most critical APPM (IRI) was completed for a concession that has been under management for 4 years. The analysis was completed to determine if it would be possible to predict the rate of deterioration of IRI to assist in

developing intervention criteria prior to reaching IRI non-conformance. An example of the IRI measurements for the years 2010 to 2013 is shown for Northbound Lane 1 in Figure 3.

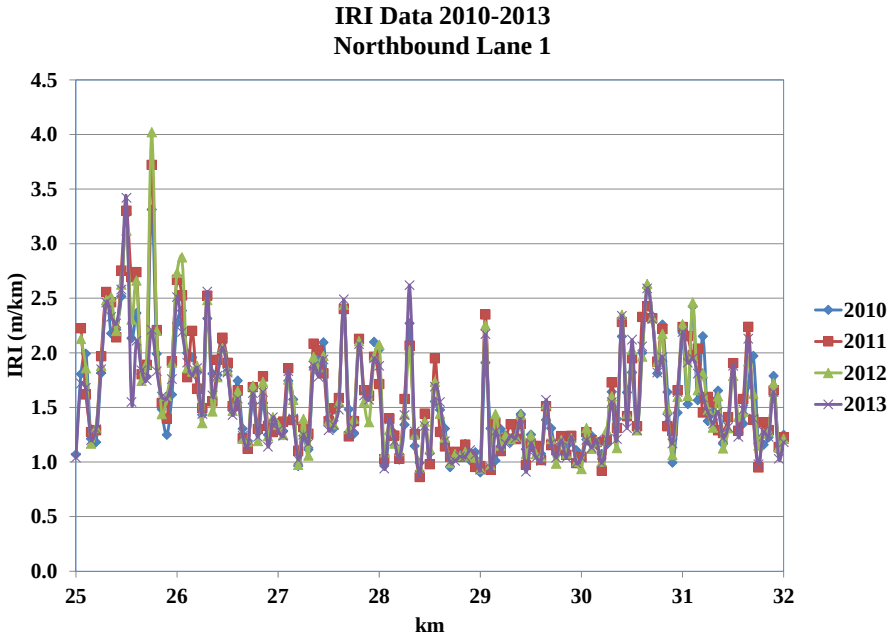

FIGURE 3 Representative historical comparison of IRI.

The repeatability of the IRI measurements for 50 m sections of roadway is very good when compared on a year to year basis. While the measured IRI shows some increase from year to year in some of the 50 m sections, the change in IRI from year to year is not consistent or predictable. In fact, the majority of the IRI values in each section have not changed significantly during the 4 measurement years. Over the past 5 years since the highway construction was substantially complete, approximately 30,000 mainline highway sample units (50 m in length) have been inspected for IRI. The overall age versus IRI for the highway sections is shown in Figure 4. The data in the figure includes almost 30,000 points with many simply being plotted on top of each other.

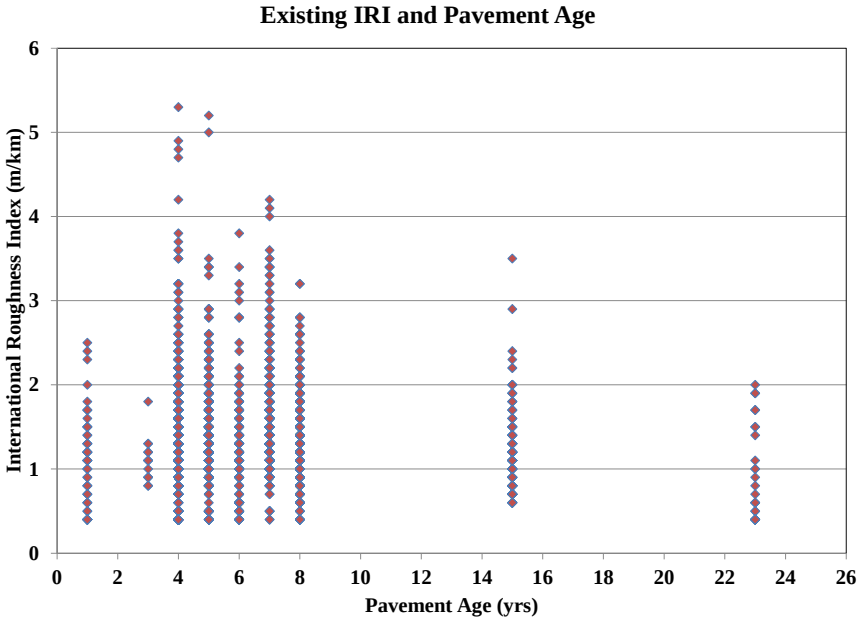

FIGURE 4 IRI versus Pavement Age.

Developing a performance model based on the data shown in Figure 4 is problematic. There are no trends in the data and the vast majority of the IRI measurements are toward the left side of the graph and overly represent new pavements. Further, as the IRI measurement reporting length is only 50m, localized bumps or depressions, at bridge deck expansion joints, for example, result in a high average IRI for the section. An attempt at developing an IRI performance model was completed using the data from selected years as shown in Figure 5.

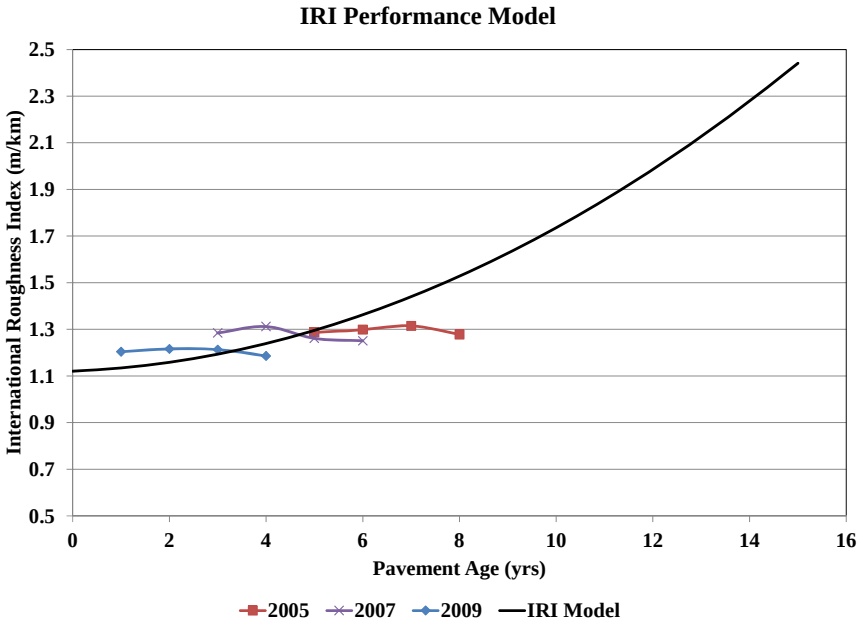

FIGURE 5 Highway Mainline Pavement IRI Performance Model.

The model starts at 1.2 m/km, at year zero which is the level of IRI which a contractor will receive full payment (no bonus or penalty) for smoothness. This is a reasonable assumption considering that paving to correct smoothness issues could be limited to 50 m or in fact if the bump or dip causing the high IRI is very localized, only the subsection within the 50 m measurement unit that is causing the high IRI. It should also be noted that for initial construction smoothness, the measurement sample length is 100 m not the 50 m required for concession management.

The treatment of localized areas of high IRI, while meeting the concession agreement for one APPM, does little to "manage" IRI for the required distribution of IRI shown in Figure 1. This particular concession agreement requires that 50 percent of the measured sections have an IRI of less than 1.2 m/km and in fact that 10 percent of the total have an IRI of less than 0.8 m/km.

RECOMMENDED ALTERNATIVE MANAGEMENT STRATEGY FOR IRI

Managing the highway pavements based on IRI to meet the cumulative distribution curve would require that many of the pavement sections with relatively good IRI values would have to be resurfaced fairly frequently to achieve the high smoothness requirements at the low end of the distribution curve. This means that sections meeting the IRI specifications for an individual measurement unit would have to be improved each year to ensure that the overall distribution is met. The analysis for this particular concession would have 50 m sections with IRI values in the good range requiring improvement to the excellent range to meet the

distribution requirements. Therefore, a new method for the IRI monitoring and action limits has been proposed.

The management of an entire highway based on 50 m sections is problematic and does not allow for simple long-term planning of rehabilitation treatments. The IRI data was analyzed in 500 m sections to develop action limits for the prediction of potential need for rehabilitation action beyond the simple, "if IRI is greater than 2.5 mm/m, action is required within 1 year". The performance model was then used to establish the monitoring and action limits outlined in Table 2.

Table 2. IRI Monitoring and Action Limits

From IRI (mm/m)	To IRI (mm/m)	Action
0	1.5	No Action Necessary
1.5	2.25	Review density of sample units in this range within 500 m. If less than 20 percent, program for localized maintenance. If greater than 20 percent, program for micro-surfacing or mill and pave within 3 to 5 years
2.25	2.5	Review density of sample units in this range within 500 m. If greater than 40 percent, consider for micro-surfacing or mill and pave in current program (0 to 2 years)
2.5	>2.5	Program for localized repair as soon as possible

The monitoring and action limits outlined in Table 2 were applied to all 50 m sections within each 500 m long section in each lane along the highway beginning with the IRI measured in 2013. Once a 500 m section was identified for action, it was programmed for maintenance or rehabilitation according to the action outlined in Table 2. At the year of action, the IRI of all of the 50 m sections within the 500 m maintenance and rehabilitation unit was reset to 1.2 m/km which is the project level smoothness requirement for full payment for construction projects for this agency. For the remainder of the sections, the current year IRI was used to predict the following year IRI based on the correlation equation shown in Figure 5. The process was then repeated for the next year through the last year of the concession. Figure 6 shows the cumulative IRI distribution predicted at the end of the concession contract.

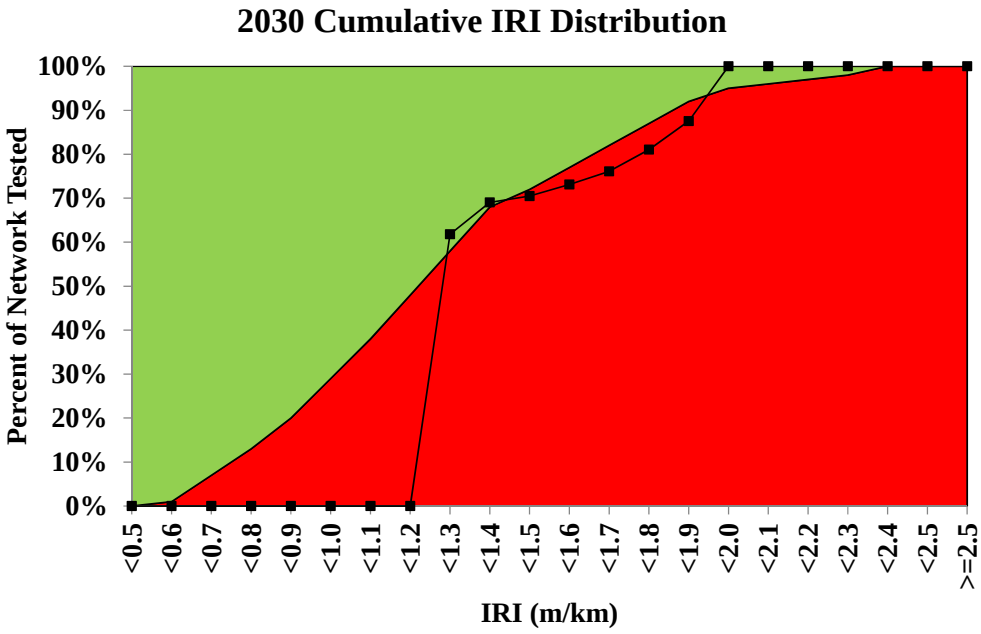

FIGURE 6. Cumulative distribution of IRI at the end of the concession agreement.

While the distribution of IRI shown in Figure 6 does not satisfy the originally required distribution, it provides for a much more reasonable pavement management section. The analysis assumes that the contactor will only be able to achieve a post treatment smoothness of 1.2 m/km IRI. If a higher level of smoothness is achieved, the cumulative distribution curve would further improve.

CONCLUSIONS

The pavement maintenance and rehabilitation plan is an important component of the P3 project and is used to assess the funding requirements to meet the APPM requirements of the concession agreement. However, there are new and significant challenges associated with applying traditional pavement management practices on concession projects. Although the background theory and test procedures used are consistent with historic practices, the level of precision may be too high to effectively management the long-term performance of the pavement.

Frequent and collaborative communication can assist in managing the expectations of the owner as well as the concessionaire. The majority of the asset management data collection for public/private/partnership projects is completed by subcontracted subject matter experts. The subject matter expert frequently has worked with the owners on similar projects but in the case of a PPP project, has no direct relationship with the owner. It is strongly recommended that a

meeting be held including the owner, concessionaire and subject matter expert prior to the commencement of any asset management data collection work to ensure that everyone fully understands their role in the project. This would ensure that the work can be completed as efficiently as possible and that the concessionaire owner obtains the information necessary for the management of the concession.

REFERENCES

1. *Schedule 20 – Safety and Standards Protocols*, Ontario Ministry of Transportation, 1998.

2. *Technical Provisions for Toll Lane Projects – Performance and Measurement Table Baseline*, Texas Department of Transportation, April 2014.

3. *Highway Asset Performance Measures for Highway Concessions*, British Columbia Ministry of Transportation, 2004.