# The importance of quality control in the data processing of automated pavement condition surveys in municipal networks


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ABSTRACT

Automated pavement condition surveys have progressed in the past few years. Mainly developed for superior road network needs, such as highway pavements, they are now very often used in the context of surveys and analysis for municipal network pavements. At this level, quality control of the data is of primary importance to obtain accurate and repeatable results that will allow trend detection and fill the needs of municipal pavement managers.

Profiler surveys for road roughness measurement and 3D imaging technologies for cracking and rutting measurements need a focus adapted to municipal networks. Special cases relating to this domain will be presented (acceleration and deceleration areas of survey vehicles, interlocking paving stones on pedestrian crosswalks, railway crossings, surface defects related to snow-removal equipment, speedbumps, unpaved and work zones). In the absence of adequate quality control of the data, each of these special cases introduces inaccurate global indicators for each segment, such as IRI (ASTM E950) and PCI (ASTM D6433).

This paper pinpoints the impact of these special cases in the computed values of the indices. In some cases, IRI and PCI values differing up to an order of magnitude of 100 % have been noted between datasets before quality control and after quality control.

From these findings, a few approaches to supervise quality control are introduced for the data treatment phase. These approaches are complimentary to equipment specifications prescribed by municipalities

RÉSUMÉ

Les relevés automatisés d'état des chaussées ont beaucoup progressé dans les dernières années. Souvent développés pour des besoins de gestion du niveau routier supérieur, comme par exemple les chaussées autoroutières, ils sont maintenant très souvent utilisés dans le contexte de relevés et d'analyses de chaussées municipales. À ce niveau, le contrôle-qualité des résultats devient très important afin de produire des données précises, répétables et permettant de déceler des tendances pour répondre aux besoins des gestionnaires municipaux.

Les relevés de profilométrie pour fin de mesure du confort au roulement et à technologies d'images laser 3D pour fin de détermination de la fissuration et de l'orniérage doivent donc faire l'objet d'un encadrement adapté au milieu municipal. Des études de cas particuliers relatifs à ce milieu seront présentées (zones d'accélération et décélération des camions multifonction, traverses piétonnes en interblocs, traverses de chemin de fer, défauts de surface associés à l'utilisation d'équipements de déneigement, dos d'âne, présence de gravier et travaux sur la chaussée). En l'absence d'un contrôle-qualité adéquat, chacun de ces cas introduit des inexactitudes dans le calcul des indicateurs globaux de segments de chaussées que sont l'IRI (ASTM E950) et le PCI (ASTM D6433).

Cet article met en lumière l'impact de ces cas particuliers municipaux sur les résultats des indicateurs. Dans certains cas, des valeurs d'IRI et de PCI différant jusqu'à un ordre de grandeur de 100 % ont été observées entre les jeux de données avant contrôle-qualité et après contrôle-qualité.

À partir de ces constatations, certaines approches d'encadrement du contrôle-qualité sont présentées en phase de traitement des données. Celles-ci sont complémentaires aux lignes directrices instaurées par les municipalités pour s'assurer de la qualité des équipements utilisés.

## 1.0 Introduction

Pavement surveys in municipal networks have improved significantly in the last decades with the arrival of new devices, such as 3D imaging technologies, that now allow to measure at a high degree of precision and at posted speeds the characteristics of the pavement surface, such as cracking and rutting. Combined with high-speed profilers and more accurate GPS data, these devices are now commonly prescribed by municipalities as part of their Requests for Proposals across Canada.

Since these devices are very efficient in terms of accuracy, sampling rate and defect determination, they are often assumed to be a guarantee of quality, which is often true in terms of performance. However, the need for quality control (QC) of the results is very important when it comes to the use of the data for pavement management purposes.

Indeed, 3D imaging technology libraries cannot take every particular case into account when hundreds and often thousands of kilometres are surveyed in a city where a wide range of specificities are encountered.

In order to pinpoint the QC needs and the impact of the QC procedures on the results, this paper present different case studies collected from the authors experience in municipal networks. It intends to show, by many examples, the difference between data produced with QC and data produced without QC. At the end, the objective is to show that QC helps improve the quality of the data and, finally, the decisions taken at the network level in the municipalities.

## 2.0 Basics

### 2.1 Surveys

Typical pavement surveys are conducted with multi-function vehicles. These kind of vehicles combine different equipment allowing the survey of multiple pavement characteristics as well as an accurate positioning on the road network.

They are designed to perform surveys with limited passages, usually only one, in order to quickly measure data. The survey efficiency is important at network level where hundreds and often thousands of kilometres need to be surveyed.

Figure 1 shows a typical multi-function vehicle used for pavement surveys at municipal level.

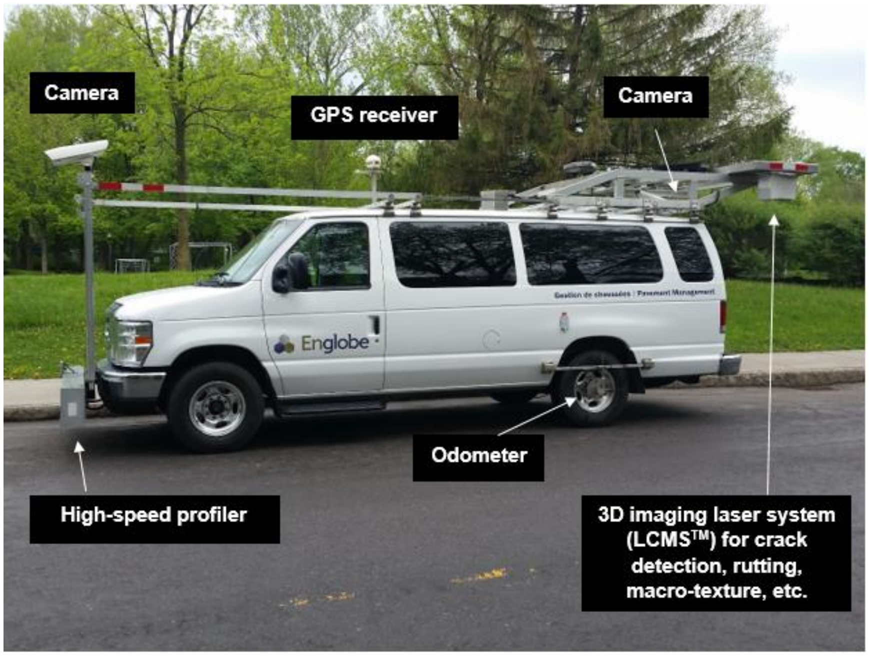



*Figure 1: A typical multi-function vehicle*

This vehicle is equipped with a front mounted high-speed profiler to measure ride comfort. A precision GPS and a precision odometer are also included in the multi-function equipment in order to adequately position the surveys. A front mounted right-of-way camera and two back mounted 3D imaging laser sensors (LCMS$^{TM}$) are also included. These sensors allow crack detection, rut and macro-texture measurement.

### 2.2 Technical specifications

Requests for Proposals (RFP) for pavement surveys in municipal networks across Canada usually include technical specifications related to the equipment. The following are usually prescribed.

| Equipment | Technical specifications often prescribed in RFPs |
|---|---|
| GPS | X, Y position accuracy (m) |
| Odometer | Distance accuracy (%) |
| Cameras | Orientation (angle and items pictured), Resolution (pixels) |
| High-Speed profiler | ASTM E950 for profiler surveys and ASTM E1926 for IRI computation (Class 1 profilers are commonly prescribed) |
| 3D Imaging laser technology | Width surveyed (m), sampling rate (mm), crack detection (mm). ASTM D6433 for PCI calculations (commonly used in Canada), ASTM E1703 for rutting computation |

*Table 1: Usually prescribed technical specifications found in RFPs.*

Technical specifications for equipment are often complemented by test sections on the field. Usually controlled by the municipalities or their mandatory using manual devices and/or visual surveys, this process requires the vendor to comply with specified bias and repeatability criteria for limited sections during its mandate. Any failure will require adjustments and resurvey of the test sections until the criteria are satisfied. All data collected before non-compliant test sections shall be discarded.

## 2.3 Need for higher-degree quality-control procedures

Technical specs, standards compliance and test sections process are required and very useful in the context of pavement surveys in municipal networks. They comfort municipalities with the equipment accuracy and repeatability and with the fact that state-of-the-art and well-accepted methods are used to collect and compute data.

However, some concerns remain with the data even if the equipment, standards and surveys are done perfectly in compliance with these aspects. These concerns are related to the intrinsic particularities of municipal networks: for example, typical speeds and accelerations, urban assets, urban maintenance, obstacles and presence of dirty surfaces just to name a few. These conditions exist extensively in municipal road networks and need particular quality control procedures to discard bad data contamination. This cannot be done only with technical specs and test sections.

The following sections will address some particular aspects of municipal pavements related to ride comfort and cracking data in the form of case studies.

## 3.0 Case study for Ride Comfort

In Canada, the International Roughness Index (IRI) is often used as an indicator of the ride comfort in municipal networks. The IRI (in m/km) is an incremental index that cumulates the displacements of a quarter-car model rolling on a pseudo-profile, which is measured by an inertial profiler. By definition, this quarter-car model simulates the movements of a damped mass at a 80 km/h speed.

In municipal networks in general and local streets in particular, this speed is impossible to attain during the vast majority of surveys. First, it exceeds the speed limits and, second, the surveys done at this speed would not be secure for the citizens and other road users. That’s the reason why it is more appropriate to consider the IRI as an index correlated to the ride comfort in urban networks, more than a direct index measuring the road roughness as it is at a superior level, such on highways.

Since the IRI in municipal networks are calculated from the pseudo-profiles measured by an inertial profiler, the values obtained are influenced by what influences the equipment. For example, it is well-known *(Karamihas et al. (1998), Karamihas et al. (1999))* that very low speed and high acceleration / deceleration are two aspects that introduce important discrepancies in the pseudo-profile measurements and, ultimately, errors in the computed IRI.

Very low speeds prevent the accelerometers from working properly since the lack of energy transmitted to the devices make them lazy. On the contrary, important accelerations and decelerations, such at the beginning of a survey pass, at a stop, after an intersection or at the end of a section influence the accelerometers a lot, which, at the outset, do not measure adequately the movement of the vehicle on the vertical axis and then introduce important errors on the measured pseudo-profiles. This leads to errors in the IRI computed at the end.

With a good quality control, these phenomena can be minimized as it is shown in figure 2.

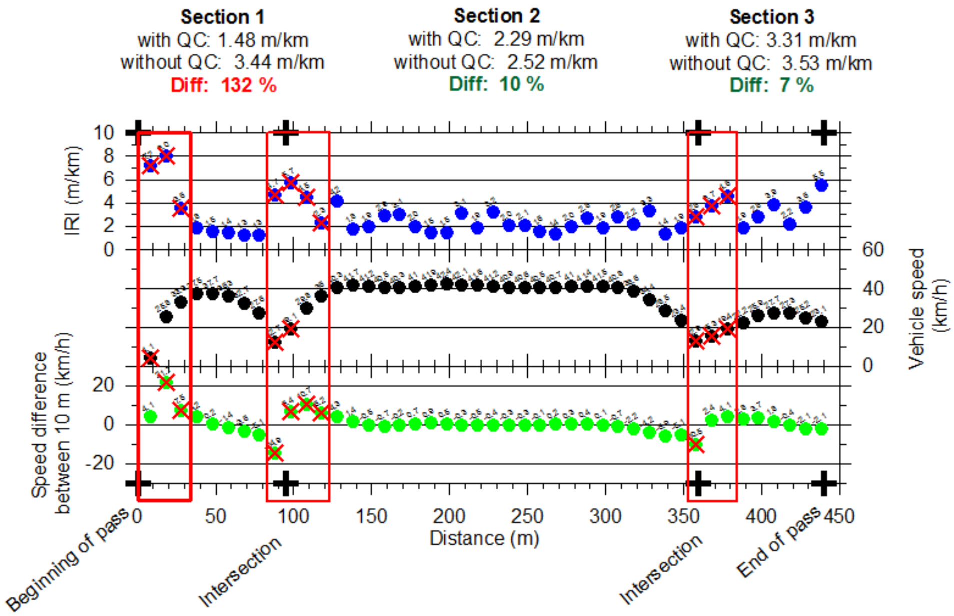



*Figure 2: A 440 m multi-function pass including three consecutive road sections*

The IRI has the particularity that it can be averaged from smaller intervals to calculate the representative value of a longer road section. Before snapping the data to the right road sections in order to get a representative value, it is usually calculated at a 10 metres interval for each pass of the multi-function.

The first chart of Figure 2 shows, in blue, the calculated 10 metres IRI for a 440 m multi-function pass regrouping three consecutive road sections.

Charts two and three of the figure show, for each 10 metres, the speed values of the profiler survey (black) and the speed difference (increment is positive and decrement is negative) between each 10 m (green). This latter chart can be considered as representative of the acceleration and deceleration affecting the profiler device.

As one can see, speeds below 20 km/h and speed differences below 6 km/h in absolute values were flagged in the charts. These values occur mainly at the beginning and the end of the road sections, where the survey vehicle needs to accelerate and decelerate, such as intersections, beginning of passes and end of passes.

As part of QC, these locations were flagged in red rectangles and the corresponding 10 metres IRI were discarded from the average calculated for the road sections assuming that their values were contaminated with improper accelerometer behaviors.

The impact of the QC for the three road sections can be found in table 2 below.

| Road section | Length (m) | With QC | | Without QC | | Difference |
|---|---|---|---|---|---|---|
| | | Nb of 10 m IRI | Average IRI (m/km) | Nb of 10 m IRI | Average IRI (m/km) | |
| 1 | 95 | 5 | 1.48 | 9 | 3.44 | 132 % |
| 2 | 264 | 23 | 2.29 | 27 | 2.52 | 10 % |
| 3 | 81 | 6 | 3.31 | 8 | 3.53 | 7 % |

*Table 2: Impact of the QC on the calculated average IRI of the road sections*

Table 2 shows clearly that QC related to ride comfort measurements made an important difference between the computed average IRI, particularly for road section number one.

In fact, a difference of 132 % between the QC value and the non-QC value was computed. The differences for sections two and three were much smaller at 10 % and 7 % respectively.

A combination of low IRI and small length section is responsible for the big difference in section one as the QC operations took off higher 10 metres IRI and lowered significantly the sample size to calculate the average value. The vehicle was starting from zero speed and the driver had to take a decent speed quickly, which led to important acceleration and, finally, important deceleration at the approach of the intersection. Nonetheless, the value of 132 % is significant and shows the importance of QC in the data processing of the IRI.

**4.0 Case studies for 3D imaging technologies analyses**

Like ride comfort, the automated pavement data collection by 3D imaging technologies can benefit from an extensive quality control in a municipal environment.

3D imaging technologies usually include manufacturer's libraries that perform automatic analysis from their sensors outputs using some state-of-the-art and long-time developed algorithms. These libraries are often updated with new versions in order to be more accurate or to include new capabilities. The results are quite impressive in general.

However, municipal pavements present several distinct events likely to generate false defects by the manufacturer's libraries and thus influence the Pavement Condition Index (PCI) calculated for a given road section.

It is therefore useful to review and check the automatic analyses performed by the manufacturer's libraries in order to identify and remove 10 metres sections including events that may influence the accuracy of the results.

This section intends to show a few case studies where these events affect the results, starting with a few basics.

**4.1 The PCI mechanic**

The Pavement Condition Index (PCI) is a standardized index that is representative of the surface condition of a pavement. It is impacted by the severity and extent of many defects such as the different types of cracks, rut depth as well as other surface defects (bleeding, weathering, raveling,…) and deformations (depression, bumps and sags, corrugation,…), just to name a few. The PCI ranges from 0 to 100, 0 being the worst possible condition and 100 being the best possible condition of the pavement surface.

As per ASTM 6433, the PCI calculation has to be done on samples of approximately 225 ± 90 square metres. Assuming a 4.0 metre width for a survey with 3D imaging systems, the samples are then to be approximately 60 metres long in average.

In municipal networks, road sections are usually longer than 60 metres. When this occurs, the resulting PCI is an average of the consecutive sample PCI.

Table 3 shows an example for a 180 metres section including three samples.

| Sample | Length (m) | Sample PCI | Average PCI for the 180 metres section |
|---|---|---|---|
| 1 | 60 | 68 | 67 |
| 2 | 60 | 75 | |
| 3 | 60 | 58 | (68+75+58) / 3 |

*Table 3: A PCI calculation for a section using the average sample PCI*

**4.2 Sensitivity tests**

In order to show the impact of municipal events that need to be extracted with QC, the basic sample length of 60 metres has been used in the following PCI sensitivity tests.

In each case, a 10 metres section including a particular municipal event was added to typical 50 metres sections to compare the average PCI of the 60 metres resulting sample.

The 60 metres sample including the particular event is called the ‘’ Without QC ‘’ sample and the 50 metres former sample is called the ‘’ With QC ‘’ sample.

This methodology is based on the assumption that each of the particular cases could have been found on each of the road sections. In fact, it could very well be.

All PCI were calculated with PAVER 6.5.7, following ASTM D6433 with all the defects measured by a 3D imaging technology library output, namely cracking and rutting.

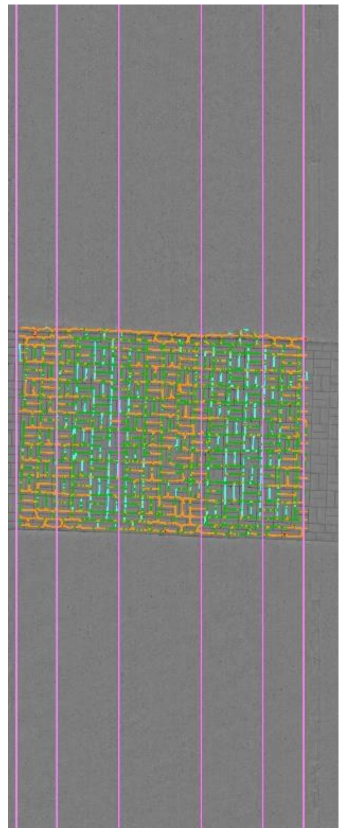
Three typical samples were used. These samples have rather good PCI of 98, 75 and 81 respectively. All the simulations are done with a comparison to these values.

### 4.2.1 Brick pedestrian crosswalks (interlocking paving stones)

Interlocking paving stones pedestrian crosswalks are often interpreted by the automated crack measurement system libraries as low and medium severity alligator cracking, which has a significant impact on the PCI.

This 10 metres section was added to the three typical samples. As mentioned in the previous section, the QC here consists in removing the 10 metres with the event before processing. The impact is significant, as the difference between PCI with and without QC ranges between 23% and 51% for a sample.

*(3)*



*(4)*

*Figures 3 and 4: Video image and analyzed image of an interlocking paving stones crosswalk*

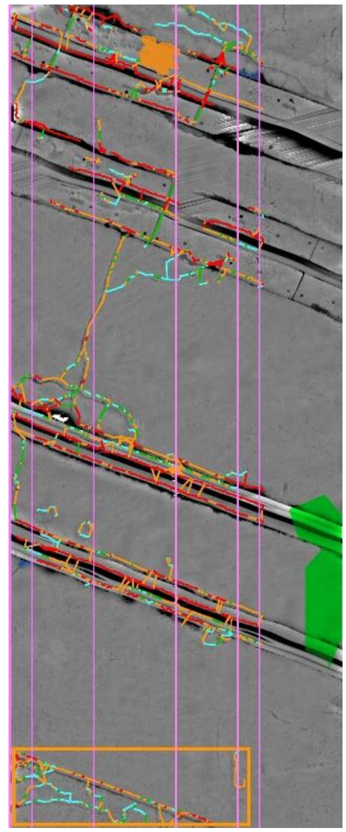
| Sample | Length (m) | PCI | | Difference |
|---|---|---|---|---|
| | | With QC (without the event) | Without QC (with the event) | |
| 1 | 60 | 98 | 65 | 51 % |
| 2 | 60 | 75 | 61 | 23 % |
| 3 | 60 | 81 | 61 | 33 % |

*Table 4: Impact of the QC on the calculated PCI for a sample with interlocking paving stones*

### 4.2.2 Railroad crossings

Railroad crossings generate a lot of defects such as cracking, rutting and potholes. This 10 metres section was added to the three typical samples. Here, the PCI changed by more than 60%, and up to 88 % for a new pavement with a PCI of 98.

*(5)*



*(6)*

*Figures 5 and 6: Video image and analyzed image of railroad crossing*

| Sample | Length (m) | PCI | | Difference |
|---|---|---|---|---|
| | | With QC (without the event) | Without QC (with the event) | |
| 1 | 60 | 98 | 52 | 88 % |
| 2 | 60 | 75 | 45 | 68 % |
| 3 | 60 | 81 | 47 | 73 % |

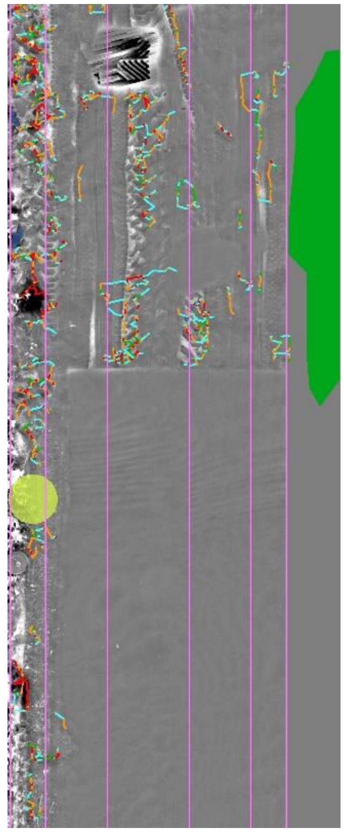
*Table 5: Impact of the QC on the calculated PCI for a sample with a railroad crossing*

### 4.2.3 Work zones

Work zones on pavements will also generate defects. In addition, the survey vehicle must deviate from its trajectory, which can cause inadequate rutting measurements that affects significantly the PCI.

This 10 metres section was added to the three typical samples. Potholes, cracks and rutting encountered in the work zone section lowered the PCI by 29 to 46 points depending on the samples.

*(7)*



*(8)*

*Figures 7 and 8: Video image and analyzed image of work zones*

| Sample | Length (m) | PCI | | Difference |
|---|---|---|---|---|
| | | With QC (without the event) | Without QC (with the event) | |
| 1 | 60 | 98 | 52 | 88 % |
| 2 | 60 | 75 | 46 | 63 % |
| 3 | 60 | 81 | 49 | 66 % |

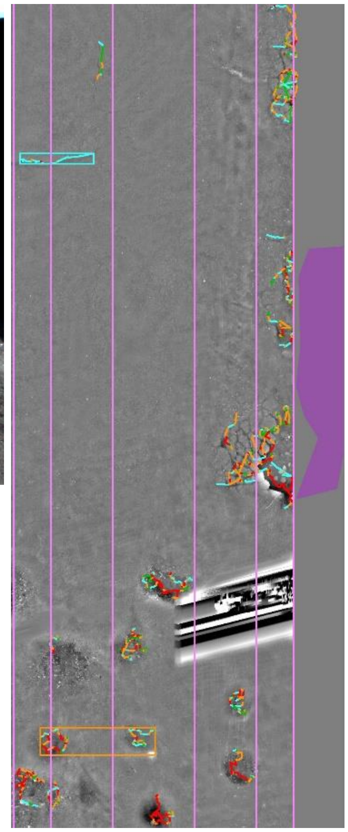
*Table 6: Impact of the QC on the calculated PCI for a sample with work zones on the road*

### 4.2.4 Gravel sections

QC also allows the identification of any unpaved sections that may affect the PCI. For example, dead ends often have gravel surface at their end. Therefore, it may bring defects that are not representative of the road section if kept in the samples.

This 10 metres section was added to the three typical samples. High severity cracks and medium severity rutting were identified in this section and affected the PCI.

*(9)*



*(10)*

*Figures 9 and 10: Video image and analyzed image of graveled surface*

| Sample | Length (m) | PCI | | Difference |
|---|---|---|---|---|
| | | With QC (without the event) | Without QC (with the event) | |
| 1 | 60 | 98 | 64 | 52 % |
| 2 | 60 | 75 | 56 | 34 % |
| 3 | 60 | 81 | 59 | 38 % |

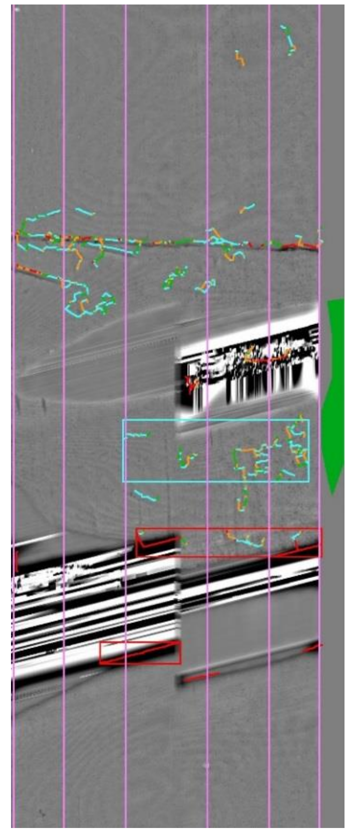
*Table 7: Impact of the QC on the calculated PCI for a sample with graveled surface*

#### 4.2.5 Speedbumps

In addition to the need for extraction in the IRI values under QC, a speedbump can also generate false defects that can be caused either by the speedbump itself or distorted focus of the 3D imaging equipment, which can produce false cracking detection. The identification of this event and its removal from the sample is then required in the QC process.

This 10 metres section was added to the three typical samples. Low and high severity transverse cracks were inadequately identified in this section and affected the PCI.

*(11)*



*(12)*

*Figures 11 and 12: Video image and analyzed image of a speedbump*

| Sample | Length (m) | PCI | | Difference |
|---|---|---|---|---|
| | | With QC (without the event) | Without QC (with the event) | |
| 1 | 60 | 98 | 82 | 19 % |
| 2 | 60 | 75 | 71 | 6 % |
| 3 | 60 | 81 | 75 | 8 % |

*Table 8: Impact of the QC on the calculated PCI for a sample with a speedbump*

### 4.3 Distress removal

QC can also be performed on an entire road sample simply by removing incorrect distresses. Cracks on a manhole or caused by a joint beside a flat concrete curb can easily be removed manually so that a PCI can be calculated without the defects.

An example of a distress removal is shown in 4.3.1.

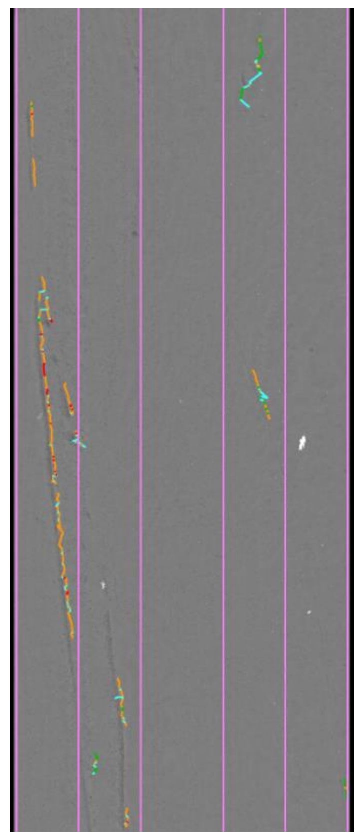
#### 4.3.1 Machinery marks on new pavement

In winter, the passage of snow removal vehicles can produce marks on the pavement. It can significantly affect the PCI, particularly on a new pavement, as the 3D imaging libraries can interpret those marks as medium or even high severity cracks.

For example, the PCI without QC of this 60 metres road sample is 83. With QC of the entire sample, it goes up to 96, which is more representative of the pavement condition.

In this example, the QC consisted in removing the false cracking for the entire sample before data processing.

*(13)*



*(14)*

*Figures 13 and 14: Video image and analyzed image of surface defects related to snow removal vehicles*

## 5.0 Conclusion

New technologies in pavement surveys allow fast and efficient pavement data collection. However, their use in municipal road networks must be complemented by adequate procedures of quality control of the data collected and processed.

Indeed, municipal pavements present multiple specific events that influence the IRI and PCI calculated. The use of incorrect indices values caused by lack of QC could ultimately lead to bad current-state evaluation, poor prioritization of road sections to rehabilitate, bad determination of the interventions to be carried out and improper evaluation of costs at the network level.

In this paper, it has been shown by the analysis of several case studies, that QC procedures of the processed data could have an impact ranging anywhere between 6 % and 132 % on the indices calculated. These values are obviously sensitive to the methodology. However, the magnitude of these differences between ''With QC'' and ''Without QC'' prompts to the following recommendations:

1. All IRI data should be subject to minimal QC of discarding small-interval (10 metres) values obtained with slow speeds and/or important acceleration and deceleration. This should be done before any averaging of the values for an entire segment.

2. 3D imaging systems data should be subject to QC at the post-processing stage looking for particular situations where the libraries are subject to incorrect analyses due to events. The incorrect analyses due to events should then be removed piece by piece. This QC can be done either:

    a. Systematically by viewing each analyzed image in search for specific events such as those mentioned in this paper;

    b. On a sampling basis introducing some statistical approach in order to get a confidence interval on the data quality.

    c. With the aid of survey data with some special events highlights on site.

These QC procedures, coupled with technical specs, standards compliance and test sections process will ensure better data to municipal organization, which will ultimately lead to better decision making at the network level.

## 6.0 References

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