Characteristics of Utility Cuts and Their Impacts on Pavement Serviceability in the City of Saskatoon

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ABSTRACT

It is with increasing frequency that agencies are faced with the impact utility cut installations have on their roadway networks. Excessive utility cuts in pavements are known to cause premature deterioration, pavement weakening, excessive road roughness for the pavement structures, and decrease of pavement asset values. In 2018 the City of Saskatoon (the City) with the assistance of Tetra Tech Canada Inc. (Tetra Tech) completed a study to demonstrate the difference in pavement performance resulting from the presence of utility cuts between 2014 and 2017 on the City's roadway network.

First, roadway condition data (International Roughness Index (IRI) and Pavement Condition Index (PCI)) were assessed for sections with and without utility cuts installed between 2014 and 2017. The features and patterns in the change of IRI and PCI are explored for each City roadway class. Significant differences in reported IRI and PCI were found between pavement with and without utility cuts. Second, the characteristics of utility cuts including the size of the cuts, pavement age, and the IRI and PCI when the cuts were conducted were analyzed. The resultant costs relative to the loss in service life over the pavement life-cycle were determined. Based on pre-utility cut condition instead of pavement age, the pavement performance impacts and potential loss of service resulting from utility cuts were assessed. Finally, linear regression models of IRI and PCI were determined for each roadway class with and without utility cuts. IRI and PCI deterioration curves were developed to evaluate the expenses for utility cuts, loss of service life, pavement rehabilitation cost. Asset value impact matrix were proposed for each roadway class.

It is found that the impacts of utility cuts can be quantified, and an associated reduction in roadway asset value and pavement serviceability can be calculated. The information in this study may ultimately be used by the City to assist in determining the costs associated with the utility cuts on their roadway pavement network, and in quantifying the impact of utility cuts on pavement serviceability and the typical loss in pavement asset value.

1. INTRODUCTION

Studies [1,2,3] have found that utility cuts and maintenance work represent a continual challenge to urban municipalities. The construction of utility is often proven a challenging exercise. The backfilling of pavement granular materials in confined areas makes achieving the appropriate levels of compaction difficult. Compaction challenges are further worsened with the potential variability in backfill materials, compacted at different times, with different levels of effort. The result is a pavement cross section that reacts differently to the traffic and environmental loading. These operations put significant pressure on the existing roadway infrastructure by reducing ride quality and serviceability. They can also lead to lane closures which have significant impacts to roadway users.

To mitigate the negative impacts of utility cuts, various policies and technologies have been developed. By introducing Manual for Controlling and Reducing the Frequency of Pavement Utility Cuts [4], the Federal Highway Administration has been helping the state and utility managers to control and to reduce the frequency of pavement utility cuts, and to make information available to agencies, utility companies, and other organizations about such policies and technologies. The Canadian national guide to sustainable municipal infrastructure [5] has provided procedures to minimize the impact of utility cuts on lessening the life of pavement infrastructure. While these guidelines and manuals exist, agencies continue to observe poor pavement performance for roadways where utility cuts exist.

2. BACKGROUND

The City of Saskatoon (the City) owns and operates more than 1,400 centreline kilometres of roads. The City has recognized that utility cuts can lead to significant deterioration of the City's pavements. The installation, replacement and maintenance of these utility cuts can result in both a rough pavement and a reduction in the service life of a pavement. There were 4406 utility cuts completed between 2014 and 2017 [6] on the City's road network and the impact on the service life of the road network could be significant. Although the City has attempted to administer a standard for the reinstatement of these utility cuts, they have recognized that in practice, there are inconsistencies in how these utility cuts are constructed. These inconsistencies result from a wide range of City departments, private contractors, and developers completing these utility cuts for a wide range of purposes: emergency repairs, property utility connections, etc.

In 2018, the City with Tetra Tech Canada Inc. (Tetra Tech) completed a study into the potential impact utility cuts have on the City's roadway infrastructure. The primary objective of this impact analysis was to determine if the amount of pavement degradation and loss of pavement serviceably could be quantified using the City's pavement utility cut database combined with the City's 2014 and 2017 roadway network condition databases. This paper provides a summary of this study.

3. PREMISE FOR THIS STUDY

Historically, the City has recognized that utility cuts can lead to significant deterioration of the City's pavements. The installation of utility cuts can result in both a rough pavement and a reduction in the service life of a pavement. The City is in a fortunate position to complete this type of impact analysis through its accurate record keeping of utility cut installations, tracking of pavement maintenance and rehabilitation activities, and relatively frequent assessment of their roadway network condition.

Loss of service life can be quantified in several ways. The City recognized early in this assessment that loss of service, and how the loss in service is quantified in terms of loss of asset value, is important in establishing an "impact cost" as a result of a single utility cut installation. For example, the installation of a utility cut in a pavement in excellent condition has a greater impact on loss of services, and loss of asset value than one installed in a pavement in poor condition. Also, the impact of the utility cut is different for different roadway classifications. For example, a rough utility cut installed on a smooth arterial roadway with a posted speed limit of 60 km/hr has a greater impact on the loss of service than the same cut on a rough local road with a posted speed limit of 30 km/hr.

Therefore, it was fundamental to this study that the impact of utility cuts included the investigation of two performance measures: pavement distress (PCI) and roadway smoothness (IRI). In addition, it was equally fundamental that the impact utility cut installation has on these two performance measures is assessed on the City's three primary roadway classes independently: local roads, collector roads, and arterial roads.

Therefore, this study specifically focused on answering the following questions:

- Is there a difference in PCI and IRI condition for roadway segments where utility cuts are installed compared to roadway segments without utility cuts?
- If a difference in condition is observed and can be quantified, is the magnitude of the change influenced by the pre-utility cut condition of the roadway (utility cuts in good condition pavements vs. poor condition pavements)?
- Can these changes in performance be quantified in terms of an equivalent loss in service life, and if so, a loss in pavement asset value?
- Can this loss in pavement asset value be used to determine a utility cut installation impact cost?

Through detailed technical analysis and ongoing consultation with key City personnel, tables summarizing the resultant costs relative to the loss in service life over the pavement life-cycle were determined for three City roadway classes: local roads, collector roads, and arterial roads. The information in these tables may ultimately be used by the City to assist in determining the costs associated with the construction utility cuts on their overall roadway pavement network.

4. PRACTICES FOR UTILITY CUTS IN THE CITY OF SASKATOON

City had previously developed Specification Section 14001 "Surface Infrastructure Restoration for Utility Cuts" [7] providing specifications for utility cut construction. General comments pertaining to this specification include:

- In general, shallow buried utilities are categorized by: 1) Size, 2) Summer/Winter Construction, 3) Local vs. Collector of "Greater" Roadways, and 4) Paved vs. non-paved roadway surfaces.
- Shallow depth and narrow width cuts typically required backfilling with some type of low-strength concrete fill and surfaced with hot mixed asphalt.
- Shallow depth and wide width cuts typically required backfilling with some type of control density non-shrink fill and surfaced with hot mixed asphalt or backfilled with gravel and surfaced with hot mixed asphalt.
- Only emergency repairs less than 300 mm in width are allowed on Collector of "Greater" Roadways during winter months.
- There is an allowance for cuts during winter months on Local roads. In most cases, the cuts are filled with gravel and left (and maintained) until spring for surfacing.
- There is an allowance for cuts greater than 300 mm in width during winter months on Collector or "Greater" Roadways. In most cases, the cuts are filled with low-strength concrete, surfaced with cold mix, and left (and maintained) until spring for surfacing.
- The specification provides a provision for utility cuts on unfinished paved roadways.

- All cuts completed by an external corporation are subject to a two-year warranty.
- All deep buried utility cuts are to be backfilled with granular material and surfaced with hot mixed asphalt.
- Standard details are provided for each utility cut type.

The City has maintained an accurate record of most roadway utility cut installations for many years. A database including details pertaining to each induvial utility cut, including location, date of installation, contractor, and utility cut size is maintained and updated regularly. This database is linked to the City's Geographic Information System (GIS) allowing for the geographic location referencing of each individual utility cut. In total, 2410 utility cuts recorded between 2014 and 2017 located on 1252 unique roadway segments. The general characteristics of these 2410 utility cuts include:

- The mean utility cut area accounted for 1.07% of the roadway segment area;
- The median utility cut area accounted for 0.64% of the roadway segment area; and
- The 75th percentile utility cut area accounted for 1.39% of the roadway segment area.

A summary from the City's utility cut database for utility cuts completed between 2014 and 2017 is shown in Figure 1.

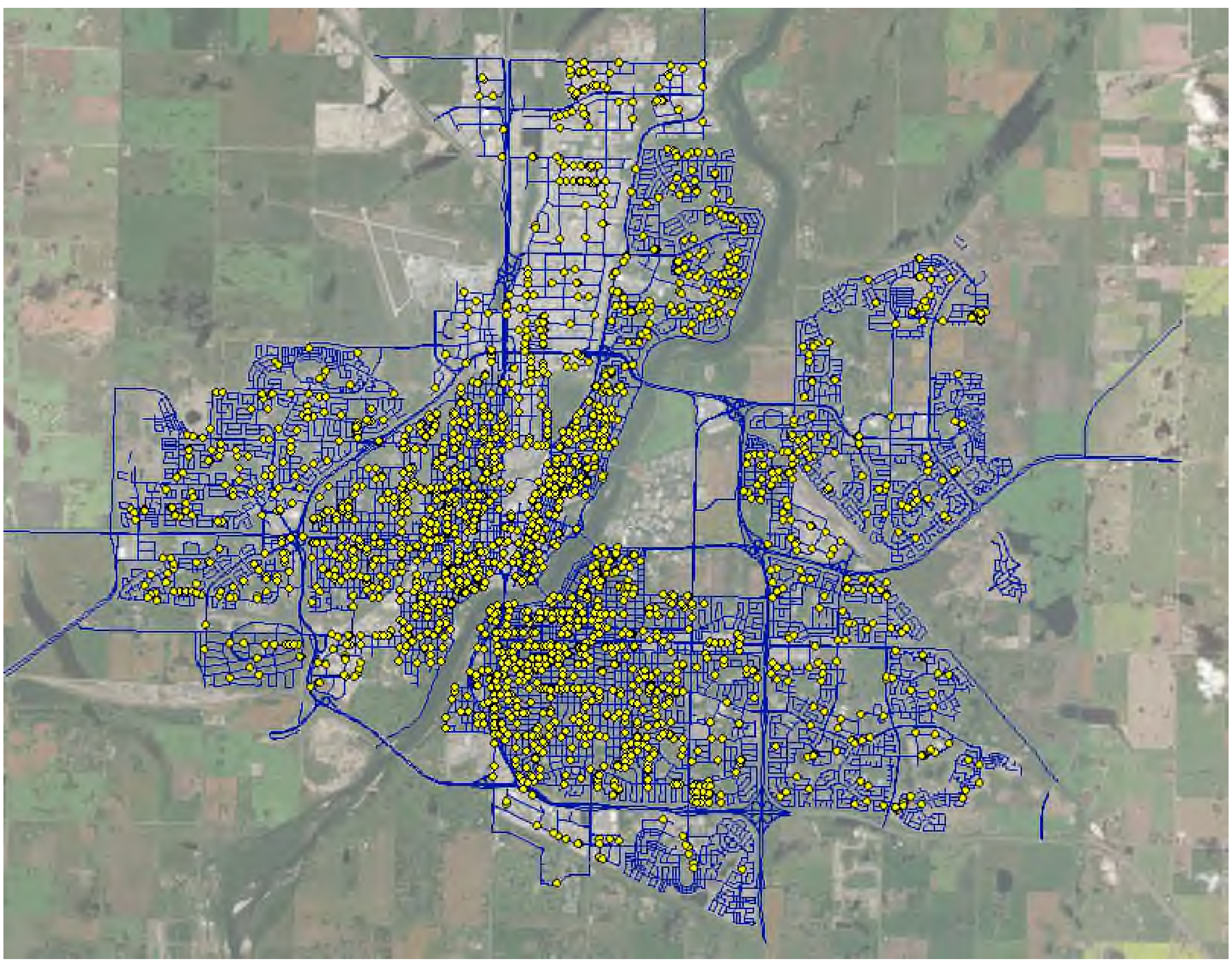

Figure 1. Summary of 2015 and 2016 Utility Cuts – each yellow point is one utility cut.

5. STATE OF INDUSTRY PRACTICES FOR UTILITY CUTS

The reduction in service life of pavements due to utility cuts is inevitable. Recent studies carried out by The City of Calgary [1] and the City of Toronto [2] determined a pavement degradation fee based on the reduction in service life of the pavements due to the installation of utility cuts. A pavement degradation fee is based on the resultant loss in pavement life and the additional maintenance and/or rehabilitation costs due to the construction of utility cuts. Other cities including the City of Vancouver and City of Langley have also implemented pavement degradation fees of their own. Those studies evaluated the impacts separately for arterial, collector, and local roads. A summary of pavement degradation fees is provided in Table 1.

Table 1: The Implemented Pavement Degradation Fees in Various Municipalities

<table>
<tr><th rowspan="2">Road Class</th><th rowspan="2">Age at Time of Utility Cut (year)</th><th colspan="4">Pavement Degradation Fees ($/m²)</th></tr>
<tr><th>City of Vancouver</th><th>City of Calgary</th><th>City of Langley</th><th>City of Toronto</th></tr>
<tr><td rowspan="8">Arterial Road</td><td>0-5</td><td>55.60</td><td>57.00</td><td rowspan="24">10.00</td><td rowspan="3">40.00</td></tr>
<tr><td>5-10</td><td>44.48</td><td>52.00</td></tr>
<tr><td>10-15</td><td>33.37</td><td rowspan="2">47.00</td></tr>
<tr><td>15-20</td><td>22.25</td><td rowspan="2">32.00</td></tr>
<tr><td>20-30</td><td rowspan="4">11.12</td><td>38.00</td></tr>
<tr><td>30-45</td><td rowspan="3">29.00</td><td>24.00</td></tr>
<tr><td>45-55</td><td>18.00</td></tr>
<tr><td>55-70</td><td>11.00</td></tr>
<tr><td rowspan="8">Collector Road</td><td>0-5</td><td>55.60</td><td>51.00</td><td rowspan="3">34.00</td></tr>
<tr><td>5-10</td><td>44.48</td><td>47.00</td></tr>
<tr><td>10-15</td><td>33.37</td><td rowspan="2">42.00</td></tr>
<tr><td>15-20</td><td>22.25</td><td rowspan="2">27.00</td></tr>
<tr><td>20-30</td><td rowspan="4">11.12</td><td>34.00</td></tr>
<tr><td>30-45</td><td rowspan="3">26.00</td><td>20.00</td></tr>
<tr><td>45-55</td><td>14.00</td></tr>
<tr><td>55-70</td><td>9.00</td></tr>
<tr><td rowspan="8">Local Road</td><td>0-5</td><td>55.60</td><td>46.00</td><td rowspan="3">34.00</td></tr>
<tr><td>5-10</td><td>44.48</td><td>42.00</td></tr>
<tr><td>10-15</td><td>33.37</td><td rowspan="2">38.00</td></tr>
<tr><td>15-20</td><td>22.25</td><td rowspan="2">27.00</td></tr>
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<tr><td>30-45</td><td rowspan="3">23.00</td><td>20.00</td></tr>
<tr><td>45-55</td><td>14.00</td></tr>
<tr><td>55-70</td><td>9.00</td></tr>
</table>

As shown in Table 1, three of the four municipalities provide a utility cut fee schedule for three roadway classifications: arterial roads, collector roads, and local roads, with two of these three municipalities using a “sliding scale” fee schedule based on pavement age, where younger roadways carry a higher fee than older roads. (The City of Vancouver fee schedule is the same for all three road classes.)

All four municipalities administer the fee schedule based on dollars per square metre ($/m²), where square metres represent the size of the utility cut, however the $/m² cost varies widely from municipality to municipality and by road class and pavement age. None of the municipalities investigated apply a utility cut degradation fee based on pre-cut pavement condition.

6. PAVEMENT CONDITION DATA ANALYSIS AND DISCUSSION

A summary of the City's roadway pavement condition data was compiled based on its existing linear roadway segment GIS shapefile and the up-to-date pavement management polygons that are defined with a unique ID for each polygon (Roadway ID). Tetra Tech performed a network condition assessment of pavement surface distress with Tetra Tech's Pavement Surface Profiler (PSP) platform in both 2014 and 2017 [8], which provided the source of the roadway condition data.

The 2014 and 2017 roadway datasets were filtered to refine the roadway segments database based on the following criteria:

- Removed roadway segments that had undergone some form of treatment between 2014 and 2017, as identified in a roadway treatment geodatabase provided by the City.
- Removed roadway segments where roadway condition data was not collected in 2014 and/or 2017.
- Filtered out roadway segments where the 2014 to 2017 PCI increased, indicating that the roadway condition improved between 2014 and 2017.
- Filtered out roadway segments where the 2014 to 2017 IRI decreased, indicating that the roadway got smoother between 2014 and 2017.
- Filtered the roadway network into two datasets: roadway segments with and without utility cuts completed in 2015 and 2016.

Table 2 and Table 3 shows the number of selected roadway segments by road classification that were considered for the analysis.

Table 2: Roadway Database for PCI Comparison

Road Class	Roadway Segment Count	
	No Utility Cuts	With Utility Cuts
All Classes	3357	561
Local	2121	311
Collector	740	155
Arterial (Major and Minor)	496	95

Table 3: Roadway Database for IRI Comparison

Road Class	Roadway Segment Count	
	No Utility Cuts	With Utility Cuts
All Classes	1394	260
Local	162	44
Collector	760	122
Arterial (Major and Minor)	472	94

As shown in Tables 2 and 3, a larger roadway network of viable segments was available for PCI versus IRI comparative analysis. This difference in network size is a result of the City not collecting IRI data on many of its local road network.

From the roadway database summary shown in Tables 2 and 3, a smaller database was developed to complete the assessment of pre and post utility cut roadway condition. By excluding roadway segments with any surface treatments within this study period, this refined database was developed to provide a single source of roadway segment data to focus solely on the impacts of utility cuts for both the PCI and IRI data comparisons. A summary of the refined database is shown in Table 4.

Table 4: Refined Database for PCI and IRI Comparisons

Roadway Class	Number of Observation	
	No Utility Cuts	With Utility Cuts
All Classes	1529	276
Local	188	45
Collector	810	125
Arterial	531	106

Details pertaining to the PCI and IRI analysis and comparison is provided in the following sections.

6.1 PCI Analysis and Comparison

The PCI is a numerical rating of the pavement condition that ranges from 0 to 100 with 0 being the worst possible condition and 100 being the best. The PCI was determined based on the ASTM-D6433-18 [9] standard. The PCI is an indication of the overall health of the pavement segment and includes all the measured surface distresses including rutting, fatigue cracking, longitudinal and transvers cracking which are the three major asphalt concrete pavement distresses constituting main factors that affect the performance and ride quality of pavements. It does not include IRI which will be discussed in the next section of this paper.

The average PCI and its standard division for all the observed roadway segments for each class were calculated separately for roadway segments with and without utility cuts and presented in Table 5.

Table 5: Average PCI of Various Roadways from 2014 to 2017

Road Class	Average PCI ± Standard Division (mm/m)							
	No Utility Cuts				With Utility Cuts			
	2014	2017	Change from 2014 to 2017		2014	2017	Change from 2014 to 2017	
Local	75±15.7	63±20.5	-12	-16.2%	70±18.3	57±22.2	-13	-19.0%
Collector	70±19.2	64±21.6	-6	-8.1%	67±19.5	59±21.5	-8	-11.7%
Arterial	74±17.5	63±18.9	-11	-15.3%	68±18.9	58±18.8	-10	-13.5%

As can be seen from Table 5, from 2014 to 2017, the PCI values decreased, as expected, for all roadway classes irrespective of segments with or without utility cuts. However, more significant decrease was noted for the roadways with utility cuts compared to those without utility cuts. For example, the averaged PCI decreased from 70 in 2014 to 64 in 2017 for 810 collector roads without utility cuts, which is about 8.1% of decrease. In contrast, the averaged PCI decreased from 67 to 59 during the same time window for 125 collector roads with utility cuts, which is about 11.7% of decrease. The exception are arterial road classes, when a greater decrease was noted for roadways without utility cuts compared to those with utility cuts.

6.2 IRI Analysis and Comparison

Developed by World Bank [10], the IRI is an industry-recognized standard for the measurement of road roughness and was employed in this study. The average IRI which collected by following ASTM E950 [11] and its standard division for all the observed roadway segments for each roadway class were calculated and presented in Table 6.

From 2014 to 2017, the IRI values increased, as expected, for all classes of the roadways irrespective of segments with or without utility cuts. However, more significant increase was noted for the roadways with utility cut compared to those without utility cuts. For example, the average IRI increased from 5.30 mm/m in 2014 to 5.59 mm/m in 2017 for 188 local roads without any utility cuts, which is about 0.29 mm/m or 5.5% increasement. In contrast, the average IRI increased from 6.03 mm/m to 6.94 mm/m during the same time window for 45 local roads with utility cuts, which is about 0.91 mm/m or 15.1% increasement.

Table 6: Average IRI of Various Roadway Segments in 2014 and 2017

Roadway Class	Average IRI ± Standard Division (mm/m)							
	No Utility Cuts				With Utility Cuts			
	2014	2017	Increase from 2014 to 2017		2014	2017	Increase from 2014 to 2017	
Local	5.30±1.98	5.59±2.25	0.29	5.5%	6.03±2.39	6.94±3.09	0.91	15.1%
Collector	4.01±1.51	4.31±1.72	0.30	7.5%	4.44±1.64	4.95±1.85	0.51	11.5%
Arterial	3.19±1.26	3.26±1.14	0.07	2.2%	3.96±1.43	4.19±1.48	0.23	5.8%

7. PAVEMENT SERVICEABILITY LOSS MODELS

7.1 PCI Deterioration Model and Comparison

For each roadway class, the City provided PCI deterioration model (exported from their Pavement Management System) which was adjusted in this study by using a best fit condition to provide a continual rate of deterioration as shown in Figure 2.

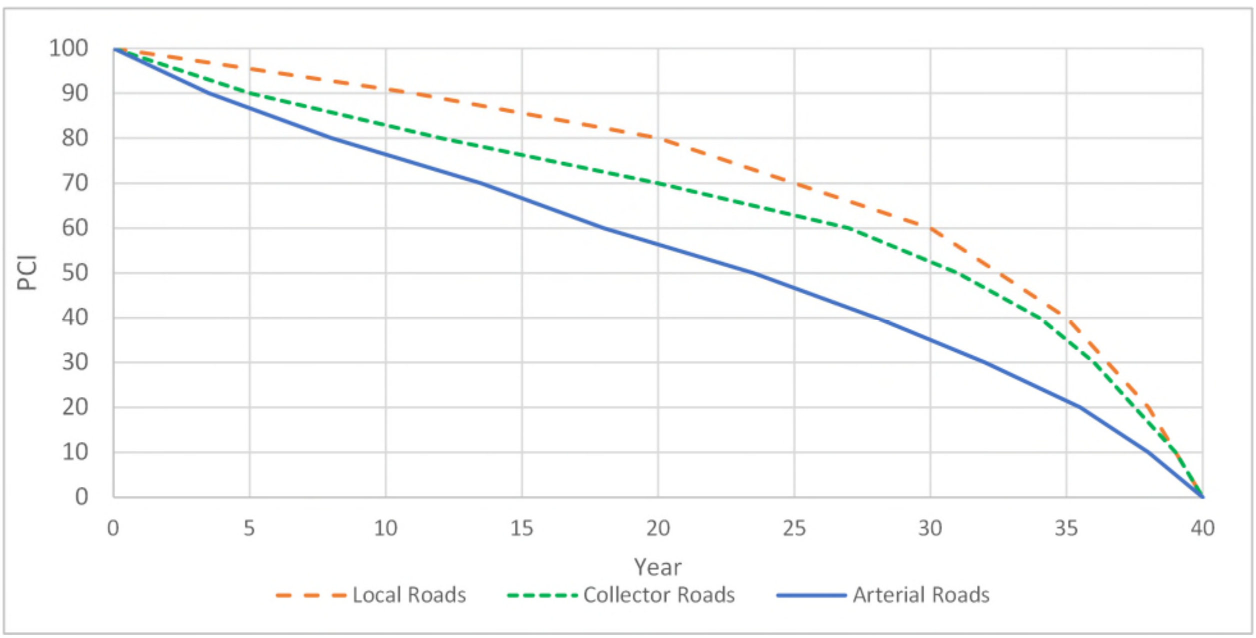

Figure 2. PCI Deterioration Model for Each Road Class

In order to account for the impact that utility cuts have on the PCI of a roadway segment, PCI adjustment factors were calculated based on these PCI deterioration models as shown in Figure 2. PCI adjustment factors were applied to roadways with utility cuts over four ranges of pre-utility cut PCI condition: Poor – PCI 40 to 60, Fair – PCI 60 to 80, Good – PCI 80 to 90, and Very Good – PCI 90 to 100. These PCI condition ranges were established based on review of the City's complete roadway condition network and are slightly different than the ranges established by ASTM.

The averaged PCI adjustment factors for each pre-utility cut roadway condition are presented in Table 7.

Table 7: PCI Adjustment Factors for Various Roadways with Utility Cuts

Road Class	PCI Range and Associated % Change				
	40 to 60[1,2]	60 to 80[1,2]	80 to 90[1,2]	90 to 100[1,2]	Adjustment Used in Analysis[3]
Local	-19% (27)	-15% (133)	-12% (85)	-9% (55)	-4.3%
Collector	-20% (21)	-19% (50)	-7% (84)	-7% (13)	-5.0%
Arterial	-20% (28)	-16% (33)	-13% (85)	-14% (20)	-5.3%

[1] – % Change is over a three-year period: 2014 to 2017.
[2] – The number in parenthesis represents the number of roadway segments used to determine the % change.
[3] – "Adjustment Used in Analysis" is representative of a single year change (i.e., three-year change divided by three).

Based on these adjustment factors, PCI deterioration models for roadways with utility cuts were developed for each road class when utility cuts were conducted at PCI of 95, 85, and 70 (the mid-point of each roadway condition range) which represents very good, good, and fair pavement condition. As examples, Figure 3 and Figure 4 show the PCI deterioration models with utility cuts for arterial road and collector roads, respectively. Similar models were developed for local roads.

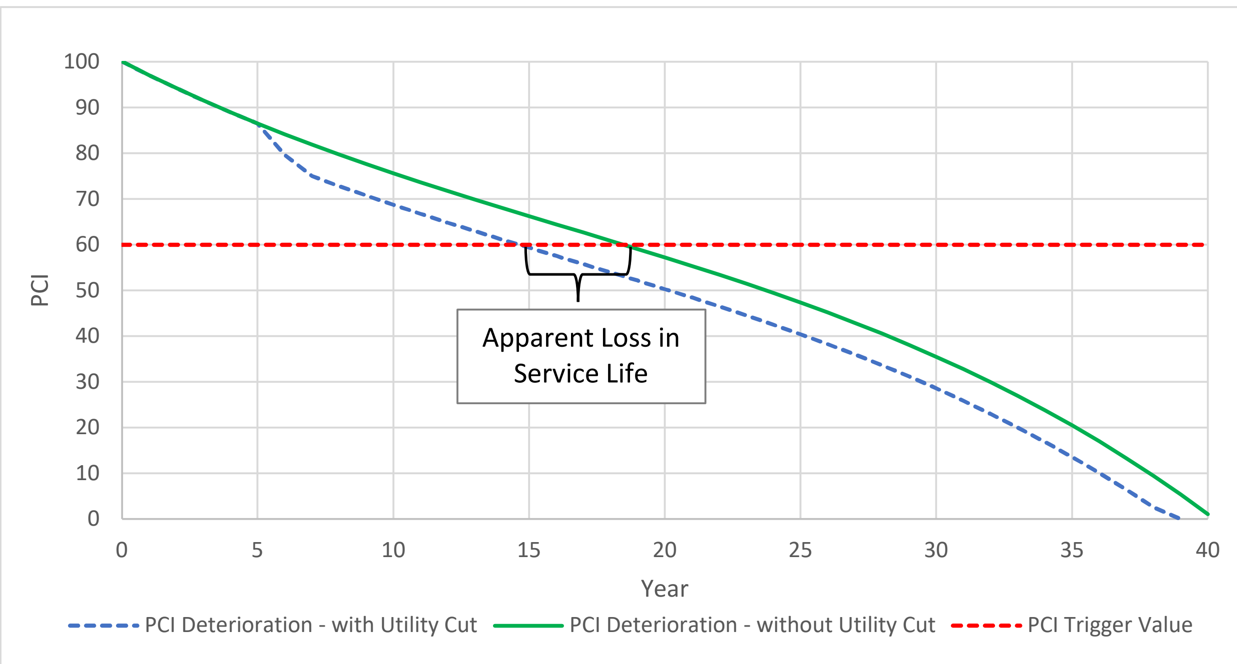

Figure 3. PCI Deterioration Model for Arterial Road with Utility Cut at PCI of 85

Figure 3 shows that a utility cut installed in an arterial roadway with a PCI of 85 results in an apparent loss in service life of approximately four years (using a PCI trigger value of 60). This loss of service life represents the impact of the utility cut installation.

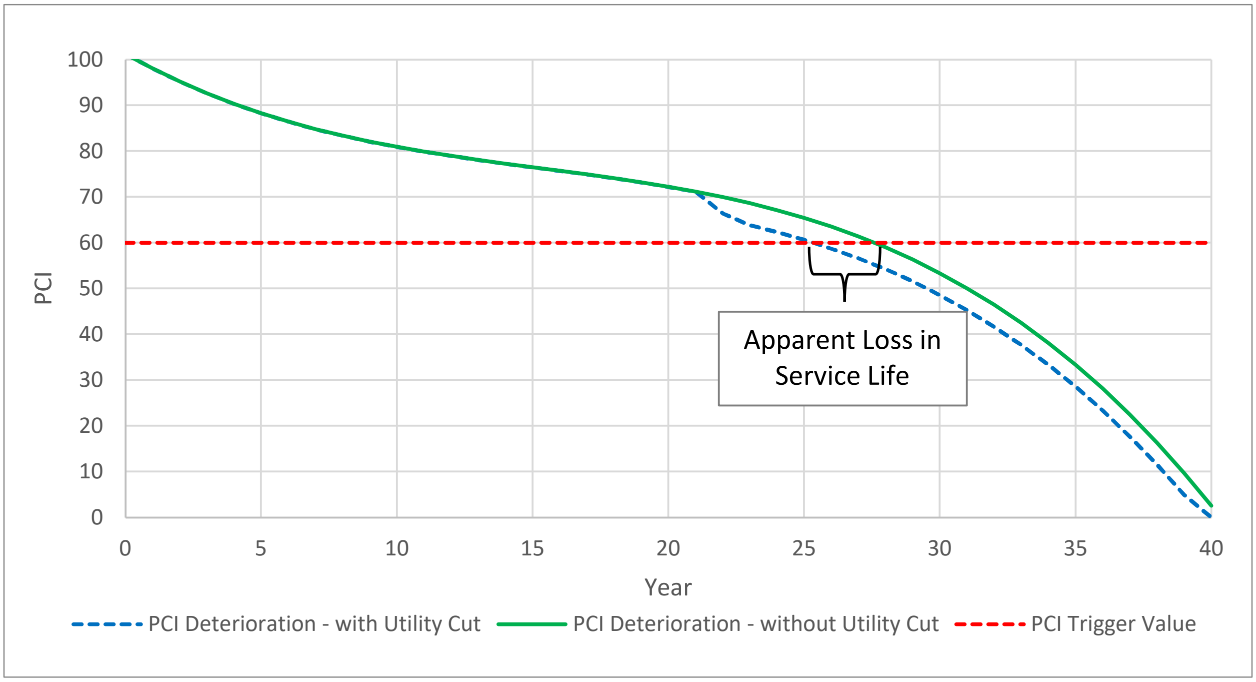

Figure 4. PCI Deterioration Model for Collector Road with Utility Cut at PCI of 70

In this instance, Figure 4 shows that a utility cut installed in a collector roadway with a PCI of 70 results in an apparent loss in service life of approximately 2.5 years (using a PCI trigger value of 60). Compared to the utility cut impact shown in Figure 3, the apparent loss of service life is less for a roadway in worse condition (lower pre-cut PCI).

7.2 IRI Deterioration Model and Comparison

Similar to the PCI adjustment, an IRI adjustment was developed based on four ranges of pre-utility cut IRI condition of very good, good, fair, and mediocre depending on roadway classification and assumed operating speeds [12] as shown in Table 8.

Table 8: Pavement Rating and IRI Ranges at Various Speeds for Each Road Class (source: [12])

Road Class	IRI Ranges for Each Roadway Class (m/km)				
	Typical Operating Speed	Mediocre	Fair	Good	Very Good
Local	40 km/hr	5.70 to 8.08	4.50 to 5.69	2.86 to 4.49	< 2.86
Collector	50 km/hr	4.55 to 6.25	3.60 to 4.54	2.28 to 3.59	< 2.28
Arterial	50 km/hr	4.55 to 6.25	3.60 to 4.54	2.28 to 3.59	< 2.28

A single IRI deterioration model was developed for all roadway classes based on the World Bank Highway Development and Management (HDM-4) manual, and calibrated to local City conditions. These models served as the basis for developing IRI adjustment factors. Annual IRI adjustment factors were then developed at various pavement conditions for each road class as summarized in Table 9.

Table 9: IRI Adjustment Factors at Various Pavement Condition for Each Road Class

Road Class	IRI Condition and Associated Adjustment Factor[1] (m/km)			
	Mediocre	Fair	Good	Very Good
Local	0.25 (12)	0.33 (5)	0.41 (10)	Not applicable
Collector	0.14 (28)	0.23 (26)	0.28 (37)	0.32 (9)
Arterial	0.11 (24)	0.15 (22)	0.20 (33)	0.24 (11)

[1] – The number in parenthesis represents the number of roadway segments used to determine the factor.

As examples, Figure 5 and Figure 6 show the IRI deterioration models with utility cuts for arterial road and collector roads, respectively. Similar models were developed for local roads.

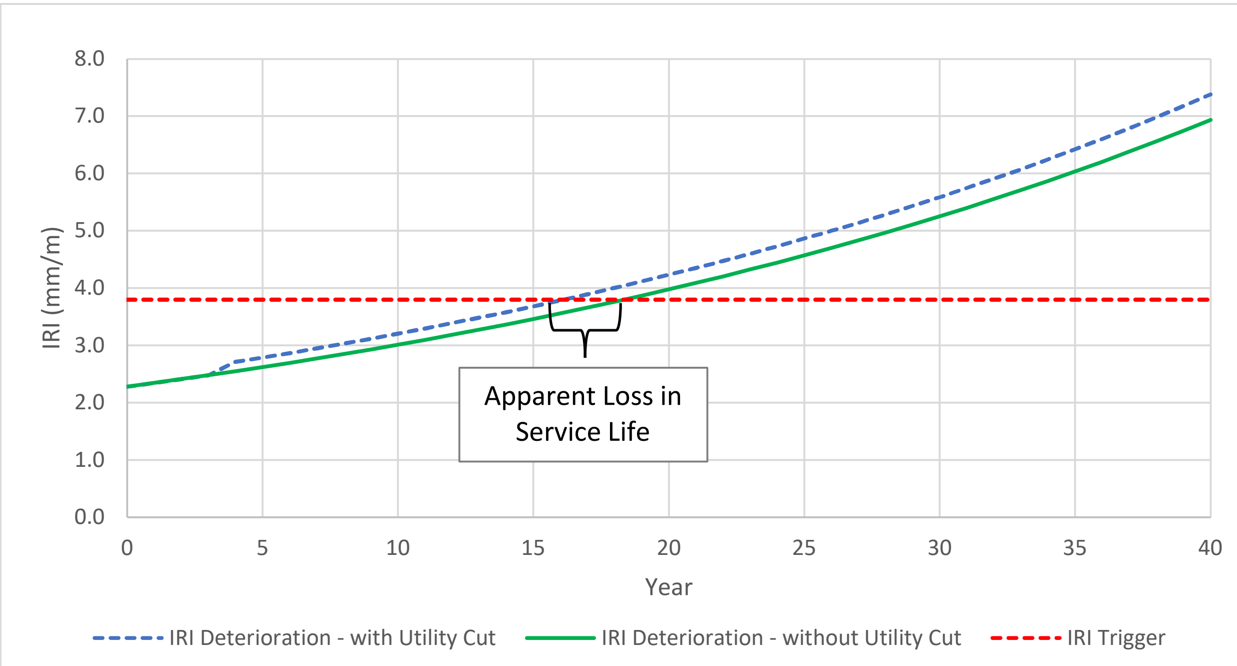

Figure 5. IRI Deterioration Model for Arterial Road with Utility Cut at IRI 2.5 mm/m

Figure 5 shows that a utility cut installed in an arterial roadway with an IRI of 2.5 mm/m results in an apparent loss in service life of approximately three years (using an IRI trigger value of 3.8 mm/m). This loss of service life represents the impact of the utility cut installation.

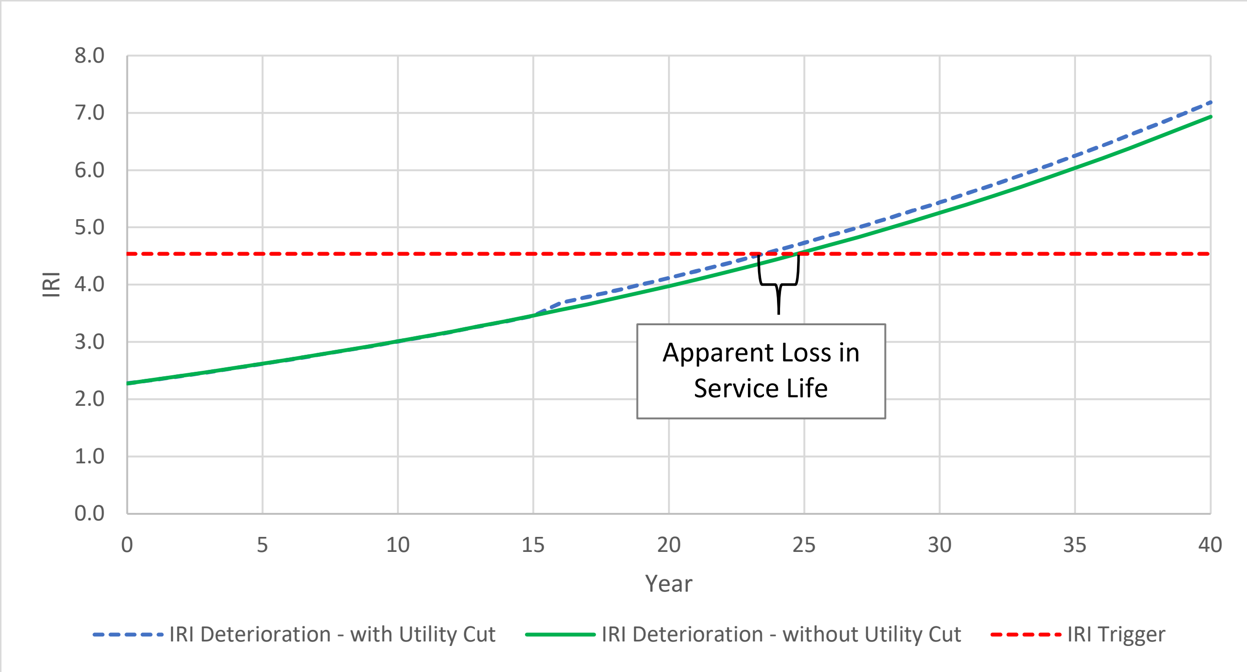

Figure 6. IRI Deterioration Model for Collector Road with Utility Cut at IRI 3.5 mm/m

In this instance, Figure 6 shows that a utility cut installed in a collector roadway with an IRI of 3.5 mm/m results in an apparent loss in service life of approximately 1.5 years (using an IRI trigger value of 3.8 mm/m). Compared to the utility cut impact shown in Figure 5, the apparent loss of service life is less for a roadway in worse condition (higher pre-cut IRI).

8. COST IMPACT OF UTILITY CUT INSTALLATION

The cost of a single utility cut installation was estimated based on the median utility cut size for each roadway class. The present value cost of a "typical" roadway rehabilitation treatment was determined based on the median roadway segment size, and the year when the PCI or IRI condition reaches the assigned trigger value from the time at which the pavement was new.

Other inputs required to complete the impact analysis are:

- Assumed the average "typical" treatment cost was $20/m² based on the practice of the City
- Discount rate of 4%
- Median roadway segment size of 1748 m²
- Median cut area of:
  - Local roads = 12 m²
  - Collector roads = 16 m²
  - Arterial roads = 18 m²

The cost impact analysis was conducted from both PCI and IRI perspectives in the next sections.

8.1 Cost Impact of Utility Cut Based on PCI Values

A PCI value of 60 was determined as the trigger value, as shown in Figure 5, which generally represents the inflection point in the PCI deterioration curves where the deterioration rate increases more rapidly compared to that ahead of this trigger value. In addition, an initial PCI value of 100 was assumed for new pavement.

Table 10, Table 11, and Table 12 present the cost impacts for local road, collector road, and arterial road, respectively.

Table 10: Resulting Cost Impact for Local Roads Based on PCI Values

Index	No Cut	Cut at PCI 95	Cut at PCI 85	Cut at PCI 70
Years to PCI Trigger	29	28	28	28
Apparent Loss in Service Life (Year)	Not applicable	1	1	1
Rehabilitation Cost ($)	11,210	11,658	11,658	11,658
Value Difference (Compared to no-cut Condition) ($)	Not applicable	448	448	448
Cost Impact of Utility Cut ($/m²)	Not applicable	37.37	37.37	37.37

Table 11: Resulting Cost Impact for Collector Roads Based on PCI Values

Index	No Cut	Cut at PCI 95	Cut at PCI 85	Cut at PCI 70
Years to PCI Trigger	27	23	24	25
Apparent Loss in Service Life (Years)	Not applicable	4	3	2
Rehabilitation Cost ($)	12,125	14,184	13,639	13,114
Value Difference (Compared to no-cut Condition) ($)	Not applicable	2,059	1,514	989
Cost Impact of Utility Cut ($/m²)	Not applicable	128.72	94.62	61.84

Table 12: Resulting Cost Impact for Arterial Roads Based on PCI Values

Index	No Cut	Cut at PCI 95	Cut at PCI 85	Cut at PCI 70
Years to PCI Trigger	18	14	14	15
Apparent Loss in Service Life (Years)	Not applicable	4	4	3
Rehabilitation Cost ($)	17,257	20,189	20,189	19,412
Value Difference (Compared to no-cut Condition) ($)	Not applicable	2,931	2,931	2,155
Cost Impact of Utility Cut ($/m²)	Not applicable	162.85	162.85	119.71

As can be seen from Table 10 through Table 12, the earlier the utility cuts being conducted on a pavement, the higher the cost impact will be for all the roads; the most significant impact is observed when utility cuts are conducted on arterial roads as expected. Some detailed observations are as follow:

- For a new pavement, it takes 29 years, 27 years, and 18 years to reach the PCI trigger value of 60 for local roads, collector roads, and arterial roads, respectively if no utility cuts are being conducted during their life spans.
- The installation of a utility cut reduces the service life of the roadway pavement from one to four years, depending on the roadway classification and pavement condition at the time of the utility cut installation.
- For local roads, no significant difference of cost impact is observed whether a utility cut is being conducted at PCI of 95, 85, or 70. However, for collectors or arterials, the earlier the utility cuts are being conducted (the better the roadway condition at the time of the cut), the higher the cost impact. For example, the cost will be $128.72 and $61.84 when a utility cut is being conducted at PCI of 95 and PCI of 70, respectively for a collector road as shown in Table 11.
- When a utility cut is conducted at PCI of 95, the cost could be 4.4 times higher for an arterial road compared with a local road.

8.2 Cost Impact of Utility Cut Based on IRI Values

IRI trigger values were established based on other studies and industry practice [12]. A summary of the IRI trigger values used in the impact analysis is presented in Table 13.

Table 13: IRI Trigger Values for Each Road Class

Road Class	Typical Operating Speed	IRI Trigger Value (m/km)
Local	40 km/hr	6.89
Collector	50 km/hr	4.54
Arterial	50 km/hr	3.79

Table 14, Table 15, and Table 16 present the cost impacts for local roads, collector roads, and arterial roads, respectively. As can be seen from Table 14 through Table 16, the earlier the utility cuts are being conducted on a pavement, the higher the cost impact will be for all the roads; the most significant impact is observed when utility cuts are conducted on arterial roads. These observations agree with those from PCI's perspective as discuss above.

Table 14: Resulting Cost Impact for Locals Based on IRI Values

Index	No Cut	Cut at IRI of 2.5 (m/km)	Cut at IRI of 3.5 (m/km)	Cut at IRI of 4.5 (m/km)	Cut at IRI of 5.5 (m/km)
Years to PCI Trigger	31	27	28	30	31
Apparent Loss in Service Life (Year)	Not applicable	4	3	1	0
Rehabilitation Cost ($)	10,364	12,125	11,658	10,779	10,364
Value Difference (Compared to no-cut Condition) ($)	Not applicable	1,760	1,294	415	0
Cost Impact of Utility Cut ($/m²)	Not applicable	146.70	107.84	34.55	0

Table 15: Resulting Cost Impact for Collectors Based on IRI Values

Index	No Cut	Cut at IRI of 2.5 (m/km)	Cut at IRI of 3.0 (m/km)	Cut at IRI of 3.5 (m/km)	Cut at IRI of 4.5 (m/km)
Years to PCI Trigger	24	21	22	23	24
Apparent Loss in Service Life (Year)	Not applicable	3	2	1	0
Rehabilitation Cost ($)	13,639	15,342	14,752	14,184	13,639
Value Difference (Compared to no-cut Condition) ($)	Not applicable	1,703	1,113	546	0
Cost Impact of Utility Cut ($/m²)	Not applicable	106.44	69.56	34.10	0

Table 16: Resulting Cost Impact for Arterials Based on IRI Values

Index	No Cut	Cut at IRI of 2.5 (m/km)	Cut at IRI of 3.0 (m/km)	Cut at IRI of 3.5 (m/km)	Cut at IRI of 4.5 (m/km)
Years to PCI Trigger	18	16	16	17	18
Apparent Loss in Service Life (Year)	Not applicable	2	2	1	0
Rehabilitation Cost ($)	21,572	23,332	23,332	22,434	21,572
Value Difference (Compared to no-cut Condition) ($)	Not applicable	1,760	1,760	863	0
Cost Impact of Utility Cut ($/m²)	Not applicable	97.79	97.79	47.94	0

Some detailed observations are as follows:

- For a new pavement, it takes 31 years, 24 years, and 18 years to reach the IRI trigger value for local roads, collector roads, and arterial roads, respectively if no utility cuts are being conducted during their life spans. Utility cuts have negative impact to their service life. The loss of service varies for local roads, collector roads, and arterial roads when utility cuts are conducted at different pavement conditions.
- The installation of a utility cut reduces the service life of the roadway pavement from zero to four years, depending on the roadway classification and pavement condition at the time of the utility cut installation.
- More detailed cost impact of utility cuts can be achieved from an IRI perspective compared with those from a PCI perspective. One possible reason is that different IRI trigger values shown in Table 11 are employed based on road class rather than a single PCI trigger value of 60 irrespective of local roads, collector roads, or arterial roads.

A general summary of the resulting cost impact information provided in Tables 10 through 12 (for PCI) and Tables 14 through 16 (for IRI) is provided in Table 17.

Table 17: Resulting Cost Impact of Utility Cut Installation Summary

Roadway Classification	PCI Condition	Cost Impact of Utility Cut ($/m²)	IRI Condition	Cost Impact of Utility Cut ($/m²)
Local Roads	Very Good	$37	Very Good	$147
	Good	$37	Good	$108
	Fair	$37	Fair	$35
Collector Roads	Very Good	$129	Very Good	$106
	Good	$95	Good	$70
	Fair	$62	Fair	$34
Arterial Roads	Very Good	$163	Very Good	$98
	Good	$163	Good	$98
	Fair	$163	Fair	$48

9. CONCLUSIONS

The City's pavement utility cuts database and the roadway network condition database were reviewed and analyzed in this study. By employing statistical analysis, pavement PCI and IRI degradation models, as well as pavement serviceability loss models were developed. It was found that the amount of pavement degradation, loss of pavement serviceably and pavement asset value can be quantified by using pavement surface condition indices of PCI or IRI.

The primary objective of this impact analysis was to determine if the amount of pavement degradation and loss of pavement serviceably could be quantified using the City's pavement utility cut database combined with the City's 2014 and 2017 roadway network condition databases. Through detailed technical analysis and ongoing consultation with key City personnel, tables summarizing the resultant costs relative to the loss in service life over the pavement life-cycle were developed for three City roadway classes: local roads, collector roads, and arterial roads. The information in these tables may ultimately be used by the City to assist in determining the costs associated with the construction utility cuts on their overall roadway pavement network.

From both pavement condition (as represented by PCI) and pavement smoothness (as represented by IRI) perspectives, this study evaluated the loss of service life and associated financial loss due to utility cuts in the City of Saskatoon's situation. This information positions the City to establish pavement degradation fees that reflect the actual loss of service life associated with utility cuts as demonstrated by this analysis. The pavement degradation fees ultimately assigned based on this analysis will be "defendable" to the City's stakeholders responsible for reinstatement of utility cuts.

The analyses and their results of this project can be a useful reference to other agencies that may encounter similar utility cut challenges.

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