Case Study: Research and Implementation of a GIS Based Sidewalk Assessment System

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Abstract

Although sidewalks and trails act as the foundation infrastructure for active modes, they are often secondary concerns to many municipalities. With limited budgets and resources, there is often greater emphasis in focusing investment towards primary infrastructure (such as roadways and bridges), which are typically backed by greater operational information and condition investigations that are used justify the use of public funds. While the focus on main infrastructure is justified, this often leaves very little funding or consideration for secondary infrastructure like sidewalks and trails. This issue of limited funding for sidewalks and trails, combined with potential high public use yet limited background data, increases the risk of lawsuits from conditions like trip hazards. Such lawsuits can be quite costly to municipal agencies and detrimental to public perception of safety and mobility. These practices of minimum funding and high liability lead to an inconvenient truth - sidewalks and trails carry a high level of liability and many agencies are not focusing on them enough. One reason for the omission in funding and priority is that municipalities struggle with how to approach condition rating their sidewalk and trail networks. There can even come a point where only condition rating the network is not enough. Simply put, this situation can place agencies in a position of having the data and being unable to use it effectively. To address these problems, the City of St. Albert set out to not only develop an acceptable condition rating system, but to also work closely with its GIS and IT departments on how to best represent it. This resulted in a network level condition rating which allows the city to have its sidewalk network represented in 10 m sections, all condition rated in a range of 1 to 5, 1 being “good condition”, 5 being “poor condition”. This system has allowed the City to better coordinate capital funding to ensure that as much work is accomplished in approved capital programming while being responsible with tax funds in complete transparency.

Keywords: Pavement Management, Sidewalks, Municipalities, Asset Management, GIS.

Introduction

Cities around Canada are constantly balancing risks in their ownership of several types of transportation infrastructures. Whether it is roads, bridges or sidewalks, a common challenge amongst agencies is to identify their risks, properly plan for their timely restoration or rehabilitation, and most importantly, find the funding and resources to do so.

While finding funding is agreed to be a constant issue with several complicated factors, so to is asset risk identification and condition rating. There exists many tools and research on inspection and primary infrastructure, such as roads and bridges. Not much exists on how to approach secondary infrastructure, such as sidewalks. As such, this work is often sourced out to private consultants in order to develop a plan where municipal agencies can identify and prioritize their risks. However, while the agency may achieve a plan on how to approach their asset(s) in the short term, long term consistency of application of condition ratings can be lost, or possibly never developed.

Sidewalks and other walking surfaces present a potential high liability for any municipal agency. According to news articles, lawsuits in Canada over trip hazards can be as high as $92,000 [1] if the municipality is found negligent, when the treatment for such an issue can be as low as $50 for a simple shaving of the trip hazard. This makes the issue of sidewalk condition important for municipal agencies to take seriously, since there is not only a financial incentive to find these issues and deal with them in a timely matter, but public safety of these assets is a paramount concern.

Since 2013, the City of St. Albert has been building its own internal sidewalk condition rating system. The system started in response to questions of how to manage and plan multiple asset renewals in the most efficient way possible. The City already made use of a pavement management system (PMS) where a consultant collected road data. This system was intended to run in parallel with the city's PMS. The goal was to create a system for sidewalks that could do the following:

1. Provide a consistent rating system which any member of the City could apply in a given situation
2. The data would be accessible to any member of the City that needed it
3. Could be easily analyzed using existing off the shelf tools
4. Be used in parallel with other asset tools (such as the pavement management system and GIS)

The resulting system has taken 6 years of iterative implementation, review and redevelopment. This system, while imperfect, provides the City with an in-house tool and database of all known sidewalk condition issues within the City of St. Albert. Additionally, this system can be modified depending on needs or priorities as required.

History

In 2011, the City of St. Albert sent out a Request for Proposal (RFP) for engineering firms to investigate and provide both a condition assessment and 3-year capital plan of priorities within its sidewalk and trail network. The consultant completed the work in 1 month using a team of people on bikes. The result of the condition produced a map, found in the figure below:

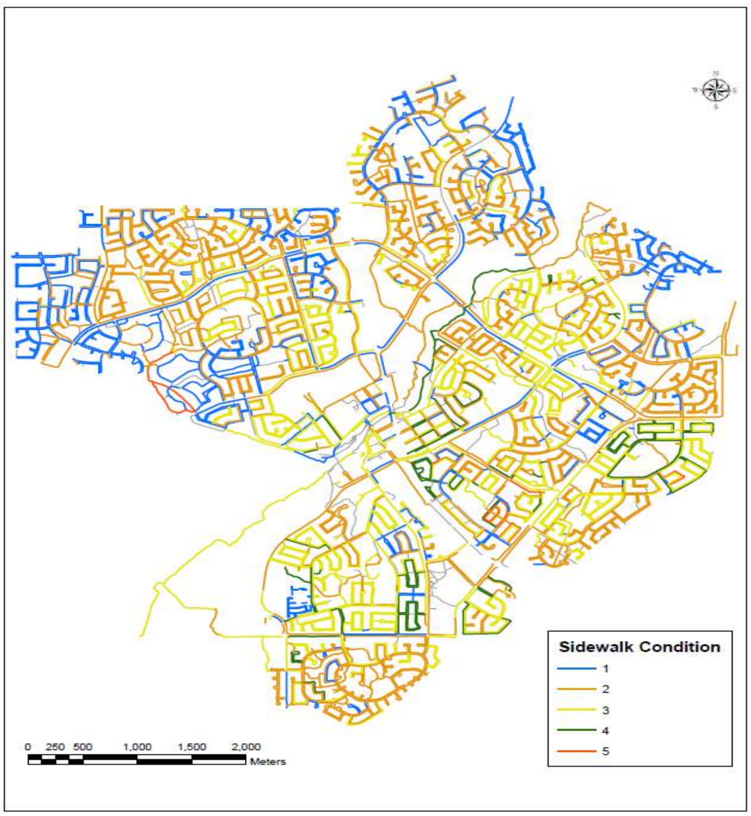


Figure 1 - City of St. Albert Sidewalk Condition (2011) – OPUS [2]

The work the consultant completed was a high level, efficient assessment of the City's overall sidewalk and trail network. This map was completed by collection of approximately 11,000 points across a network of ~430 kms of sidewalk. It was the City's first real assessment of its secondary transportation infrastructure.

While the City was able to rely on this information for the short term, some issues came to light:

1. The lack of a consistent rating system often pitted maintenance and capital priorities against each other
2. The information in this study was difficult to access by many in the organization
3. Lack of in-house knowledge on how to condition rate was causing inefficiencies within the organization
4. The information was static, with no efficient way for updating without restarting the RFP process

System Development

The City used this data for 2 years before performing a review of the current program. In 2013, the City's then Infrastructure and Capital Planning (ICP) Branch reviewed the previous report and data and opted to do a "refresh" of the data in house. The goal of the update was simple:

1. Complete the entire network review in 1 summer season
2. Use existing off-the-shelf technology, which the City currently had in its possession
3. Collect the data in the City's own servers so that it could be reviewed at a later date

To accomplish this, the City hired a 4-month term engineering co-op student to research existing practices in similar and neighbouring agencies. This review included literature reviews and interviews with several municipal agencies, which in turn provided the City with insight as to what criteria other agencies were using and how to best adopt the system to its own needs. The result was a chart of sidewalk assessment criteria that would form the basis of all conditions collected.

Criteria

- **Distortions**
    - Distortions are when the slabs have begun to move independently from one another. This may include joint displacements, heaves or dips, crack displacements, or tree roots.
- **Defects**
    - Defects are when loss of material from the slabs has been noticed. This may include potholes, popups, edge loss, or presence of utilities (such as valves).

- **Surface Conditions**
    - Surface conditions are when an issue is affecting the walking surface itself. These include spalling, vegetation cover, or pooling of water.
- **Cracking**
    - Cracking is when a slab has broken or failed. The types of cracks that were assessed were longitudinal, transverse, and corner cracks.

- **Trip Hazards**
    - Trip hazards were defined by the City as any displacement of a part or whole of a slab greater than 25 mm. While the City collected data on these, they ultimately were not a measure of condition.

- **Multiples**
    - Multiples was a condition that was used to set slabs exhibiting 2 or more of the issues above.

The City went on to develop similar styles of criteria for asphalt trails in 2014 and curb and gutter in 2015. While each had their own specific types of issues that were rated, they ultimately followed the same process of literature and agency review.

Condition

Once the measurement criteria had been developed, the City also researched a rating system that would be effective at disclosing the levels of condition that would evaluate the network. The City opted to continue using a scale of 1 to 5 with the following descriptions:

Table 1 - St. Albert Condition Ratings

Condition Rating	Description
1	New and uniform
2	Slightly used, weathered, fairly uniform
3	Issues may be present, aged, weathered – acceptable state
3.5	Imminent Repairs – acceptable state
4	Repairs required in section
5	Priority repairs in section

The condition ratings were designed to be indicators that took the value of all issues present within a given section of sidewalk and summarize it into a single number. The condition rating was ultimately a measure of risk in the section; with anything at or below a condition level 3.5 being in “acceptable condition”. What “acceptable condition” means varies from agency to agency. It is important to understand that “acceptable condition” in this context does not mean “no issues”; at this rating, there can exist cracks, displacements, distortions, and more. The condition of an “acceptable” section of sidewalk means that the issues present are currently not of concern to the City from a strictly condition perspective. This meant that the City could better prioritize its resources for future work and focus on “need” areas.

The condition rating level 3.5 came as a result from discussion and preliminary data review. During development of the condition ratings, the City would conduct “field checks” to confirm if the calculated conditions would indeed represent what was found “in field”. In many cases where sections were measured to be a 4, it was found that not many of them were truly in a full state of replacement. Some slabs showed some issues, but not necessarily enough to warrant priority. That’s when the range of 3.5 was created. A 3.5 signifies that the section is likely still in “good” condition. But, if during a major capital renewal there was sufficient budget, then the project or program manager could prioritize their replacement. It was designed to be a discretionary criterion to help in decision making during project execution.

2013 Program

The 2013 data was collected over the course of two and half months. An engineering student biked the entire network collecting data on a Trimble GPS. The data was then uploaded into the City’s ArcGIS system to be downloaded into a .CSV file later for analysis. The data yielded a strong picture of the network that was otherwise consistent with the 2011 assessment. See figure below:

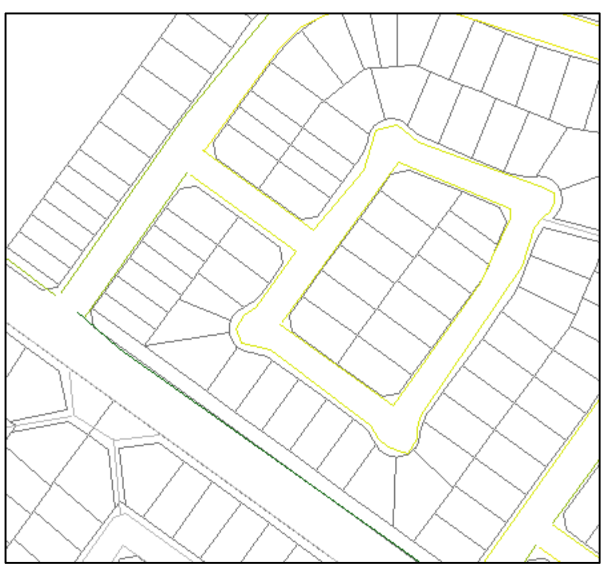


Figure 2 - 2013 Analysis Example

With the data compiled and maps completed, the City used the data for the next 3 years to inform on capital planning. However, as capital planning and execution was completed, some unforeseen difficulties were encountered:

1. Desktop review of the data still did not yield strong enough location of site specific issues. Project Managers still had to field confirm the locations of the issues for their scopes. This was problematic, since most Project Managers were busy during the summer and could not do field validations ahead of time
2. When work was completed, locations that were completed were not always captured in the system. This made tracking work history difficult
3. City maintenance crews were still unable to access the data

After internal discussion, it was decided that after 3 years of relying on this data, it was time to implement an update.

2016 Update

In 2016 the City took on a holistic review of its sidewalk program from the past 3 years. With that review came the need to address the issues found in 2013's data and management. To address the issues brought up in the 2013-2015 program, the City made several key changes to how it approached condition rating:

1. The entire sidewalk network shape files in ESRI were subdivided into 10 m sections. This length was decided upon as a "minimum mobilization" value that could still be assessed at a network level
2. More data would be collected in this update. As much detail as possible would be collected so as to identify the quantity and severity of separate issues within the network
3. Better metrics were required in order to deduce the City's current asset levels for sidewalks specifically so risks could be properly addressed

Prior to collecting data, the City's Engineering GIS Specialist began the tedious process of breaking down individual sections of sidewalk into sections approximately 10 m in length. This standardized length allowed the City to complete an analysis on consistent and repeatable lengths of sidewalk. Additionally, this 10 m length was considered a "minimum mobilization" amount for work, in the event the section needed to be completely removed.

Each year for 3 years (2016, 2017 and 2018) a second year engineering co-op student was sent out to complete a condition assessment of $^{1}/_{3}$ of the City's sidewalks. The areas are shown in the figure below:

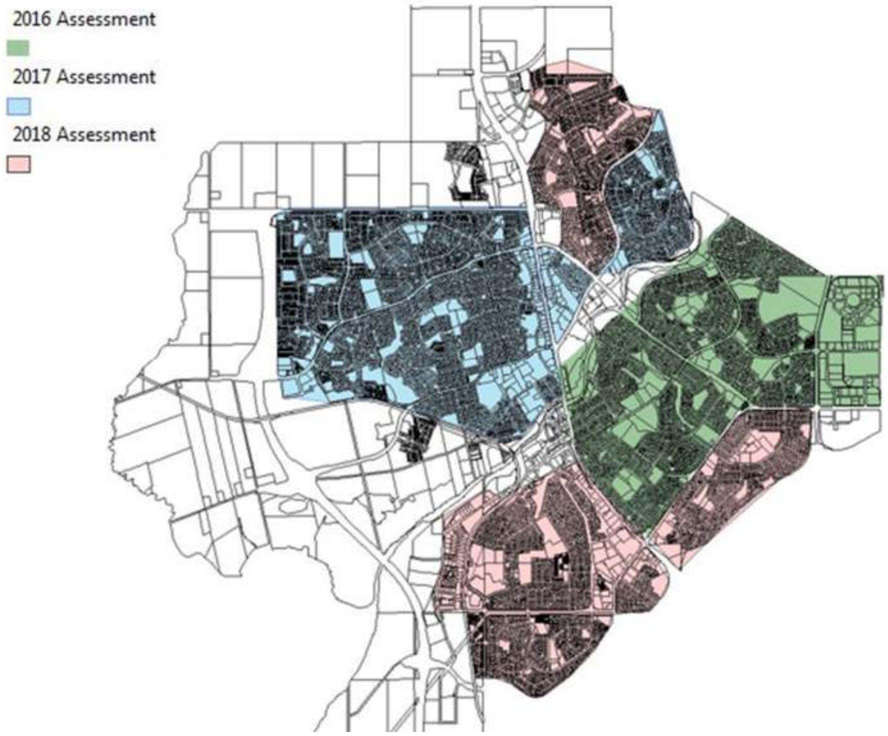


Figure 3 - 2016 Update Data Collection Staging Map

By splitting the City into thirds and spreading out the data collection over time, resource needs were minimized. Only 1 student was needed per year, and their focus was on collecting sidewalk data from June to October and analysing the collected data from October to December.

Data Collection

Data collection was completed using an iPad mini 4 and the ESRI Collector app. The Collector app was preloaded with the City's existing sidewalk criteria for selection by the surveyor. See screenshot on the following page:

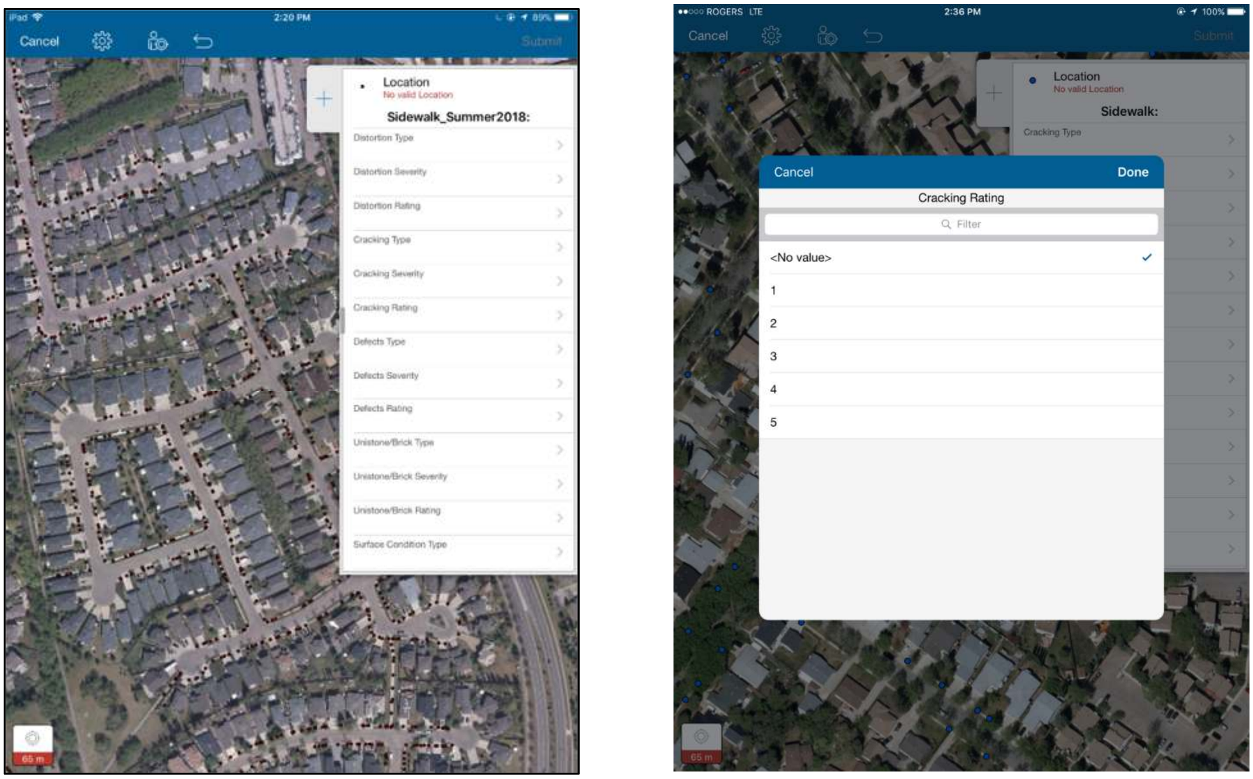


Figure 4a & 4b - ESRI Collector App Screenshot

In the figure above, each dot is a location of an issue on a slab. When no issues were found, no data was collected. The student could place a dot on their location of where the issue was located, then select all known issues within the slab where it was found. With each student walking the length of the network, rate of progression was dependent on the level of issues found within each neighbourhood. The table below outlines how much data was collected in total:

Table 2 – Overall Sidewalk Year Data Collected

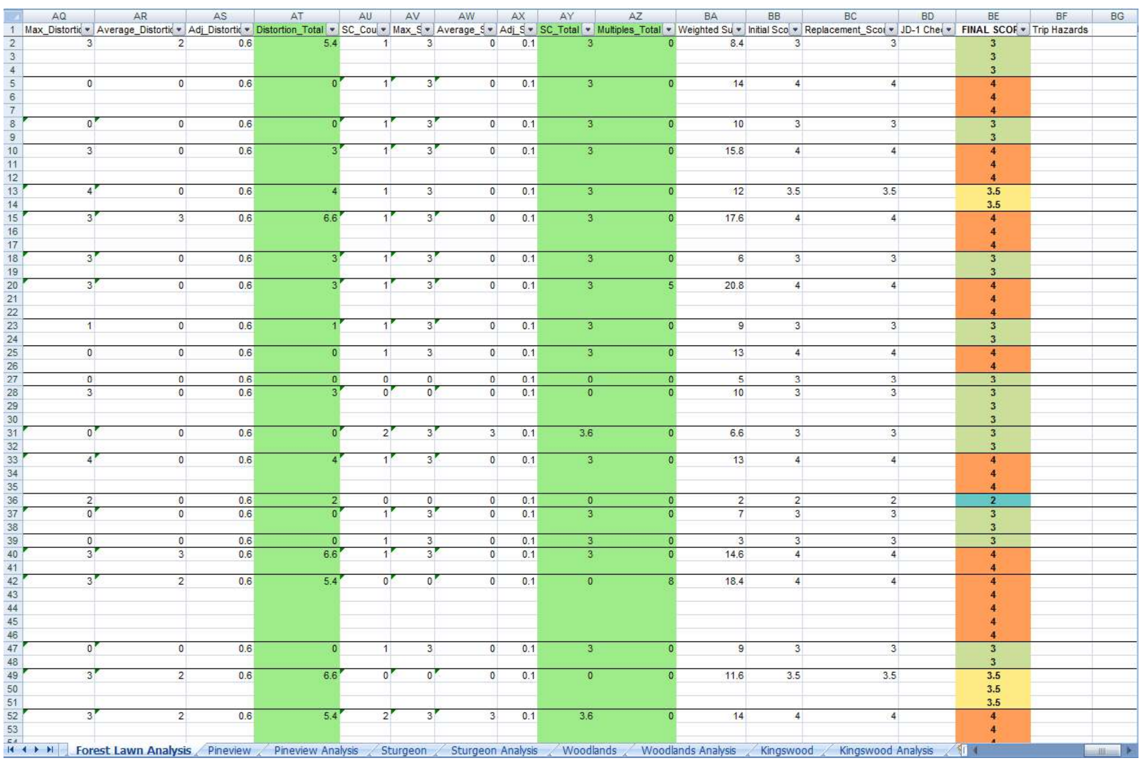
Year	Est. Kms Walked	Data Points Collected	Neighborhoods Rated	Average Points per km
2016	127	32,000	7	252
2017	167	56,000	5	335
2018	133	47,000	7	353
Total	427	135,000	19	Average: 314

As Table 2 shows above, this process was very tedious on the surveyors. The students were tasked with collecting a lot of data over a large area as quickly as possible. At times, this was done in very difficult weather conditions, varying from extensive heat to overcast and cold.

Analysis

Data was collected until either the completion of planned network evaluation, or when seasonal changes (snow) occurred, making it to difficult to evaluate site conditions. Following completion of the data collection, the students would turn to post-processing their data. To accomplish this, they would download the data from ESRI into a .csv Excel file and begin sorting and analysing the data.

With each point collected being separate from the assigned 10 m section, the GIS Coordinator and Transportation Data Coordinator created a macro to sort each singular data point into “bins” using a black line. The black line would denote how many points of data were found in each 10 m section. From there the data could be analysed using weighted averages developed by the infrastructure team.



	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG
1	Max_Distortic	Average_Distortic	Adj_Distortic	Distortion_Total	SC_Cou	Max_S	Average_S	Adj_S	SC_Total	Multiples_Total	Weighted Su	Initial Sco	Replacement_Scor	JD-1 Che	FINAL SCOR	Trip Hazards	
2	3	2	0.6	5.4	1	3	0	0.1	3	0	8.4	3	3		3		
3															3		
4															3		
5	0	0	0.6	0	1	3	0	0.1	3	0	14	4	4		4		
6															4		
7															4		
8	0	0	0.6	0	1	3	0	0.1	3	0	10	3	3		3		
9															3		
10	3	0	0.6	3	1	3	0	0.1	3	0	15.8	4	4		4		
11															4		
12															4		
13	4	0	0.6	4	1	3	0	0.1	3	0	12	3.5	3.5		3.5		
14															3.5		
15	3	3	0.6	6.6	1	3	0	0.1	3	0	17.6	4	4		4		
16															4		
17															4		
18	3	0	0.6	3	1	3	0	0.1	3	0	6	3	3		3		
19															3		
20	3	0	0.6	3	1	3	0	0.1	3	5	20.8	4	4		4		
21															4		
22															4		
23	1	0	0.6	1	1	3	0	0.1	3	0	9	3	3		3		
24															3		
25	0	0	0.6	0	1	3	0	0.1	3	0	13	4	4		4		
26															4		
27	0	0	0.6	0	0	0	0	0.1	0	0	5	3	3		3		
28	3	0	0.6	3	0	0	0	0.1	0	0	10	3	3		3		
29															3		
30															3		
31	0	0	0.6	0	2	3	3	0.1	3.6	0	6.6	3	3		3		
32															3		
33	4	0	0.6	4	1	3	0	0.1	3	0	13	4	4		4		
34															4		
35															4		
36	2	0	0.6	2	0	0	0	0.1	0	0	2	2	2		2		
37	0	0	0.6	0	1	3	0	0.1	3	0	7	3	3		3		
38															3		
39	0	0	0.6	0	1	3	0	0.1	3	0	3	3	3		3		
40	3	3	0.6	6.6	1	3	0	0.1	3	0	14.6	4	4		4		
41															4		
42	3	2	0.6	5.4	0	0	0	0.1	0	8	18.4	4	4		4		
43															4		
44															4		
45															4		
46															4		
47	0	0	0.6	0	1	3	0	0.1	3	0	9	3	3		3		
48															3		
49	3	2	0.6	6.6	0	0	0	0.1	0	0	11.6	3.5	3.5		3.5		
50															3.5		
51															3.5		
52	3	2	0.6	5.4	2	3	3	0.1	3.6	0	14	4	4		4		
53															4		

Figure 5- Screenshot of Analysis of Sidewalk Data

Once sorted, the data was analysed using a modified weighted average formula. The formula prioritized the maximum condition rating of a particular criterion (Distortions, Cracking, Defects, Surface Conditions, and Multiples), then applied an adjustment factor to the remaining total number of points. Each criteria A summary equation of the analysis is below:

$$Total\ Criteria\ Points = C_{max} + (\#\ of\ issues\ in\ section)(C_{Avg})(C_{Adj})$$

Where:

- **Total Criteria Points**: The total points each criteria in the section has calculated
- **C_{max}**: The highest level of condition reached in the section
- **# of issues in section**: The total number of specific criteria issues in the section
- **C_{avg}**: Average of all criteria conditions in section (exempting C_{max})
- **C_{adj}**: Adjustment factor for criteria

The "adjustment factor" is a constant parameter applied depending on the type of criteria. They are determined based on the severity of the criteria on the sidewalk condition. Table #3 outlines the adjustment factors for each sidewalk criteria.

Table 3 - Adjustment Criteria for Sidewalks

Criteria	Adjustment Factor
Defects	0.8
Distortions	0.6
Cracking	0.5
Surface Conditions	0.1
Multiples	N/A*

Defects have the greatest adjustment factor because issues such as potholes and "popups" pose greater concern than, for example, spalling which falls under the surface conditions criteria. Therefore, every additional defect identified in a section will carry 0.8 of its in-field rating, whereas each additional surface condition identified will only carry 0.1 of its in-field rating. Applying adjustment factors prevents skewing of the sidewalk condition, allowing for a more accurate representation of the section. The multiples were not analysed in this fashion as they were already adjusted in field.

Once each criteria's points are calculated, the total points are summed in the following equation:

$$Weighted\ Sum = TP_{Defects} + TP_{Distortions} + TP_{Cracking} + TP_{Surface\ Conditions} + TP_{Multiples}$$

Where:

- **Weighted Sum:** The total points of all criteria in section
- **TP**: The total points of each criteria from the previous analysis

Using these total points, they are then assessed in a range, which then assigns the section an overall condition rating:

Table 4 - Weighted Sum of Condition Rating for Sidewalks

Weighted Sum Range	Condition Rating
0	1
0.1 to 2.5	2
2.6 to 10.0	3
10.1 to 15	3.5
15.1 to 22.0	4
22.1 +	5

The ranges referenced in Table 4 are the result of several iterations of field truthing and re-analysis on test locations. These ranges were developed and finalized once the field conditions in the test locations approximated what was being observed in field.

Once analysed, the condition rating data was then re-attached to the GIS shape file to create a coloured base map. See figure below:

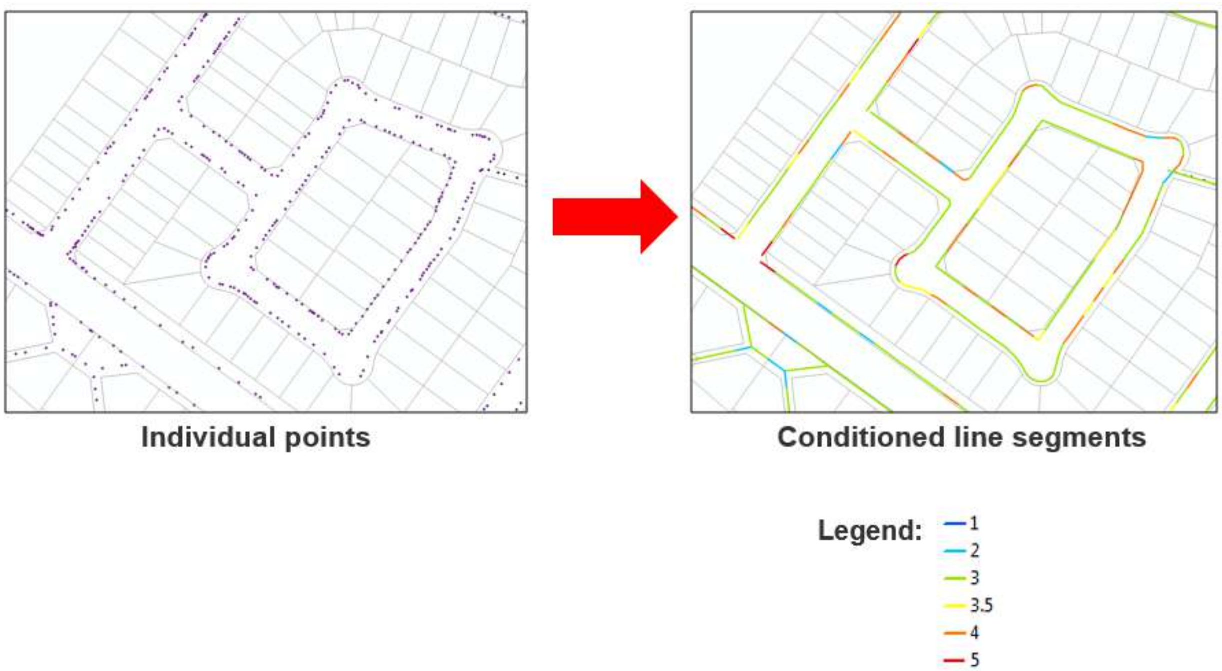


Figure 6 - Example of Analysis Application in GIS

The figures above are the same referenced figure from Figure 1. In these, all identifiable sections for work could be found within the street, making this map easier for project/program managers to identify and prescribe work.

Final Condition Rated Network

Once all data was collected in 2018, the City was able to piece together a full picture of the sidewalk conditions across the City. See the overall map below:

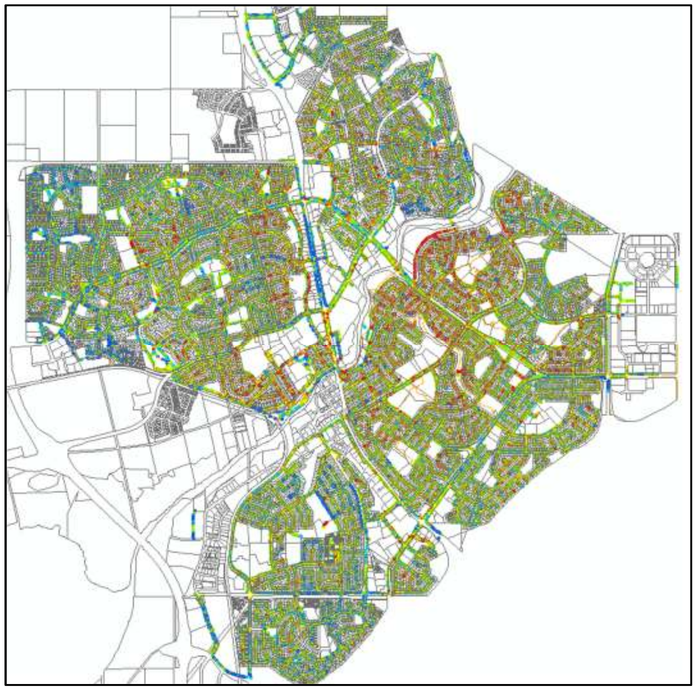


Figure 7 - City Condition Rating Map

The 10m sections created a very observable “heat” map of the city. Additionally, the data allowed for easy identification of trip hazards, since they were noted as singular points. These points could be looked up easily as a query in the ESRI system:

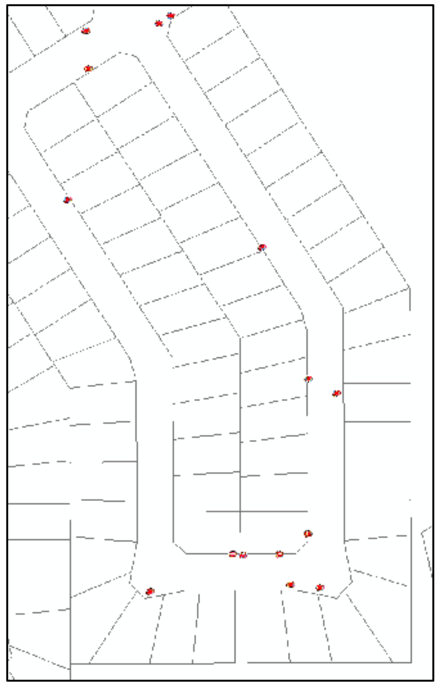


Figure 8 - Trip Hazard Location Example

Figure 8, above, shows locations of trip hazards that would be prioritized to be addressed for liability in the City. This allowed for simple tendering of slabs that could be shaved (only joint displacements) and those that needed to be removed and replaced (all other issues).

Additionally, while researching how to best share this information with other departments, it was discovered that this data could be easily exported into .kmz files. These files could be shared and used in free software such as Google Maps - which made sharing information with ESRI locally installed on a computer much simpler.

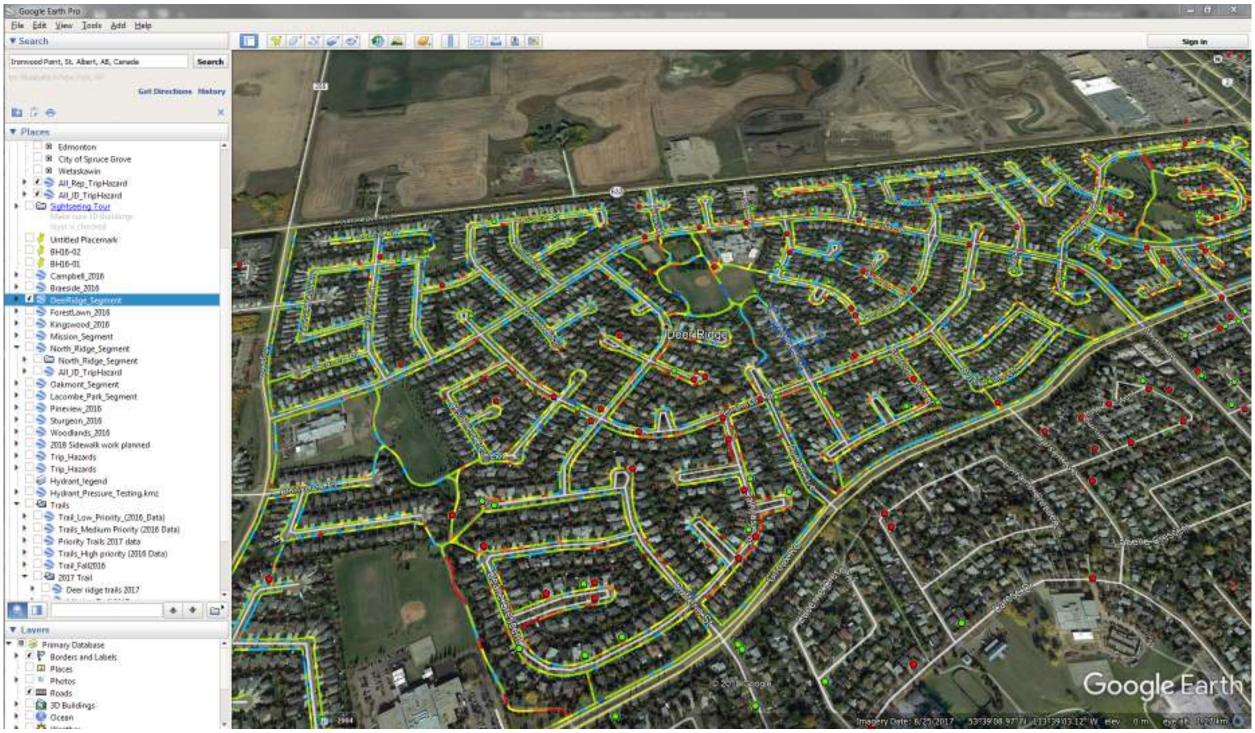


Figure 9 - Google Earth Export of Data Example

This ability to export information to a common, free program made sharing information with internal stakeholders and external contractors much easier, since this software could be downloaded by anyone. Additionally, this process was applied to asphalt trails with very similar results.

Close

The City of St. Albert set out to build an in-house sidewalk condition rating system that was consistent and repeatable from all facets of the asset. This included the condition assessment, data collection, analysis, and presentation of results. This information has since been shared with internal stakeholders such as the City's Operations Branch, and is now being used to develop prioritization standards that will help the City better target capital investment over the next 5 years.

Future Work

Future work with this system will include:

1. The gradual implementation and further "ground truthing" from field confirmation by City Project Managers and Team Leads to better tweak the data to field conditions
2. The development of an in-house prioritization system to prioritize sidewalk assets around the City
3. Updating work history data as these issues are addressed and creating a consistent reporting process to keep data up to date
4. A full data update beginning in 2023 with lessons learned

References

[1] J. Green, "89-year-old wins $192K settlement after tripping on cracked Hamilton sidewalk," 10 June 2015. [Online]. Available: http://www.cbc.ca/news/canada/hamilton/news/89-year-old-wins-192k-settlement-after-tripping-on-cracked-hamilton-sidewalk-1.3108350.

[2] OPUS, "City of St. Albert Sidewalk Condition," St. Albert, 2011.