Sidewalk Repair Cost Estimation Project

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Executive Summary:

Sidewalks are an invaluable part of any town or university as they enable pedestrians to walk from place to place safely and efficiently. Many people living in urban or suburban environments use them every day to commute to work or classes. However, sidewalks do not last forever and will eventually need to be repaired or replaced as they can quickly deteriorate in certain conditions. Rundown sidewalks are not only aesthetically unpleasing, they are unsafe, as defects such as cracks, vertical faults, and spalling can cause people to trip and injure themselves. They can also impede the travel of people using wheelchairs, bikes, skateboards, etc. When it is time to fix the sidewalk, however, it may be difficult for contractors to estimate the costs for repairing large areas of sidewalk when factors such as condition level are put into play. Our team's primary goal is to do a preliminary examination of the sidewalk conditions on campus. This would be done to generate a standard so that we may then create a cost estimating tool that can facilitate estimating the costs of repairing sidewalks over a large area of sidewalk.

To create this tool, we chose six 45 panel segments of sidewalk to examine using a sidewalk scoring system providing by the Americans with Disabilities Act (ADA). This would allow us to create six different condition levels that any sidewalk could be classified under. These conditions were graded from A-F with each grade having a similar repair cost. Because contractors might not have the time to score all panels of sidewalk on a project, creating conditions levels is an easy and efficient way for them to categorize large portions of their sidewalks into groups that have similar cost for repair or replacement. We then found the costs to fix them using three different methods which include: replacing any panel that has scored any points on the ADA scale; replacing any panel that scores more than ten points on the ADA scale; or replacing all panels that score more than ten points after all vertical faults have been repaired. Using the damage data and cost data we created a tool that uses user inputs for miles per condition, cost per square foot, and panel dimensions to give a rough cost estimate to fixing the sidewalks of any large project. Our tool is practical because it provides project managers with the ability to quickly estimate the cost for their projects. While at the same time not having to consume massive amounts of man hours as recording a 45 panel of sidewalk only takes about 5-10 minutes, and using our tool only requires it to be done once for every condition level.

Introduction:

Thousands of students walk the sidewalks on any given day, and thus it is crucial to keep these walkways safe, efficient, and visually appealing to pedestrians. There are several stretches of sidewalk on campus that have fallen into disrepair and pose hazards to students. The safety of pedestrians should be a priority for any institution that has such a large walking population. Sidewalk damage can pose a tripping hazard that can lead to injury. The City of Los Angeles spends an average of $355,000 annually on sidewalk trip-and-fall payouts (Dillon 2013). Even trips that do not lead to serious injury are disruptive to the busy flow of foot traffic on a college campus.

The main reason cities can be slow to repair deteriorated sidewalks is the high initial cost of replacement. There is a need for a cost estimation tool that can predict the cost of repair for a large amount of sidewalk based on project specific input. There are many different variables that can significantly impact the cost to repair a large sidewalk area and it is important to account for all of them.

One factor is the cost per square foot for replacement. Whether the project is new construction or replacement of an existing slab is something that can affect this number. The State of New York estimates the cost for new construction of sidewalk as $8 per square foot, but the removal and disposal requires another $1 per square foot. This may seem insignificant, but for the replacement of 1 mile of 5-foot-wide sidewalk this makes a difference of $26,400. The addition of curbs, ramps, and crosswalks will also have a huge impact on the cost per square foot and will need to be accounted for in any cost estimation tool.

Table 1: *Description and point value for sidewalk defects. (Burns 2010)*

Defect Category	Description	Score
Vertical Fault	Vertical offsets in the Sidewalk. Severity measured in 1/2 -1”, 1-3”, >3” increments	15,25,35
Horizontal Fault	Horizontal gaps or openings of 2” or greater	25
Cross Slope	Surface deterioration of 1/4” or greater	15
Cracking	4 or more surface cracks in a sidewalk panel	10
Spalling	Greater than a 1 in 12 cross slope on a sidewalk	10
Ponding	Standing water or evidence of standing water	5
Cleanliness	Excessive debris on sidewalk	5

It can be costly to replace an entire stretch of sidewalk. Deciding which panels need replacement or repair is crucial to estimating the cost. The Americans with Disabilities Act sets standards for what is considered a safe and accessible sidewalk. Most cities have some sort of plan to work towards total ADA compliance and it is the main motivation behind sidewalk repair. The act focuses on deterioration types that are likely to cause trips or impair the movement of a wheelchair. Cities often create a scale for quantifying sidewalk panel condition, shown in **Table 1**.

Defects that would affect a sidewalk’s ADA Compliance include vertical faults, horizontal faults, spalling, and excessive cross slopes (Burns 2015). Vertical faults are vertical offsets in the sections of sidewalks. These are tripping hazards and reduce wheelchair accessibility. Horizontal faults are gaps between two sidewalk sections. They have a negative effect on the drainage scheme by providing an alternate path for water runoff. Spalling is surface deterioration with indents greater than a quarter inch, which provides a rough walking surface and accelerates future deterioration. While having a slight side slope on a sidewalk is important, a slope greater than 1 inch per foot is considered unsafe for pedestrians.

Most of the panels deemed deteriorated enough to affect accessibility will be addressed through panel replacement. The most common exceptions to this are vertical faults. They are often levelled using a grinder for a fraction of the cost of replacement. This can have a significant effect on cost estimates.

One of the main causes of vertical faults is slab sinking. This is due to a void in the sub-base or sub-soil below the concrete panel. This can be remedied with a process known as mudjacking or slabjacking. It involves drilling several holes in strategic spots on the concrete slab, then pumping a soil/cement mix through the holes and into the foundation of the slab that lifts the slab back to its original position without requiring replacement. This option does not require the removal of the existing pavement or the pouring of a new slab which leads to mudjacking costing 10-50% of what it would cost to remove and replace a slab. There is also no waste material, thus making mudjacking a much more environmentally friendly method. (Rajani 2002)

Figure 1: *Examples of damage types from Mathews Street Urbana, Illinois.*

There are several sustainable solutions beyond the conventional remove and replace method of repairing sidewalks that could be implemented on campus. The city of Logan, Utah is partnering with the University of Utah to implement flexible plastic sidewalk panels in areas where tree roots have pushed existing sidewalk panels out of place (shown in **Figure 2**). The panels, created by the company Terrewalk, are 2 by 2-foot interlocking panels that flex around growing roots without creating a vertical or horizontal fault. Conventional repair methods would have required an expensive tree removal while the Terrewalk panels allow for the preservation of the tree. The panels are also environmentally friendly and are made from 100% recycled materials. (Mendiola 2017)

Figure 2: *Terrewalk sidewalk panels shown expanding around tree roots (Mendiola 2017)*

Figure 3: *Ultra-Light Inertial Profiler*

Currently, the most common approach to analyzing sidewalks and creating a cost estimate is manually recording the condition of each sidewalk panel. The tools used include measuring wheels, smart-slope meter, and a tablet computer. (Bennet, 2016) This method is very labor intensive and there is plenty of potential for improvement. One alternative method of sidewalk analysis is the use of an Ultra-Light Inertial Profiler (ULIP). A ULIP is a Segway outfitted with various sensors that aid in sidewalk analysis. sidewalk cross slope, running slope and bumps. (FWHA)

<u>Objectives:</u>

The purpose of this Project was to create a simple, easy to use tool for the cost estimation of sidewalk replacement/repair. The tool is important because it saves man hours of surveying previously required for a preliminary cost estimate of a project. The condition of six 45 panel sections of sidewalk were evaluated around the central campus of the University of Illinois. The data was then used to create six condition levels labeled in the descending order of condition A-F. Then a formula for estimating the cost of repairing a large section of campus was created using the cost and quantity of each condition level. While the numbers were used just as placeholders for the tool, it showcases the tool's simple but effective way to estimate the cost to repair a certain project up to a specified condition level. The data, analysis, estimation, cost-estimation tool, and conclusion were put in a final report.

Methodology:

Task 1: Collection Sidewalk data and Creation of Condition levels

Six Sections of 45 sidewalk panels were chosen within campus that represented different types and magnitudes of deterioration. Then each section was walked to measure the point values of each panel based on the ADA scale. Once the data was collected and put into Microsoft Excel, six condition levels of sidewalk in descending order A-F were created.

Task 2: Analysis of Percentage of Section in each Condition level and Creation of Formulas

The percentage of panels in each section considered “Satisfactory”, “0-Score”, and “Satisfactory with Repair” was calculated and recorded. The cost of repairing each section back to acceptable condition (Less than 10 points of the ADA scale) was found by referencing the city reimbursement invoices. From this six formulas were created based of the inputs of condition level, cost, and quantity in order to estimate the cost of repairing each condition level back to acceptable condition.

Task 3: Creation of the Cost-Estimation Tool and Conclusion

A tool was made that uses several inputs such as panel size, replacement cost per square foot, and condition level percentages to create a cost estimate for repairing several miles of sidewalk using multiple repair methods. To provide an example of the tool in use, the cost data collected from the city reimbursement invoices was used to prove validity. The effectiveness of the tool was analyzed and proved to be reasonably valid when used to provide a preliminary estimate of repair cost for a project.

Task 4: Compilation of Report

The Background, objectives, executive summary, grading scale of sidewalk damage, data collected from campus, cost scaled to campus, tool, and the conclusion was compiled into a final report.

Results and Discussion:

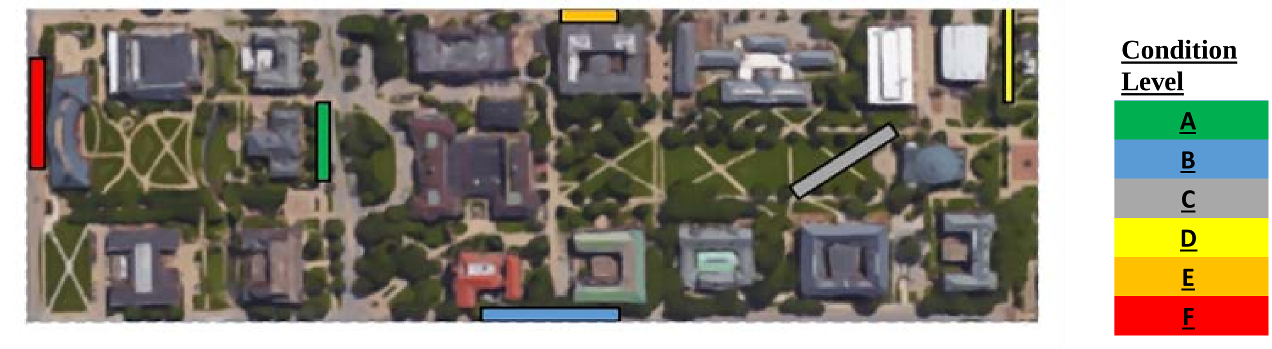
After analyzing the ADA scale shown in **Table 1**, individual panels were broken down into 3 categories:

<u>0-Score:</u> A panel with no defects and registers 0 points on ADA Grading Scale
<u>Satisfactory:</u> A panel with 10 points fewer on ADA Scale and does not need replaced
<u>Satisfactory w/ Repair:</u> A Satisfactory panel or a panel that can be made Satisfactory by grinding the vertical faults

Based on these categories, 3 repair methods are available:

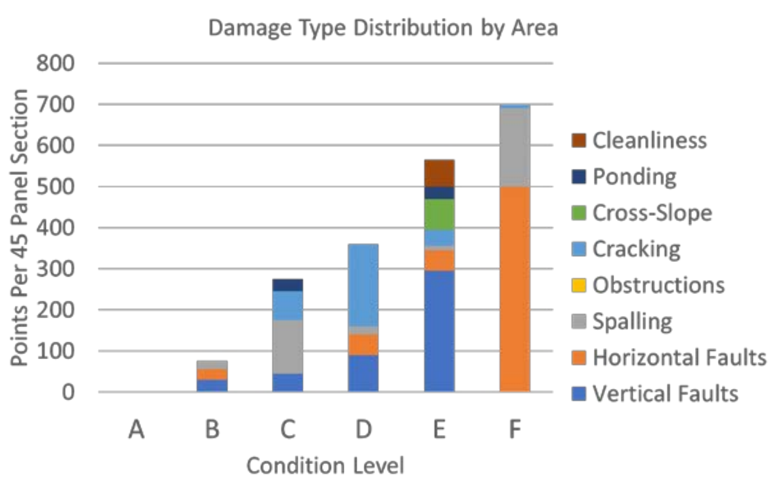
<u>Repair Damaged:</u> Repair all panels that are not 0-Score
<u>Repair Unsatisfactory:</u> Replace all panels that are not Satisfactory
<u>Repair and Replace:</u> Repair vertical faults by grinding then replace the panels that are still unsatisfactory

Figure 4: *Locations of Data Collection*



The purpose of collecting the condition data on the 6 sections mentioned earlier is to use them as condition levels for a cost estimation tool. The first aspect of our results is the data collection on the sidewalk sections on campus. This allowed for the definition of the 6 condition levels A-F. Section A was a freshly cast sidewalk section North of the UIUC Student Union. It scored 0 points per panel on the ADA scale and served as the highest condition level. Section B had minimal damage with 91% of the panels falling into the 0-score category.

Figure 5: *Data Collection by Condition Level*



Sections C-D were moderately deteriorated and had the exact same percentage of 0-score panels. Where these conditions differed is in the types of damage and their distributions throughout the panels. This caused the Satisfactory and Satisfactory with Repair percentages to be different enough to warrant C and D being separate condition levels.

Section E had a variety in its damage distribution. Only 42% of the damaged panels registered as a 0-score. This makes the Repair Damaged method a very expensive repair option. Horizontal faults caused by spalling accounted for almost 75% of the damage points in Section F. These cannot be repaired by grinding, thus the Satisfactory and Satisfactory with repair percentages are the same.

The Cost Estimation Tool works by importing the percentages shown in **Table 2** from the data sheets to the input section of the tool. The first calculation multiplies the percentages of each damage category per condition level by the number of panels per section. This provides the number of panels that are 0-Score, Satisfactory, or Satisfactory w/ Repair in each section.

INPUT						
Location	A	B	C	D	E	F
"0-Score"	100%	91%	51%	51%	42%	49%
Satisfactory	100%	93%	82%	87%	60%	56%
Sat w/ Repair	100%	97%	94%	89%	73%	56%
	A	B	C	D	E	F
Miles per Condition	36	90	30	36	5	12
	To Replace (ft^2)	To Repair (ft^2)				
Cost	$8	$5				
Panel size (ft^2)		25		Panel Width	Panel Length	
Sidewalk Section Size		45		5	5	

Table 2: *User Input for Cost estimation tool*

Cost to repair 1 mile of a specific condition through Repair and Replace Method.
*$ Panel Replacement = [(Panel width * Panel Length) * (Replacement Cost ft2)]*
*$ Panel Repair = [(Panel width * Panel Length) * (Repair Cost ft2)]*
Section cost 1 = [(1-% Satisfactory)(Section size)*($ Panel replacement)]*
Section cost 2 = [(%Satisfactory w/ Repair)-(%Satisfactory)](Section Size)*($ Panel Repair)*
Section Cost = (Section cost 1)+(Section cost 2)
$ Per mile = (5280/[(Panel length)(Section size)])*Section Cost*

The panel dimensions are multiplied to find the square footage of each panel. This is multiplied by the cost per square foot to get the cost to replace a panel. Then the panel cost is multiplied by the number of panels in each section that need replaced. A similar process is used for panel repair, then both are added together to get the cost per section. The cost per section then needs converted into cost per mile. This is done by dividing the footage in a mile by the length of each section to find the sections per mile. The sections per mile is multiplied by the cost per section to get the cost per mile.

The cost per mile calculation needs repeated for every condition level A-F to get the cost per mile of each section. Then the formula needs repeated with Section Cost 2 removed to get the cost per mile of the Repair Unsatisfactory method. The formula needs repeated once more for each condition level with the (%Satisfactory) replaced with (%0-Score) and Section Cost 2 still removed. The result of these calculations should yield a table similar to **Table 3**.

CALCULATIONS						
Cost per mile						
A	$ -	$ -	$ -			
B	$ 18,000	$ 14,000	$ 11,000			
C	$ 98,000	$ 36,000	$ 27,000			
D	$ 98,000	$ 28,000	$ 25,750			
E	$ 116,000	$ 80,000	$ 70,250			
F	$ 104,000	$ 90,000	$ 89,250			
Replace	Damaged	Satisfactory	Repair/Rep			
Cost Per Section						
Replace:	A	B	C	D	E	F
Damaged	$0	$9,000	$49,000	$49,000	$58,000	$52,000
Unsatisfactory	$0	$7,000	$18,000	$14,000	$40,000	$45,000
Replace/Repair	$0	$5,500	$13,500	$12,875	$35,125	$44,625
Conditon of Panels in Section						
	A	B	C	D	E	F
Damaged	0	45	245	245	290	260
Unsatisfactory	0	35	90	70	200	225
Beyond repair	0	15	30	55	135	220

Table 3: *Calculations based on user input.*

After the cost per mile calculations have been completed, it is time for those to be converted into the final output costs. The cost per mile for each condition level and repair method are multiplied by the mileage of each condition put in by the user. This gives a cost of repairing a specific mileage of a condition level based on the repair method used. Those costs are finally added down their columns to provide a total cost for repairing all sidewalks by repair method. This is the final product of this project.

OUTPUT				
Condition Level	**Miles Per Condition**	**Replace Damaged Panels**	**Replace Unsatisfactory Panels**	**Repair/Replace**
A	36	$ -	$ -	$ -
B	90	$ 1,656,000	$ 1,242,000	$ 621,000
C	30	$ 3,036,000	$ 1,104,000	$ 483,000
D	36	$ 3,643,200	$ 828,000	$ 703,800
E	5	$ 598,000	$ 414,000	$ 310,500
F	12	$ 1,214,400	$ 1,048,800	$ 1,048,800
Total Miles:	209			
Total Cost by Improvement Method		$ 10,147,600	$ 4,636,800	$ 3,167,100

Table 4: *Final output of tool*

Conclusions:

With our project we can conclude that two different sidewalks with the same points of damage may not necessarily cost the same to repair. The increase in number of sidewalks in a sample increases the accuracy of the cost calculated. The cost varies by the dimensions entered. The cost of repair and replace increases by increasing the width of a sidewalk. However, the cost goes down with the increase in the length of the slab as the number of slabs per mile goes down.

The cost can also be increased by increasing the number of parameters like cost of labor and time. Our project saves time as compared to traditional methods. Walking a 45-panel section of sidewalk takes about 10-15 minutes. For 6 conditions it might take slightly over an hour to record sufficient data. When done traditionally, someone would have to walk miles of sidewalk for hours.

Budget:

We did not spend any money on this project, so our budget is $0.

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Group Reflection:

Our direction for people who would like to recreate our project would be to fix several aspects. First, would be to contact the people who have expertise in the field and have worked on sidewalks for years. Their guidance can help us determine parameters for our tool based on past experience. Things they had forgotten to consider as a cost. Our tool can also have an error estimation aspect. For cost estimation we could have gotten in touch with city planners, city engineers and contractors. New parameters could include cost variable such as the increase in cost of grinding a sidewalk panel with increase in width per panel.

Going forward in our project we believe we can find ways to make the surveying process even quicker and more accurate by using cameras attached to drones or golf carts to film the sidewalk, getting rid of the need to physically survey it. Attaching infrared scanners or laser measurements to analyze the sidewalk damage and score it can completely automate the process and yield highly accurate results. We believe this tool to be an effective way to estimate costs for repairing sidewalks over a large area and with time and resources can make it even better.

References:

Bennet, B. (n.d.). “Sidewalk Network Inventory and Assessment FOR THE CHAMPAIGN URBANA URBANIZED AREA.”

Burns & McDonnell Engineering Company, Inc. (2011). “Public Sidewalk Inventory Analysis Report .”

Department of Justice. (2010). “2010 ADA Standards for Accessible Design.”

Dillon, L. (2013). “Why Sidewalk Falls Don't Lead to Windfalls.” *Voice of San Diego*[ma1] , <https://www.voiceofsandiego.org/topics/news/why-sidewalk-falls-dont-lead-to-windfalls/> (Nov. 8, 2017).

FWHA. (n.d.). *Starodub, Inc.*, <http://www.starodub.com/ulip.html> (Dec. 15, 2017).

Mendiola, D. (n.d.). “Plastic Sidewalks Save Real Trees In Logan.” *UPR Utah Public Radio*, <http://upr.org/post/plastic-sidewalks-save-real-trees-logan> (Nov. 8, 2017).

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NYSDOT. (n.d.). “SIDEWALK FINANCES .” http://walkbikecny.org/wp-content/uploads/2014/06/SSM_ch6_Sidewalk_Finances.pdf.

Oseguera, J. (n.d.). “Audit of the City’s Sidewalk Repair Process.” *https://www.cityofsacramento.org/-/media/Corporate/Files/Auditor/Audit-Reports/Audit-of-the-Citys-Sidewalk-Repair-Process-Report.pdf?la=en*.

Rajani, B. (2002). “Best Practices for Concrete Sidewalk Construction.” *Construction Technology Update*, 54.