5. Scenarios/Recommendations

In order to create recommendations on spending strategies and setting performance goals, a number of budget-based scenarios were created. These scenarios were designed to address "what-if?" type questions. Each scenario used a set budget and projected the effects on the overall condition of the network. The projections were performed using Deighton Limited's dTIMS BA, for a 15-year period, from 2019 to 2034.

Once all of the data was processed, it was put into a dTIMS model to develop long term performance projections and to run a number of scenarios to determine optimal budgeting and assess the impact of using the recommended standards herein.

5.1. Modelling

dTIMS BA (Deighton's Total Infrastructure Asset Management Software – Business Analytics) is a computer program developed by Deighton Associates Limited for use in storing infrastructure asset data, developing projections of infrastructure asset performance, estimating remaining life in various infrastructure assets, determining when they need to be replaced or repaired, and estimating how much the treatment will cost. It allows for any and all asset data to be entered, there is no limit to what information can be stored within the program and considered during the modelling process. However, the user must manually program how all of the data relates to each other, assign costs, develop the treatment triggers and effects, create funding pools that each treatment will pull from, and develop their own life-cycle curves for the infrastructure assets. Once this is accomplished, dTIMS' primary feature goes to work; it runs a heuristic algorithm (a series of tests using general rules and guessing approaches for determining optimal solutions) to identify an optimal "Strategy" for maintenance and replacement of the infrastructure assets in question, given the budget, treatments, and life-cycle information supplied by the user.

Some manipulation through GIS was required to combine the IPMP data with outside data sources from the City and State before it could be imported into dTIMS. After the data were compiled in GIS, it was imported to dTIMS and the models were run.

5.2. Determining Need

5.2.1. Defining Need

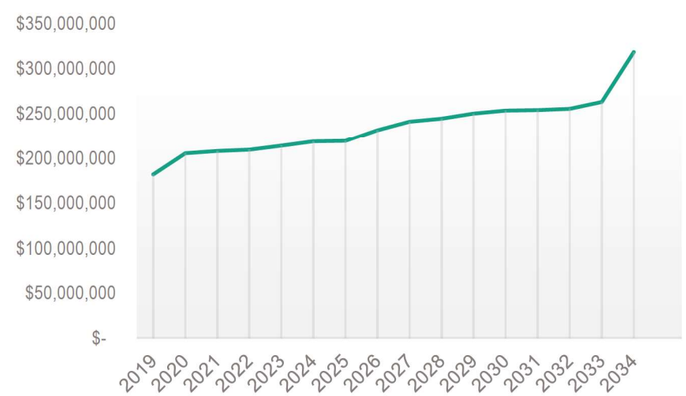
The first step in running various scenarios in dTIMS BA is to determine the "Need." Need is defined as all outstanding work and forthcoming work in the analysis period. Some agencies may consider this as a "Backlog" projection.

Essentially, dTIMS BA analyzes the current conditions and creates condition projections for every management section in the database, after which it chooses the default treatment alternative for each segment, in every year, regardless of budget. This acts as a baseline scenario which could be considered as a Pavement Management Program operating at 100% efficiency with complete funding.

5.2.2. Needs in Waterloo

Using the pavement condition data collected by Pathways and distributed by IPMP, dTIMS BA analyzed the existing conditions of the roadway network in Waterloo, and an overall Need was determined.

The current Need for pavement repairs, the total cost to address every single roadway distress in the City, bringing the network to "Very Good" condition, is approximately $182 Million. That Need is projected to grow to $318 Million by 2034.



Current Need (2019) = $182 Million

Projected Need by 2034 = $318 Million

Figure 48: Projected "Need"

This figure displays the existing funding required to bring every pavement up to "Very Good" condition, i.e. "Need" as well as its projected Growth over the next 15 Years.

5.3. Scenarios

In order to address the existing backlog (Need), the City will need to commit a substantial amount of funding to improve, and possibly just to maintain its roadways. A number of budget options were tested, as to determine a theoretical budget for the City of Waterloo.

Fiscally Constrained, or Budget-based Scenarios take a fixed annual budget and attempt to optimize pavement management spending, on major treatments (see ***Table 3 on page 18***).

The funding comparisons keep all of the proposed work within the assigned budget, while maximizing the "Benefit" provided to the public. Benefit was determined as the difference between the conditions of the road network if nothing was done and the selected treatment effect (measured by difference in CityPCI scores). This method is standard practice when determining optimal treatments. The model used in this plan also factored in the amount of traffic (based on annual average daily traffic or AADT) on the affected roads. The final result represents both the number of people who will receive the benefit of driving on a newly reconstructed road and the magnitude/duration of the improvement. With these constraints of maximizing benefits while adhering to a strict budget the program determined how the overall condition of Waterloo would perform over a 15-year period.

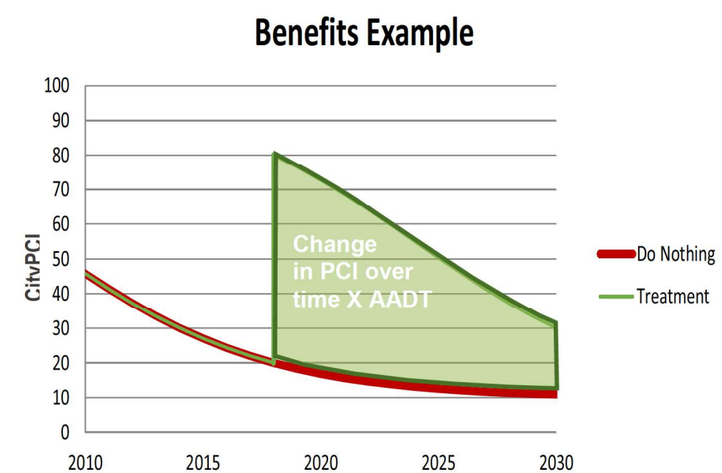


Figure 49: What The Benefits Calculation Looks Like

The red line is the "base-line" scenario, the green area is the "Benefit" the public experiences, calculated as the difference between the base-line and the new improved condition, factored by the number of people who drive on that road (Annual average daily traffic, AADT)

dTIMS BA checks each individual roadway segment to see if it triggers a specific treatment type, then calculates the "Benefit" of performing that treatment. Afterwards dTIMS BA will then compare each treatment option and determine the one that gives the best ratio of benefit to cost. It then goes out further and sees if any treatments would trigger in future years that would give better benefit-cost returns (such as waiting to reconstruct a pavement rather than overlaying it). After comparing all of the initial treatment selections across all of the years, the program also considers subsequent treatments and their effects. Complex dTIMS models might look at dozens of treatments in sequence before picking the best choices, these are called "treatment strategies".

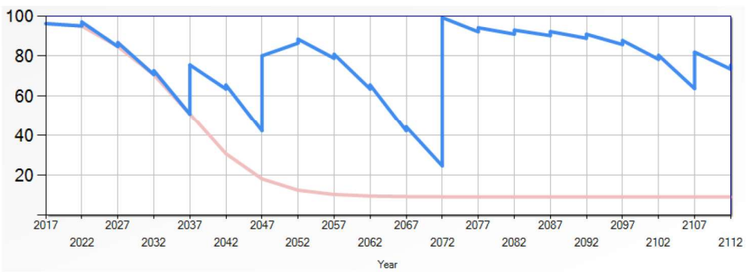


Figure 50: Example of a Treatment Strategy Executed by dTIMS.
The blue line is the effect, pink is what would happen if nothing was done. The jaggedness is from regular maintenance activities, the first peak is a PCC restoration, the second is a crack and seat overlay, the jump in 2072 is a reconstruction, and the final peak is another PCC restoration.

Of course, the best choice of treatment may not always be the one that can be afforded within the City's budget. The program then ranks each treatment strategy based on their benefit-cost ratio and picks those that it can afford, deferring those it can't, and occasionally picking less optimal treatments because it would allow the program to use more of its budget in a timely manner.

The funding scenarios used were designed to hone in results that enable actionable changes in the existing pavement management program in Waterloo. Questions were asked at a high level and the dTIMS BA model was adjusted to address those questions. The results were then interpreted to clarify what the number truly mean.

The funding scenarios performed looked at following questions:

- How does the system perform if funding stays the same?
- What happens if the City does nothing?
- What happens if we increase funding?
- What happens if funding decreases?
- What if funding increases to match inflation?
- What if Seal Coat funds are diverted to other projects?
- What if more budget is assigned to Seal Coat roads?
- How much money to maintain a network average PCI of 70?
- What is the proper distribution of funds across Reconstruction/ Rehabilitation/ Restoration?

5.4. Results

5.4.1. Budget Projections

The City of Waterloo is currently in "Good" condition and it is easier to maintain a network than it is to improve a network. As such, the City is well positioned to keep operations going on a limited budget while still ensuring a high quality of infrastructure.

Since 2014, the City has spent approximately $6.5 Million per year on Reconstruction and Rehabilitation (overlays) treatments alone, and another $900,000 on Seal Coat treatments. There is usually another $1.5 Million in LOST revenue that is spent on city staff salaries and matching funds for state/federal grants, that will not be considered as part of the available funds.

The base budget scenario as such, was $7.5 Million with $900,000 reserved for Seal Coat roads exclusively. The effects of this can be seen in ***Figure 52 on page 67*** as well as ***Figure 53 on page 68.*** The base budget can be seen as the black line. The projections show that it would remain relatively steady for the next 7 or so years, at that point it begins to drop off slowly. This is most likely due to the large volume of "Fair" pavements in the 16 to 20-years old range that will need addressing in a short period of time, as well as the general effects of inflation. A reduced budget will likely not be feasible at all, as such. Tests showed that dropping below $6 Million per year of funding for capital improvements would cause the City to drop into steady decline.

The "Do Nothing" scenario option points out the value the LOST funding, network condition would quickly drop out of "Good" in less than 15 years without it. It also shows the general trend the City can expect. The line shows that pavement deterioration, in Waterloo, is accelerating already; the line begins its turn downward immediately when treatments stop being applied.

As for increasing the budget, options were explored ranging from $6.5 Million all the way up to $12 Million annual funding, with half-million dollar intervals. ***Figure 52 on page 67*** shows only the scenarios based on million dollar increments. The results show very marginal improvements in the first 5 years. It takes an additional $2 Million per year just to raise the network CityPCI by 1 point by 2024. It takes a total of $10.5 Million ($4M increase) per year to increase the condition by 2 points. Looking slightly further out reveals that the accelerating need and growing construction costs, based on inflation, impact every budget. Only the scenarios over $9.5 Million can hold steady with PCI and Backlog; every budget below that point will end up dropping below 70/100 by 2034 and increase the backlog compared to today.

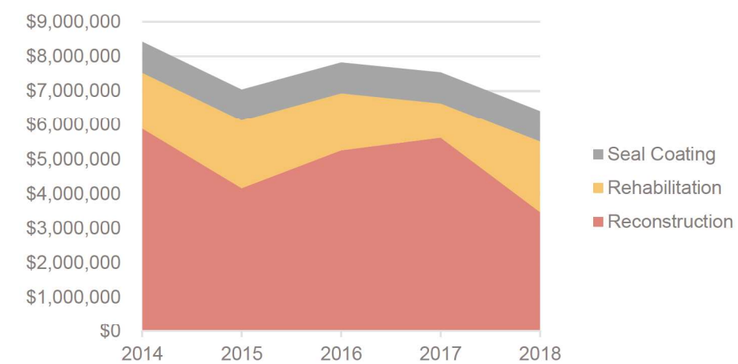
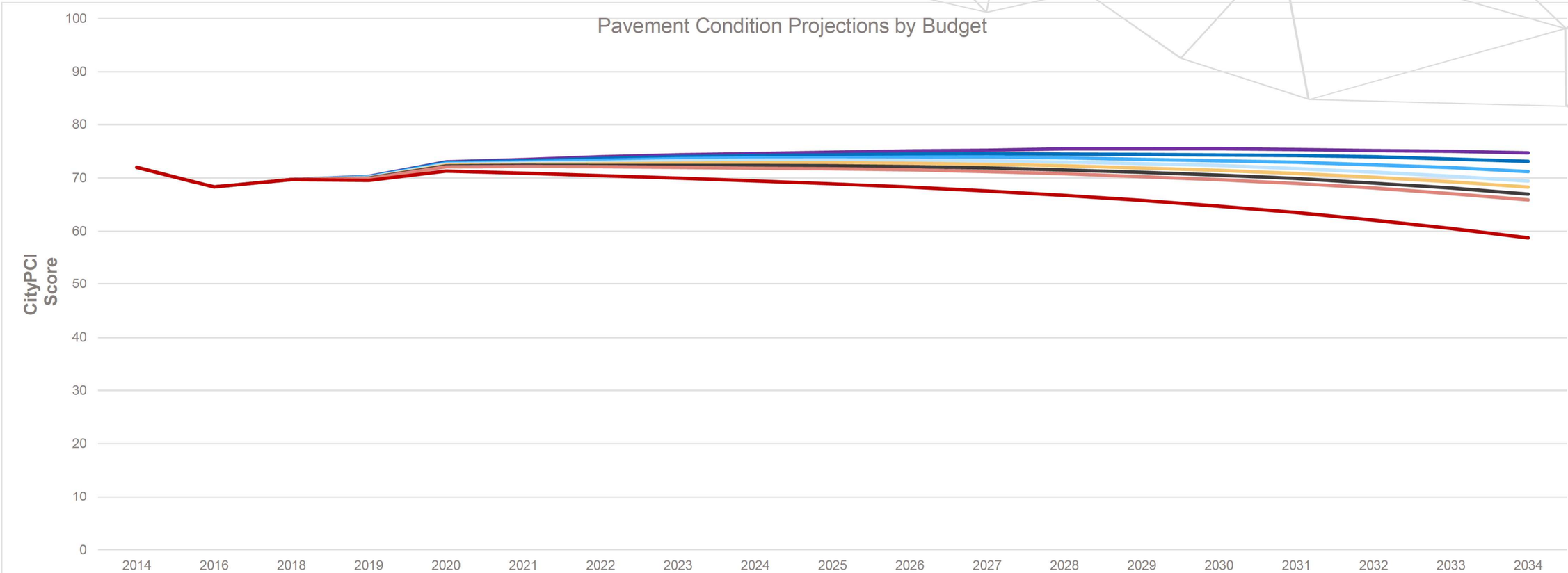


Figure 51: Historical Pavement Management Expenditures
This graph displays the historical pavement management expenditures for the City since 2014.

Table 16: Historical Summary of Annual Roadway Improvements by Miles Resurfaced

Year	Reconstruction	Overlay	Seal Coat	Total Miles
2014	3.15	3.04	9.17	**15.36**
2015	1.59	5.52	13.11	**20.22**
2016	2.61	2.23	10.30	**15.14**
2017	3.35	0.64	10.40	**14.39**
2018	3.52	1.91	10.79	**16.22**
5-Year Total	**14.22**	**13.34**	**53.77**	**81.33**



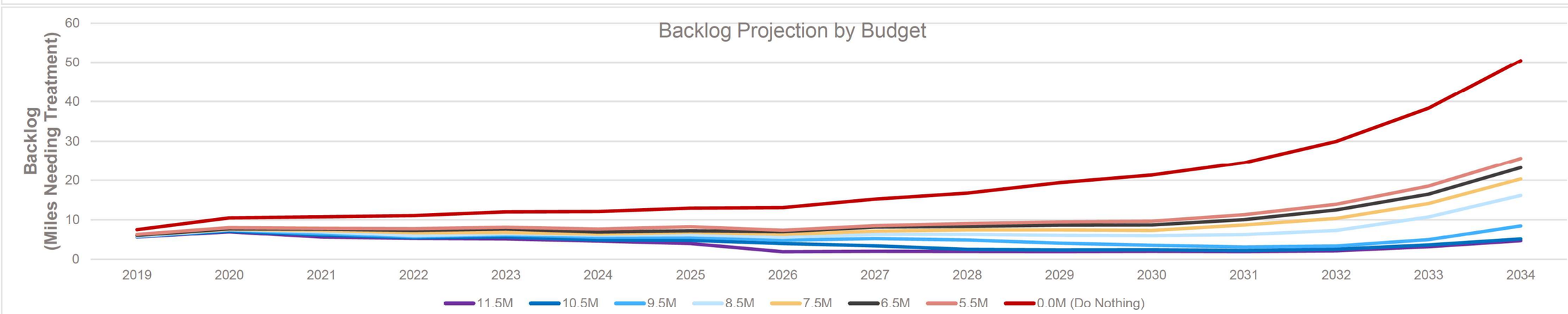


Figure 52: CityPCI and Backlog Projections by Budget

The results of the dTIMS BA modelling. These graphs represent the effects of adopting various budget and what happens over the next 15 years. Changes to the network level Pavement Condition Index is on top and the bottom represents the miles of road that will need to be deferred for future treatment

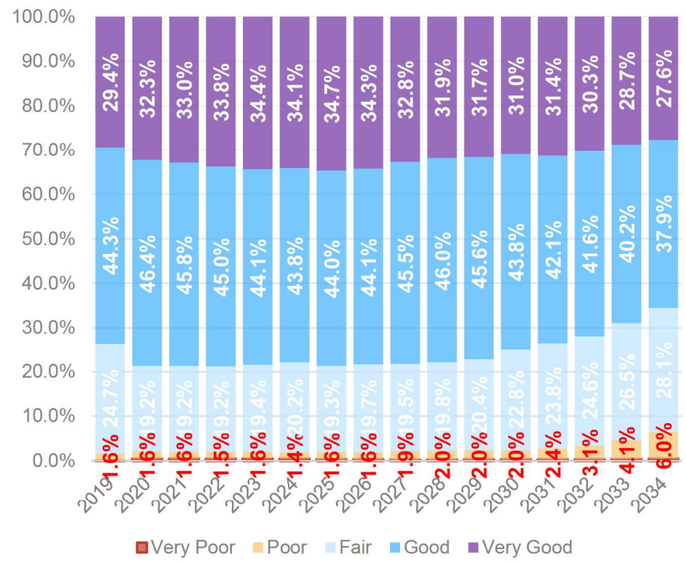


Figure 53: Condition Distribution Projection – Base Budget ($6.5M)

This graph is from the dTIMS BA results for continuing the current budget over the next 15 years. Each bar represents the proportion of the network in one of the five condition categories.

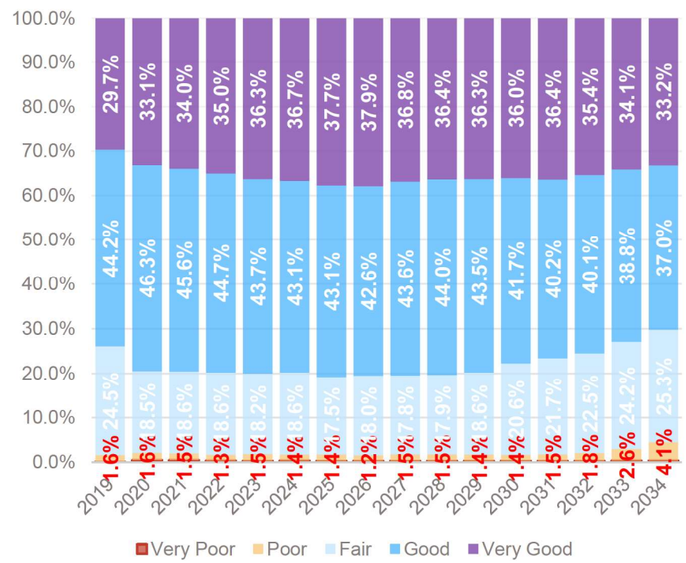


Figure 54: Condition Distribution Projection – Increased Budget ($8.5M)

This graph is from the dTIMS BA results for increasing the budget by $2 Million over the next 15 years. Compared to the Base Budget the difference is incredibly minor.

Of course, an immediate funding increase of $3 million per year is quite unreasonable, and improvement is not the goal. Based on the current "Good" condition of Waterloo's streets, maintenance should be the goal. As such, increases to funding are not critically needed until around 7 years out (2026), giving the city time to strategize or slowly ramp up.

One scenario was tested where funding grew organically with inflation, which is very possible through a LOST. The funding started at 6.5 Million and increased by 3% every year, ending at $10.1 Million in 2034. Unfortunately, this growth only matches the projected increases in construction costs, but not the accelerating deterioration. This organic growth keeps the network in the "Good" regime, but is too slow to stay ahead of the deterioration curve.

Based on these results, if Waterloo wishes to maintain their current level of pavement quality a larger increase in funding within the next 5-7 years will be needed. Looking at a 15-year time horizon, inflation alone makes most budget levels unsustainable. That far out, only an increase of $5 Million or more will keep the network near its relatively high 70/100 CityPCI level. The City may want to consider allowing that CityPCI goal to slip down to 65/100 or even 60/100.

There is always the option of bond financing 2 years of construction near 2026 to quickly deal with the rapidly deteriorating roads and then paying debt service for a number of years afterwards. This scenario performed nearly equivalent to the $12 Million per year option, but it is a more drastic option requiring a very large bonding authorization (>$80 Million).

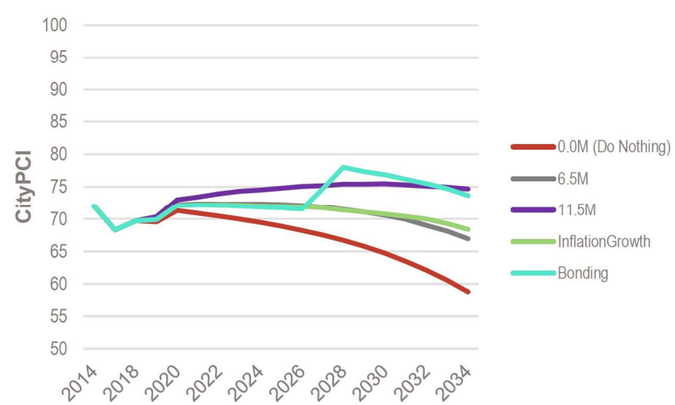


Figure 55: Effects of Alternate Funding Scenarios

These trends are the dTIMS BA results for the funding scenarios related to inflation or bonding.

Figure 56: Example of Arterial Target Condition (70/100)

This image from the 2018 data collection was taken on Rainbow Drive between Niagra and Hackett. Ideally, all other arterial class roads would be at this condition level or higher.

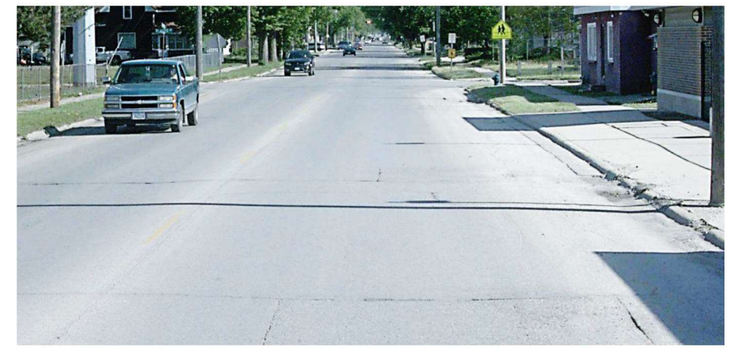


Figure 57: Example of Collector Target Condition (65/100)

This image from the 2018 data collection was taken on 4th Street East, between Adams and Webster. Ideally, all other collector class streets would be at this condition level or higher.

Figure 58: Example of Local Target Condition (60/100)

This image from the 2018 data collection was taken on Blackhawk Road, between Paul and Falls Ave. Ideally, all other local class streets would be at this condition level or higher.

5.4.2. Ideal Budget Proportions

When looking at the types of treatments applied there is an optimal balance, unique to each city. Too much reconstruction can eat up your budget quickly and not leave anything to maintain older pavements, meaning more early failures. Too much rehabilitation means you maintain the ideal candidates really well, but end up ignore the "lost-causes" for extended periods while you try to carve out funds for reconstruction every once in a while. Both cases can result in a lopsided distribution of pavement conditions that is heavy on the two extremes.

Historically, the City has maintained around a 66% Reconstruction to 34% Rehabilitation funding split, and that has worked very well for Waterloo. Research performed by HR Green has indicated that cities in Iowa tend to perform best with 60/40 split or 55/35 with the remaining 10% focused on restoration treatments like crack sealing and patching. Not every city has the capabilities for such large programs, however.

The dTIMS BA model when developing the recommended construction program for Waterloo provided 2 majorly different recommendations regarding funding split. The results depended mostly on the use of the "Failure" distress, which is coded inconsistently. When ignoring failure, the program leaned heavily on Mill and Overlay treatments, which are fantastic to use on HMA and COM pavements to restore the surfaces.

When avoiding pavements that have been identified as having high amounts of failure distresses, or increasing the unit cost of the Mill and Overlay treatment to account for addressing these failures, the shift is very pronounced; almost all of the Mill and Overlay budget goes to Reconstruction reaching an outrageous 80/20 ratio and performing quite poorly. In these cases, where failures are an issue, it is a delicate balance. The only thing that can really separate what makes a good Mill and Overlay candidate from a road where Reconstruction is the only option, is good engineering judgement.

Failures are a significant issue that shouldn't be ignored, but the reality is likely that many of these distresses should not be classified as true failures. Since the truly optimal choice is somewhere between the two extremes, HRG still recommends maintaining a ratio around 60% Reconstruction funds to 40% Rehabilitation funds.

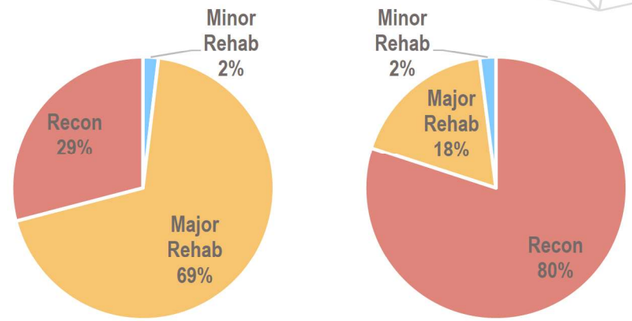


Figure 59: dTIMS BA Recommended Budget Proportions
This figure shows the two very different results returned by dTIMS BA. The left ignores failure distresses, the right accounts for those failures as a treatment selection criterion. Ideally the City would be between these two options.

5.4.3. Seal Coat Budgeting

The City indicated that they have budgeted exactly $900,000 each year, over the past five (5) years, to perform chip sealing activities. The seal-coating is done by city personnel and equipment, though they occasionally have used contractors to perform the work.

Each year, that $900,000 pays for the chip sealing of 12-13 miles of roads. Since there are approximately 65 miles of seal coat streets, this puts the city at slightly better than a 5-year rotation on seal-coating every street. The rotation often aligns with the various ward boundaries, as such.

Chip seal treatments, however, according to several sources (ASTM, SUDAS, FHWA…etc) extend pavement lives as much as 7 years, with some estimating it all the way out to 10! This might mean that the city could consider performing less seal coating and moving that money towards rehabilitation of its other streets. The saved money could also be banked towards eventual replacement of some existing seal coat streets using traditional PCC or HMA pavement.

HRG does not recommend assuming the 10-year life. Some more conservative sources, such as Johnson's Pavement Maintenance Handbook, only estimate 4-6 years for seal coating. The instability of soils in the Upper-Midwest due to freeze thaw cycles, impacts from heavy rains, and occurrence of "clay-heave" in certain areas means that seal coat roads cannot be expected to last overly long and need to be watched closely for unexpected failures.

Instead, a modest budget of $650,000 likely could pay for renewing one-seventh of the seal coat streets in the City, for a given year. This budget would also have enough extra to account for full-depth base repairs, milling as needed, as well as any unexpected seal coat failures on streets not in the annual list.

A 7-year rotation could certainly save the city money; as little benefit is gained by chip sealing more frequently. Projects would be chosen based on an annual inspection and rating rather than rotating by ward.

One caution about this reduction in seal coat budget is that the City will need to be mindful of the effects of inflation on construction costs and labor (which is one of the largest budget items for in-house work). In 5-10 years' time $650,000 will not buy nearly as much rehabilitation work. Because of this, budgeting a fixed amount is probably not sustainable. Instead the city focus on a mileage goal, probably 9 miles, rather than a specific dollar amount. Maintaining a flexible budget, will help prevent shortages in the fiscal year causing overall quality to slip. This is especially true if construction costs and labor continue to increase. Either the city can over-budget and save for the future or be ready to increase seal coat funding at the same time they are investigating funding solutions for maintaining the rest of network as well.

According to the dTIMS BA model, even $900,000 is not a sustainable budget, long-term. So the goal is not about the money spent, but so that the City can stay ahead of the expiration-rate of its seal coat surfaces. Waterloo will need to annually reassess the real estimated costs of keeping up at least a 9-mile per year program, if not the existing 12 to 13-mile annual seal coat renewal program.

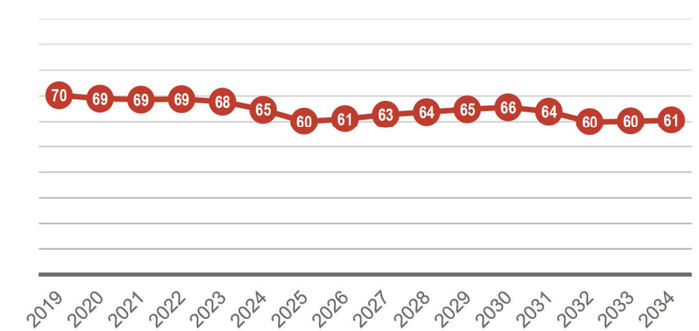


Figure 60: Projected Effects of $900,000 Seal Coat Budget
The dTIMS BA results show that the existing $900,000 is more than sufficient for now, but eventually falls short in the next 10 years or so due to inflation.

5.5. Funding

While the current City LOST budget has historically allowed Waterloo's streets to perform exceptionally well, changes in the future will likely be required. Starting in 2026, the annual funding need will begin to outpace the current spending patterns.

The gross revenue from the local-option sales-tax has grown approximately $200,000 per year, on average, since 1992. That equates to an annual increase of 2.8%. Revenue growth has begun to slow, however, beginning in 2008 and roadway improvement spending has remained relatively static over the past 5 years.

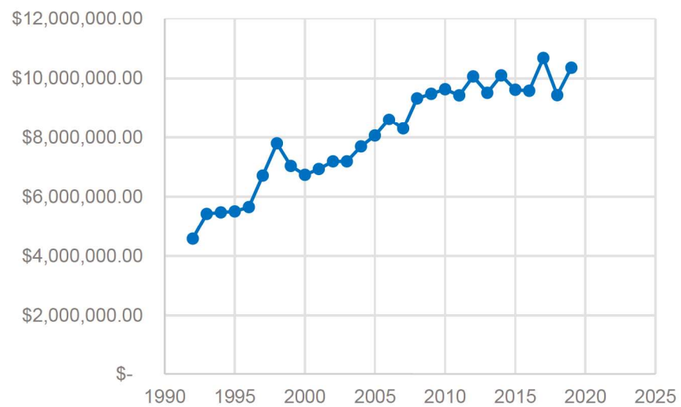


Figure 61: Revenue Growth of LOST Since 1992
This graph shows the steady growth of gross receipts for the local option sales tax since it was created in 1992.

The average revenue growth since 1992, does seem like a substantial increase to the available LOST funds, $200,000 is a large sum. When looking at inflation rates, though, we can see that the average growth rate is falling behind inflation. Federal guidance for financial projections advise local agencies to assume inflation rates of 3.0% to 3.5%.

The result is that overall need is growing but the LOST funding is not growing to match. In fact, the expected purchasing power of this funding source is expected to shrink because it growing slower than the inflation rate

To prevent a decline in network-wide condition over the next 15 years, it will require either a $3 Million increase in annual expenditures or a one-time infusion of money, approximately $60 Million, most likely through bonding.

As for seal coat activities, a reduction in annual expenditures is possible in the near term. Nearly $250,000 could be diverted by reducing the frequency of scheduled seal coat renewal to 7 years from 5 years. That would only be temporary, however, as the effects of inflation would raise the annual construction costs back up to $900,000, same as the current allocation, in around 10 years. As such, it may not be worth the effort to change the allocation method and the excess funds could be reserved to defray future seal coating expenditures.

5.6. Performance Metrics and Goal Setting

Pavement Management Programs are ongoing processes. Adopting a plan and analyzing potential budgets are not enough. They need to be actionable and have clear, measurable performance goals.

The first steps in moving forward are to approve the findings of this pavement management plan, identify a funding strategy, and then develop an objective, data-driven Capital Improvement Plan. The Capital Improvement Plan will assist decision makers in determining the most cost-effective actions are to use the funding they have available to improve or maintain conditions in Waterloo.

With the Scenario results in mind, Waterloo needs to set some measurable performance goals for the near future, that will be addressed by said Capital Improvement Program. This allows a City to track its performance, ensuring that it remains on track and is actually effective.

5.6.1. Recommended Performance Metrics

- Maintain an ideal Reconstruction split of around 60%
- Determine an Increased Funding Strategy to be put in place by 2026
- Maintain Overall Network CityPCI at or around 70/100
- Perform at least 9 miles of seal coating each year
- Maintain target average conditions for each functional class of 70/100 for arterials, 65/100 for Collectors, and 60/100 for Local streets.

5.6.2. "Living Documents"

Another important part of this performance tracking and goal-setting is to renew this plan as physical, fiscal, and political conditions change. HRG recommends that Pavement Management Plans act as "Living Documents" that grow with cities and adapt to their needs by regular updates and changes. By default, for most agencies this will mean renewing the plan every 2-4 years, complete with new pavement condition data.

5.6.3. Recommended Goals

1) Provide better coordination between the Engineering Department and Public Works Department for maintenance activities.
2) Allow for better coordination between the Public Works Department and the Engineering Department for streets that are deteriorating faster than expected, based on repetitive maintenance, and provide a mechanism to adjust rehabilitation priorities accordingly.
3) Determine what routine maintenance items can be completed in-house, collaboratively with Public Works and Engineering, and determine which activities would need to be contracted.
4) Review current budget to determine what if any additional funding is required to maintain current rating of City streets or if additional funding will be necessary.
5) Assess if maintaining the overall condition at a 70 is realistic or allowing the overall condition to "slip" a couple of points allows for better use of LOST funding.
6) Identify appropriate condition thresholds for Arterial, Collector and Local streets and trigger points for different types of rehabilitation.
7) Update plan including new condition data every two years beginning in 2021.
8) Plan Update including new condition data and revised funding strategy (2025)
9) Council approves new funding strategy (2026)

6. Capital Improvement Plan

The Capital Improvement Plan (CIP) is a list of recommended projects for Waterloo to complete over the next 7 years. This list of projects was generated using the results of the dTIMS BA model, as well as several other factors, including the sewer separation mandate. The project list is optimized for the most effective use of available funds, based on the pavement condition data and planning-level information provided by the City.

The complete list of recommended projects and maps identifying the location for the proposed treatments can be found in ***Appendix A: Capital Improvement Plan starting on page 72.*** Projects are sorted into three phases, Phase 1 (2020-2022), Phase 2 (2023-2024), and Phase 3 (2025-2026).

These lists and maps will serve as a tool to assist City staff during the project planning process, but they do not replace engineering judgement. Project types may change from what is in the CIP and projects will likely move between phases for various reasons. Some projects may even leave the plan entirely as new ones are added. Some reasons the program may change include field conditions not captured by the IPMP data, required utility improvements, or environmental hazards causing changes to local conditions.

Consisting of ***151 Projects***, the recommended projects contained within the CIP will address nearly ***32 Miles*** of roads. The majority of which will actually be on local streets; primarily because the Arterial/Collector streets are generally in good condition while Local streets make up the majority of the network.

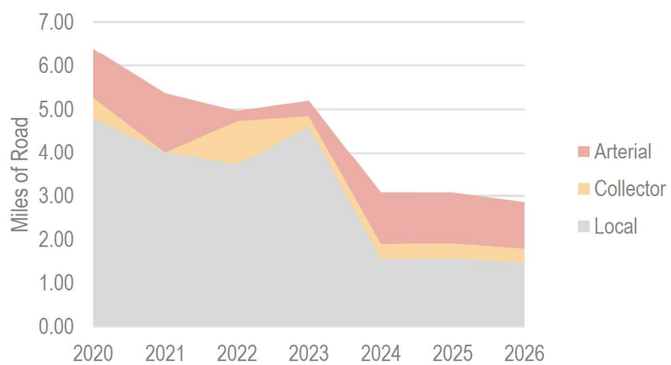


Figure 62: Treatment Distribution by Functional Class Over Time
This area graph shows the treatment distribution for each year of the CIP.

The number of miles addressed each year by the CIP, on average, is expected to decline somewhat over time, however. This is due to to the increase of recommended Reconstruction projects over the 7-year period. Reconstruction expenditures in the CIP start low in Phase 1, averaging $1.5 Million per year, but they rise to near $5 Million, per year, by Phase 3. Since Reconstruction costs substantially more than other treatment types, this results in fewer miles of roads that can be improved in later years.

That decline in project mileage is intentional, however. Starting in Phase 2, many of the pavements currently rated as "Fair" will begin falling into "Poor" condition and a number sewer separation projects are expected to come up. In order to address these streets Reconstruction activities needed to increase. This also allowed the proportion of Reconstruction and Rehabilitation treatments costs, in the CIP, to come closer to the recommended ratio of 60% Reconstruction to 40% Rehabilitation.

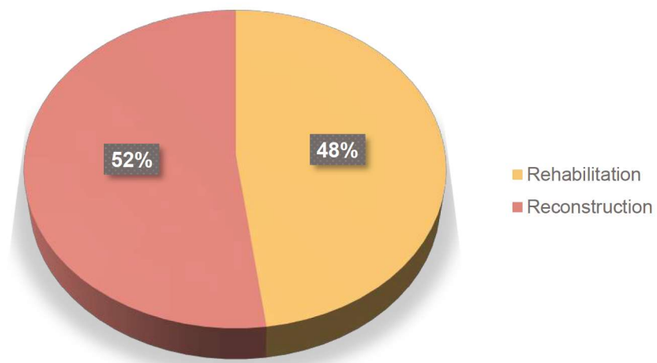


Figure 63: Treatment Type Proportion for Recommended CIP
This pie chart shows the relative proportion of reconstruction to rehabilitation activities recommended in the CIP.

7. Keep in Touch!

The City of Waterloo wants to remain engaged with its citizens as part of the pavement management program over the next 7 years!

If you have comments on this publication, wish to provide input for future plan updates, or want to inquire about upcoming construction projects, there are a number of means by which people may contact the City.

You can find out more on the City's website, where there is a dedicated pavement management page, or can engage them on social media:

City of Waterloo Website:

http://www.cityofwaterlooiowa.com/departments/street_department/pavement_management.php

Facebook: https://www.facebook.com/WaterlooIACityHall/

Twitter: https://twitter.com/waterlooiowa or @WaterlooIowa