3.3. dTIMS Business Analytics (PMS)

A Pavement Management Software (PMS) is a decision-making tool that assists a City in making cost-effective decisions related to the maintenance and rehabilitation of roadway pavements. It provides a process or system for rating pavement condition, establishing a consistent maintenance and repair schedule, and evaluating the effectiveness of maintenance treatment strategies.

The PMS used by the City of Waterloo is called "Deighton Total Infrastructure Management System: Business Analytics" or dTIMS BA. This software was developed by Deighton Limited as an asset management software capable of storing all sorts of physical infrastructure assets and specializes in how it uses heuristic algorithms to optimize spending patterns.

dTIMS® Business Analytics

Each road is separated into pavement management sections, typically broken up by city block or by other physical features like bridges and railroads. Segments are associated to the road as a whole using a "Linear Reference System" where each segment would appear in sequence based on its distance from the start of the road. The pavement distress data, including the CityPCI ratings, are then imported into the web-based software and were used to develop a customized pavement management model for the City of Waterloo.

The dTIMS BA model is a collection of the raw distress data, equations, variables, and rules for treatment applications as well as their effects. One of the most important equations used are the performance curves which dictate the behavior of pavements over time.

3.4. Performance Curves

Different types of pavement behave differently, and different classes of road have different stressors. To accommodate these factors, a pavement life cycle curve was developed for asphalt and concrete pavement types. separated further by the type of road, either Arterial or Local/Residential.

These curves were calibrated to follow the general assumption that a pavement reaches "Fair" condition at 75% of its design life and "Very Poor" condition at the end of its design life. These curves do not necessarily represent the traditional design life-cycle curve; instead they address the performance of the pavement and how much longer we can realistically expect it to last without having to determine the structural characteristics and history for every street in the City.

Each pavement management section has an effective "performance age" that determines its behavior. This performance age is determined based on previous data collections. Using that data, a rate of deterioration can be determined for each street individually and then fit to the appropriate family curve. The CityPCI rating is then projected along the curve and tested to see if various treatments would be appropriate at each point along the individual performance curve.

Other curves were similarly created for specific distresses, such as Alligator Cracking, Spalling/D-Cracking, and Rutting. These distresses progress in predictable ways and occasionally preclude certain types of treatments from being applied. For example, a street with severe rutting (> 0.5") would not be a good candidate for a slurry seal or thin overlay. Conversely, if these distresses progress past a certain allowable threshold, more expensive treatments, like reconstruction, will be selected as the only reasonable option even if the CityPCI would not necessarily indicate that on its own.

Figure 23: dTIMS BA Interface
The dTIMS BA software is accessed through normal computer browsers and operates over cloud-based technology. Calculations are performed on remote servers, meaning any computer can use it, regardless of hardware capabilities!

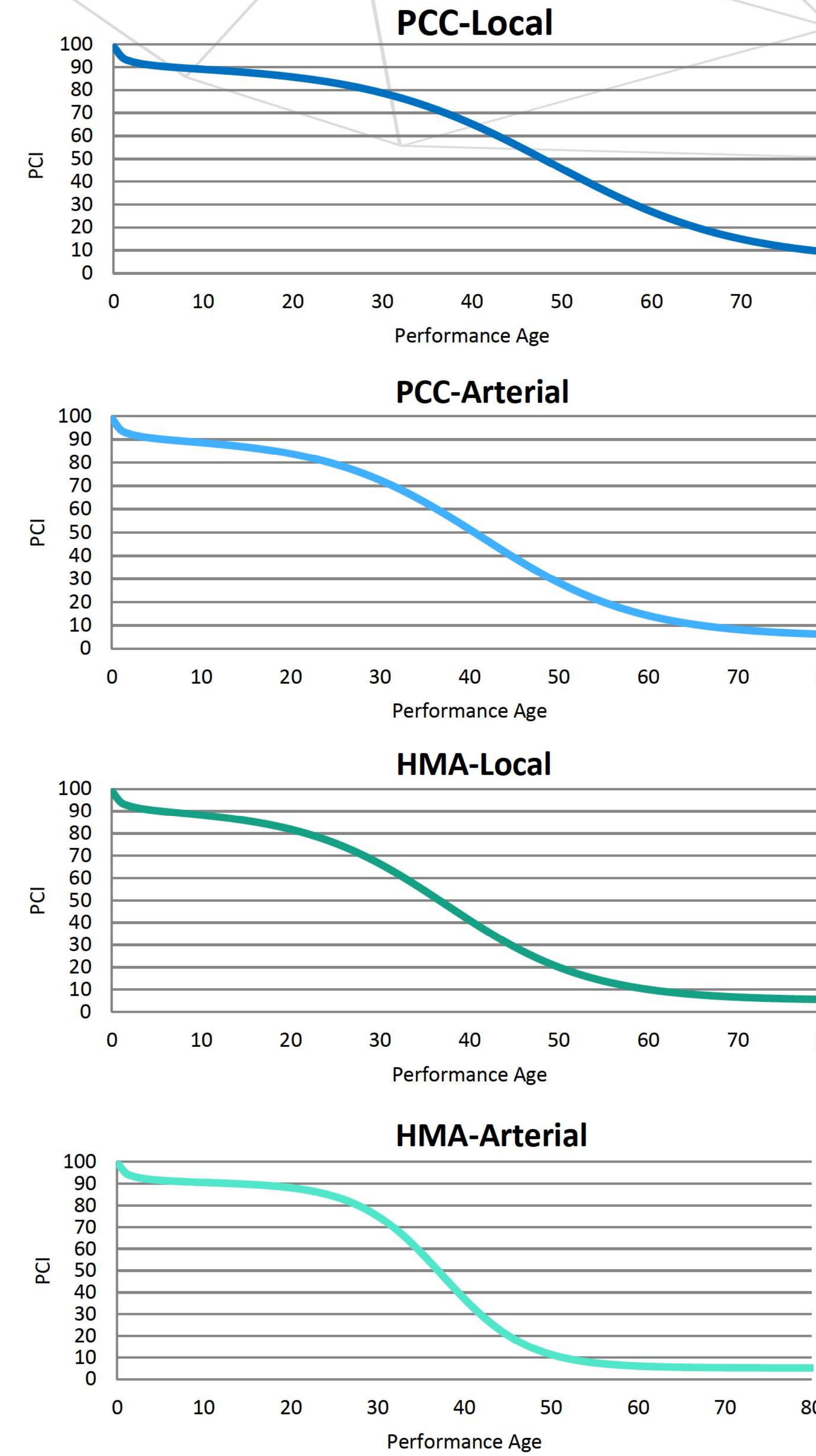

Figure 24: Pavement Performance Curves
These 4 curves are the pavement performance curves utilized in the Waterloo dTIMS BA model.

3.5. Treatment Alternatives

> ***"The success of a pavement-preservation program is based on selecting the right treatment for the right pavement at the right time" (FHWA).***

A single pavement treatment, when properly applied, can extend the life of a roadway by as much 15 years. Before a decision on when and where a treatment can be applied, an agency must know what treatments it will consider. Dozens of potential products and techniques are available; however, not all treatment options are feasible, affordable, or effective. Climate, cost, and capability considerations must be made ahead of time.

The group of treatments available for a given municipality can be thought of as a "toolbox" filled with options appropriate for the tasks they would expect to encounter. The toolbox recommended for the **City of Waterloo** consists of three primary types of treatments often referred to as the 3 R's of Pavement Management: **Reconstruction**, **Rehabilitation**, and **Restoration**.

Every pavement will eventually deteriorate to a point that it cannot effectively be repaired in an economical fashion leaving reconstruction as the only viable option. Reconstructing a road from the base up is always an appropriate and effective treatment but it is also typically the most expensive solution. As such, rehabilitation fills an important role in a pavement's life-cycle.

Rehabilitation treatments usually cost significantly less than full reconstruction and can extend a pavement's life substantially. Rehabilitation treatments in this section are split into major and minor variations. The former provides structural improvements to help a deteriorated pavement recover whereas the latter provide relatively smaller improvements and are typically more preventative in nature.

Restoration treatments, sometimes referred to as "preservation" or "maintenance", are those applied regularly to prevent issues from developing or to prevent existing problems from spreading.

Construction standards and specifications for the following treatment alternatives should follow the Iowa ***Statewide Urban Design and Specification (SUDAS)*** manual, where applicable. These research-backed approaches to construction and pavement management techniques will extend pavement life beyond traditional methods. Often costing more, the increased performance life still makes it the cost-efficient and sustainable approach, long-term.

3.5.1. Reconstruction

- Reconstruction

Reconstruction of pavements is often the only way to save a deteriorated roadway. Unfortunately, these needs usually outstrip available funding. This treatment type should be reserved for pavements that cannot be salvaged through rehabilitation or on high-profile corridors where safety and capacity needs are paramount.

When Reconstructing a pavement, the City can use any material they wish. Most commonly for Waterloo, Full-depth HMA is used because it often receives cheaper bid prices from contractors. However, full-depth PCC, or a composite pavement of PCC with an HMA overlay, may be considered when design constraints warrant. To provide for this option the City uses "bid-alternates" where contractors can choose which structure to use and bid based on the equivalent design of their choice.

Figure 25: Reconstruction of I-94 (NDDOT)
This photo shows the Construction of a brand new asphalt cement concrete pavement

Figure 26: Reconstruction of Michelmore Street (Bidgee)
This photo shows a road torn out and being prepared for reconstruction

3.5.2. Major Rehabilitation

- Thick Overlay
- Mill and Overlay
- Crack and Seat

There are few substitutes for adding new concrete on top of old to help keep it functioning and healthy. HMA is the most commonly-applied material (black-topping) but PCC (white-topping) is gaining acceptance in Iowa and is being applied in many locations as appropriate. HR Green recommends the use of HMA by default but also encourage the exploration of white-topping as a secondary option where conditions allow and costs are comparable.

Major rehabilitations suggested herein are all variants of overlays where moderately-thick layers of HMA are placed upon existing pavements, sometimes with special preparations. A minimum of 3 inches of HMA is preferable for each treatment as any less will not provide significant structural benefit. Overlays exceeding that amount are commonly referred to as a ***"Thick Overlay."*** Note, however, that amounts greater than 3 inches can become costly and sometimes may cause logistical difficulties. Overly-thick HMA overlays can affect side street elevations, drainage patterns, driveways, and fill up curbs leaving little remaining to control storm water and delineate the edge of the roadway. A thick overlay is the most common rehab used in most agencies and, for the purposes of this report, is recommended to be placed at the end of a pavement's life.

Figure 27: HMA Overlay Placed On Milled Pavement (Famartin)
This is a picture of an asphalt overlay placed on I-80 through Elko, Nevada after part of the original pavement was milled off.

When dealing with a full-depth HMA pavement, or one overlaid previously, milling off 2-3 inches of the top can provide significant benefits. It can help smooth the underlying pavement for the final surface, remove harmful defects, help create a more stable bond between pavements, and prevent the overlay from causing the referenced logistical difficulties with side streets, drainage, driveways, and curbs. ***"Mill and Overlay"*** treatments are important in keeping a pavement going strong. Once the first thick overlay is placed, it should be milled off approximately every 15 years and replaced to keep the surface from deteriorating too far.

One other major rehab treatment to consider on fairly stable and older PCC roads is called a ***"Crack and Seat Overlay."*** This prepares an existing roadway as a suitable base for what is effectively a new HMA pavement on top of it. The PCC is cracked using a drop-hammer apparatus, or other devices, to create a flexible base of concrete before placing 3 or more inches of HMA on top of it. This process may require the reconstruction of curbs if the depth of asphalt to be placed would be problematic; however, a milled edge notch may be utilized in some cases to eliminate the need for curb replacement. The new crack and seat pavement is typically a long-lived rehabilitation treatment as it is effectively a new road altogether.

Other major rehabilitations, such as hot-in-place recycling and cold-in-place recycling, were considered but are not recommended for use in Waterloo due to their limited applications in urban environments and the City's limited asphalt roadways. The equipment required to perform these do not leave much flexibility in staging or timing. Even if it were feasible, it would likely be excessively disruptive to local traffic patterns.

Figure 28: Cold Milling Machine (Anthony Neff)
Cold Milling Machines like the Caterpillar PM 622 above are used to strip off the top layer of pavement. Those millings could then be used for in-place recycling, or the pavement could receive a new 3" overlay.

3.5.3. Minor Rehabilitation

- Slurry Seal
- Thin Overlay
- Microsurfacing
- Bituminous Seal Coat (Chip Seal)
- Cape Seal
- PCC Restoration
- Diamond Grinding

Minor Rehabilitations fill a different role than the aforementioned Major Rehabilitations. They usually are placed to prevent moisture and seasonal weather effects like rain and heat from causing too much damage. They will seal the pavement from water and provide a new "wearing surface" for cars to drive on instead of damaging the underlying pavement.

Slurry seals are one of the most common surface treatment used in the United States, though still somewhat rare in more northern climates. It is effective at sealing low-severity cracks, waterproofing the pavement, and restoring friction to surface for increased driver safety. Slurry seals also address raveling, oxidation, and hardening of asphalt. This treatment consists of a mixture of crushed, well-graded aggregate, mineral filler, and asphalt emulsion that is spread across the full width of the pavement, or used as a strip treatment for targeted treatment of low distress areas and cracks. The thickness of the seal coat is generally less than 1/2 inch, but it can still extend a pavement's life up to 7 years, when applied at the right time. However, the low amount of aggregate means it will not be effective at addressing anything beyond superficial distresses.

Thin Overlays are essentially the same treatment as a Thick Overlay; except they are approximately 1 ½ inches of HMA, instead of 3+ inches used for Thick Overlays. 1 ½ inches is the recommended thickness for Thin Overlay because, if it was thinner, it may be susceptible to cracking or rutting very quickly due to vehicle loads. Thin Overlays are also not appropriate on roadways with significant deformities like severe rutting and structural distresses, such as severe alligator cracking or warping, but they do have more broad uses than slurry seals. It is also common to see the use of recycled asphalt and rubber materials in Thin Overlays which can reduce costs and possibly increase durability.

Microsurfacing, on the other hand, consists of a thin application like a slurry seal but uses a polymerized binder with finer aggregate. It can smooth over minor deformities while still adding a small amount of structural durability. It also creates that same seal against water and wear that Minor Rehabilitations need. It is a versatile and relatively cheap treatment that can address a wide variety of distresses, even load-based ones. A relatively new technique, it is not very common in the state of Iowa, yet. However, the City of Des Moines has recently invested heavily into this treatment method and begun incorporating it into their regular pavement management practices.

Figure 29: Slurry Seal Being Placed by Hand (Miraflores)
This slurry seal is being placed to refresh the surface of the Villeno Rey Bridge in Miraflores, Peru.

Figure 30: Microsurfacing Crew at Work. (Eric Pulley).
This is picture shows a crew using a Microsurfacing machine to lay a new surface on this street.

Figure 31: Close-up View of Chip Seal Surface
This close-up picture of a road that has been chip seal shows how coarse the application is and how aggregates tend to be more loose on top of the new surface compared to other treatments that evenly mix the aggregate into the binder.

Bituminous Seal Coats, also known as ***Chip Seals***, are effective treatments for improving surface friction, inhibiting raveling, correcting minor roughness and bleeding, and sealing the pavement surface from moisture. Bituminous Seal Coats are also used to address longitudinal, transverse, and block cracking, as well as for sealing medium severity fatigue cracks. Chip Seals can even be applied in multiple layers to address more serious problems. The application of a Chip Seal consists of an asphalt emulsion that is applied directly to the pavement surface and is followed by the laying of aggregate "chips" on top of the emulsion. Those chips are then immediately rolled into the emulsion in order to embed them. It is a cost-effective and versatile treatment but, unfortunately, often is not recommended for urban applications due to a number of perception issues. The large amounts of loose aggregate chips that fail to bond are often kicked up or tracked elsewhere by vehicles, and since the binder tends to bleed in the few days after application, vehicles tend to leave blackened tracks on neighboring streets.

Cape Seals somewhat solve the issue of Chip Seals by using the same basic technique but then finishing it with a Slurry Seal or a layer of Microsurfacing over the top. This additional seal coat locks in the loose aggregate chips and inhibits the binder bleeding. This approach has many of the same benefits as a Thin Overlay and comes at a somewhat comparable cost.

PCC Restoration is a holistic repair to a PCC construction street, including any or all of the following actions: panel replacement, profiling, repairing utility cuts, full depth patching, and joint repair. PCC Restoration is more than simply pavement patching, it is strategic repair to existing deficiencies and can help save an otherwise stable road. A typical application removes and replaces 10%-20% of the existing pavement, to address specific localized issues. This type of repair could be performed by either internal city forces or as part of larger contracts for outside contractors.

Diamond Grinding is not a commonly applicable treatment, but due to its low cost should be considered when the conditions are ripe. Diamond Grinding is best used when a weathered pavement is beginning to show signs of aggregate polishing to add texture back to it for cars, or when settling early on in a pavement's life caused minor faulting. Diamond Grinding can smooth those faults and leave an otherwise stable pavement intact with its ride significantly improved. It would not, however, be appropriate for pavements with substantial cracking or signs of structural deficiencies such as severe alligator cracking, spalling, or d-cracking.

Figure 32: PCC Restoration (City of Cedar Rapids).
This is a picture of a city maintenance crew in Cedar Rapids performing a panel replacement as part of a larger concrete restoration project.

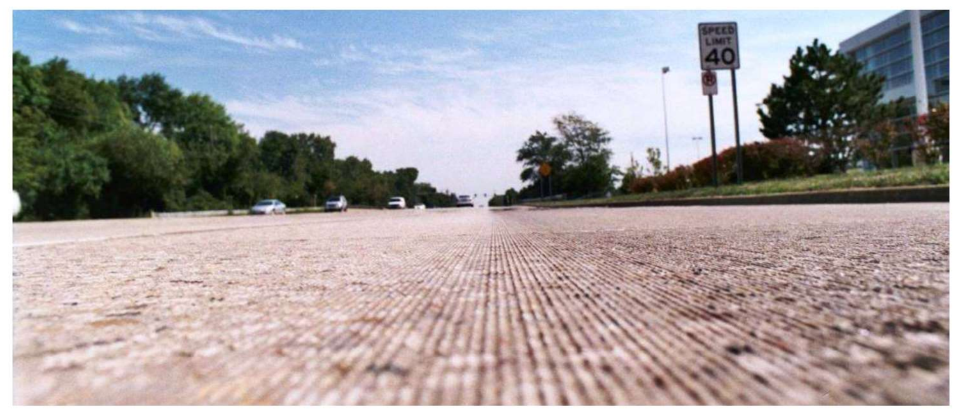

Figure 33: Pavement After Diamond Grinding (John Roberts).
This picture shows the texture of PCC pavement after diamond grinding was used on it. The image was taken on a project near Chicago Illinois.

Figure 34: Cape Seal (Michael Quinn-NPS)
This picture taken by the National Parks Service near the entrance to Grand Canyon National Park shows a loose chip seal (right) that is having a slurry seal applied (left) to effectively turn it into a cape seal.

3.5.4. Preservation

- Crack Sealing
- Pavement Patching

Restoration treatments use simple techniques to seal defects from moisture infiltration and prevent them from spreading. ***Crack Sealing***, for example, is a standard maintenance practice, recommended to be performed by city forces every 3-5 years on a road. Larger contracts for outside construction firms may be considered for crack sealing if the timing and amount of work warrant. Cracks that have slightly deteriorated edges may also need to have the loose pavement cleaned out and rough edges of the crack corrected using a concrete saw or router to improve the sealant bond. However, this is not necessarily recommended as the standard application due to increased costs and inconsistent performance.

Crack Sealing in a timely manner, and on a regular basis, is the most important tool in any pavement management program because will keep a pavement in good or fair condition much longer than it would without attention.

Figure 35: Crack Sealing Performed W/ Routing (USAF/Kenna Jackson)
This is an example of crack sealing being performed with special preparation in the form of using a router to clean up the crack profile, as being performed by 35th Civil Engineer Squadron.

Pavement Patching is different from Crack Sealing in that it is typically done by city forces after a pavement distress has already deteriorated to the point of becoming a more substantial issue. Patching is typically done with HMA, sometimes with partial removal of the area around the defect or distress. Patching is not intended to serve as a long-term fix, but serves mostly as a way to maintain service, and act as a stop-gap until a more appropriate rehabilitation treatment can be applied.

When a surface issue is due to a structural defect, full-depth removal and replacement of the pavement, as well as the base material, may be appropriate. This is referred to as full-depth patching or FDP. This can be costly, but often is the only solution for addressing faulting/spalling of concrete joints or edge/corner breaks, when combined with dowel-bar replacements.

It is recommended, that by default, that surface patching be performed using localized removals by cutting the pavement in a rectangular or square shape (following joints where possible) and replacing it with new HMA pavement after ensuring the base-material is suitable. When patching a PCC pavement, use of similar materials is recommended as well as full removal of panels where appropriate. In cases where failures are located around joints, removals along both adjacent panels and full depth patching should be performed.

Figure 36: HMA Patching with Localized Pavement Removal (KOMU)
This is an example of an asphalt patch applied with appropriate localized removals and some base repair.

3.5.5. Maintaining Chip Seal Roadways

The City of Waterloo has a substantial amount of roadways constructed using a type of design no longer recommended, called "seal coat roads" or "chip seal roads." These seal coat streets were constructed using only a few layers of chip seal over a rock base; sometimes even directly on compacted dirt subgrade.

While no longer a recommended technique they are common throughout the state of Iowa and once were thought to be great for cost savings. The low cost of construction made it easy for cities and developers to construct new roads. Despite the short life-spans, only 4-7 years, they are relatively cheap to maintain given that another chip seal will bring it to "like-new" status.

Unfortunately, many municipalities learned that the long term cost of continually re-paving streets on a 4 to 7-year basis quickly became nearly just as expensive over time. On top of that, it created a large volume of work because large portions of roadway networks would all need to be addressed in a shorter timeline.

Other issues arose over time. Many seal coat streets are not constructed with curb and gutter or any drainage improvements, nor do they have much structural integrity on their own. Inclement weather and heavy loads often cause seal coat streets to fail unexpectedly and completely. Even the best seal coat streets present issues of loose aggregate, edge failures, and binder bleeding. Many communities in Iowa are now dedicating much of their budgets to rebuilding these streets using modern standards, ***if they can afford it***. While expensive in the near term, it is generally accepted that the long term costs will be reduced and the quality of driving surface will be increased by building them as traditional HMA or PCC pavements with curbs and storm sewer systems.

Currently, Waterloo maintains approximately 60 miles (13% of its network) of chip seal roads and spends nearly $1 Million each year on keeping them serviceable by repaving around 12 miles each year. This is a substantial amount of the City's budget spent on just these streets which typically carry very little traffic.

When looking for effective and affordable means to maintaining these seal coat streets it is important to understand that they do not function as traditional pavements. Patching and crack sealing are mostly ineffective, plus there is not enough structural stability to place traditional overlays over top. The only improvements that can be made are reconstructing them or "re-sealing" them. The question is then, what small improvements to chip seal design can be made.

National Cooperative Highway Research Program ***(NCHRP) Synthesis 342*** and the Federal Highway Administration's ***(FHWA) Guide to Preventative Maintenance Treatments*** highlight key design components and recommended best practices. Aggregate quality and weather conditions when laid are the most important factors in chip seal design, but there are secondary considerations for specific conditions.

For example: to prevent reflective cracking from deeper existing distresses, geotextile fabric or interlayer tack coats can be used. Another example secondary consideration is that polymer-modified binders can be used to provide better structural support where rutting or distortions are present.

To extend the life of chip seal pavements three main improvements are recommended:

- Where subgrade or base material are insufficient structurally, consider using double chip seal coats.
- Heavier trafficked roads should consider using slurry, sand, fog, or Microsurfacing seal coats over the chip seal to convert it to a more stable Cape Seal.
- Where alligator cracking and potholing are present, consider adding edge drains and ditches, or a curb-based storm sewer system to stabilize the pavement by preventing drainage problems. Ensure the pavement slopes are sufficient to drain.
- When edge cracking is occurring, pavement edge and bank stabilization may be required. Also grinding down the pavement center to flatten the street's peak can help distribute vehicle loads better.

Figure 37: Rural Chip Seal Road (Ben Grimm)
This is an example of typical chip seal road. This road near Kempton Indiana exhibits raveling, bleeding, and weathered aggregate indicative of an older pavement in need of a new coat

3.5.6. Preferred Treatment Alternatives

Table 1: Primary Capabilities And Functions Of HMA Pavement Preservation Treatments

Source: Adapted from Johnson, Best Practices Handbook on Asphalt Pavement Maintenance, 2000.

Treatment	Reasons for Use						
	Friction	Raveling	Rutting	Potholes	Cracking		
					Low	Med	High
Crack Treatments							
Crack Repair with Sealing							
Clean and Seal					X	X	
Saw and Seal							
Rout and Seal					X	X	
Crack Filling						X	X
Full Depth Crack Repair							X
Surface Treatments							
Fog Seal		X					
Seal Coat	X	X					
Double Chip Seal	X	X					
Slurry Seal	X	X					
Microsurfacing	X	X	X				
Thin Overlay		X	X				
Pothole and Patching Repair							
Cold Mix Asphalt				X			
Spray Injection Patching				X			
Hot Mix Asphalt				X			X
Patching with Slurring or Microsurfacing Material				X			X

Table 2: General Expected Performance of Maintenance Treatments

Source: Adapted from Iowa Statewide Urban Design and Specification guide.

Treatment	Expected Performance (Treatment Life), Years
PCC	
Crack Sealing	4 to 8
Joint Resealing	4 to 8
Partial Depth Patches	5 to 15
Full Depth Patches	10 to 15
Diamond Grinding	5 to 15
Pavement Undersealing/Stabilization	5 to 10
HMA	
Crack Filling	2 to 4
Crack Sealing	2 to 8
Pothole Patching	1 to 3
Full/Partial Depth Patches	3 to 15
Fog Seals	1 to 3
Slurry Seals	3 to 6
Microsurfacing	4 to 7
Bituminous Seal Coats	4 to 6
Double Chip Seal	7 to 10
Thin Overlays	7 to 10

All of the treatments in this section may be considered for projects in Waterloo, some are more preferred than others. The CIP will not normally differentiate between types of projects within the same treatment category, as the actual treatment selection should be performed on a project-by-project basis and reviewed by a Professional Engineer. ***Table 1*** provides some simple guidance on which types of treatments are appropriate based on the distresses that a pavement presents and ***Table 2*** helps compare the effectiveness of each treatment over time.

For planning purposes, treatments are assigned to via a “Decision Tree” in the dTIMS BA pavement management software. This decision tree is then used in determining the total budgetary needs for the network and in assessing each of the Scenarios.

The treatments used in the dTIMS BA model represent those that are expected to be the most commonly selected given certain conditions. These are the “preferred treatments” that will likely make up the majority pavement preservation work performed in Waterloo. This list, however, is merely a tool to aid in budgeting and planning and not a prescriptive result. It is not designed to be interpreted as you “Must do X”; rather the results from dTIMS are general recommendations based on severity and types of surface distresses. These recommendations will then need to be individually assessed for appropriateness against similar treatment alternatives by a licensed engineer before it is designed and constructed.

3.5.7. Estimated Treatment Costs

One of the most critical components in any financial planning endeavor is accurately predicting the costs that will be incurred. In this case, the primary costs of concern are the design, construction, and ancillary costs associated with executing a roadway improvement project. Waterloo has historical information about its expenditures on roadway projects throughout the years, however in past years it has seen high growth rates on project costs. It was estimated overlay type projects had increased nearly 3% on average each year for the past 5 years. This unusually high cost is likely attributable to the recent expansion of gas-tax expenditures throughout the state causing demand for construction services to go up, allowing contractors and consultants to charge premium prices. This growth was taken into account via a 3% inflation factor applied to all project costs in dTIMS BA.

Treatment types were assigned planning-level costs through a thorough review of bid tabs supplied by the City as well as other local cost information available. Assumptions were made regarding mobilization rates, design fees, traffic control, and other ancillary costs based on percentages of the overall material costs.

Since the costs used in this report are planning-level it is recommended that each project be reviewed during the annual capital improvement budgeting process, in order to assess each proposed action for ripeness and reasonableness; e.g. is this the right time? Is this the right treatment? The City Engineer may elect to move projects around, into different years, or change the treatment type.

For most practical purposes, treatments within the same category are interchangeable because they will likely be appropriate for a project of a certain condition category, regardless, and the actual treatment applied should be based on comprehensive review and engineering judgement. When determining ripeness and reasonableness it may be useful to perform Life-Cycle Cost Analysis to evaluate various treatment alternatives within the same category against each other, or even when considering leaving it to be reconstructed at a later time.

3.5.8. Treatment Selection Criteria

With the treatment alternatives selected for the toolbox, the criteria for selecting one treatment over another needed to be determined. Cost and funding availability is regularly the deciding factor for local agencies; getting the most benefit for the least amount of investment possible. Therefore, cost estimates for each treatment were developed using bid tabulations and project histories from various cities' pavement management programs.

The other main factors in treatment selection are condition and distresses. The overall condition of a pavement should determine when it needs work and what severity of work. The types of distresses should then be considered when evaluating equivalent treatments based on appropriateness.

Table 3 includes a full overview of the treatment toolbox with descriptions, cost estimates, triggers, and the expected effects of each individual treatment alternative. This information is what will be used in the dTIMS BA scenario modelling process, to be performed as part of the Waterloo Pavement Management Program.

Table 3: Treatment Alternative Details

Category	Treatment	Description	Cost	Trigger	Effect
Reconstruction	Reconstruction	The complete reconstruction of a roadway and all associated improvements. This assumes new HMA pavement, but full-depth PCC or COM may be considered based on relevant design criteria.	$140/sy	CITYPCI =Poor OR Very Poor	Full reset
Major Rehabilitation	Crack and Seat Overlay	>=3 In. Asphalt Overlay with preparation including breaking up existing pavement and setting it up as a good structural base for the new asphalt surface. Effectively creates a new pavement.	$65/sy	CITYPCI =Poor, Surface = PCC, Low D Crack	Reset IRI, deduct 20 years from performance age, set CITYPCI to 80
	Mill and Overlay	1.5 to 3 inches of asphalt pavement is milled off and then replaced with 3 inches of asphalt. Repairs surface issues and improves structural character.	$60/sy	CITYPCI =Poor, Surface = HMA, IRI > 250, Moderate Alligator Cracking	Reset IRI, deduct 15 years from performance age, set CITYPCI to 80
	Thick Overlay	Sometimes called a "Structural Overlay." 3 inches of Asphalt that adds enough thickness to increase the durability of the roadway, and provides a new wearing surface. Can be done with asphalt or PCC (black-topping/white topping) May require replacing curb and gutter.	$45/sy	CITYPCI =Poor, Low D Crack, Low Spalling, Moderate Alligator Cracking, Moderate Patching	Reset IRI, deduct 15 Years from performance age, set CITYPCI to 80
Minor Rehabilitation	Thin Overlay	A "non-structural overlay." Laid on top of existing pavement; typically 1-2 inches of asphalt. Improves smoothness and extends the life of roads in good to fair condition.	$30/sy	CITYPCI =Poor or Fair, Low D Crack, Low Spalling, Low Alligator Cracking, Low Patching, Low Rutting	Reset IRI, deduct 8 Years from performance age, set CITYPCI to 80
	Seal Coat (Various)	Slurry Seals, Chip Seals, Cape Seals, etc. Applications of finer aggregate and binder to affordably extend life of existing pavements. Type is condition and location specific.	$5/sy	CITYPCI = Fair or Good, Surface=HMA, Low Alligator Cracking, Low Patching, Low Rutting, Local Only	Reset IRI, deduct 5 Years from performance age, set CITYPCI to 80
	Microsurfacing	Thin asphalt polymer that seals the pavement from weather effects and corrects for minor irregularities. Typically used as a preventative measure, rather than a corrective one.	$6/sy	CITYPCI = Fair or Good, Low D Crack, Low Alligator Cracking, Low Patching, Moderate Rutting	40% reduction in IRI, deduct 8 Years from performance age, set CITYPCI to 70
	PCC Restoration	Portions of the street in bad repair are torn out and replaced. This may include patching, full panel replacement, and full depth repairs at joints. Slightly improves overall condition and helps extend life by addressing problem areas before they spread	$21/sy	CITYPCI = Fair or Good, Surface=PCC	40% Reduction in Cracking, IRI, & CITYPCI deductions. Deduct 8 Years from Performance age.
	Diamond Grinding	Top ¼ inch to a ½ inch of PCC pavement is ground off and textured. This is only done on rough pavements with good structure to improve ride smoothness and increase vehicle traction for safety purposes.	$5/sy	CITYPCI=Good, IRI>250, Low D Crack, Low Spalling, Low Alligator Cracking, Low Patching, Low Rutting	30% reduction in IRI and CITYPCI deductions
Restoration/ Preservation	Crack Sealing	Sealant on cracks and joints is used to prevent spreading and moisture from getting into the pavement structure. Deteriorated cracks may be routed or sawed out to provide better seal and bond.	$10,500/ Mile/Lane	Applied every time Last Work Done counter reaches a multiple of 4 years	Maintains
	Pavement Patching	Asphalt placed at spot locations. Used only on good pavements with minor failures, or as a stop-gap on poor pavements until a better, more permanent, solution is applied.	$3/sy	No trigger assigned	Maintains

The treatment costs listed in Table 3 are considered "all-in" numbers. These costs represent not only the materials to perform the construction of the project but all of the expected costs that would be associated with the given treatment type. For example, the Reconstruction treatment includes costs related to storm sewer as that will be needed as part of the new pavement system. Table 4 through Table 14 provide example calculations for each of the treatment types. Note that these are ***planning-level costs***, only, however. While based on engineering judgement and historical bid tabulations, they are not a replacement for an engineering opinion of probable cost.

Table 4: Reconstruction Cost Calculation

Reconstruction	
Excavation	$ 5.00
Subgrade	$ 2.00
Subbase	$ 6.00
Subdrain	$ 6.00
Storm Sewer*	$ 25.00
Pavement Removal	$ 10.00
Pavement (HMA)	$ 42.00
Driveways/Sidewalks	$ 10.00
Seeding/Paint Markings, etc.	$ 5.00
Mobilization, Traffic Control, Survey (15%)	$ 16.00
Contingency (10%)	$ 13.00
Total (Rounded Up)	$ 140.00

Table 5: Crack and seat Cost Calculation

Crack and Seat w/ Overlay	
Crack and Seat	$ 6.00
Milling	$ 2.00
3" HMA Overlay @ $100/Ton	$ 18.00
Tack and Patch @ $200/Ton	$ 3.00
Curb and Gutter/Patching	$ 8.00
Driveways/Sidewalks	$ 10.00
Mobilization, Traffic Control, Survey (15%)	$ 7.00
Contingency (10%)	$ 6.00
Total (Rounded Up)	$ 60.00

Table 6: Mill and overlay Cost Calculation

Mill and Overlay	
3" HMA Overlay @ $100/Ton	$ 18.00
Tack and Patch @ $200/Ton	$ 3.00
Milling	$ 5.00
Curb and Gutter/Patching	$ 8.00
Driveways/Sidewalks	$ 9.00
Mobilization, Traffic control, survey (15%)	$ 7.00
Contingency (10%)	$ 5.00
Total (Rounded Up)	$ 55.00

Table 7: Thick Overlay Cost Calculation

Thick (3 In.) Overlay	
3" HMA Overlay @ $100/Ton	$ 18.00
Tack and Patch @ $200/Ton	$ 3.00
Curb and Gutter/PCC Patching	$ 8.00
Driveways/Sidewalks	$ 6.00
Mobilization, Traffic control, survey (15%)	$ 5.50
Contingency (10%)	$ 4.50
Total (Rounded Up)	$ 45.00

Table 8: Thin Overlay Cost Calculation

Thin (1.5 In.) Overlay	
1.5" HMA Overlay @ $100/Ton	$ 9.00
Tack and Patch @ 200/Ton	$ 3.00
Curb and Gutter/PCC Patching	$ 8.00
Driveways/Sidewalks	$ 3.00
Mobilization, Traffic control, survey (25%)	$ 4.00
Contingency (10%)	$ 3.00
Total (Rounded Up)	$ 30.00

Table 9: PCCR Cost Calculation

PCC Restoration	
10% Remove and Replace	$ 10.00
Crack Fill/Seal	$ 2.00
Profiling	$ 4.00
Mobilization, Traffic control, survey (15%)	$ 2.00
Contingency (10%)	$ 2.00
Total (Rounded Up)	$ 21.00

Table 10: Seal Coat (Various)

Seal Coat (Various)	
Seal Coat Treatment	$ 3.00
Patching	$ 0.50
Mobilization, Traffic control, survey (25%)	$ 1.00
Contingency (10%)	$ 0.50
Total (Rounded Up)	$ 5.00

Table 11: Microsurfacing Cost Calculation

Microsurfacing	
Polymerized Surface Treatment	$ 1.50
Tack and Patch @ 200/Ton	$ 3.00
Mobilization, Traffic control, survey (25%)	$ 1.00
Contingency (10%)	$ 0.50
Total (Rounded Up)	$ 6.00

Table 12: Diamond Grinding Cost Calculation

Diamond Grinding	
Grinding and Mobilization	$ 5.00
Total (Rounded Up)	$ 5.00

Table 13: Crack Sealing/Filling Cost Calculation

Crack Sealing/Filling	
Crack Sealing (per Mile per Lane)	$10,500
Total (Rounded Up)	$10,500

Table 14: Patching Cost Calculation

Patching	
Patch @ 200/Ton	$ 3.00
Total (Rounded Up)	$ 3.00

4. Existing Condition Analysis

The City of Waterloo maintains approximately ***420 Miles of roads*** and the transportation infrastructure network, not including bridges, is valued at ***over $1.2 Billion.*** This is the 4th largest road network in the state.

Network Value = $1.2 Billion

Pavement condition information from the 2018 automated data collection vehicle run by IPMP's sub-consultant Pathways was joined to the processed baseline information from the City of Waterloo using the ESRI ArcGIS software. That data was analyzed to create overview statistics and investigate various trends, both over time and spatially. Detailed maps were created to illustrate the pavement characteristics and the collected condition data, which can be found starting on ***Page 25.***

4.1. Functional Class and Pavement Type

4.1.1. Functional Classification

Roads in Waterloo are separated into three broad categories to help differentiate their use; ***Local Streets***, ***Collector Streets***, and ***Arterial Streets***.

Local Streets, also called "residential" are those that serve low levels of traffic that are at the beginning or ending of their trips. These streets often have many points of direct access from driveways, have lower speed limits, and sometimes on-street parking. Local Streets make up the majority of any transportation network.

Collector Streets are those that connect locals and concentrate traffic to help move efficiently between adjoining neighborhoods or provide access to the primary street network, namely Arterial Streets. These Collector Streets are generally wider and have slightly higher speed limits than Locals.

Arterial Streets are those that carry the most traffic. These trunk roads travel at higher speeds and efficiently move traffic from one end of town to the other. They are also the gateway routes into and out of the City.

The reason for this distinction is that Arterial and Collectors are designed for higher volumes of traffic and more heavy-vehicles like semi-trucks. As such, they are designed differently, costing more per square yard of pavement than Local streets. They also perform differently, by comparison. The higher traffic causes Arterials/Collectors to wear out faster on average than Locals, and motorists are more sensitive to surface distresses due to the higher speeds. That said, because Arterials/Collectors carry the vast majority of vehicle miles travelled in Cities, they are more valuable to maintain in good condition. As such, for the purposes of modelling and planning using dTIMS BA, Arterial and Collector streets are considered separately from Local Streets.

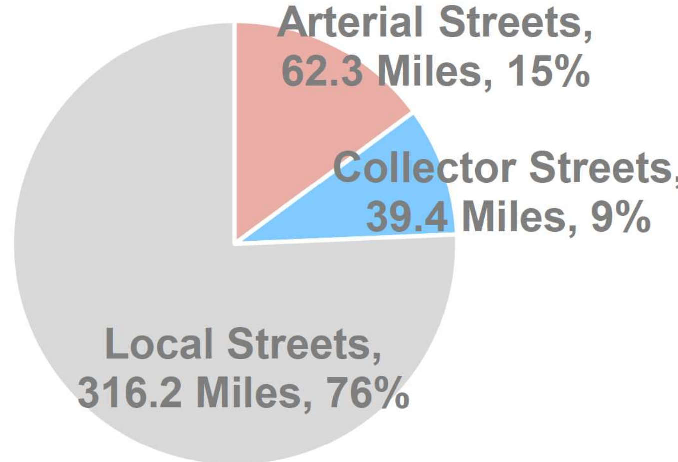

Figure 38: Functional Class Distribution (By Centerline Miles)
This figure shows the breakdown of the various street classifications in Waterloo, based on the official Federal Functional Classification used by Iowa DOT.

4.1.2. Pavement Type

Roads can also be separated by their surfacing type. Different pavement surfaces perform differently, have different types of treatment alternatives, and have initial different construction costs. Each type of road was considered separately in the dTIMS BA model for the City of Waterloo.

The four main categories considered by this plan are Seal Coat (***SEAL***), Portland Cement Concrete (***PCC***), Asphalt Cement Concrete (***HMA***), and Composite Pavements with HMA over the top of PCC (***COM***). Some agencies also refer to HMA has Hot-Mix Asphalt or HMA.

The vast majority of pavements in Waterloo are "black-top." They are either full-depth HMA, composite (COM) with HMA over PCC, or are Seal Coat (SEAL) which is also an application of asphalt. A full ***78% of all streets in the City have an asphalt-based surface material***. This has large ramifications for the types and costs of treatments for the area and sets Waterloo significantly apart from each of the other urban agencies in the state. The average proportion of asphalt streets across all metropolitan planning organizations in Iowa is less than 45%, by comparison.

Another point where Waterloo differs substantially is the amount of Seal Coat surfaces in the city. These streets require dedicated work forces to keep an eye on and maintain. These streets even have a separate $900,000 budget to maintain on their own. The next closest urban area in the State is the Muscatine MPO who maintain 11.5% Seal Coat. Most of the other larger cities in the state (of which Waterloo would be considered) have nearly negligible amounts.

This difference is not necessarily a negative, however, it only means that analogous agencies in Iowa may not be suitable standards of comparison for pavement management techniques and treatments. The Iowa SUDAS guide, likewise, does not have nearly as many useful standards and specifications for HMA as they do PCC.

In fact, this may actually be a strength for the city to have so many asphalt streets, which have been referred to as "perpetual pavements" due to their ability to be resurfaced many times to achieve "like-new" status. This can keep overall rehabilitation costs lower in Waterloo than with an equivalent PCC-focused network, and de-emphasizes reconstruction.

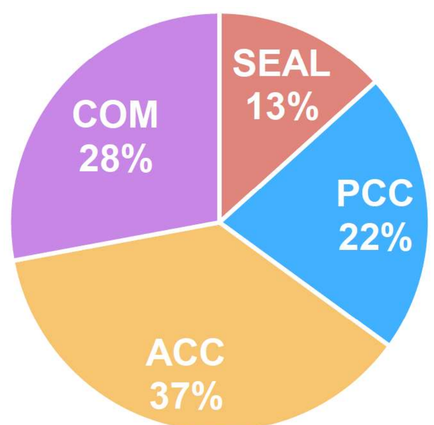

Figure 39: Pavement Type Distribution
This figure shows the distribution of pavement types in Waterloo. Of note is the high proportion Seal Coat, and the relatively small proportion of PCC surfaces.

4.2. Pavement Condition

Most likely the result of Waterloo's unique pavement mix and long standing Local Option Sales Tax, Waterloo can firmly state that its streets are, on average, in "Good" condition. The Network-wide CityPCI of the City is 70/100, and is one of the highest scores in the state for urban agencies!

CityPCI = 70

(Good)

A very notable fact about the current pavement conditions is that it fairly homogenous based on pavement type. The City has not overly focused on one type of street or ignored others in a way that created a distinctive change in quality. PCC pavements are slightly better and Seal Coat roads are marginally worse, but neither to a statistically significant degree

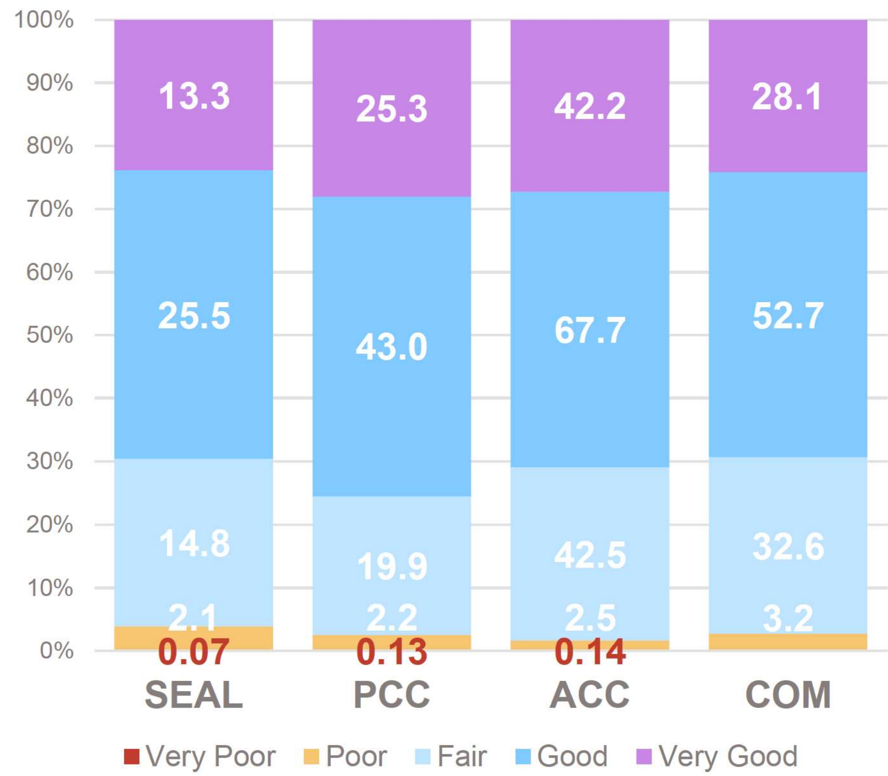

Figure 40: Condition Distribution by Pavement Type

This figure shows the distribution of pavement conditions for each of the four pavement types. Each type has a high overall quality and conditions are fairly homogenous

When looking at functional classification, again there is very little in the way of variation between types. Collector streets, do however, show a slightly wider spread, than the others. They have the highest proportion of "Good" and "Very Good" streets, but also the largest proportions of "Poor" and "Very Poor." Collectors in Waterloo comprise only 9% of streets in the City, though, which makes them more susceptible to outliers from a statistical sense. This is not likely a result from any sort of systemic issue, but quite possibly a small oddity considering the distribution is still nearly identical in shape.

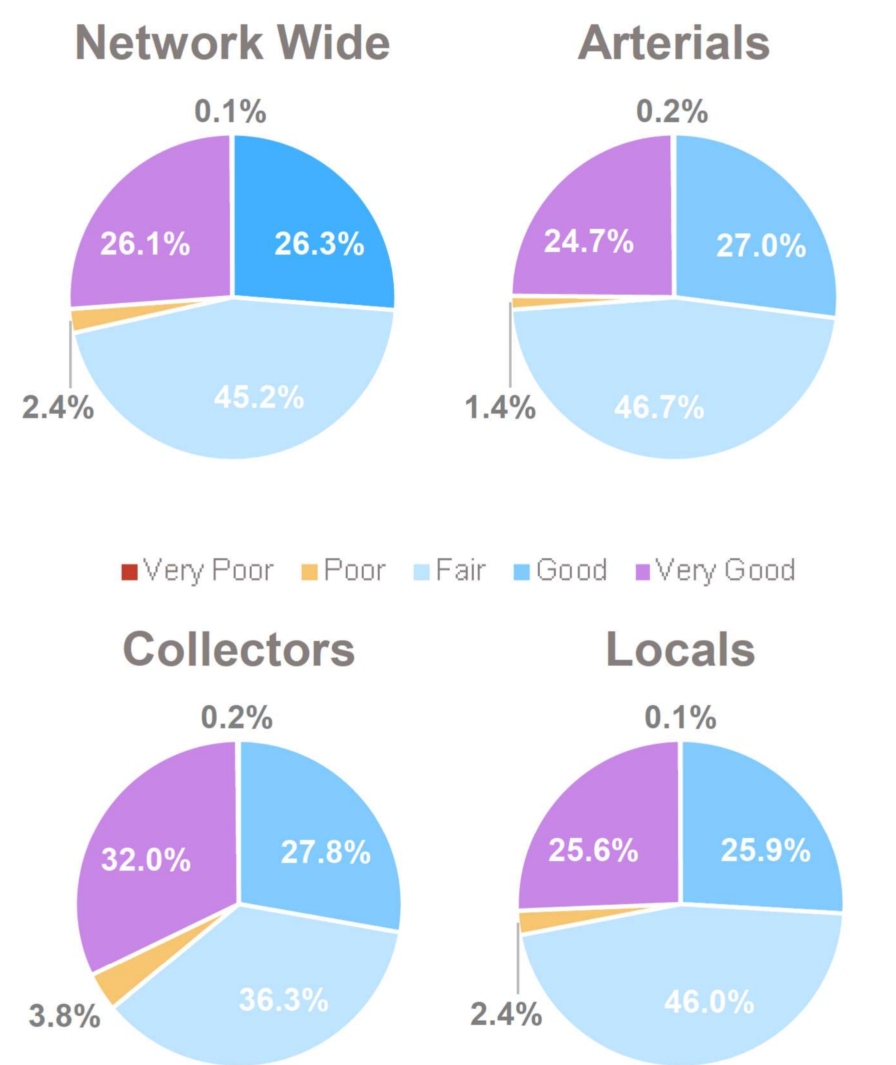

Figure 41: Condition Distribution by Functional Class

This figure shows the distribution of pavement conditions for each functional classification, as well as the network overall. Classifications show very little variance.

4.2.1. Comparing Across the State

Waterloo's overall pavement condition is exceptional in the State of Iowa. Of all the large cities in the state, Waterloo boasts the highest network-wide CityPCI at 70.4/100. The next closest city is Council Bluffs, but that is only at 63.9/100 and only maintains approximately 260 miles of roads, similar to Iowa City at 63/100 that only maintains approximately 220 miles of roads. Based on miles maintained and condition, Waterloo's achievements are certainly noteworthy.

The reason for Waterloo's success may lie with its heavy use of asphalt and possibly with the how long the LOST has been in place (since 1991). In any case, there is a lot of positives for the City and the question may not be how to *improve* the condition in Waterloo so much as how to *maintain* it in the long run.

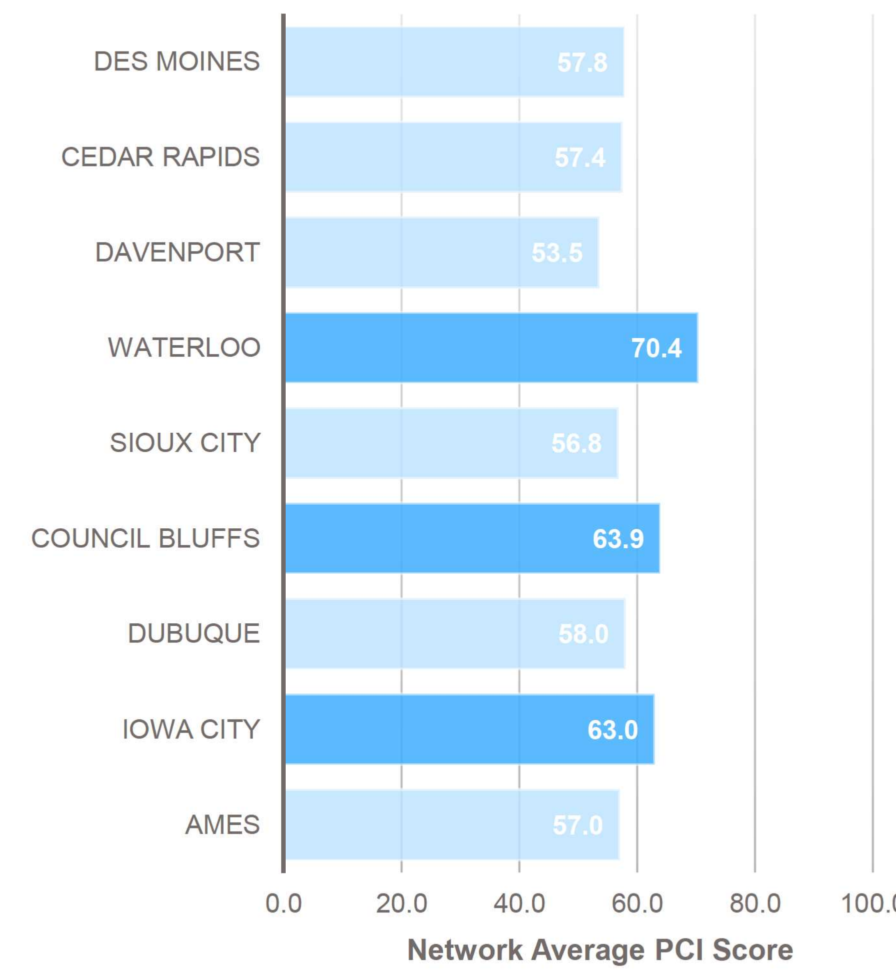

Figure 42: Iowa Urban Agency Comparisons

This figure lists the nine largest urban areas in Iowa by miles of road they maintain and compares their network level PCI scores

4.2.2. Wards

Historically, budgeting was assigned across each of the five (5) wards in Waterloo to spread money around. As such, it's not surprising that the different areas are fairly homogenous as well. The difference between the Ward with the lowest CityPCI average and the Ward with the highest CityPCI average is slightly over 2 points out of 100; this is quite negligible and those numbers could easily vary by that much between data collection cycles due to collection biases.

Each of the 5 wards have average CityPCI scores in high 60's and low 70's. This categorizes them "Good" across the board. Ward 3 is a bit of an outlier, however. Ward 3 has the most streets in "Poor" condition, albeit there are very few. Ward 3 also has the most streets in "Very Good" condition.

Interestingly the roads that are on the border of two different Wards are slightly worse off on average, compared to those that are squarely within one Ward or the other. There are only a few points of difference on average, but considering it is only 16 miles of roads with 5% in "Poor" condition, they are quite a bit more likely to be in bad repair compared to only 3% in Ward 3.

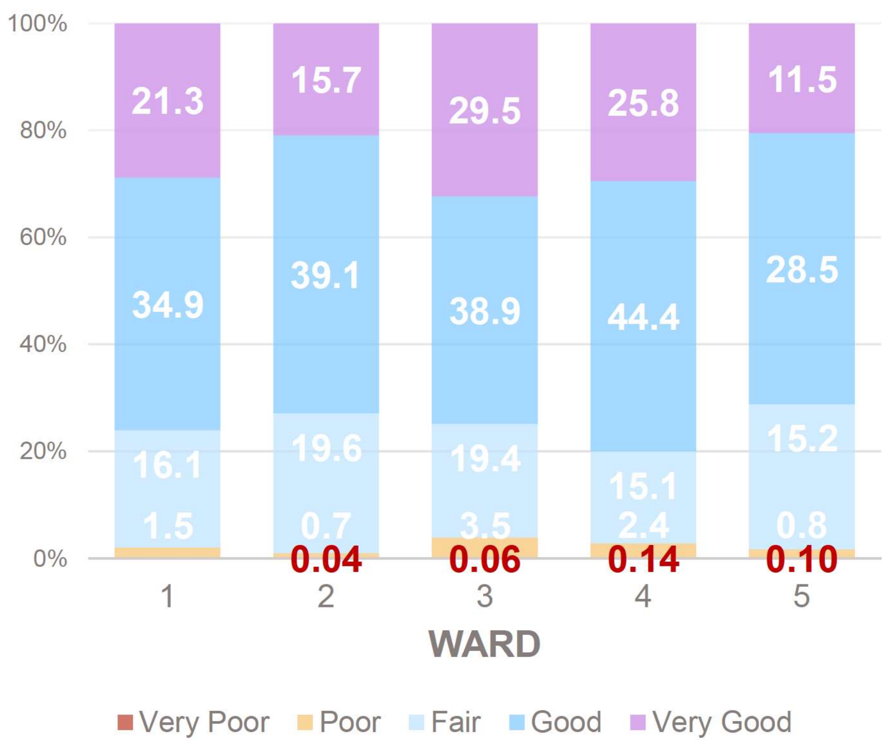

Figure 43: Comparison of Condition Distribution by Ward
This figure shows the pavement condition distribution by ward and how each has a high overall quality and relatively homogenous distribution.

4.3. Pavement Condition Trends

One of the biggest values of the IPMP Program and the data it provides is the fact that there are multiple years of data to work with. This allows for better trend predictions, due to having a 6-year period to work with, and it increases the statistical relevance of the data due to the higher volume of data points. This volume helps refine the precision of the modelling processes and identify specific conditions that may warrant further investigation.

Every other year IPMP receives over 40,000 raw data points from the automated collection vendor, just for the city of Waterloo. Approximately 150,000 data points go into this analysis section.

Note, however, that the trend figures only use sections that have at least 3 data points, so may differ slightly from the network level statistics provided. Approximately 250 road segments have less than the full 3 data cycles, but every street has at least 1 year of data to work with.

Looking at the network over time reveals a slight decline in quality since 2014, it dropped from 72 in 2014 to 68 in 2016 and slightly up again to 69 in 2018. Not a substantial drop but statistically significant given the data quantity processed. Action may need to be taken to prevent further decline. One potential explanation is that Waterloo's spending has been somewhat static over the past 5 years, but construction costs have certainly been growing due to increased demand caused by the gas-tax raise.

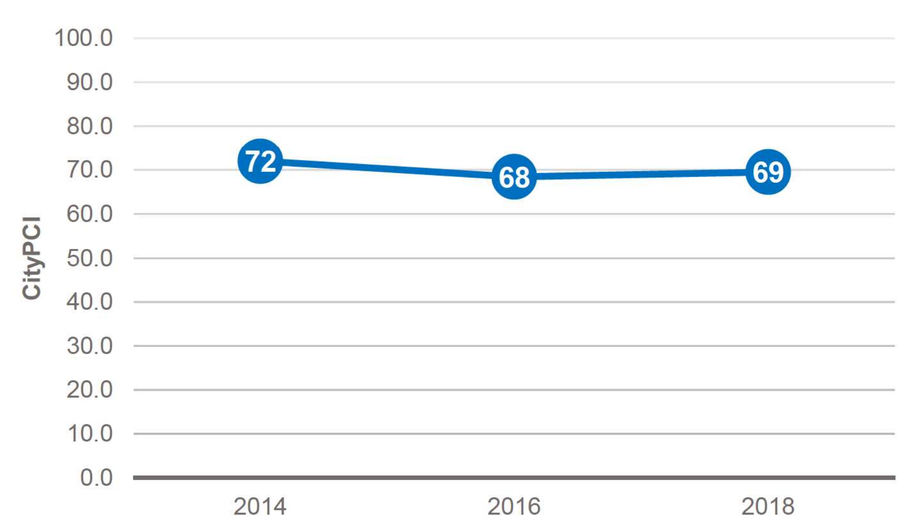

Figure 44: Network-Level Pavement Condition Trend
This figure demonstrates the slight decline the overall network has experienced since 2014. The data differs slightly from other figures because it only includes streets collected all 3 data cycles.

When looking at trends based on pavement types, each surface type shows similar drops in quality since 2014. Comparatively, they are all dropping around the same rate. One trend worth pointing out, however, is that Seal Coat streets with 3 years of data have been underperforming compared to the other pavement types.

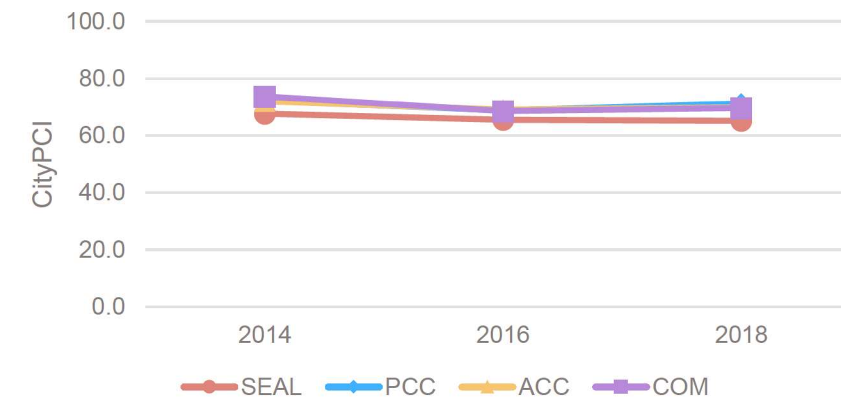

Figure 45: Condition Trend by Pavement Type
This figure demonstrates the slight decline across Waterloo by Pavement Type

4.4. Cross Comparisons

Cross comparisons for the current performance of pavement types and classes, identified that local streets with composite pavements are performing less well, on average, in Waterloo. This issue may be alleviated through thicker overlays or interlayer material. Arterial and Collector Pavements made from asphalt are also experiencing high wear, likely due to higher truck loads and traffic volumes in general. Modifying binder strengths or lift thicknesses might improve this trend.

Seal coat streets are underperforming, but this is expected due to the surface material used. It is not appropriate to directly compare these streets to other pavement types. See ***Section 3.5.5***, on ***Page 16*** for recommendations specific to seal coat streets.

More attention to local streets may be warranted, however. While common for networks this size, it may not be desirable to have such a drop off.

Table 15: Cross Comparison of PCI by Pavement Types and Classes

Pave Types	Arterial	Collector	Local	All Classes
SEAL	N/A	69.5	64.6	**65.2**
PCC	77.9	75.3	71.7	**74.8**
HMA	71.6	70.7	69.8	**70.1**
COM	71.9	72.1	68.1	**69.6**
All Surface Types	**74.9**	**72.4**	**68.7**	**70.4**

4.5. Pavement Age

Another consideration for pavement performance is the age of the surface. Older pavements can be more volatile and deteriorate suddenly and drastically so a close eye needs to be kept on those that are late in their design lives.

Fortunately, Waterloo has kept a good history of their construction and rehabilitation efforts over the years so a reasonably complete history exists for the roadway network. 97% of all roads in Waterloo have surface ages that are less than 20 years old. This result is quite good and matches expectations created by the high overall condition.

The 28-year old LOST and use of asphalt resurfacing treatments has helped keep surfaces relatively young, and operating well. However, the design life of HMA pavements is typically 30 years and overlays usually last 10-15 years on average. This means that the heavy proportion of streets in the 16 to 20-year age range is somewhat concerning. 205 miles of roads (51% of Waterloo) fall into this mid to late performance age. These streets may not be as stable and could develop more severe distresses quickly. Streets in that range will need to be monitored closely as they are either in, or near the steepest part of the pavement degradation curve (see ***Section 3.4***). The PCC roads in that age range are not nearly as concerning, though; due to their longer term stability.

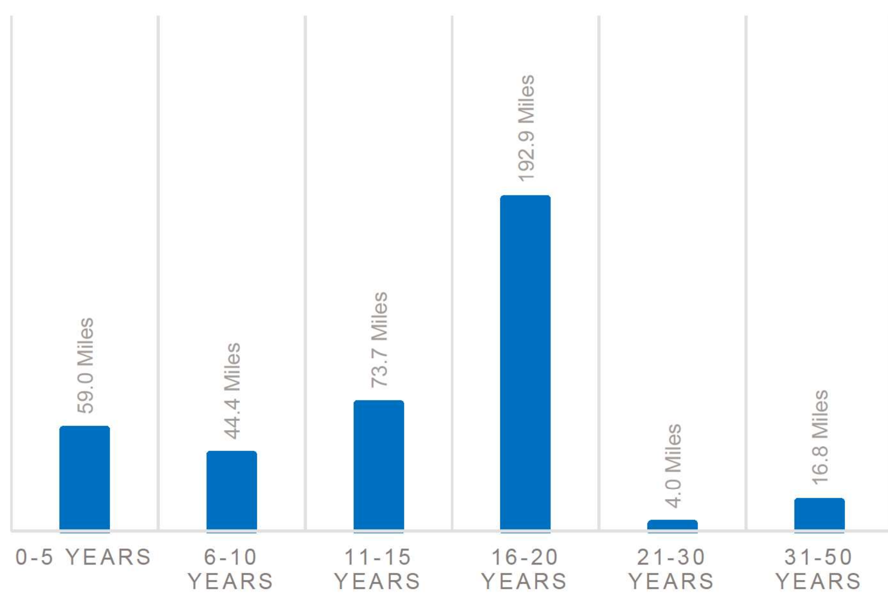

Figure 46: Pavement Surface Age in Waterloo
This figure displays the distribution of ages for pavement surfaces in Waterloo, per historical records.

4.6. Success in Waterloo & Cautions

Waterloo has many reasons to be proud:

- Highest network CityPCI of large cities in Iowa
- 28-year old LOST dedicated to maintaining street conditions
- Minimal pavement in "Poor" and "Very Poor" condition
- Evenly distributed conditions throughout the City
- Average pavement surface age of only 14-years

This does not mean, however, that there is no work to be done. In fact, there are some specific weaknesses in the IPMP data that may superficially hide the true conditions of the streets in Waterloo. Some of those data gaps are caused by the way the data is collected, the types of data collected, and completeness of information.

The ***sampling methodology*** used by the IPMP data vendor consultant only addresses one direction of travel for a road and has certain restrictions. That means the data set, while extensive and significantly better than subjective manual rating, it is not fully comprehensive. In 2018, undivided roads with fewer than 5 lanes were only driven in one direction, meaning that up 75% of pavement area may not be covered on wide streets. Similarly, on-street parking can limit the vehicle's ability to read a continuous section of road accurately due to weaving maneuvers resulting in readings based on skewed angles and in areas outside the normal driving lane.

Roughness data can only be collected when travelling at 20 mph or more, and requires a steady speed for at least 200 feet. Short street segments, dead-end roads, on-street parking, pedestrian crossings, and stop sign–controlled intersections can be very disruptive to the roughness measuring equipment, meaning that an urban area with many local streets will likely have low coverage for roughness data. Over 10 miles of streets in Waterloo did not collect any roughness data, in 2018, and the data that was collected may not be reliable. For those 10 miles, roughness had to be assumed based on other distress data. Luckily, the effect of roughness on CityPCI scores are minor.

Other distresses, even though they were collected, may not factor at all into the CityPCI rating. Prime examples include punch-outs and failures. ***Failures*** are potholes and potholes that have been filled, identified as irregularly shaped asphalt patches. Failures are a critical distress both in pavement performance as well as driver perception of road quality. Unfortunately, these distresses are treated the same as other patches, if included at all. The CityPCI rating system for full-depth asphalt does not formally include failure as a distress and is inconsistent in whether it should be considered at all, because the failure is not always indicative of the rest of the roadway conditions. Ridgeway Avenue near Kimball had a very high failure rate the last time it was collected, but still was rated as a CityPCI of 53-68.

Punch-outs are another failure completely ignored by the CityPCI rating. Punch-outs are when the edge of road breaks off, typically in conditions where there is no curb, or the curb was constructed separately. Pavement edges may continue sinking due to erosion of the base material. The condition is commonly caused by poor bank stability on roads with ditches, and erosion prone subbase materials in urban areas where subsurface drainage issues are not addressed. Dysart Road in the southeast part of Waterloo suffers from this particular distress throughout its length but is still considered to be in "Fair" condition.

The final caveat to this data collection system is that it can only ever address ***SURFACE*** distresses. Underlying problems such as voiding, eroding subgrade/subbase, and structural deficiencies cannot be identified, only the symptoms. High priority is paid to alligator cracking, spalling, and patching because of their associations with these problems, but evidence of these major deficiencies are not possible to collect directly without ground penetrating radar or pavement cores (both of which are comparatively expensive).

Underlying pavement ages are similarly important from a deterioration standpoint. Older, more distressed, bases mean new surfaces will deteriorate faster, due to a lack of stable support. Construction history is not as readily available so base age was assumed, in many cases.

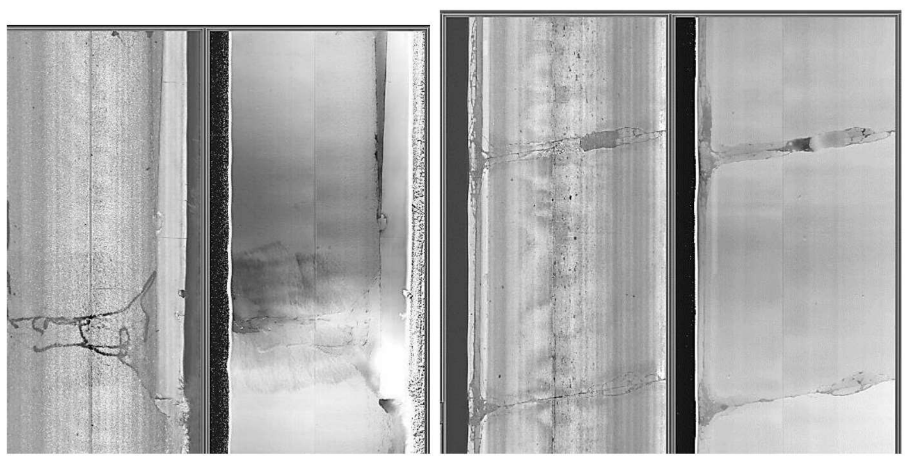

Figure 47: Unaccounted for Failures
These images are of a failure (left) and some punch-outs (right) that are not included in the pavement ratings for the associated roads of Ridgeway Drive and Dysart respectively.