Town of Lapel Pavement Management Program

March 2022

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1. INTRODUCTION

In July 2021, Kimley-Horn received authorization from the Town of Lapel to proceed with updating the pavement management program, developed in 2020, for the Town of Lapel's roadway network. The project consisted of confirming the roadway pavement inventory, a reassessment of existing pavement conditions, and an update to the pavement management program for the Town-maintained roadways. The pavement management program covers approximately 30 miles of roadways that are currently maintained by the Town of Lapel. The state and privately maintained roadways were excluded from this pavement management program.

The pavement management program includes preparation of pavement condition assessments and prioritized pavement maintenance activities. The results of this study can be used by the Town for future fiscal year planning efforts, and future community crossing grant decisions. The pavement management program applies value engineering decisions in the development of budget planning. It serves as a tool for developing short- and long-term capital funding projections to keep the overall pavement network in an acceptable and operationally safe condition. The following report provides an overview of the pavement evaluations and network-wide work plan projections developed as part of the pavement management program.

2. PAVEMENT MANAGEMENT APPROACH

One of the primary goals of this pavement management program was to develop conceptual, network-wide work plans to help predict future repair and funding needs. CartéGraph PavementVIEW and PavementVIEW Plus software (CartéGraph), was utilized to assist in generating the work plans. This program can be easily customized to fit the requirements and philosophies of the Town of Lapel, as they may change in future years. This pavement management approach and acceptable operation conditions were developed in conjunction with the Town of Lapel staff.

2.1 Strategy

The basic philosophy of pavement management is to apply preventive maintenance treatments at appropriate times to slow the rate of pavement deterioration. Both preventative maintenance and rehabilitation techniques should be applied at times when they are cost-effective instead of letting the pavement deteriorate to failure, which requires more expensive reconstruction. The pavement management strategy used for the Town of Lapel program follows this same philosophy. A repair strategy that combines preventative maintenance, rehabilitation, and reconstruction, where necessary, is targeted. Numerous studies have shown that a strategy of only reconstruction of failed pavements, or reconstruction of pavements that do not require it, will cost significantly more than this combined approach throughout a defined analysis period. The reason for this is that properly applied preventive maintenance and rehabilitation treatments effectively extend the life of the pavement. When this approach is applied on a network-wide level, it frees up a considerable portion of the budget to spend on these cost-effective strategies that may have previously been dedicated to reconstruction of a much smaller percentage of the pavement network.

2.2 Program Inputs

The pavement condition prediction model, CartéGraph, requires a significant amount of input information. Some of the input factors were easily defined, whereas others required some assumptions and interpretation of related technical data. Changes to any of the technical inputs or parameters will affect the results of the analysis. The inputs were selected based on field results, input from Town of Lapel staff, geotechnical investigations completed by ECS Midwest, LLC, and engineering judgement. The program has the potential to be modified in the future to account for changing goals, varying budgets, or altering management philosophies as requested by the Town of Lapel. The following sections describe the key inputs to CartéGraph.

2.2.1 OCI and PASER Rating System

One of the inputs to CartéGraph is the existing condition of the pavement. The pavement condition is used to determine whether pavement segments need maintenance, repair, or reconstruction. The condition of the pavement is defined in terms of an Overall Condition Index (OCI), which is based on the Pavement Surface Evaluation and Rating (PASER) system. PASER was developed by the University of Wisconsin-Madison, Department of Engineering Professional Development, in conjunction with the Federal Highway Administration (FHWA). The PASER system utilizes a simple 0 to 10 scale to rate pavements based on observed distresses without requiring quantification of each distress. The Asphalt PASER Manual is contained in Appendix A. The OCI values in the pavement management plan use a 0 to 10 scale, with 10 representing new pavement. By utilizing the PASER method, pavement segments can be rated in direct correlation to the type of repairs that should be performed. In addition to making the evaluation process fairly simple, the PASER method makes the conceptual analysis more streamlined. The OCI rating scale corresponding with the PASER ratings are displayed in Table 1.

Table 1: Asphalt PASER Ratings

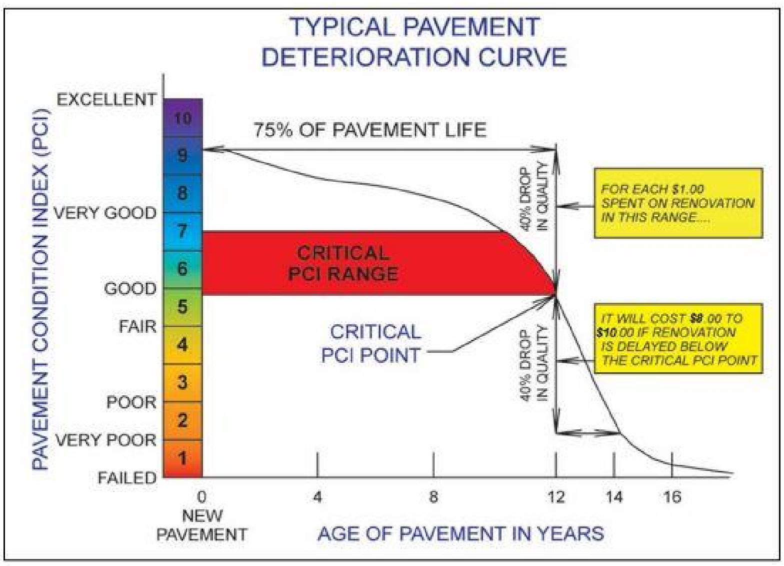
OCI Rating	Visible Distress
10 – New Pavement	None.
9 – Excellent	None.
8 – Very Good	No longitudinal cracks except reflection of paving joints. Occasional transverse cracks, widely spaced (40' or greater). All cracks sealed or tight (open less than 1/4").
7 – Good+	Very slight or no raveling, surface shows some traffic wear. Longitudinal cracks (open 1/4") due to reflection or paving joints. Transverse cracks (open 1/4") spaced 10' or more apart, little or slight crack raveling. No patching or very few patches in excellent condition.
6 – Good	Slight raveling (loss of fines) and traffic wear. Longitudinal cracks (open 1/4"–1/2"), some spaced less than 10'. First sign of block cracking. Slight to moderate flushing or polishing. Occasional patching good condition.
5 – Fair+	Moderate to severe raveling (loss of fine and coarse aggregate). Longitudinal and transverse cracks (open 1/2") show first signs of slight raveling and secondary cracks. First signs of longitudinal cracks near pavement edge. Block cracking up to 50% of surface. Extensive to severe flushing or polishing. Some patching or edge wedging in good condition.
4 – Fair	Severe surface raveling. Multiple longitudinal and transverse cracking with slight raveling. Longitudinal cracking in wheel path. Block cracking (over 50% of surface). Patching in fair condition. Slight rutting or distortions (1/2" deep or less).
3 – Poor	Closely spaced longitudinal and transverse cracks often showing raveling and crack erosion. Severe block cracking. Some alligator cracking (less than 25% of surface). Patches in fair to poor condition. Moderate rutting or distortion (1" or 2" deep). Occasional potholes.
2 – Very Poor	Alligator cracking (More than 25% of surface). Severe distortions (More than 2" deep). Extensive patching in poor condition. Potholes.
1 – Failed	Severe distress with extensive loss of surface integrity.

2.2.2 Pavement Deterioration Curves

Another input into CartéGraph is the pavement deterioration curve that is associated with each section of pavement. A typical pavement deterioration curve, shown in Figure 1, demonstrates how the deterioration rate can vary depending on the Pavement Condition Index (PCI) throughout the life-cycle of a pavement segment. In this study, because the OCI is rated based on the surface distresses and defects noted during the site investigations completed by Kimley Horn field staff, the PCI is directly related to the OCI condition.

Deterioration rates are dependent upon several other factors, in addition to the OCI, including the original section design, quality of original construction, subgrade condition, traffic loadings, climate, and the quality and extent of the maintenance program in place. Pavement deterioration can fluctuate significantly depending on these factors. As pavement condition reaches the critical range; loadings, moisture intrusion, and other environmental conditions can cause the pavement to deteriorate from good condition (OCI 6-8) to poor condition (OCI 1-3) in a relatively short time frame.

Figure 1: Typical Pavement Deterioration Curve



Typical pavement deterioration follows a curve with a critical PCI range that is generally considered to be between a PASER OCI rating of 6.2 and 5.7 on the curve. The "critical point" of 5.7 on the curve is considered the threshold where preventative maintenance measures become less cost-effective. Some form of rehabilitation is required for the pavement to restore serviceability when pavement falls below the critical point and typically requires costlier repairs. Upon further deterioration, the end of the useful life is reached when the pavement is considered to be a safety hazard. At this point, more costly and extensive reconstruction repairs are required to restore the service condition. A PASER OCI rating of less than 2.5 is typically viewed as the end of the pavement's useful life. Less than 7.9% percent of roadways evaluated in the Town of Lapel and maintained by the Town are near the end of useful life OCI rating. These roads may be recommended for heavy rehabilitation and/or reconstruction during the pavement management program work plan. Evaluation of the pavement on a consistent basis will optimize capital expenditures by providing the most cost-effective repairs relative to the type and extent of distresses in inspected or projected pavement.

When the road network average OCI is significantly more than the approximate critical point of 5.7 on the deterioration curve, the best management strategy will focus primarily on preventative maintenance while providing required rehabilitation and reconstruction repairs where needed. Alternatively, a network with an average OCI much lower than the approximate critical point will require a management strategy focusing on heavy rehabilitation and reconstruction while providing preventative maintenance where needed.

2.2.3 Pavement Surface Type

Pavement surface types are also an input into CartéGraph. The pavement surface type defines the types of pavement that make up a roadway. Each type of pavement performs differently under variable loading conditions. For this project, the only pavement surface type classified was conventional asphalt pavement. If any unpaved/gravel roads are paved in the future, the new pavement should be added to the CartéGraph database for future inclusion in the work planning of suggested maintenance and repair projects.

2.2.4 Repair Activities and Cost

There are inputs relating to the repair strategies and costs. The cost inputs used in this updated pavement management program are opinions of probable costs based on bid information submitted by multiple local contractors for recent pavement repair projects similar in nature to the repairs anticipated throughout the Town of Lapel.

2.2.5 Network Priority Ranking

CartéGraph uses the concept of Network Priority Ranking (NPR) to prioritize the pavement segment repair selection. This calculation for prioritization computes a weighted average based on the selected input fields and weighting factors. The higher a particular segment's NPR, the more likely it will be chosen for repair. The variables involved in the NPR calculation are almost limitless, but generally contain at least the OCI. Each factor has a rank (weight) associated with it, which is defined by the CartéGraph user. In our discussions with Town staff, only the OCI was identified as a priority field for the program development.

3. DATA COLLECTION

3.1 Geotechnical Data

Pavement cores were obtained throughout the Town of Lapel (see Figure 2 for locations) to determine typical pavement thicknesses, base materials and thicknesses, and subgrade soil characteristics. ECS Midwest, LLC., a subconsultant for Kimley-Horn, completed the subsurface exploration of the pavement cores. The core results are summarized in Table 2, with full pavement core maps and additional information located in Appendix B. Pavement and Subgrade data was compiled and incorporated in the design parameters for the pavement deterioration curves.

Figure 2: Coring locations in the Town of Lapel

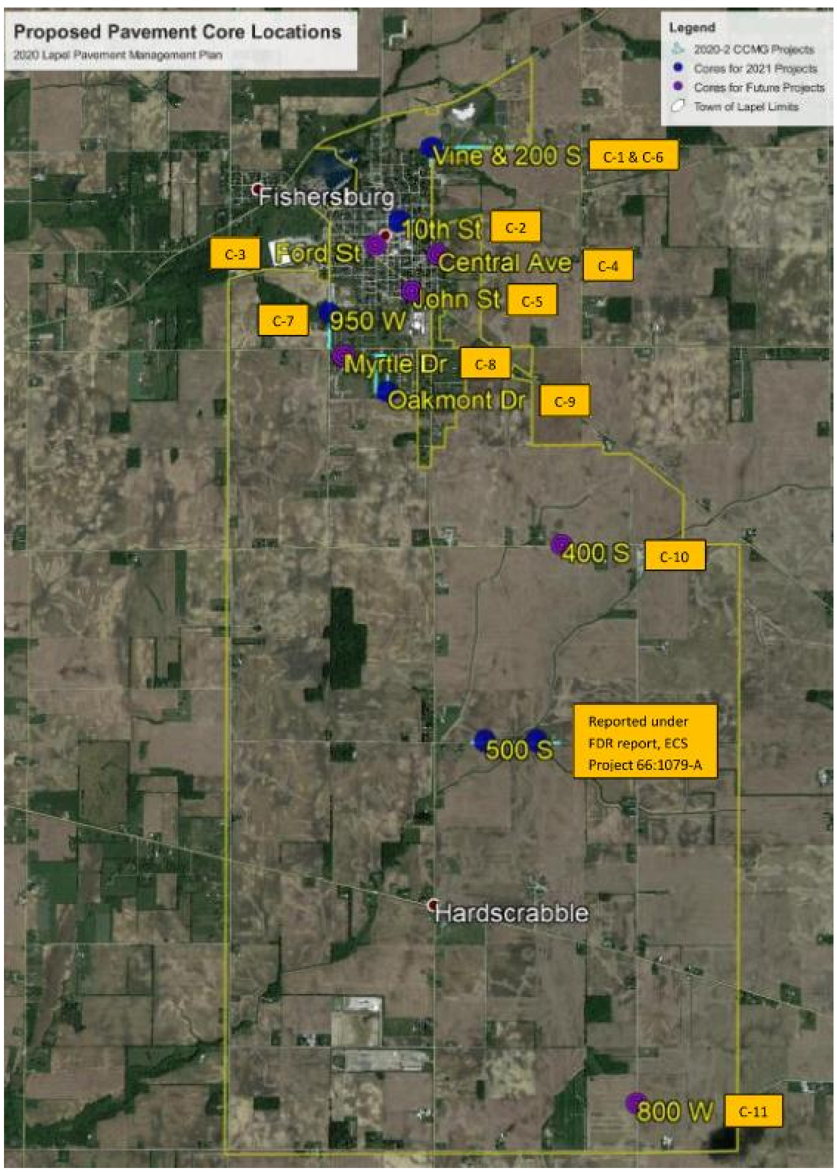


Table 2: Coring and Subgrade Sampling Observations

Core No.	Location	Pavement Thickness	Layer and Thickness	Base Type and Thickness	Subgrade Type and Condition
C-1	Vine and 200 S (First Attempt)	6-3/4”	5” Asphalt Surface (3 layers) 1-3/4” Asphalt Base	Concrete underlying asphalt	N/A—did not get below concrete
C-2	10th Street (between Ford and Main)	8-1/2”	1-1/2” Asphalt Surface 2-1/2” Asphalt Base 4-1/2” Concrete Base	2” Bank run sand	Dark brown sandy CLAY with some gravel, soft to firm
C-3	Ford Street	7-3/4”	5” Asphalt Surface (3 layers) 2-3/4” Asphalt Base	8” Bank run sand	Dark brown sandy CLAY with some gravel, firm to stiff
C-4	Central Avenue	4-1/2”	1-1/2” Asphalt Surface 3” Asphalt Base	4” Bank run sand	Dark brown sandy CLAY with some gravel, soft to stiff
C-5	John Street	6-1/2”	1-1/2” Asphalt Surface 5” Asphalt Base	4” Bank run sand	Dark brown sandy CLAY with some gravel, medium stiff to stiff
C-6	Vine and 200 S (Second attempt)	10”+	4” Asphalt Surface (2 layers) 1-1/2” Asphalt Base	4-1/2” Concrete Base	N/A--Unable to core beyond 10” and still in concrete
C-7	950 W	5”	2-1/2” Asphalt Surface 2-1/2” Asphalt Base	2” Bank run sand	Medium brown sandy CLAY with gravel to clayey sand with gravel
C-8	Myrtle Drive	4-1/4”	1-3/4” Asphalt Surface 2-1/2” Asphalt Base	4-1/2” Crushed aggregate base	Brown silty CLAY with trace sand, firm to stiff
C-9	Oakmont Drive	4”	1-1/2” Asphalt Surface 2-1/2” Asphalt Base	6-3/4” Crushed aggregate base	Brown to dark brown silty CLAY, firm to stiff
C-10	400 S	3”	1-1/2” Asphalt Surface 1-1/2” Asphalt Base	2” Bank run sand	Dark brown sandy CLAY to brown silty C, firm to stiff
C-11	800 W	3”	3/4” Asphalt Surface 2-1/4” Asphalt Base	2” Bank run sand	Dark brown sandy CLAY with some gravel, soft to firm

3.2 Field Assessments

Kimley-Horn performed field investigations of the roadways with GIS mapping data provided by the Town. The roadways were segmented based on discussions with Town staff, and color coded to graphically represent each segment’s current PCI. A color-coded Pavement Condition Map is included in Appendix C1. Rather than creating road segments on a block-by-block basis, the road segments were developed in a way that allows Town staff to look at longer sections of roads. This is more consistent with current practices of the Town of Lapel. With these larger segments, once a project is selected, a detailed “project-level” analysis should be performed. See section 6.3 of this report for additional information about “project-level” analyses.

Each segment of pavement for each roadway was assigned a unique Segment ID for later input into CartéGraph. A consistent method was used when assigning Segment IDs to individual pavement segments. Each Segment ID describes the road that it represents, and was created by taking the road name, adding an underscore, and including a numerical number (starting at "001" and counting consecutively through the segments alphabetically) to assist with the data linking to the GIS system. For example, the Segment ID "Caldwell_18" would represent the road Caldwell Lane, and after being sorted alphabetically, this segment is 18th in the database.

3.2.1 Network Conditions

The Town maintains approximately 3.45 million square feet of road pavements across their local street network. The weighted average OCI for the Town-maintained roads within the pavement network is 5.74.

The two charts, Figure 3 and Figure 4, display the pavement conditions by total area and percentage distribution, respectively. Approximately 44.8% of the Town of Lapel pavement assets currently have an OCI of 5.5 or greater and are, at a minimum, in "good" condition. An additional approximately 34.6% of pavement assets have an OCI between 3.5 and 5.5 and are considered "fair" condition.

Figure 3: Network Pavement Condition Areas

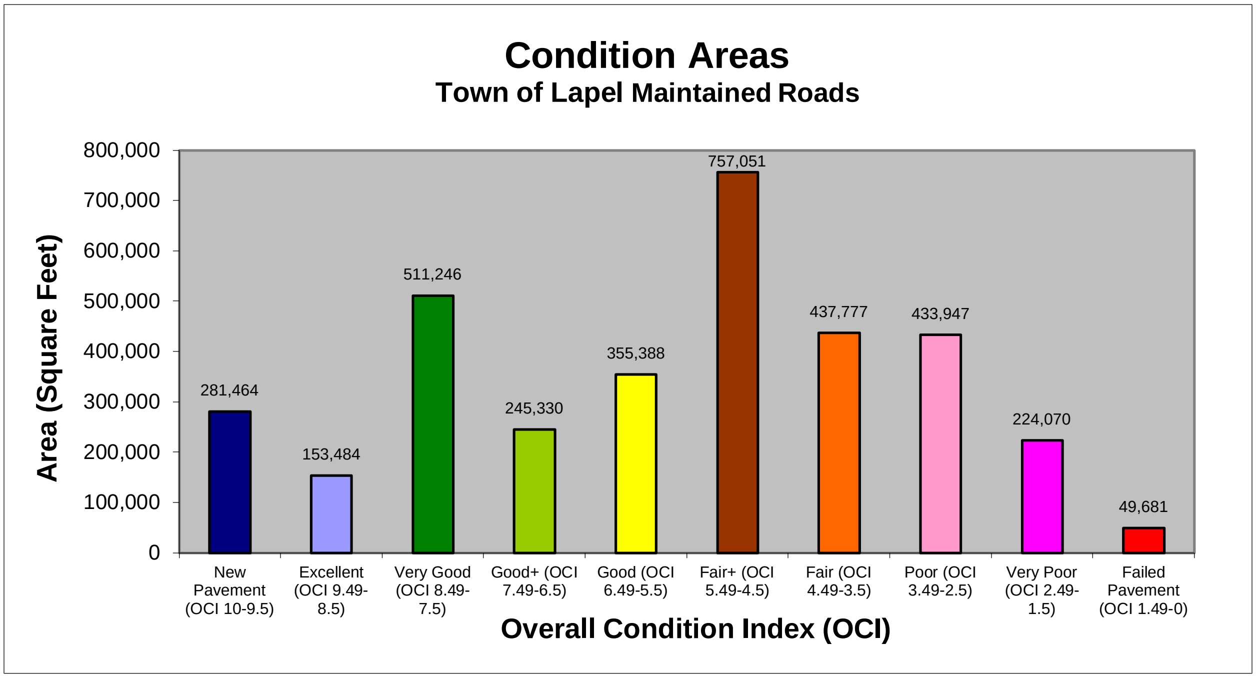
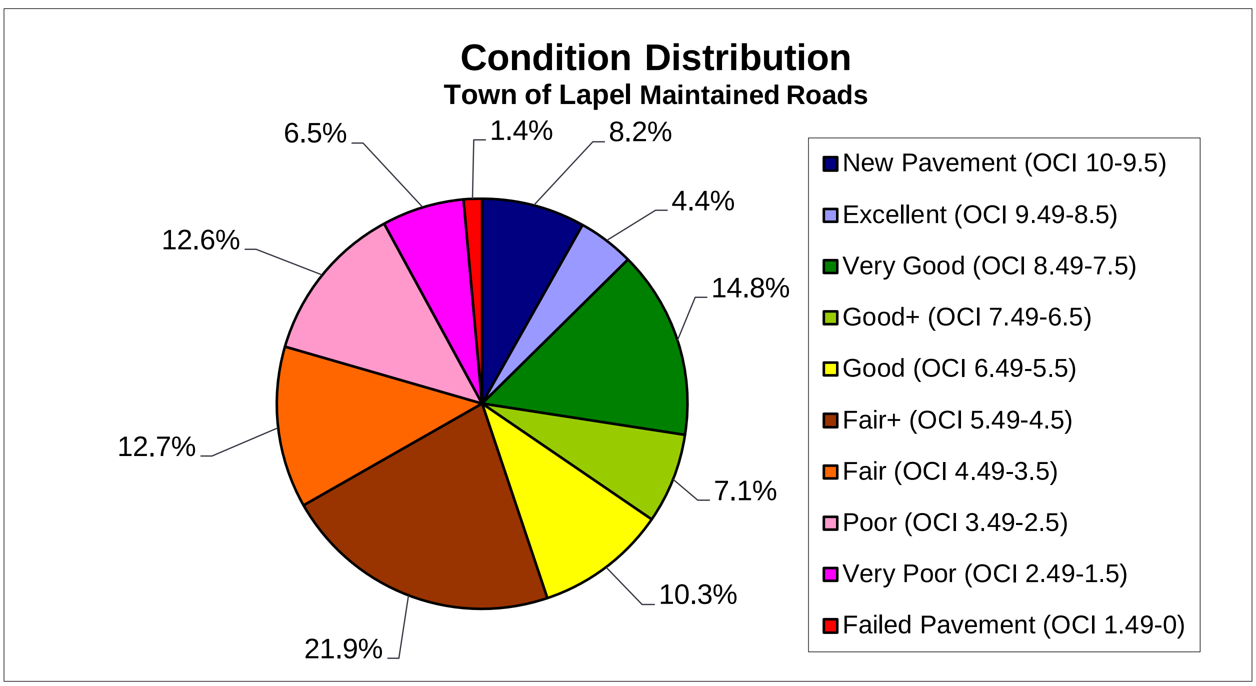


Figure 4: Network Pavement Condition Distribution



4. WORK PLAN DEVELOPMENT

The pavement management program develops a conceptual, network-wide work plan to help predict future repairs and funding needs for the Town's road network. The work plan utilizes a budget based on the Town of Lapel's projected funding allocations, and then distributes the funds for preventative maintenance, rehabilitation, and reconstruction repairs, based on the input parameters for each pavement segment. CartéGraph reevaluates each segment in every year of the plan. For each year, a current OCI condition is determined based on the deterioration curve and any repairs that may have been assigned to a segment in a previous plan year. The system then prioritizes the overall network to determine which segments receive funding that year, how much funding is received, and how the conceptual repairs will improve the overall network OCI. The steps taken to develop the work plan are listed below and described in detail in the following sections.

- Define program parameters
- Establish prioritization system
- Define repair activities and costs
- Develop deterioration curve(s)
- Analyze scenarios

4.1 Program Parameters

The budget and parameter inputs into CartéGraph were developed with Town of Lapel's staff. The current pavement maintenance and rehabilitation budget provided to Kimley-Horn was $600,000. This budget is based on a shared cost with the Indiana Department of Transportation (INDOT) through the Community Crossings Grant. Based on the funding program, the construction costs would be split with the Town responsible for 25% of the construction costs ($150,000) and State providing a 75% match ($450,000). While one scenario assumes a $600,000 budget, Kimley-Horn also reviewed network performance utilizing several other budget scenarios to compare how changing the annual budgets may impact the Town of Lapel's ability to meet the Town's goals of maintaining an overall acceptable network OCI.

Five years was determined to be an appropriate analysis duration. It was determined that a 5-year work plan could provide the Town of Lapel with a future projection that was realistic. As with any model that makes future projections, the results become more conceptual the further into the future projections are made.

The Town's current weighted OCI network is around 5.74. For each budget scenario, CartéGraph will be targeting an OCI value between 5.7-6.0. In a network with an overall PCI around or above the critical point (5.7 to 6.0), most of the work will be more cost-effective repairs, such as preventive maintenance and rehabilitation, with occasional reconstruction type repairs.

CartéGraph can also adjust the inflation and interest rates for the plan period. For the Town of Lapel network analysis, the interest rate was set to zero, assuming a loan will not be taken out for the repairs, and the inflation rate was set at 2.0% to account for the increase in repair activity costs in future years.

4.2 Prioritization

To determine the order in which repairs will be completed, a prioritization system must be established. Based on discussions with Town staff, no factors, other than the OCI of the road segments, were considered for determining the prioritization of repair projects. It was the desire of the Town staff to let the condition of the roadways only dictate which roads receive priority. Therefore, this pavement management program utilizes a “worst first” scenario approach in which the lowest OCI conditioned pavements are given the highest priority for repair. The advantage to using the worst first scenario is that it prevents pavement from deteriorating too low. The disadvantage is that repairs may not be identified at the earliest time possible in the lifecycle. A second option that the Town could consider would be to give the highest OCI conditioned pavements the highest priority for repair, a “best first” scenario. The advantage to using the best first scenario is that the newest pavement is extended to the longest possible life. The disadvantage is that the poorest pavement segments will continue to drop to unacceptable OCI levels. During discussions with Town staff, it was determined that the worst first scenario aligns more closely with current practices of the Town as well as with the goals of preventing roads from deteriorating to a “poor” or “failed pavement” condition. Therefore, the worst first scenario was applied to the pavement program.

To prevent better conditioned pavement segments from dropping beyond acceptable OCI levels, repair strategy budgets were developed to promote more balanced prioritization management practices in the program. Defining separate repair strategy budget categories also helps assure that the appropriate funding levels are being applied to areas of need in a cost-effective way, as the most important goal in prioritization is performing the correct repair strategies at the optimal times. A percentage of the annual budget in each plan year was set by Kimley-Horn for preventative maintenance repairs, rehabilitation repairs, and reconstruction repairs. It is important to note that while the benefit to cost ratio is much higher for preventative maintenance repairs, these repair types are also much less expensive per square-foot of pavement. Therefore, it takes a much smaller percentage of the budget to complete these types of repairs across a larger percentage of the overall pavement network when compared to rehabilitation and reconstruction type repairs. In this case, much of the budget is reserved for the rehabilitation repair strategy. The repair strategy budget breakdown is shown in Table 3.

Table 3: Repair Strategy Budget Plan

Maintenance Type	Allocation
Reconstruction (OCI 0-2.4)	20%
Rehabilitation (OCI 2.5-6.4)	75%
Preventative Maintenance (OCI 6.5-10)	5%
Total	100%

4.3 Repair Activities

The next step in developing the work plans was to determine the appropriate repair activities at each point in a pavement's life cycle and the cost associated with that repair. Repair activities and associated costs were determined from industry research as well as bid information submitted by several contractors for recent pavement repair projects similar in locale and nature to the repairs anticipated throughout the Town of Lapel.

4.3.1 Repair Activity Types

Repair activities are intended to increase the pavement life expectancy. Repairs in the preventative maintenance category, such as crack sealing and surface sealing, are intended to slow the deterioration of the pavement, as opposed to dramatically increasing the pavement condition. Although rehabilitation or reconstruction will be needed eventually, the preventative maintenance activities provide the most cost-effective way to increase life expectancy. Once a pavement reaches the point where rehabilitation repairs are required, the associated costs rise exponentially as the condition deteriorates. Repairs such as cut and patching, overlays, and partial-depth milling and replacement, increase the pavement condition rating and extend the life significantly, but at a greater cost than applying preventative maintenance. The repairs associated with reconstruction are the most extreme scenario. This essentially begins a new pavement life cycle by increasing the condition rating to 10, but at the highest expense. The effects of different repairs on the pavement life expectancy are shown in Table 4, on the following page. This information was obtained from the FHWA; it estimates the number of years of benefit to the pavement, not for the treatments themselves. It is important to understand that these are estimated values, as the actual gains depend on numerous factors such as original construction quality, varying traffic loadings, sub-grade type, and climate conditions.

Table 4: Extended Service Life Gains for Pavement Treatments

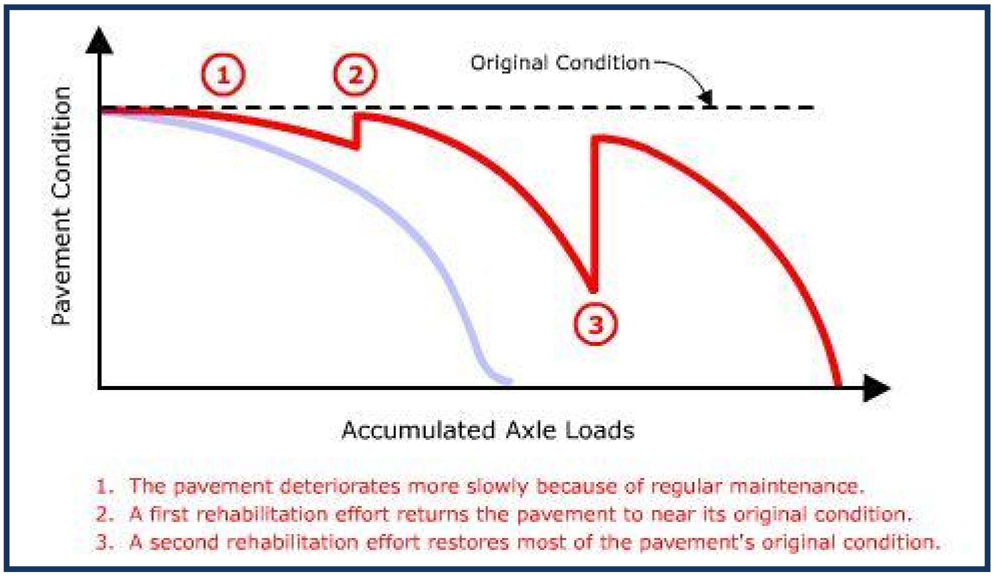
Repair Activity	Pavement Type	Extended Service Life (Years)	Maintenance Type
Overband Crack Sealing	Flexible	Up to 2	Preventative Maintenance
	Composite	Up to 2	
Crack Sealing	Flexible	Up to 3	Preventative Maintenance
	Composite	Up to 3	
	Rigid	Up to 3	
Single Chip Seal	Flexible	3 to 6	Preventative Maintenance
	Composite	NA*	
Double Chip Seal	Flexible	4 to 7	Preventative Maintenance
	Composite	3 to 6	
Slurry Seal	Flexible	NA*	Preventative Maintenance
	Composite	NA*	
Micro-surfacing (Single Course)	Flexible	3 to 5**	Preventative Maintenance
	Composite	NA*	
Micro-surfacing (Multiple Course)	Flexible	4 to 6**	Preventative Maintenance
	Composite	NA*	
Ultrathin Asphalt Overlay (0.75")	Flexible	3 to 5**	Rehabilitation
	Composite	3 to 5**	
Asphalt Overlay (1.5")	Flexible	5 to 10	Rehabilitation
	Composite	4 to 9	
Mill and Overlay (1.5")	Flexible	5 to 10	Rehabilitation
	Composite	4 to 9	
Mill and Overlay (2.0")	Flexible	7 to 12	Rehabilitation
	Composite	7 to 12	
Pulverization and Overlay	Flexible	8 to 14	Rehabilitation
	Composite	8 to 14	
Full Reconstruction	Flexible	15 to 40	Reconstruction
	Composite	15 to 40	
Joint Resealing	Rigid	3 to 5	Preventative Maintenance
Spall Repair	Rigid	Up to 5	Preventative Maintenance
Full-depth Concrete Repairs	Rigid	3 to 10	Rehabilitation
Diamond Grinding	Rigid	3 to 5**	Rehabilitation
Dowel-bar Retrofit	Rigid	2 to 3**	Rehabilitation
Concrete Pavement Restoration	Rigid	7 to 15**	Rehabilitation
Full Reconstruction	Rigid	15 to 50	Reconstruction

*Sufficient data is not available to determine life-extending value

**Additional information is necessary to quantify the extended life more accurately

Figure 5, below, demonstrates the effects on pavement condition that preventative maintenance, rehabilitation, and reconstruction have throughout the life cycle.

Figure 5: Repair Effects of Pavement Deterioration with Time



Source: http://classes.engr.oregonstate.edu/cce/winter2012/ce492/Modules/11_pavement_management/11-2_body.htm#effect

4.3.2 Repair Activity Schedule

Pavement deterioration rates are dependent on several different factors. Despite the rate of deterioration, it has become a well adopted concept proven continuously in the field that the deterioration of a pavement can be offset, and the life of a pavement greatly extended by properly performing maintenance and repair strategies at the appropriate times during the life cycle of a pavement. As the life of a pavement is extended by performing less costly preventative maintenance and rehabilitation repairs, rather than constantly allowing a pavement to deteriorate to the point where more costly reconstruction is required, the more cost efficient the pavement lifecycle will be. Over an entire pavement network, performing these typical repairs can yield significant long-term cost savings. While every pavement will require its own assessment to determine the best repair at the best time, there have been several studies performed to try to determine the typical preventative maintenance and rehabilitation schedule during the life of a pavement. Table 5 shows the results of one study completed by the Minnesota Department of Transportation (MnDOT). While the typical MnDOT pavement segment might slightly vary from that of an Indiana pavement segment due to differing environmental conditions, the maintenance schedule outlined in Table 5 is still relevant for local roads in Lapel and generally a good practice to follow.

MnDOT has studied the typical pavement repair cycle for multiple scenarios, such as for asphalt pavement and concrete pavement, and for high traffic loading and low traffic loading. Table 5 is for an asphalt surface type with lower traffic counts. It is important to note that the time shown for each repair assumes that all previous preventative maintenance and rehabilitation repairs have been performed. For example, the first mill and overlay can be expected somewhere around year 20 of the pavement life. This assumes that proper crack sealing was performed when needed and a surface treatment, such as a seal coat, was also performed when needed. If no work was done prior, it should be anticipated that the mill and overlay would be required significantly sooner than year 20 of the pavement life.

Table 5 provides helpful insight for planning future repairs for the Town of Lapel program; however, it should be noted that the years shown are just approximate, and that each pavement segment could require preventative maintenance or rehabilitation repairs much sooner or later than the years provided below.

Table 5: Typical Preventative Maintenance and Rehabilitation Schedule

Year	Asphalt Pavement with 20-year BESALs less than 7 million
0	Initial construction
6	Rout and seal cracks
10	Surface treatment
20	Mill and overlay
23	Rout and seal cracks
27	Surface treatment
35	Mill and overlay
38	Rout and seal cracks
43	Surface treatment
50	End of analysis (no residual value)

4.3.3 Repair Activity Inputs to CartéGraph

Pavement repair activities were developed in CartéGraph for planning and budgeting purposes. The type of repair activity is set up to be chosen based on the OCI and pavement surface type. For example, an "AC-5" repair activity is applied if the segment is asphalt and the OCI falls within the range of 4.5 to 5.4. Since the activities are intended to address multiple segments that may fall into an OCI range due to varying distresses, they are setup to account for multiple repair actions instead of a single action for one particular distress. For example, an "AC-4" activity likely consists of a partial-depth mill and replace of the asphalt surface throughout a segment's entire area. However, before maintenance is performed on a specific segment, a detailed evaluation of this segment needs to be performed. Based on this project-level analysis, it may be determined that an alternative approach, such as isolated patching with a thick asphalt overlay, is more desirable based on field conditions. Further detail for specific repairs on each segment will be determined on a yearly basis in the project-level analysis and subsequent design process. Some repair types are intended to repeat on a normal schedule but may not be necessary on annual basis. These repairs are particularly those associated with preventative maintenance, like crack filling segments on a periodic basis, such as every few years, which is typically recommended. These general repair activities were created for asphalt pavement surface types throughout the condition spectrum. The only exceptions are for pavements with an OCI more than 8.5. Pavements with these ratings generally require no action because they are in new or excellent condition.

The unit costs for repair activities used in the program also greatly affect the plan results, and in this case, were modeled to parallel bid results from recent, actual projects near the Town of Lapel. Each activity has a specific unit cost and budget type associated with it. Table 6 outlines the CartéGraph asphalt repair activities used in the Town of Lapel work plan. A preliminary Pavement Maintenance Activity Plan for the Town of Lapel is included in Appendix C2. However, before any work is performed on a specific segment, a detailed evaluation of each identified segment needs to be completed. This re-evaluation verifies if the repairs assigned in the plan are sufficient based on field conditions.

Table 6: CartéGraph Asphalt Repair Activities

Repair Activity	Maintenance Type	Typical Repairs	*Average Cost ($/ SF)
AC-8 (OCI 8.49-7.5)	Preventative Maintenance	Crack sealing	$0.11
AC-7 (OCI 7.49-6.5)	Preventative Maintenance	Crack sealing (some cracks may require routing)	$0.26
AC-6 (OCI 6.49-5.5)	Rehabilitation	Crack sealing (requires routing) Crack repairs (partial depth milling and patching) Cut and patch (up to 3% of area) Surface seal (seal coat or slurry seal) Re-stripe	$1.02
AC-5 (OCI 5.49-4.5)	Rehabilitation	Crack sealing (requires routing) Cut and patch or isolated mill and replace (up to 10% of area) Surface seal (slurry seal or microsurface) Thin asphalt overlay Re-stripe	$1.89
AC-4 (OCI 4.49-3.5)	Rehabilitation	Cut and patch or isolated mill and replace (up to 20% of area) Thick overlay or partial-depth mill and replace (shallow-depth or profile) entire area Re-stripe	$2.84
AC-3 (OCI 3.49-2.5)	Rehabilitation	Partial-depth mill and replace entire area Proof-roll and perform incremental milling and replacement or full depth repairs where required Repair isolated distress areas and overlay entire segment depending on existing site conditions Re-stripe	$3.86
AC-2 (OCI 2.49-1.5)	Reconstruction	Remove existing asphalt with full depth milling or pulverization 20% base repair with undercutting to strengthen sub-grade Addition of sub-base as needed Install replacement asphalt section Re-stripe	$5.61
AC-1 (OCI 1.49-0)	Reconstruction	Full-depth asphalt and base reconstruction required Re-stripe	$8.27

* Average cost associated with a series of repairs anticipated for the designated condition.

4.4 Deterioration Curves

Pavement deterioration curves are used to predict the deterioration cycles of the pavement segments found within the pavement network. The deterioration curve should consider construction factors such as pavement type, pavement thickness (surface layer and base layer, if applicable), aggregate base thickness, and subgrade composition. Other environmental factors such as pavement use, traffic volumes (car volumes and heavy vehicle volumes), and drainage conditions also affect the rate of deterioration.

To help continuously improve the accuracy of the deterioration curves, it is recommended that scheduled inspections of each roadway be performed to compare the actual pavement deterioration and condition ratings with the predicted ratings of the model. Each time an inspection is performed on a segment, OCI ratings should be updated within the CartéGraph database and the deterioration curve(s) should be re-evaluated. Over time, as more and more data is obtained from these periodic site inspections, additional deterioration curve(s) can be added, and the existing predicted deterioration curve(s) can be modified, to allow for even greater accuracy in the prediction of the deterioration for each pavement segment. These condition updates and deterioration curve adjustments are a necessary, standard application for all pavement management programs.

4.5 Analyze Scenarios

After all the inputs were entered into CartéGraph, the final step in developing the work plan is to run the analysis. Several analyses were run for the Town of Lapel's roadways to evaluate a variety of scenarios and determine the most appropriate approach for future pavement maintenance activities. These scenarios are described in the following sections.

4.5.1 No-Funding Scenario

The no-funding scenario projects the future condition of the pavement network when there is no funding and no repairs made. The no-funding scenario provides an indication of the rate of pavement deterioration when no action is taken. This scenario was provided to show the consequences of not performing the appropriate repairs on an annual basis. For this analysis, a 5-year duration was analyzed.

4.5.2 Budget-Driven Scenario

Budget-driven analysis predicts the repairs and resulting pavement network conditions in future years using predetermined budget allocations. The calculation of the budget-driven work plan involved CartéGraph running a detailed analysis while accounting for the previously discussed program inputs. CartéGraph determines the NPR of each segment and then determines what repair activities can be performed within the allocated annual budget, giving the segments with the highest NPR priority to receive repairs within each budget type. The program selects segments to repair until the annual budget allocations are gone or until no additional segments meet the criteria for a repair activity within a certain budget type. It will progress down the NPR ranking until it finds a suitable project that will raise the network OCI while also minimizing costs.

CartéGraph adds any activities that weren't completed because of lack of funds to the next plan year. Similarly, surpluses are also created due to unused budget funds available in subsequent plan years.

CartéGraph continues to roll any surplus dollar amount to the next year's budget to allow for any repairs that may be too expensive for the specified budget numbers.

For the Town of Lapel pavement network, the budget-driven scenario was run with an annual budget of $600,000 ($150,000 Local and $450,000 INDOT) over a 5-year period for Town-maintained roads only.

4.5.3 OCI-Driven Scenario

OCI-driven analysis predicts the repairs and costs that will be required to keep the overall pavement network at a user-specified OCI level. The OCI-driven scenario was provided to aid the Town of Lapel in developing an appropriate annual budget for its network. Although these are only projections, they provide an additional conceptual assessment of where the network stands based on current conditions, quantity of pavement, and other potential funding scenarios. This analysis was evaluated over a 5-year duration with a target OCI for the entire network set to be 5.5 to maintain existing conditions.

4.5.4 Unlimited Funding Scenario

To provide a basis for comparison, a budget scenario with unlimited funding was run to help determine the approximate budget that would bring the Town of Lapel network up to the maximum condition rating within the parameters of the other inputs. In the unlimited funding scenario, each segment of roadway received any repair that helped increase the overall OCI. Although this is an extreme comparison, it demonstrates where the Town of Lapel's current repair budget is compared to the "best-case" scenario and shows how the difference in the budgets impact the overall network OCI throughout the 5-year plan.

5. ANALYSIS RESULTS

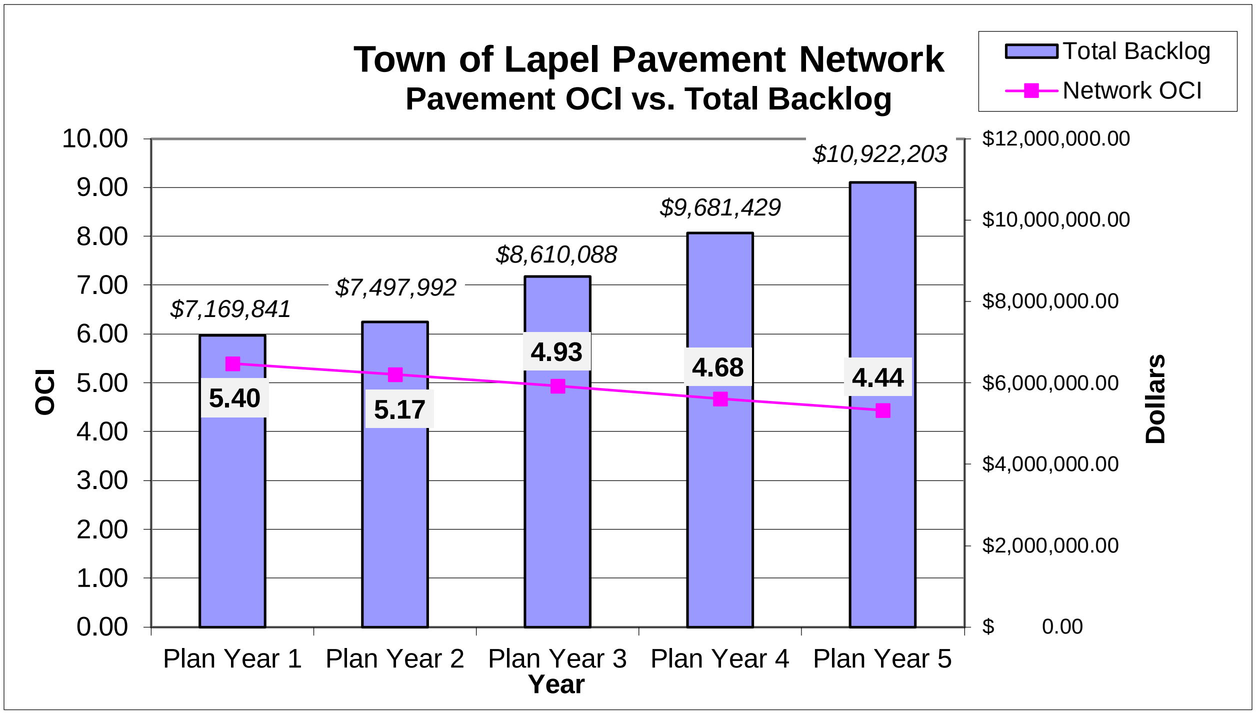
As discussed in the previous section, several analyses were run on the Town of Lapel's pavement network using CartéGraph software. The purpose of the analyses is to provide the Town of Lapel with a projection on the future condition of the Town of Lapel's pavement network under different budget and OCI constraints. The results of the analyses are presented in the following sections. The budget summary reports from CartéGraph are contained in Appendix D.

5.1 No-Funding Scenario

The no-funding scenario was evaluated over a 5-year period. The CartéGraph results show that in the scenario where no funding is applied to the network, the OCI drops from 5.4 at the end of plan year 1 to a level of 4.44 at the end of the 5-year period.

Each year that no repair work is performed on the network, the value of the work backlog, or accumulation of needed repairs, steadily increases as the pavement conditions decrease. The backlog projection is the funding needed over the 5-year period if the required work during each plan year is delayed until the following year. If no work is undertaken, the average pavement condition in plan year 5 is expected to fall to an OCI of 4.44 with a substantially high backlog of approximately $11,000,000 as shown in Figure 6. This backlog representation is especially critical for the Town of Lapel to understand the consequences of not performing the appropriate repairs on an annual basis. For each project that is eligible for a repair each year, the cost of pushing the repair to a later year in the work plan will directly increase the overall spending to maintain the same network wide average OCI rating. It should also be pointed out that the first year alone has a work backlog of over $7,000,000, which shows the network's need for maintenance and repair work.

Figure 6: Pavement OCI versus Network Backlog Comparison



5.2 Budget-Driven Scenario

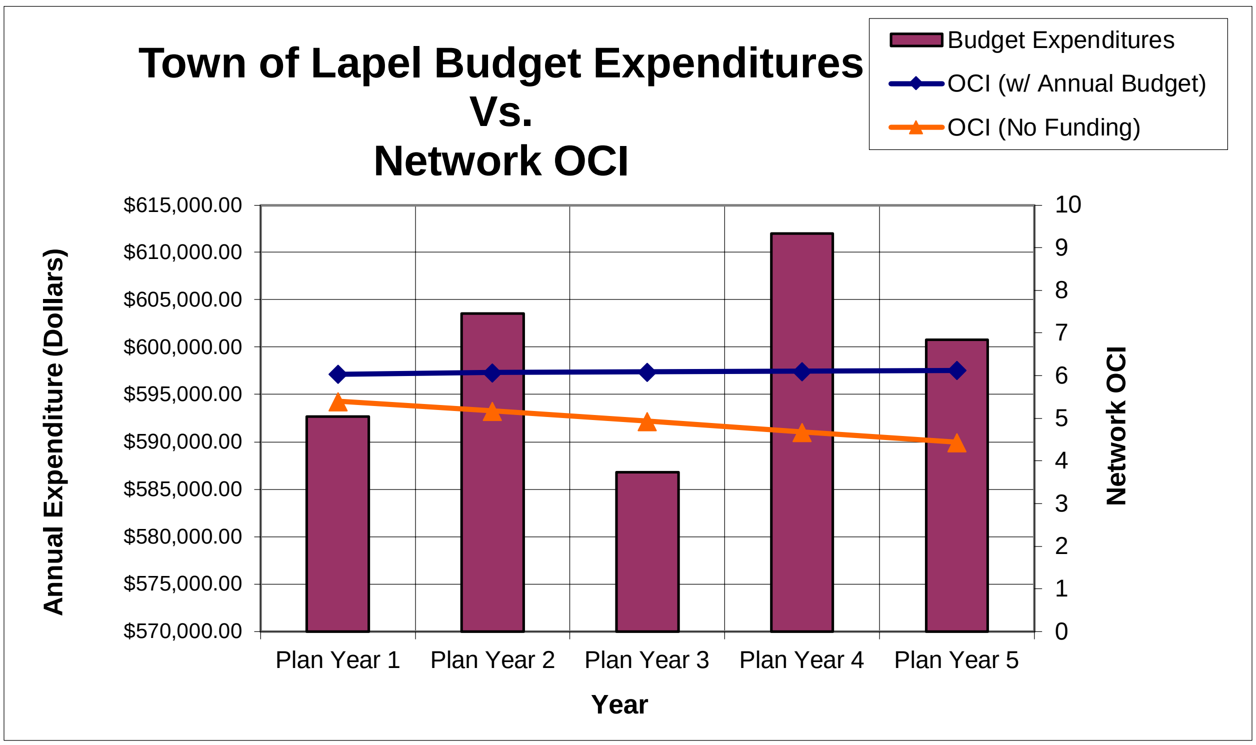
A 5-year budget-driven scenario was implemented for a $600,000 ($150,000 Local and $450,000 INDOT) annual budget to provide the Town of Lapel with a projection of the impact the anticipated funding would have on its pavement network. The results of the 5-year plan analysis indicate that the network OCI steadily increases throughout the 5-year work plan, starting from the current OCI value of 5.74 and ending at approximately 6.13.

Over the 5-year work plan, a total of approximately $2,995,731.11 is expended, with a network OCI of 6.13 at the end of plan year 5. Figure 7 shows the results of the 5-year work plan on the network-level OCI, compared to the network-level OCI in the scenario where no funding is applied to the network. The repair strategies under the given budget keep the pavement condition higher than the no funding scenario year over year. In the scenario where no funding is applied to the network, the OCI drops to a level of 4.44 at the end of the 5-year period, as opposed to 6.13 with the budget expenditures. Due to the OCI value slowly rising from 6.04 at the end of plan year 1 to 6.13 at the end of plan year 5, it can be concluded that an annual budget of $600,000 ($150,000 Local and $450,000 INDOT) is anticipated to be sufficient to improve the existing OCI for the town.

Table 7: Summary of Budget-Driven Scenario

Year	Annual Expenditures		Network OCI
Plan Year 1	$592,689.32		6.04
Plan Year 2	$603,518.17		6.08
Plan Year 3	$586,794.13		6.09
Plan Year 4	$611,941.51		6.11
Plan Year 5	$600,787.98		6.13
Scenario Type	Total 5-Year Cost	Equivalent Annual Budget	Network OCI (end of Year 5)
OCI-Driven			
Target $600,000/year	$2,995,731.11	$599,146.22	6.13

Figure 7: Town of Lapel Budget Expenditures versus Network OCI



5.3 OCI-Driven Scenario

The OCI-driven scenario was provided to aid the Town of Lapel in developing an appropriate budget for its network. In the OCI-driven scenario, after CartéGraph determines the NPR of each segment, CartéGraph begins picking the optimal repair for each segment starting at the highest NPR (regardless of project cost) until the chosen repairs allow the overall network OCI to meet or exceed the target OCI. As soon as the target OCI is met, CartéGraph performs no more repairs during the plan year. The total costs of the chosen repairs, as well as the final, improved OCI are noted for each plan year. Although these OCI-driven scenarios are only projections, they provide additional conceptual assessments of where the network stands based on current conditions, quantity of pavement, and other potential funding scenarios.

With the current network wide OCI slightly below the critical point, an OCI-driven scenario was performed for the Town of Lapel to see what level of funding would be required to sustain the OCI average near its current condition (or slightly better) and close to the critical point. As noted earlier, in Section 2.2.2, when the average OCI is near the critical point, the network tends to allow for more cost-effective preventative maintenance techniques. The information in Table 8 summarizes the results of the OCI-driven scenario with a target OCI of 5.5.

Table 8: Summary of OCI-Driven Budget Scenario

Year	Target OCI	Annual Expenditures	Network OCI
Plan Year 1	5.50	$316,466.36	5.51
Plan Year 2	5.50	$794,570.64	5.52
Plan Year 3	5.50	$794,991.64	5.52
Plan Year 4	5.50	$1,177,718.31	5.70
Plan Year 5	5.50	$423,543.67	5.58
Scenario Type	Total 5-Year Cost	Equivalent Annual Budget	Network OCI (end of Year 5)
OCI-Driven			
Target OCI 5.5	$3,507,290.40	$701,458.08	5.57

In the OCI-driven scenario that targets a network OCI of 5.5, the total 5-year cost is approximately $3,507,290, which is about 15% (or approximately $512,000) more than the predicted $2,995,731.11 budget used in the budget-driven analysis. Note that in this scenario the town would increase the amount money it spends and end with a lower OCI value than in the budget-driven scenario. This trend can be explained with the same concept as the discussed in the no funding scenarios. In plan year 1 under the OCI-driven scenario, significantly less is spent than during the $600,000 annual budget scenario. Despite the total 5-year cost being higher, the delayed repairs in plan year 1 created additional backlog across the portfolio, thus requiring added spending in the remaining 4 years of the OCI-driven scenario. This reinforces the importance of implementing the pavement management plan as soon as possible for the Town's best interest.

5.4 Unlimited Funding Scenario

The information in Table 9 summarizes the results of the unlimited funding scenario. The majority of expenditures are in plan year 1 to repair the backlog of projects that currently exists. With a total 5-year cost of approximately $8,177,000, approximately $7,170,000, or 87.6%, of the 5-year total budget is being spent in plan year 1. By spending this extensive amount initially, the OCI significantly increases to 8.25 and allows the remainder of the work plan to focus on preventative maintenance and light rehabilitation. As a result, after year 1 the average expenditures per year for years 2 through 5 is approximately $251,850.

The 5-year work plan using the unlimited funds scenario requires a total cost of over $8,177,000, or an equivalent annual budget of approximately $1,635,000, and the network will result in an average OCI of 7.82 after the 5-year duration.

It is unrealistic for the Town of Lapel to spend more than $8,000,000 over the next 5 years, nor is it necessary for the Town of Lapel to maintain a network OCI at 7.0+. The key is for the Town of Lapel to find a median spending level that both meets a realistic budget plan while maintaining the network OCI to an acceptable level.

Table 9: Summary of Unlimited Funding Budget Scenario

Year	Target OCI	Annual Expenditures	Network OCI
Plan Year 1	100	$7,169,840.75	8.25
Plan Year 2	100	$310,541.01	8.16
Plan Year 3	100	$54,313.01	7.92
Plan Year 4	100	$291,563.64	7.87
Plan Year 5	100	$350,985.79	7.82
Scenario Type	**Total 5-Year Cost**	**Equivalent Annual Budget**	**Network OCI (end of Year 5)**
OCI-Driven			
Target OCI 100	$8,177,244.62	$1,635,448.92	7.82

Even in the unlimited funding scenario, the network OCI peaks in plan year 1 at 8.25. Then, regardless of the "unlimited" amount of money spent, the OCI falls during each of the remaining years of the plan. An explanation is found by examining what repairs will be most common for a network with an OCI over 7.5. Preventative maintenance repairs (e.g., crack sealing) and light-duty rehabilitation (e.g., isolated patching, surface sealing, etc.) consume most of the annual expenditures. While these repairs are critical to extending the life of pavement, they do not improve each segment's individual OCI as drastically as a reconstruction or heavy-duty rehabilitation repair would. Therefore, the increase in the network-level OCI from performing these repairs is not always substantial enough to offset the network-wide deterioration as all pavement segments fall down their deterioration curve(s). Performing reconstruction or heavy rehabilitation on other pavements that do not require it would greatly boost the OCI values but does not represent a cost-effective repair strategy.

6. RECOMMENDATIONS

6.1 Annual Pavement Repair Budget

The overall network analysis with the $600,000 annual budget, representing the current spending patterns described to Kimley-Horn by the Town of Lapel, produced an overall network OCI of 6.13 at the end of the 5-year work plan. This represents an average OCI slightly above the range typically identified as the critical point, between 5.7 - 6.0. Networks with an OCI in this range typically have a diverse pavement network with a management program showing preventative maintenance, rehabilitation, and reconstruction repairs in each year of the plan. Based on the analyses performed during this project, the current optimal budget breakdown is as follows: 5% preventative maintenance; 75% rehabilitation; and 20% reconstruction. The budget breakdown should be evaluated annually to obtain the most efficient program results. For example, some years it may be necessary for the reconstruction budget to exceed 20% in order to address larger road segments that cost more than the typical reconstruction budget is able to provide.

The results of the CartéGraph analysis indicated that the Town of Lapel's current budget of $600,000 is sufficient to maintain a goal condition, and slightly improve network wide OCI, over the next 5 years.

6.2 Project Prioritization

A cost-effective pavement maintenance plan requires a system of prioritization. Through conversations with the Town of Lapel staff, segments for this pavement management program were prioritized based on the current conditions, with the lowest OCI segments prioritized the most. Additionally, to ensure a well-rounded pavement maintenance program that included preventative maintenance, rehabilitation, and reconstruction, separate budgets were established for each repair strategy and projects were prioritized within these separate budgets.

An overview of the recommended yearly maintenance and repair costs for each of the Town of Lapel's roadway segments is provided in the Segment Analysis Recommendations found in Appendix D3. Although the reported costs reflect a $600,000 annual budget, based on the recommendations described in this report, the same prioritization approach can be applied for a budget of any size.

It is important to note that the model is set up to account only for costs associated with pavement maintenance and repair construction projects. Therefore, items such as material, equipment, labor, mobilization, and other standard construction costs to perform pavement repair projects have been included in the estimated annual expenditures. However, items such as engineering fees, permitting costs, costs to apply for Community Crossing grants, or repair costs for non-pavement improvements (e.g., building, landscaping, drainage, utilities, curbs, sidewalks, unpaved shoulders, ADA) have not been accounted for in the analysis, and may need to be listed as separate line items to future Town of Lapel repair projects when performing the project-level analysis.

6.3 Project-Level Analysis

It is recommended that the Town of Lapel take caution in using this plan for direct funding of repair projects. The purpose of an analysis of this level is to confirm network funding levels and assist in selecting projects. Once projects are selected, a detailed "project-level" analysis should be performed. A project-level analysis should identify the most cost-effective repair techniques, establish the scope of the project, develop a detailed project budget, and prepare a project schedule. The Town of Lapel should enlist the services of a licensed engineer to assist in the development of design plans. Additionally, it is recommended that the Town perform inspections during construction for quality control and quality assurance measures. The most current Town of Lapel and State of Indiana standards and specifications should be followed for all design and construction services.

6.4 Program Updates and Maintenance

Significant investment has been made to inventory the Town of Lapel network of pavement and in the development of this management program. Continued investment into the program is strongly recommended. Once the data is input into CartéGraph, the model runs continuously reflecting the constant deterioration of the network's pavement segments. At a minimum, the maintenance and repair database within CartéGraph should be updated annually, or as repair measures are completed. It is also recommended the Town of Lapel assess the work plan annually to account for any changes that may have occurred throughout the network.

7. OCI VISUALIZATION IN ARCGIS

To help the Town of Lapel easily identify areas of concern, a visualization tool was set up in ArcGIS that uses a defined color-coding scheme based on the PASER OCI ratings. First, the centerlines associated with each individual pavement segment were exported to a GIS shapefile and assigned a unique ID. The unique ID was then linked to the data exported from CartéGraph to associate each centerline with output from the model. The color scale was then applied to the pavement segment shapefile, automatically shading sections based on the OCI value.

By utilizing ArcGIS, the method seamlessly links CartéGraph output with the individual pavement segment centerlines. The process eliminates the need to manually color individual pavement segments, saving time and cost as OCI values change year to year. After running the model and exporting the OCI values, the colors associated with each roadway can be updated automatically on the Town of Lapel's OCI map simply by replacing the OCI values in the linked spreadsheet.