NDSU UPPER GREAT PLAINS TRANSPORTATION INSTITUTE

Draft

Infrastructure Needs: North Dakota's Urban Corridor Roadways and Bridges: 2017-2036

Draft Report Requested by North Dakota Department of Transportation and North Dakota League of Cities

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Summary of Study

This report is the response to a request from the North Dakota Department of Transportation (NDDOT) and the North Dakota League of Cities (NDLC) for a study of the transportation infrastructure needs of urban roadways within the state. In this report, infrastructure needs are estimated using the most current traffic estimates, and roadway inventory and condition data available. Only the 14 largest cities were studied and only those streets designated as collector and higher within corporate limits were studied. This is an important point for the reader, as local streets make up the majority of the mileage within each city but, as agreed by the project sponsors, the local streets are not part of the study. Note that the study was developed by following similar study concepts as the Assessment of ND County and Local Road Needs, 2017-2036 Study. For the remainder of this report that study will be referred to as the County/TWP Study. Both studies generally identify the costs to maintain the existing system although additional information on future development planning is presented later in the report.

A significant data collection effort was undertaken to provide the most complete and current data on the condition of the urban collector system within each of the 14 cities. Condition information was collected by using a third party consultant, Dynatest, which utilizes instrumentation and software to provide objective assessments. The 14 individual cities provided funding for Dynatest to collect the condition data.

For purposes of analyzing traffic volumes, Travel Demand Models (TDM) were created or adapted from Metropolitan Planning Organization (MPO) TDMs. Due to the lack of urban truck classification data, a general assumptions that 2% of traffic was trucks was used to project Equivalent Single Axle Loads (ESALs). Comments were received from several cities regarding specific routes that carried a higher percentage of trucks. These were often in industrial areas where lower overall traffic existed but with a higher percentage of trucks.

For essential roadway study data, the Geographic Roadway Inventory Tool (GRIT) was used to gather and verify urban roadway inventory information such as pavement age, thickness, etc. The information was loaded into the system directly from each city's road authority. GRIT was advanced by the 2015 North Dakota Legislative Assembly through the NDSU Upper Great Plains Transportation Institute budget bill.

The overall cost to perform this study was approximately $207,000. The cost of the Dynatest pavement condition data collection and analysis process was $125,765. As stated earlier, the 14 cities reimbursed UGPTI through the League of Cities for this work. NDDOT contracted with UGPTI to for the staff time to develop the overall study at a cost of $81,231.

Study Network:

The routes included in the study network consist of the urban collectors and higher except that state system routes were excluded. This means that local residential streets were generally not included in the summary. When local streets and state corridors are excluded, a limited number of miles remain in each city. The following table shows the resulting study mileage within each city.

City	Miles in Study	City	Miles in Study
Bismarck	100.5	Mandan	25.9
Devils Lake	16.3	Minot	56.1
Dickinson	49.6	Valley City	15.7
Fargo	132.2	Wahpeton	12.7
Grafton	10.1	Watford City	4.3
Grand Forks	72.2	West Fargo	42.1
Jamestown	26.6	Williston	53.3
Total Mileage = 617.4			

Paved Road/Street Needs

The urban road analysis follows a similar approach to the one used in the 2016 County/TWP study. For the most part, the same methods and models have been used, but differing data collection has kept uncertainty low. This report shows results for individual cities. As would be expected, cities with newer pavements or with networks with higher maintenance investments generally show less investment needs per mile of network.

As shown in Table A, $601 million in paved road investment and maintenance expenditures will be needed during the next 20 years.

Table A: Summary of Urban Road Study Investment and Maintenance Needs in North Dakota (Millions of 2016 Dollars)

Period	Resurfacing Cost	Reconstruction Cost	Concrete CPR Cost	Capacity Cost	Maintenance Cost	Total Cost
2017-2018	$10.5	$104.6	$3.3	$14.0	$8.3	$140.6
2019-2020	$13.0	$36.8	$6.5	$32.2	$8.3	$96.9
2021-2022	$8.8	$20.8	$16.9	$24.9	$8.3	$79.8
2023-2024	$8.7	$9.7	$25.9	$17.2	$8.3	$69.7
2025-2026	$12.0	$8.0	$5.8	$8.6	$8.3	$42.7
2027-2031	$40.7	$11.4	$9.3	$34.3	$20.7	$116.4
2032-2036	$17.4	$1.5	$10.6	$8.8	$16.6	$54.8
Total	**$111.0**	**$192.8**	**$78.3**	**$140.1**	**$78.8**	**$600.9**

Bridge Needs

Bridges were analyzed similarly to the County/TWP study. Bridge condition data as acquired from the National Bridge Inventory System (NBIS) was obtained from North Dakota bridge inspectors. Bridge needs were developed from the NBIS sufficiency ratings as well as scores recorded for deck, superstructure and substructure condition.

Table B shows the estimated bridge investment and maintenance needs for urban bridges from 2017-2036. Most of the improvement needs are determined by the study's improvement model to be backlog needs, occurring during the first study biennium.

Table B: Summary of Bridge Investment and Maintenance Needs for Cities in North Dakota (Millions of 2016 Dollars)

Period	Statewide
2017-18	$42
2019-20	<$1
2021-22	<$1
2023-24	<$1
2025-26	<$1
2027-36	<$1
2017-36	**$43.2**

Total Statewide Needs

As shown in Table C, the combined estimate of infrastructure needs for all urban collectors and above is $644.1 million over the next 20 years. If averaged over the next 20 years, the annualized infrastructure need is equivalent to $32 million per year.

Table C: Summary of All Road and Bridge Investment and Maintenance Needs for Cities in North Dakota (Millions of 2016 Dollars)

Period	Paved Roads	Bridges	Total
2017-18	$140.6	$41.3	$181.9
2019-20	$96.9	<$1	$97.0
2021-22	$79.8	<$1	$79.9
2023-24	$69.7	<$1	$69.8
2025-26	$42.7	<$1	$42.8
2027-36	$171.2	<$1	$171.3
Total	**$600.9**	**$43.2**	**$644.1**

Extra Corporate Limit Needs:

Extra-corporate limit needs were difficult to study, because corridors beyond the corporate limits either do not exist or are part of a county or township road network at this time. It was agreed that the study would present this information as well as possible but the sources of this information would need to be from the individual long-range transportation plans (LRTP). The state's three MPO areas are required to maintain fiscally-constrained LRTPs and update them every five years. Several other cities voluntarily, or in cooperation with NDDOT, developed long-range plans. However, non-MPO cities generally have not applied fiscal constraints to the project schedules, and therefore, their plans may exceed the currently anticipated funding levels.

An overview of the extra corporate investments is presented in this report. The total LRTP needs identified for extra corporate limit areas was $643.5 million over a 20 year period.

Contents

1. Introduction

In response to a request from the North Dakota Department of Transportation (NDDOT) and North Dakota League of Cities (NDLC), NDSU's Upper Great Plains Transportation Institute (UGPTI) estimated urban road and bridge investment needs in 14 of the largest cities in North Dakota. This report presents results of the first statewide study for urban roadway needs. The study is based on the latest forecasts of urban traffic and road construction prices. All investment needs are forecast for a 20-year time period, starting with the 2017-2018 biennium.

In this report, investment needs are estimated for urban collectors and higher, excluding the state system routes.

2. Road Network

2.1. Data Sources

The primary GIS network used for this study was obtained from the ND GIS Hub Explorer at https://apps.nd.gov/hubdataportal/srv/en/main.home. Each individual city was then allowed to verify their roadway network and edit as necessary to improve the roadway network data. A single shapefile was utilized in the creation of the network: City Roads. The base shapefile is maintained by NDDOT, but the modified network has been maintained by UGPTI. For each of the lines representing a road, a variety of attributes, or data about the roadway, are provided.

2.2. Network Connectivity

Network connectivity is required to have a routable network for use in the travel demand modeling component of this study. This study utilized a network developed by HERE which was compatible with the Citilabs Cube routing software.

Network Functional Classifications:
The urban classifications for North Dakota include local streets, collectors, minor arterials, principal arterials and interstate. As stated earlier, local streets were omitted from the study by agreement among the parties participating in the study. In some states, collectors are divided into minor collectors and major collectors. Major collectors are generally eligible for federal funds. North Dakota does not recognize the minor collector category and only identifies collectors with the assumption that these are eligible for federal funds.

FHWA explains the functional classification of roads as follows:

> Most travel occurs through a network of interdependent roadways, with each roadway segment moving traffic through the system towards destinations. The concept of functional classification defines the role that a particular roadway segment plays in serving this flow of traffic through the network. Roadways are assigned to one of several possible functional classifications within a hierarchy according to the character of travel service each roadway provides. Planners and engineers use this hierarchy of roadways to properly channel transportation movements through a highway network efficiently and cost effectively.
>
> > **Collectors:** As their name implies, collectors "collect" traffic from local roads and connect traffic to arterial roadways. Collector routes are typically shorter than arterial routes but longer than local roads. Collectors often provide traffic circulation within residential neighborhoods as well as commercial, industrial or civic districts
> > **Minor Arterials:** Minor arterials provide service for trips of moderate length, serve geographic areas that are smaller than their higher arterial counterparts

and offer connectivity to the higher arterial system. In an urban context, they interconnect and augment the higher arterial system, provide intra-community continuity and may carry local bus routes.
Principal Arterials: There are usually multiple arterial routes serving a particular urban area, radiating out from the urban center to serve the surrounding region. Characteristics of urban principal arterials are:

- Serve major activity centers, highest traffic volume corridors and longest trip demands
- Carry high proportion of total urban travel on minimum of mileage
- Interconnect and provide continuity for major rural corridors to accommodate trips entering and leaving urban area and movements through the urban area
- Serve demand for intra-area travel between the central business district and outlying residential areas

3. Traffic Data and Model

The primary objective of the traffic study was to identify traffic volume data on urban streets throughout the state. Traffic data was generally obtained from past NDDOT urban traffic counts or existing travel demand models, where possible.

3.1. Traffic Model Development

To forecast future traffic volumes on urban streets, an effective base year traffic model must be constructed that accurately reflects existing traffic movements. The data from NDDOT urban counts provides direct observations against which the traffic model results can be compared. Only when the baseline traffic model has been shown to sufficiently model existing traffic can it be used to predict future traffic levels.

3.1.1. Cube Modeling Framework

Two methods were used to estimate and distribute traffic forecasts to the networks provided by the participating cities. The MPO cities provided the most recent versions of their travel demand models including base year and future year forecasts. This data was directly applied to the study networks including traffic volumes.

For the non-MPO urban areas, travel demand models were not readily available with the exception of Williston. NDDOT provided urban counts on a statewide basis, and these were used to develop a distribution model using Cube Analyst Drive. As the count locations were specific points, not all segments would have a traffic count. Cube Analyst Drive uses these count points as Transportation Analysis Zones, and distributes the traffic among the segments so that the accuracy on counted segments would be high.

The NDDOT counts are a snapshot in time, so a forecast growth rate of 2% annually was used to estimate increases in traffic in non-MPO urban areas. In the MPO, underlying economic activities are modeled and the forecasted traffic growth takes into consideration multiple factors in determining traffic growth.

Because of the lack of urban truck classification data, a general assumption that 2% of traffic is trucks was used to project equivalent single axle loads (ESALs). Comments were received from several cities regarding specific routes that carried a higher percentage of trucks. These were often in industrial areas where lower overall traffic existed but with a higher percentage of trucks. Additional truck analysis was performed on the routes that received these comments.

4. Pavement Structural Data

Pavement structure information was provided to UGPTI using the Geographic Roadway Inventory Toolkit (GRIT) developed by UGPTI as directed by the 2015 North Dakota Legislature. Each city roadway manager was responsible for input of the structural and geographic data for their urban networks via GRIT. Structural data that was requested included pavement layer thicknesses, base layer depth, and subbase strength. Additional geometric data such as roadway thickness, number of lanes and medians/curbs was also reported via GRIT. If structural or geometric data was unavailable or unsupplied, a statewide average was used. This data was used to calculate the pavement structural number (SN), the pavement strength for each roadway segment, and the surface area of the pavement.

5. Urban Road Analysis

The urban road analysis follows a similar approach to the one used the 2016 County/TWP study. For the most part, the same methods and models have been used.

A major part of the expanded data collection includes the use of the asset management tool GRIT. This online tool has allowed urban roadway managers to input roadway data based on past improvement projects. This tool gives us a practical view of the age and past construction practices of the cities. For the study, construction project data was taken from the inventory and input into the model to forecast future projects.

More than 600 miles of urban roads are classified as urban collectors and higher. To limit the network for the study, only these roads were selected for the study. State-owned, local and residential streets are excluded from the study.

In addition to miles of road and forecasted traffic levels, the key factors that influence paved road investments are: the number of trucks and cars that travel the road, the structural characteristics of the road, the width of the road, and the current surface condition. The primary indicator of a truck's impact is its composite axle load – which, in turn, is a function of the number of axles, the type of axle (e.g. single, double, or triple), and the weight distribution to the axle units.

5.1. Truck Axle Weights

AASHTO pavement design equations were used to analyze paved road impacts. These same equations are used by most state transportation departments. The equations are dependent upon Equivalent Single Axle Loads (ESALs). In this form of measurement, the weights of various axle configurations (e.g., single, tandem, and tridem axles) are converted to a uniform measure of pavement impact. With this concept, the service life of a road can be expressed in ESALs instead of truck trips.

An ESAL factor for a specific axle represents the impact of that axle in comparison to an 18,000-pound single axle. The effects are nonlinear. For example, a 16,000-pound single axle followed by a 20,000-pound single axle generates a total of 2.19 ESALs, as compared to 2.0 ESALs for the passage of two 18,000-pound single axles.[1] An increase in a single-axle load from 18,000 to 22,000 pounds more than doubles the pavement impact, increasing the ESAL factor from 1.0 to 2.44. Because of these nonlinear relationships, even modest illegal overloads (e.g. 22,000 pounds on a single axle) can significantly reduce pavement life.

5.2. Surface Conditions

With the funding from North Dakota League of Cities, UGPTI contracted Dynatest to collect automated distress data of all urban corridors. The data collection vehicle from Dynatest is a state-of-the-art van equipped with computer, laser, sensor, and video equipment designed to collect data and video images of the roadway and pavement surface. International Roughness Index (IRI) is calculated using the Dynatest Mark III High Speed Laser Profiler, which is equipped with seven lasers and two accelerometers to create the highest standard of profiler. This device collects the longitudinal profile of the pavement surface for both wheel paths. These longitudinal profiles are used to calculate pavement IRI values using quarter car simulation and half car simulation. Additional sensors, lasers, video, and a 3D subsystem installed on the van are used to collect and measure rut and cracking information and automatically determine pavement distress scores. The use of this equipment helped to ensure a standardized and consistent method of pavement data collection across the state.

The pavement data collection took place in summer of 2016. Fewer than 10 miles of the total system were omitted in the data collection effort. These omitted miles consisted of roads under construction. Construction projects or proposed 2016 projects were projected to a new score. The remaining miles were calculated as the average of pavement scores in each city.

The pavement data was processed and provided with GPS coordinates representing the average score of every 100’ of all paved roads collected. Each of these points representing 100’ was then averaged based on the project segments as entered into GRIT by the local road authority. The data obtained included an IRI value which represents the roughness (how it rides) expressed in inches per mile and Pavement Condition Index (PCI) which represents the distresses such as cracking and rutting. PCI is provided in ASTM Standard format on a 0 to 100 scale. These two values were then converted into a Present Serviceability Rating (PSR) (0 to 5) for ride and

[1] These calculations reflect a light pavement section with a structural number of 2.0 and a terminal serviceability (PSR) of 2.0.

condition for use with the AASTHO 93 pavement design equation. The following formulas were used for this conversion:

• IRI converted to 0 – 5 Score using straight line equation based on all urban miles collected:

$$PSR_{Ride} = .0105(IRI) + 5.3849$$

• ASTM PCI (0 -100) score converted to 0 – 5 score using straight line equation based on all urban miles collected:

$$PSR_{distress} = 0.09 * (PCI_{ND}) - 4.20$$

• Combined ride and condition with following equation:

$$PSR_{combined} = \sqrt{PSR_{ride} * PSR_{distress}}$$

This $PSR_{combined}$ score was then used for the analysis. See maps for results.

The results of the condition assessment are summarized in Table 1, which shows that 20% of miles included in the study are in very good condition, meaning they have recently been improved. Another 47% of paved road miles are in good condition; 26% are in fair condition. Eight percent of paved road miles are rated as poor or worse. Road condition ratings for each city are shown in Appendix A.

Table 1: Conditions of Urban Roads in North Dakota in 2016

Condition	Miles	Percent
Very Good	124.0	20.0%
Good	287.3	46.5%
Fair	158.9	25.7%
Poor	38.9	6.3%
Very Poor	8.3	1.4%
Total	**617.4**	**100%**

5.3. Structural Conditions

The capability of a pavement to accommodate heavy truck traffic is reflected in its structural rating, which is measured through the structural number (SN). The structural number is a function of the thickness and material composition of the surface, base, and sub-base layers. The surface (top) layer is typically composed of asphalt while the sub-base (bottom) layer is comprised of aggregate material. The base (intermediate) layers consist of the original or older surface layers that have been overlaid or resurfaced. Roads that have not yet been resurfaced or have recently been reconstructed may have only surface and aggregate sub-base layers.

In this study, structural numbers are used to estimate (1) the contributions of existing pavements at the time a road is resurfaced, and (2) the overlay thickness required for a new structural number that will allow the road to last for 20 years. The deterioration of the existing pavement is reflected in this calculation. For example, the average in-service structural number of an urban street with a 6-inch aggregate sub-base and a 5-inch asphalt surface layer in fair condition is computed as 6 × 0.08 + 5 × 0.25 = 1.7. In this equation, 0.08 and 0.25 are the structural coefficients of the sub-base and surface layers, respectively. These coefficients vary with age and the condition of the pavement.

5.4. Types of Improvement

Three types of road improvements are analyzed in this study: (1) reconstruction, (2) resurfacing, and (3) Concrete Pavement Repair (CPR). If a pavement is not too badly deteriorated, normal resurfacing is a cost-effective method of restoring structural capacity. In this type of improvement, a new asphalt layer is placed on top of the existing pavement. Many times, the city will mill a portion off of the asphalt roadway to tie the asphalt into the existing curb lines. The thickness of the layer may vary. Most cities will use a thin 2 inch overlay as a standard overlay section based on pavement age. However, it may be as thick as six to seven inches based on traffic. Without extensive truck traffic, a thin overlay will be effective in urban sections.

Reconstruction entails the replacement of a pavement in its entirety, i.e. the existing pavement is removed and replaced by one that is equivalent or superior. Reconstruction includes subgrade preparation, curbs, storm sewer, lighting, sidewalk, medians and all other roadway items. A road may be reconstructed for several reasons: (1) the pavement is too deteriorated to resurface, (2) the road has a degraded base or subgrade that will provide little structural contribution to a resurfaced pavement, (3) the road has too few lanes to accommodate forecasted traffic to the corridor and will require additional lanes in the future, or (4) the pavement has aged beyond the serviceable life of an overlay or CPR.

Concrete roadways with higher PSR ratings will slowly continue to deteriorate over the course of the study. However, many of these roadways have a 50+ year design life, and will not deteriorate to the point of replacement over the shorter 20-year study. Consequently, many concrete roadways are only slated to have maintenance costs applied to them over the course of the study, and these are shown as “Concrete CPR.” These roadways will only be slated for the standard maintenance practice of a CPR over the course of the study, and the annualized costs are applied to the segments based on age.

5.5. Improvement Logic

The forecasting procedure used in this study considers the current PSR of the road, lane deficiency, and maximum daily traffic during the analysis period.[2] The PSR of each road segment is predicted year by year, starting from its current value, using the projected traffic load and characteristics of the pavement. When the PSR is projected to drop below the terminal serviceability level, an improvement is selected based on the condition of the roadway. If the pavement is in fair or better condition and has not dropped below the reconstruction PSR, it is slated for resurfacing. The thickness of the resurfacing is based on local practices and assigned a set cost based.

For concrete segments, a standard reconstruction cost is applied if the pavement is deteriorated beyond the terminal serviceability level or is older than 50 years old. If neither of these two criteria are met, the pavement is scheduled for a CPR project within the 20 year study horizon. These CPR projects include a repair or replacement of broken panels and a crack seal. This

[2] This improvement logic expands upon the logic used in previous UGPTI needs studies and is based upon general approaches that are widely followed in practice. However, individual cities may adopt different approaches based on local conditions and insights.

maintenance work was not included in the routine maintenance costs for concrete pavement, and was considered a separate project to be completed.

Capacity issues were tested for each roadway segment. For this study, any roadway that will exceed a Level of Service (LOS) of D or worse was considered for reconstruction. LOS is determined by the capacity of the roadway and how many vehicles per day (VPD) would be running through the corridor. LOS D is the second worst available LOS, and lower capacity is considered LOS E. For this study, no traffic operations at intersections (traffic lights, stop signs, etc.) were considered. Only the traffic along the main corridor was considered. The capacity of each roadway was determined by the number of lanes the roadway currently has. If the capacity of the roadway was calculated to be under the maximum amount of vehicles passing through the corridor from the traffic model, the segment was scheduled for a reconstruction rather than a resurfacing or CPR. An additional 24' of width (2 Lanes) were slated to be constructed on the segment along with a resurfacing or CPR on the existing width for the project. The maximum capacities of roadway for LOS D used in this study are shown in Table 2.

Table 2: LOS D Traffic Capacities

Lanes	**Capacity (Veh/Day)[3]**
2	10000
3	19000
4	28000
5	34000
6	42000
7	48000

5.6. Preservation Maintenance

Preservation maintenance costs on paved roads include activities performed periodically (such as crack sealing, chip seals, and concrete pavement repairs). The maintenance costs have been derived from a survey sent to select cities (discussed further in the next section) to understand their maintenance practices and costs. Costs have been updated to 2016 levels and annualized. For example, the annualized seal coat cost would allow for at least two applications during a typical 20-year lifecycle. Maintenance costs are derived separately for concrete and asphalt sections because of the different methods of preservation.

[3] Roadway capacity was calculated using the 2010 Highway Capacity Manual and assumed that all roadways had right turn lanes

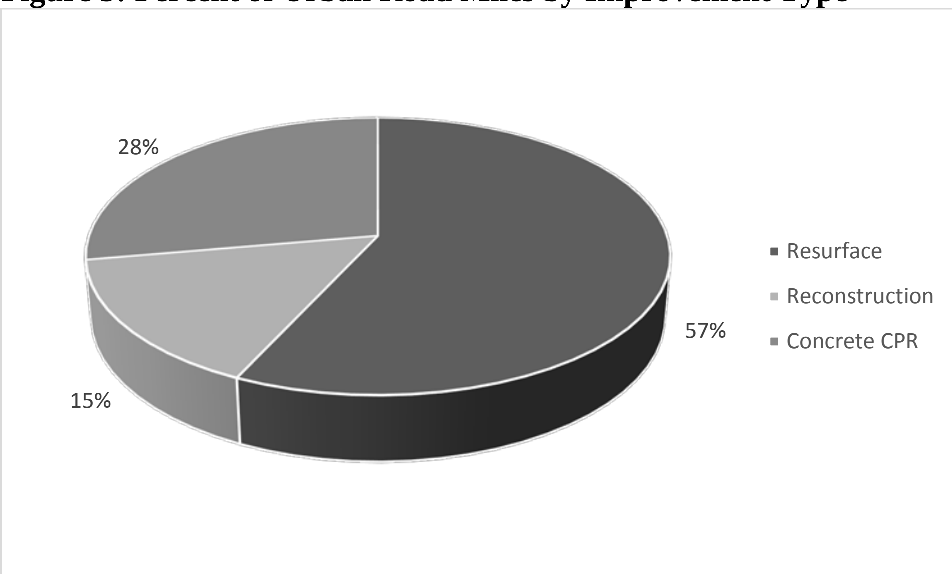
5.7. Forecasted Improvement Needs

5.7.1. Miles Improved

As shown in Figure 3, approximately 15% of the miles of urban roads in the state must receive a major rehabilitation because of poor condition or heavy traffic that will cause existing pavements to deteriorate very quickly.

Overall, the analysis shows that most of the miles of urban roads in the state can be resurfaced without major rehabilitation or widening. Additionally, around 28% of the miles in the state are concrete roadways that will continue to only require routine maintenance to be performed on them over the next 20 years.

Figure 3: Percent of Urban Road Miles by Improvement Type



5.7.2. Improvement Costs per Mile

For this study, a survey for costing data was sent to four cities (Bismarck, Williston, Grand Forks, and Wahpeton). Cost data was requested from the cities for all surface types, improvements types and maintenance. Unit costs used for this study were $22/SF of roadway for bituminous reconstructions with curb and gutter, and $25/SF for "rural" section reconstructions[4]. Concrete costs were $36/SF of roadway for reconstructions with curb and gutter, and $22/SF for "rural" sections. Asphalt resurfacing was assigned a $2.25/SF cost, regardless of overlay depth. Concrete CPR costs were assigned at $1.60/SF for pavements less than 20 years old, and $3.20/SF for all other concrete pavements not requiring reconstruction.

The survey also requested the general construction practices of each city regarding asphalt, concrete, and base depths. In some cities, the thickness of the pavement layer changed based on functional classification (and therefore traffic), while some cities have a standard depth that all roads are built to. Accounting all functional classifications, the asphalt depth was around 5" thick across all cities, and concrete depth was slightly over 8". The amount of base used under

[4] As noted earlier, all of the improvement costs utilized in this study include allowances for preliminary and construction engineering costs.

the pavement layer varied greatly, from a minimum depth of 8" to a maximum depth of 24", and an average depth of 12".

The results of the analysis are summarized in Table 4. This table shows the projected improvements and costs for each biennium during the next 10 years, a projected subtotal for the 2017-2026 period, and a grand total for 2017-2036. Appendix B describes total paved road needs by city.

Approximately 81 miles of roadways in this study must be reconstructed because of poor condition and high traffic loads. The remaining miles will need resurfacing during the next 20 years. Each mile of paved road is selected for only one type of improvement (e.g. reconstruction, overlay). In addition, routine maintenance costs are estimated for each mile of road based on traffic level.

Table 4: Summary Statewide of Forecasted Improvements and Costs for Urban Roads ($Millions)

Period	Resurfacing		Reconstruction		Concrete CPR		Maintenance Cost	Total Cost
	Miles	Cost	Miles	Cost	Miles	Cost		
2017-2018	34.3	$10.5	33.7	$118.60	8.0	$3.3	$8.3	$140.6
2019-2020	41.7	$13.0	20.5	$69.00	17.3	$6.5	$8.3	$96.9
2021-2022	28.7	$8.8	13.6	$45.70	39.5	$16.9	$8.3	$79.8
2023-2024	28.4	$8.7	8.6	$26.90	42	$25.9	$8.3	$69.7
2025-2026	39.0	$12.0	5.0	$16.60	11.3	$5.8	$8.3	$42.7
2017-2026	**172.1**	**$53.0**	**81.4**	**$276.80**	**118.1**	**$58.4**	**$41.5**	**$429.7**
2027-2031	125.2	$40.7	10.4	$45.70	24.9	$9.3	$20.7	$116.4
2032-2036	54.2	$17.4	2.7	$10.30	28.4	$10.6	$16.6	$54.8
2015-2036	**351.6**	**$111.0**	**94.5**	**$332.90**	**171.4**	**$78.3**	**$78.8**	**$600.9**

6. Bridge Analysis

6.1. Introduction

Ideally, bridges allow the highway network to meet the needs of the travelling public. However, bridge inadequacies can restrict the capacity of the transportation system in two ways. First, if the width of a bridge is insufficient to carry a modern truck fleet and serve current traffic demand, the bridge will restrict traffic flow and trucks may need to be rerouted. Second, if the strength of a bridge is deficient and unable to carry heavy trucks, then load limits must be posted and truck traffic again must be rerouted. These detours mean lost time and money for road users. A network of modern and structurally adequate bridges serves a critical role in the state’s transportation network.

This study employs the bridge needs forecasting methodology used in the previous UGPTI County and Local Needs Study. The forecast is based upon the goal of maintaining a bridge network which serves modern traffic demand.

6.2. Data Collection

Bridge inventory, condition, and appraisal data were collected from two resources: the National Bridge Inventory (NBI) database (comma delimited file) and the NDDOT's bridge inventory database (shapefile of county/urban bridges). These databases were combined and spatially merged with a shapefile of the county and local road centerlines which are the focus of this study. Each bridge was individually calibrated with regard to their spatial location and relationship to road segment.

The combined and spatially-located data set includes a total of 57 NBI (2015) urban non-culvert structures which are city-owned and currently open to traffic. This dataset represents the basis for this study's needs analysis. One note to be made about this dataset is ownership of the individual bridges. Some of these bridges are administered and maintained by the respective counties. For the purposes of this study, all bridges within city limits are considered to be under control of the city.

Bridges with total span length less than 20 feet and culverts are not included in the NBI database and are not considered in this study's needs forecasts.

6.2.1. Condition of Urban Bridges

Table 5 summarizes the age distribution of city-owned bridges in North Dakota based on the 2015 NBI, which was the most recent data available at the time of this report. Thirty-five percent of bridges in the data set are older than 50 years. Another 43% are between 30 and 50 years of age. A total of 16 bridges (3%) were built more than 75 years ago. Although 50 years was historically considered the design life of many bridges, service lives can be extended through diligent maintenance and rehabilitation.

Table 5: Age distribution of city-owned bridges in ND

Age (Years)	Frequency of Bridges	Percent	Cumulative Frequency	Cumulative Percent
≤ 20	20	35.09%	20	35.09%
> 20 and ≤ 30	12	21.05%	32	53.14%
> 30 and ≤ 40	10	17.54%	42	73.68%
> 40 and ≤ 50	5	8.77%	47	82.45%
> 50 and ≤ 75	6	10.53%	53	92.98%
> 75	4	7.02%	57	100.00%
Age is the elapsed time since original construction or reconstruction.				

The condition assessment scale used in the National Bridge Inventory is shown in Table 6. In this scale, a brand-new bridge component deteriorates from excellent condition to failure via eight interim steps or levels. Independent ratings are developed for each of the three major components which comprise a bridge structure – deck, superstructure and substructure. The latest recorded component ratings are shown in Table 7.

Table 6: Component Rating Scales

Code	Meaning	Description
9	Excellent	
8	Very Good	No problems noted
7	Good	Some minor problems
6	Satisfactory	Structural elements show some minor deterioration
5	Fair	All primary structural elements are sound but may have minor section loss, cracking, spalling or scour
4	Poor	Advanced section loss, deterioration, spalling or scour
3	Serious	Loss of section, deterioration, spalling or scour has seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	Critical	Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	Imminent Failure	Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	Failed	Out of service – beyond corrective action.

Table 7: Component Ratings

Component Ratings	Deck		Superstructure		Substructure	
	Bridges	Percent	Bridges	Percent	Bridges	Percent
Good (7-9)	31	54.4%	48	84.2%	46	80.7%
Fair (5-6)	10	17.5%	7	12.2%	10	17.5%
Poor (3-4)	1	1.8%	2	3.5%	1	1.8%
Critical (0-2)	0	0%	0	0%	0	0%
Not Rated (N)	15	26.3%	0	0%	0	0%

Component ratings are important, but are not the only factors which define a bridge's overall adequacy in supporting traffic loads. This overall sufficiency can be expressed as a sufficiency rating (SR), a single value calculated from four separate factors which represent structural adequacy and safety, serviceability and functional obsolescence, essentiality to the public, and other considerations. The formula is detailed in the document "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" (FHWA 1995), commonly referred to as the NBI coding guide. Sufficiency rating is expressed as a percentage, in which 100% would represent an entirely sufficient bridge and 0% would represent an entirely insufficient or deficient bridge. Approximately 51 percent of bridges in North Dakota have a sufficiency rating greater than 85%. Twenty-six percent of the bridges have sufficiency rating less than 60%.

Each bridge in the NBI is also assigned a status which indicates whether the bridge is functionally obsolete, structurally deficient, or non-deficient. This value depends on component ratings and other appraisal ratings. More than 28% of North Dakota's local bridges are marked either structurally deficient or functionally obsolete.

Functional obsolescence occurs when a bridge's design no longer allows it to adequately serve present-day traffic demands. This can include bridges which are too narrow or provide too little clearance for a modern truck fleet. Note that a status of functionally obsolete does not indicate structural deficiency.

Structurally deficient is a status which indicates a bridge has one or more structural defects that warrant attention. The status does not indicate the severity of defect and indeed a structurally deficient bridge can still be safe for traffic, but bridges with this status are typically monitored more closely and may be scheduled for rehabilitation or replacement.

It can be helpful to consider a bridge's status in terms of its impact on the roadway network. If the width of a bridge is insufficient to carry modern traffic volume and truck fleet, the bridge will restrict traffic flow and trucks may need to be rerouted. If the strength of a bridge is deficient and unable to carry heavy trucks, then load limits must be posted and truck traffic must be rerouted. In either case, a bridge with an NBI status flag can negatively impact the volume and weight of traffic supported by the highway system.

6.3. Methodology

6.3.1. Deterioration Model

In 2009, UGPTI developed a set of empirical models to forecast component (deck, superstructure and substructure) deterioration rates for bridges nationwide. UGPTI has since developed regional empirical regression models with a focus on North Dakota. These updated models are based on the 3,492 North Dakota bridges in the 2015 NBI database. They were validated using the updated 2015 NBI database.

For this study, a simplified version of the model was used to analyze the needs of all 57 urban bridges. An improvement selection model was developed based on current practice and discussions with NDDOT personnel for the previous studies. The decision criteria include, but are not limited to, bridge status, sufficiency rating, operating rating, bridge geometry, and component condition ratings. The decision criteria was placed into a decision tree format and published in previous studies. Two versions of the decision tree were created from the previous County/TWP studies, on system (federal) and off system (local). For this study, a simplified analysis of all the bridges using the decision tree model, rather than the full empirical analysis was completed. The on system (aggressive reconstruction) decision tree was used in conjunction with other methods of examining the bridge's current condition in order to understand the needs of the urban bridge system. The full improvement decision tree (on system) is detailed in Appendix C.

6.3.2. Improvement Selection Model

The decision tree analysis considered four possible treatment types for each bridge during each year of the analysis period: preventive maintenance, rehabilitation, replacement, and no action. Bridge rehabilitation is further separated into widening and deck maintenance. Bridge replacement is separated into three subcategories based the type of structure which will replace the existing bridge:

1. New bridge with 32-foot width
2. Single barrel reinforced concrete box culvert
3. Multiple barrel reinforced concrete box culvert

The AASHTO and Federal Highway Administration (FHWA) have defined bridge preventive maintenance as "a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without substantially increasing structural capacity)" (FHWA 2011). This can include cyclical activities such as deck washing or condition-based activities such as scour mitigation or concrete patching. FHWA notes that effective bridge preventive maintenance activities can extend the useful life of bridges and reduce lifetime cost.

Preventive maintenance can encompass a wide variety of activities, but this study's improvement model was limited to the selection of a generalized annual "preventive maintenance" treatment category. It is assumed that each bridge owner will determine the maintenance treatments and intervals most appropriate for their bridges.

Effective preventive maintenance can be described as the right treatment to the right bridge at the right time. Accordingly, bridges were considered eligible for preventive maintenance until deteriorating to a point at which preventive maintenance would provide limited effectiveness at arresting deterioration – for example, painting a steel bridge which has already experienced major corrosion and section loss. Bridges with very narrow (i.e. less than 20-foot width) decks were considered ineligible for preventive maintenance. Maintenance-ineligible bridges were allowed to proceed to rehabilitation or replacement state.

Bridge rehabilitation is defined by FHWA as "major work required to restore the structural integrity of a bridge as well as work necessary to correct major safety defects." It represents an improvement which generally exceeds the scope of preventive maintenance but does not involve complete replacement of the structure. In this study, bridges were generally considered eligible for rehabilitation if their condition had deteriorated beyond the preventive maintenance state but did not yet warrant total replacement. A number of exclusionary factors were applied to bridges for which it was determined that rehabilitation would be either undesirable or impossible. These included unknown foundation, poor substructure condition, and timber superstructure. Finally, to facilitate the movement of modern commercial traffic, bridges on the federal aid highway network were assigned rehabilitative deck widening treatment if their deck width was less than 28 feet. This study recognizes that, in general, county and local agencies do not currently practice rehabilitation. However, bridge forecasts include rehabilitation to demonstrate the possibility of reduced lifecycle cost if effective treatment plans were to be adopted.

Bridge replacement represents the final and most cost-intensive type of bridge treatment. It involves a complete replacement of the existing structure, either with a new bridge or another structure. This study assumes short span bridges will be replaced by reinforced concrete box culverts (RCBC), per current state of practice. Structures less than 40 feet in length will be replaced by a single-barrel RCBC, while structures between 40 and 50 feet in length will be replaced by multiple-barrel RCBC. Structures with total length greater than 50 feet are replaced by new bridges.

Typically when older substandard bridges are replaced by modern ones, the lengths and widths of the structures increase. Based on recent North Dakota bridge replacement project data, a new structure is roughly 70% longer than the original one. Replacement widths of 32 feet are used for bridges on and off the federal system, respectively, to allow clearance for a modern truck fleet.

Several criteria were used to qualify bridges for replacement. In general, bridges qualified for replacement if their status was functionally obsolete (FO) or structurally deficient (SD), if they had low sufficiency rating (<60), or if they included a narrow deck (≤24 feet).

For the purpose of this study's 20-year analysis period it is assumed that a bridge which receives a major improvement (rehabilitation or replacement) will not be considered for another major improvement for the remainder of the study period and will instead be assigned preventive maintenance. This is a reasonable assumption considering the length of the study and the unlikelihood of a bridge requiring multiple major treatments in a 20-year period. Culvert structures require comparatively little preventive maintenance and are not considered eligible for preventive maintenance treatment in this study.

6.3.3. Cost Model

Preventive maintenance cost estimates used an annual unit cost of $0.25 per square foot of deck area. This value represents a typical annualized cost of maintenance as derived from other state DOT preventive maintenance expenditures outlined in individual state needs studies and in NCHRP 20-68A Scan 07-05 Best Practices In Bridge Management Decision-Making (2009).

Deck replacement cost is based on a model developed by Sinha et al. in "Procedures for the Estimation of Pavement and Bridge Preservation Costs for Fiscal Planning and Programming" (2005). This model expresses rehabilitation cost as percentages of total replacement cost. Deck replacement is expected to consist of 45% of equivalent bridge replacement cost.

Bridge widening cost was estimated as 45% of potential replacement cost. This figure was based upon discussion with NDDOT Local Government and Bridge Division personnel.

Replacement costs were estimated by developing unit costs from recent (2009-2015) NDDOT bid reports and plan documents. Unit costs reflect 2015 dollars, and the final costs estimated were adjusted to reflect 2016 dollars. The type of replacement structure was based on the criteria described in the Improvement Selection Model section of this chapter.

A deficient bridge less than 40 feet long is assumed to be replaced by a culvert structure costing $400,000. A deficient bridge between 40 and 50 feet in length is assumed to be replaced by a culvert structure costing $600,000. Costs for bridges longer than 50 feet are calculated using the square footage of the deck and an average replacement unit cost. Unit replacement costs were

$250 per square foot of deck area. All costs include preliminary engineering and construction engineering costs. Preliminary engineering costs are assumed to add an additional 10% to the bid price, while construction engineering adds approximately 15% of the bid price.

6.4. Results

Estimated statewide improvement and preventive maintenance needs for the study period, 2016-2036, are $43.2 million in 2016 dollars. All of the improvement needs are determined by the study's improvement model to be backlog needs, occurring during the first study biennium. These costs were not distributed across the biennia, as has been done in other studies. The forecast projects and costs by cities are shown in Table 8. Costs by biennium for the entire state over the 20 year study period are shown in Table 9.

Table 8: Total Urban Bridge Needs by City, in 2016 Dollars

City	Total Bridges	Rehabilitation and Replacement		Preventive Maintenance Cost	Total Cost
		Bridges	Cost		
Bismarck	2	1[5]	$500,000.00	$76,000.00	$576,000.00
Devils Lake	0	0	$0.00	$0.00	$0.00
Dickinson	6	0	$0.00	$104,900.00	$104,900.00
Fargo	11	2	$6,759,200.00	$512,600.00	$7,271,800.00
Grafton	2	2	$1,828,200.00	$0.00	$1,828,200.00
Grand Forks City	3	1	$11,935,800.00	$29,700.00	$11,965,500.00
Jamestown	7	3	$1,798,700.00	$55,600.00	$1,854,300.00
Mandan	3	0	$0.00	$43,000.00	$43,000.00
Minot	12	4	$17,228,400.00	$471,200.00	$17,699,600.00
Valley City	8	1	$637,200.00	$209,200.00	$846,400.00
Wahpeton	0	0	$0.00	$0.00	$0.00
Watford City	0	0	$0.00	$0.00	$0.00
West Fargo	2	1	$963,800.00	$50,200.00	$1,014,000.00
Williston	1	0	$0.00	$6,900.00	$6,900.00
Statewide	**57**	**15**	**$41,151,300.00**	**$1,559,300.00**	**$43,210,600.00**

[5] During review of preliminary results, Bismarck informed UPGTI of a failing MSE wall not reflected in the most recent NBI.

Table 9: Total Urban Bridge Needs by Biennium, in 2016 Dollars (Millions)

Period	Rehabilitation/Reconstruction		Maintenance Cost	Total Cost
	Bridges	Cost		
Backlog	15	$41.15	$0.00	$42.61
2016-2017	15	$41.15	$0.16	$41.31
2018-2019	0	$0	$0.16	$0.16
2020-2021	0	$0	$0.16	$0.16
2022-2023	0	$0	$0.16	$0.16
2024-2025	0	$0	$0.16	$0.16
2026-2036	0	$0	$0.75	$0.75
2016-2036	15	$41.15	$1.56	$43.21

7. Extra-corporate limit corridors

This part of the study estimated the extra-corporate needs using the long-range transportation plans for respective cities. Typically, these needs are related to currently nonexistent corridors (planned to be built in the future in currently undeveloped lands) or county and township roads. Therefore, it would be difficult to assess these needs using the methodology discussed in the previous sections of the report.

Long-range transportation plans synthesize the long-term forecasts of the city growth patterns and outline associated infrastructure investment needs. The state's three largest urbanized areas (Bismarck, Fargo, and Grand Forks) are required by federal regulations to maintain and periodically update their LRTPs. Several other cities, including Dickinson, Jamestown, Minot, Watford City, and Williston, have also created such plans.

The summary of extra-corporate investment needs is presented in Table 10. The figures include only the corridor projects on the non-state network. Collector roads, interstate highway junctions, intersection improvements, and multimodal projects are excluded from the summary. It is also pertinent to note that only Bismarck, Fargo, and Grand Forks designate their future projects under fiscal constraints. Projects without guaranteed funding are distinguished as "illustrative" and presented separately. In the remaining four cities, total price tags for all projects included in the LRTP substantially exceed the currently anticipated funding levels.

Table 10: Extra-corporate corridor investment needs summary

City or metro	Implementation period	Cost (millions of $)
Bismarck - Mandan	2015-23	20.24
	2024-32	41.84
	2033-40	11.00
	TOTAL	**73.08**
	Illustrative	not provided *)
Devils Lake	**NO LRTP**	
Dickinson	2017-35	**59.60**
Fargo - West Fargo	2015-20	28.35
	2021-29	22.51
	2031-40	13.80
	TOTAL	**64.66**
	Illustrative	19.75
Grafton	**NO LRTP**	
Grand Forks **)	2018-22	5.82
	2023-30	11.47
	2031-40	14.07
	TOTAL	**31.36**
	Illustrative	6.70
Jamestown	2015-23	4.00
	2024-28	7.30
	2029-40	14.95
	TOTAL	**26.25**
Minot	2014-19	0.00
	2020-35	23.96
	2035+	60.01
	TOTAL	**83.97**
Valley City	**NO LRTP**	
Wahpeton	**NO LRTP**	
Watford City	TOTAL	**132.00**
Williston	2015-30	114.09
	2031-45	38.74
	TOTAL	**152.83**
Total extra-corporate needs		**643.50**

* Bismarck-Mandan LRTP includes a list of illustrative projects, but does not provide cost estimates
** Grand Forks LRTP provides year-of-expenditure estimates only; current dollar values were estimated using 4% inflation rate assumed by the LRTP.

8. Summary and Conclusions

This report outlines the study process to estimate the needs for maintaining and improving North Dakota's network of urban collector and above roadways over the next 20 years. The needs estimates presented in this report have been developed at a network planning level. Project specific costs may vary either above or below the estimated cost of a specific segment for a number of reasons. In addition, because this is a network planning study, project-specific enhancements such as turning lanes or signals were not modeled. These enhancements are typically included in a project as a result of a project-specific analysis.

The combined needs estimates by biennium are presented in Table 11.

Table 11: Statewide Summary of Forecasted Needs for Urban Roads and Bridges

Period	Paved	Bridges	Total
2017-18	$140.6	$41.3	$181.9
2019-20	$96.9	<$1	$97.0
2021-22	$79.8	<$1	$79.9
2023-24	$69.7	<$1	$69.8
2025-26	$42.7	<$1	$42.8
2027-36	$171.2	<$1	$171.3
2017-36	**$600.9**	**$43.2**	**$644.1**

All estimates presented in this report are based upon the best data available at the time of the writing of the report, and assumptions used to arrive at these estimates are based upon the most recent average costs, traffic counts, and pavement condition. Any significant changes in costs, forecasts, practices, condition, or highway technology may require re-estimation of the needs developed in this study.

9. Appendix A: Road Conditions by City

City	Condition	Miles	Percent
Bismarck	Very Good	11.6	12%
Bismarck	Good	45.6	45%
Bismarck	Fair	34.6	34%
Bismarck	Poor	6.9	7%
Bismarck	Very Poor	1.7	2%
Devils Lake	Very Good	0.4	2%
Devils Lake	Good	7.6	47%
Devils Lake	Fair	3.7	23%
Devils Lake	Poor	3.1	19%
Devils Lake	Very Poor	1.5	9%
Dickinson	Very Good	9.1	18%
Dickinson	Good	16.9	34%
Dickinson	Fair	19.3	39%
Dickinson	Poor	4.3	9%
Dickinson	Very Poor	0.1	0%
Fargo	Very Good	50.5	38%
Fargo	Good	57.4	43%
Fargo	Fair	18.7	14%
Fargo	Poor	5.2	4%
Fargo	Very Poor	0.4	0%
Grafton	Very Good	0.6	6%
Grafton	Good	4.0	40%
Grafton	Fair	5.4	54%
Grafton	Poor	0.1	1%
Grand Forks City	Very Good	3.2	4%
Grand Forks City	Good	36.8	51%
Grand Forks City	Fair	25.3	35%
Grand Forks City	Poor	6.6	9%
Grand Forks City	Very Poor	0.4	1%
Jamestown	Very Good	4.7	17%
Jamestown	Good	12.0	45%
Jamestown	Fair	8.2	31%
Jamestown	Poor	1.1	4%
Jamestown	Very Poor	0.6	2%
Mandan	Very Good	5.5	21%
Mandan	Good	13.5	52%
Mandan	Fair	3.3	13%
Mandan	Poor	2.6	10%
Mandan	Very Poor	0.9	3%
Minot	Very Good	5.9	11%

Minot	Good	28.7	51%
Minot	Fair	16.4	29%
Minot	Poor	4.5	8%
Minot	Very Poor	0.6	1%
Valley City	Very Good	2.1	13%
Valley City	Good	6.4	41%
Valley City	Fair	4.5	29%
Valley City	Poor	1.9	12%
Valley City	Very Poor	0.7	5%
Wahpeton	Very Good	1.2	10%
Wahpeton	Good	7.2	57%
Wahpeton	Fair	2.3	18%
Wahpeton	Poor	1.0	8%
Wahpeton	Very Poor	1.0	8%
Watford City	Good	1.2	28%
Watford City	Fair	2.2	51%
Watford City	Poor	0.6	14%
Watford City	Very Poor	0.3	6%
West Fargo	Very Good	12.2	29%
West Fargo	Good	25.0	59%
West Fargo	Fair	4.7	11%
West Fargo	Poor	0.1	0%
Williston	Very Good	17.0	32%
Williston	Good	25.0	47%
Williston	Fair	10.3	19%
Williston	Poor	1.1	2%
Williston	Very Poor	0.1	0%

10. Appendix B: Detailed Results by City and Funding Period

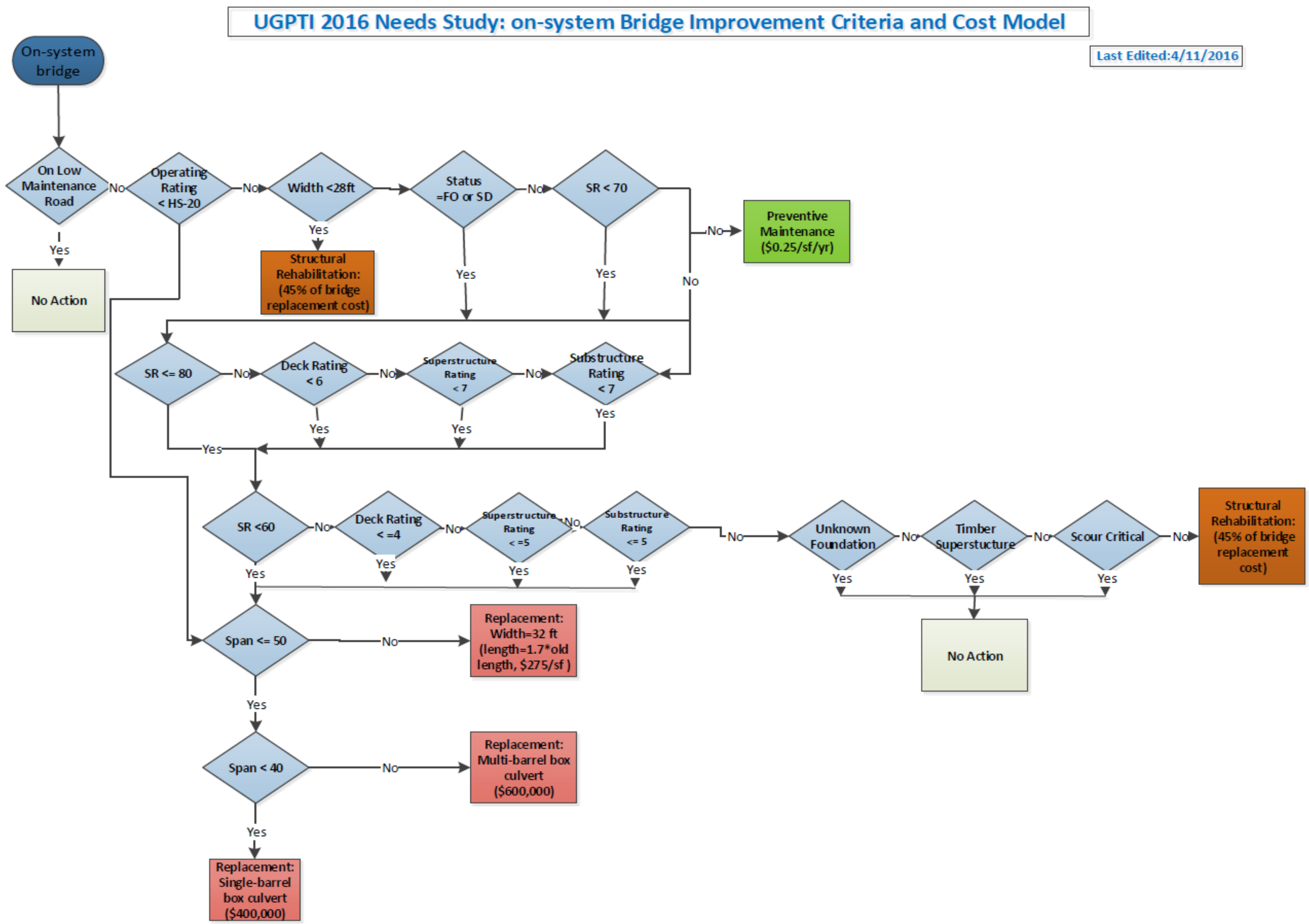
Table A: Improvement Miles by City

City	Miles Resurfaced	Miles Reconstructed	Miles Capacity Recon	Concrete CPR Miles	Total Cost ($Millions)	Annual Cost per Mile
Bismarck	62.1	11.2	14.8	12.4	$132.27	$65,821
Devils Lake	10.9	4.6	0.7	0.0	$16.90	$51,919
Dickinson	37.8	4.3	6.6	0.9	$38.74	$39,088
Fargo	52.2	5.9	68.8	5.2	$126.08	$47,687
Grafton	9.5	0.1	0.4	0.0	$3.74	$18,522
Grand Forks	18.4	9.8	40.5	3.5	$81.39	$56,372
Jamestown	21.5	3.4	1.7	0.0	$18.63	$35,032
Mandan	16.6	3.5	5.1	0.7	$21.40	$41,328
Minot	41.0	9.3	4.0	1.8	$54.46	$48,529
Valley City	9.0	3.2	3.5	0.0	$14.43	$46,069
Wahpeton	8.2	2.0	2.5	0.0	$12.13	$47,790
Watford City	3.4	0.9	0.0	0.0	$3.28	$38,329
West Fargo	21.5	0.1	14.2	6.3	$41.08	$48,761
Williston	39.4	2.6	8.6	2.7	$36.43	$34,145

Table B: Cost per Biennium by City

City	2017-18	2019-20	2021-22	2023-24	2025-26	2027-36	2017-36
Bismarck	$25,096	$28,749	$8,647	$12,408	$11,988	$45,380	$132,269
Devils Lake	$10,237	$2,079	$346	$349	$572	$3,314	$16,897
Dickinson	$7,418	$6,536	$1,447	$2,052	$1,833	$19,452	$38,739
Fargo	$25,124	$9,080	$25,933	$26,068	$6,599	$33,278	$126,081
Grafton	$315	$843	$272	$330	$666	$1,310	$3,736
Grand Forks	$31,095	$16,231	$16,647	$5,107	$3,146	$9,160	$81,386
Jamestown	$4,222	$2,324	$1,876	$2,841	$3,140	$4,231	$18,634
Mandan	$7,474	$2,051	$1,500	$1,174	$4,061	$5,142	$21,402
Minot	$12,263	$15,962	$8,982	$4,815	$1,505	$10,929	$54,455
Valley City	$5,078	$2,204	$2,778	$1,003	$978	$2,386	$14,426
Wahpeton	$6,832	$542	$1,135	$520	$192	$2,905	$12,128
Watford City	$1,364	$330	$1,038	$217	$48	$278	$3,275
West Fargo	$864	$5,902	$6,768	$9,285	$5,396	$12,867	$41,081
Williston	$3,224	$4,080	$2,408	$3,539	$2,564	$20,614	$36,428

11. Appendix C: Bridge Improvement Decision Model Flowchart



UGPTI 2016 Needs Study: on-system Bridge Improvement Criteria and Cost Model

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