DEPARTMENT OF TRANSPORTATION

Development of Pavement Condition Forecasting for Web-Based Asset Management for County Governments

Bradley Wentz, Principal Investigator
Upper Great Plains Transportation Institute
North Dakota State University

March 2020

Research Project
Final Report 2020-04

LRRB
LOCAL ROAD RESEARCH BOARD

To request this document in an alternative format, such as braille or large print, call 651-366-4718 or 1-800-657-3774 (Greater Minnesota) or email your request to ADArequest.dot@state.mn.us. Please request at least one week in advance.

Technical Report Documentation Page

1. Report No. 2020-04	2.	3. Recipients Accession No.
4. Title and Subtitle Development of Pavement Condition Forecasting for Web-Based Asset Management for County Governments		5. Report Date March 2020 6.
7. Author(s) Bradley Wentz		8. Performing Organization Report No.
9. Performing Organization Name and Address Upper Great Plains Transportation Institute North Dakota State University NDSU Dept. #2880 PO Box 6050 Fargo, ND 58108-6050		10. Project/Task/Work Unit No. n/a 11. Contract (C) or Grant (G) No. (c) 1003323 (wo) 4
12. Sponsoring Organization Name and Address Local Road Research Board Minnesota Department of Transportation Research Services & Library 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155-1899		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes http://mndot.gov/research/reports/2020/202004.pdf		
16. Abstract (Limit: 250 words) This application was developed to expand a low-cost asset inventory program called Geographic Roadway Inventory Tool (GRIT) to include roadway forecasting based on the American Association of State Highway and Transportation Officials (AASHTO) 93 model with inventory, pavement condition, and traffic forecasting data. Existing input data from GRIT such as pavement thickness, roadway structural information, and construction planning information will be spatially combined with current MnDOT Pathway pavement condition and traffic data to automatically forecast the future condition and age of roadways using the AASHTO 93 model. This forecasting model will allow roadway managers to use this information with comprehensive geographic information system (GIS) web maps to prioritize roadways in their construction schedules or multi-year plans.		
17. Document Analysis/Descriptors Asset management, Pavement management systems, Counties, County government, Forecasting		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 27 22. Price

DEVELOPMENT OF PAVEMENT CONDITION FORECASTING FOR WEB-BASED ASSET MANAGEMENT FOR COUNTY GOVERNMENTS

FINAL REPORT

Prepared by:

Bradley Wentz
Upper Great Plains Transportation Institute
North Dakota State University

March 2020

Published by:

Minnesota Department of Transportation
Office of Research & Innovation
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

ACKNOWLEDGMENTS

The research team acknowledges the Minnesota Department of Transportation (MnDOT) and the Minnesota Local Research Board, both of which funded the project and made it possible. In addition, we thank the Minnesota counties of Beltrami, Faribault, Pope, Pennington and Becker for their participation in research to develop, test and implement the application. We thank Bruce Hasbargen, Beltrami County, for serving as the project's technical liaison.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

AADT: Annual Average Daily Traffic

AASHTO: American Association of State and Highway Transportation Officials

GIS: Geographic Information System

GPS: Global Positioning System

GRIT: Geographical Roadway Inventory Tool

MnDOT: Minnesota Department of Transportation

PQI: Pavement Quality Index

RQI: Ride Quality Index

SR: Surface Rating

SQL: Structured Query Language

TAP: Technical Advisory Panel

UGPTI: Upper Great Plains Transportation Institute

EXECUTIVE SUMMARY

The primary objective of this research project was to enable county engineers to access and use reliable future pavement condition and traffic data to simplify and enhance their development of performance-based capital improvement plans. This objective was fully met with the development of a pavement performance prediction model within the Upper Great Plains Transportation Institute's (UGPTI's) Geographic Roadway Inventory Tool (GRIT).

The prediction model is based on the American Association of State Highway and Transportation Officials (AASHTO) 93 pavement design equation for structural deterioration along with an environmental pavement deterioration model derived from the latest pavement condition ratings provided by MnDOT. These models require a considerable amount of data, including current pavement condition ratings, traffic data and growth rates, and complete roadway structural information. As such, another key to the success of this project was to ensure all pavement condition and traffic data could be automatically processed and combined with construction history information behind the scenes, eliminating any need for county technical resources.

The roadway structural information, which could only be provided by the counties, also required a roadway inventory process that could be assigned to existing non-technical staff without the need for major training, county information technology or GIS resources. To accomplish this, GRIT was used by the Technical Advisory Panel (TAP) counties to provide construction history and construction planning data to the model.

With the data and models in place and reliably forecasting the Pavement Quality Index (PQI) 35 years into the future, the final objective was to provide this information to the county engineer, decision-makers, and the public in an easy-to-use web-based GIS format. Again, GRIT was used and enhanced to provide geographic information system (GIS) maps of pavement condition, age, traffic, and other data for any future year selected. System performance graphs were also developed to show the percentage of miles in the county at various age and condition levels. All pavement condition projections, maps and graphs are automatically updated as the user updates or changes the construction planning layer (long-range capital improvement plan).

The final version will be released to the GRIT production version in early 2020.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Currently, many local roadway managers have inadequate roadway inventories for effective asset management. Existing asset management programs are often cost prohibitive and require advanced technical training and staff for local governments to maintain. As part of the statewide local roadway needs study, the Upper Great Plains Transportation Institute (UGPTI) at North Dakota State University, has developed a low-cost asset inventory program for all North Dakota counties called the Geographic Roadway Inventory Tool (GRIT). This program has been extended to select Minnesota counties for further testing and development.

The goal of this project is to expand GRIT to include a pavement condition forecasting module based on the American Association of State Highway and Transportation Officials (AASHTO) 93 model. The process would be a seamless integration of MnDOT pavement condition and traffic data with GRIT inventory data. This forecasting model will then allow roadway managers to use this information with comprehensive geographic information system (GIS) web maps and services to prioritize roadways in their construction schedules or multi-year plans.

1.2 PROJECT APPROACH

The approach in this project utilized GRIT by adding new features that allow for pavement condition forecasting. Future pavement condition was based on the AASHTO 93 empirical model. Existing pavement structure and age information was obtained from data currently available from GRIT and pavement condition and traffic data was obtained from MnDOT. This data was geospatially combined with GRIT inventory data to ultimately forecast pavement condition.

The research team worked with Beltrami, Pope, Faribault, Pennington and Becker counties in Minnesota in research to develop, test and implement the additional forecasting function of the asset management program. With pavement forecast information, county roadway managers were able to better understand which roadways will deteriorate first and which will benefit from more effective, low-cost maintenance programs rather than full reconstruction. The model will not forecast suggested future projects or project costs but rather just outputs the future condition of the roadways on a yearly basis. The AASHTO 93 model will be focused on flexible pavements. Rigid pavement sections require data not available for this study. However, rigid pavements, along with flexible pavements, will be included in the forecasting using the environmental deterioration model.

1.3 GEOGRAPHIC ROADWAY INVENTORY TOOL (GRIT)

GRIT is an inventory management tool created to allow local roadway managers to document and understand their existing infrastructure using the latest mobile technology and GIS. GRIT is a browser-based tool that is easily accessible with any web browser platform. GRIT is available in a view-only mode to the public. Links for the application, viewers, and help videos are available at: https://www.ugpti.org/resources/asset-inventory/.

The four key layers in the tool include:

- **Construction Project History**. Includes items such as surfacing type, age, pavement depth, cost, base depth and type, and subgrade treatment, as well as cross section info such as width, shoulders, inslopes, striping, right of way, etc. The layer also includes maintenance data such as seal coats, crack sealing, gravel blading, graveling, dust control, etc.
- **Minor Structures (less than 20 feet)**. Includes information about culverts and bridges including dimensions, elevations, age, material, condition and restrictions.
- **Construction Planning**. Provides information on current and future construction projects such as the year construction will take place, type of project, status, bid date, impacts on traffic, etc.
- **Load Restrictions**. Provides information about year-round and seasonal load restrictions.

GRIT allows local governments to maintain and use their own data, all within the same application. The data items include information to support planning and investment decisions, design recommendations, construction and public impacts information, and maintenance activities on all types of roads. Figure 1 below provides an image of the GRIT program.

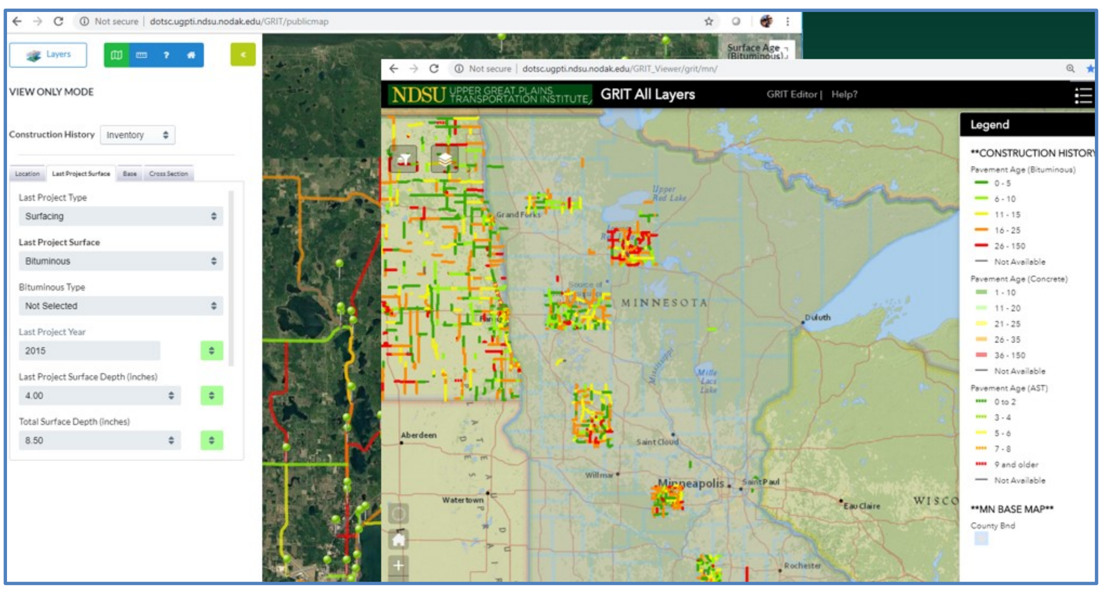

Figure 1.1 GRIT Editor and Viewer

Model Data Input

Required model input data includes information from GRIT such as pavement thickness, roadway structural information and construction planning information and MnDOT Pathway pavement condition and traffic data. The following details how UGPTI obtains and automatically processes the required model input data.

1.4 PAVEMENT CONDITION DATA

The pavement condition data process involved obtaining the most recent Pathway pavement condition data from MnDOT, which included ride quality index (RQI), international roughness index (IRI), pavement condition index (PCI), rutting and individual raw distress scores. The data was then processed to calculate the surface rating (SR) and pavement quality index (PQI) in 1,000-foot roadway sections for Beltrami, Pope, Faribault, Pennington and Becker counties in Minnesota. The processed pavement condition data was then geospatially related to the data in the GRIT construction history database.

The initial intent was to automatically receive the processed pavement condition data directly from MnDOT or from Pathway Services PathWeb. This was not possible because MnDOT does not process the data for 1000-foot sections and only the raw data is loaded to the PathWeb services. For this reason, the raw pavement data had to be received directly from Pathway Services. UGPTI utilized Pathway Service's software to process each county's segment data in 1,000-foot intervals and reconstruct the MnDOT processes to calculate the average pavement SR, RQI, and PQI. Table 1 provides further information and the rating scales for these indices. The indices were spatially joined to the construction history segments and all the data for the points falling within each segment were averaged. This code was integrated into the GRIT program. The process was automated with the development of computer script to recalculate the pavement condition for each segment whenever a construction segment changed or was added into the system.

Table 1 - MnDot Pavement Condition Indices

Index Name	Pavement Attribute Measured by Index	Rating Scale
Ride Quality Index (RQI)	Pavement Roughness	0.0 - 5.0
Surface Rating (SR)	Pavement Distress	0.0 - 4.0
Pavement Quality Index (PQI)	Overall Pavement Quality	0.0 - 4.5

1.5 TRAFFIC DATA

The traffic data process involved downloading traffic data from the MnDOT Traffic Data and Analysis Office website at https://www.dot.state.mn.us/traffic/data/. The downloaded database file and shapefile were further processed to only include county data. This traffic data included the count location information along with the annual average daily traffic (AADT) for the years 2007 to 2017. The number of AADT counts that were available varied based on the segment county schedule. This AADT data was geospatially connected with the GRIT construction history database, and if there was more than one count on a construction history segment, the higher value was used. UGPTI developed computer script to process the AADT and to calculate traffic projection factors, truck AADT, equivalent single-axle loads (ESAL), and cumulative ESALS.

The process to calculate these vales was based on the MnDOT State Aid ESAL Calculator, which is available at http://www.dot.state.mn.us/stateaid/pavement.html. The ESAL Calculator default vehicle type and ESAL factors were not modified. The base year and cumulative ESAL values were calculated for each analysis segment from 2017 to 2052 (35 years). With this data linked to GRIT and the construction history segments, GIS services were set up to make the traffic data available on the GRIT web mapping viewer tool and to other applications that use GIS services.

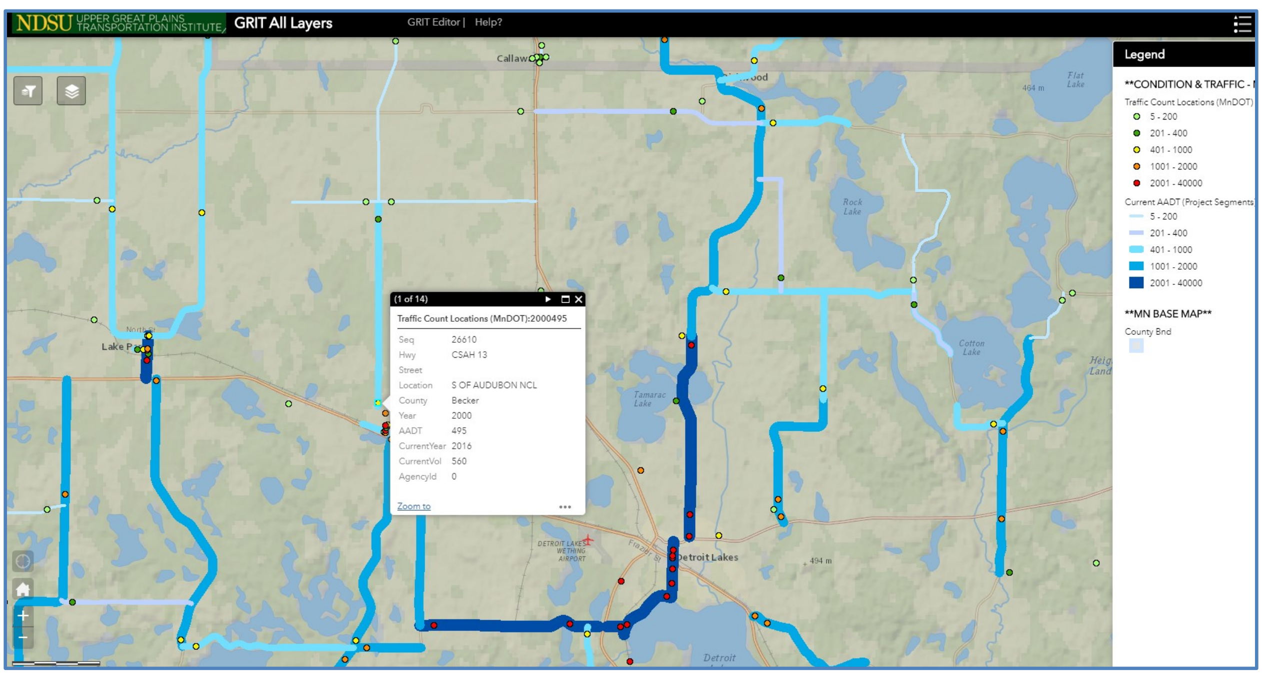

Figure 1.2 - Traffic Data in GRIT WebMap Viewer

CHAPTER 2: PAVEMENT CONDITION FORECAST DEVELOPMENT

The Pavement Condition Forecast development process involved adding an option in GRIT within the Construction History Layer called Performance. This option includes a four tabs labeled as Condition, Strength, Traffic and Future. Each of these tabs are discussed in further details below. Refer to Figure 3.1 to see a graphical snapshot of the roadway Performance option in GRIT.

2.1 CONDITION TAB

The Condition tab contains the base year (2017) pavement condition data and future projects information. This includes RQI, SR, PQI, IRI, PCI, rutting, and collection date. This data is pulled from the pavement condition database as described in Chapter 1.4. Each of these parameters includes an override input box which allows the user to fill in missing data or to correct incorrect information. The only required values to forecast the pavement condition PQI include the RQI and SR. The forecast PQI is the parameter the users will utilize to address future pavement performance.

In addition, the Condition tab includes the Planned Project Type and Year which are spatially captured from the construction planning layer and assigned to the corresponding construction history segment. It is assumed that for any roadway segment that is improved, the future pavement condition or PQI for that planning improvement year is reset to 4.5.

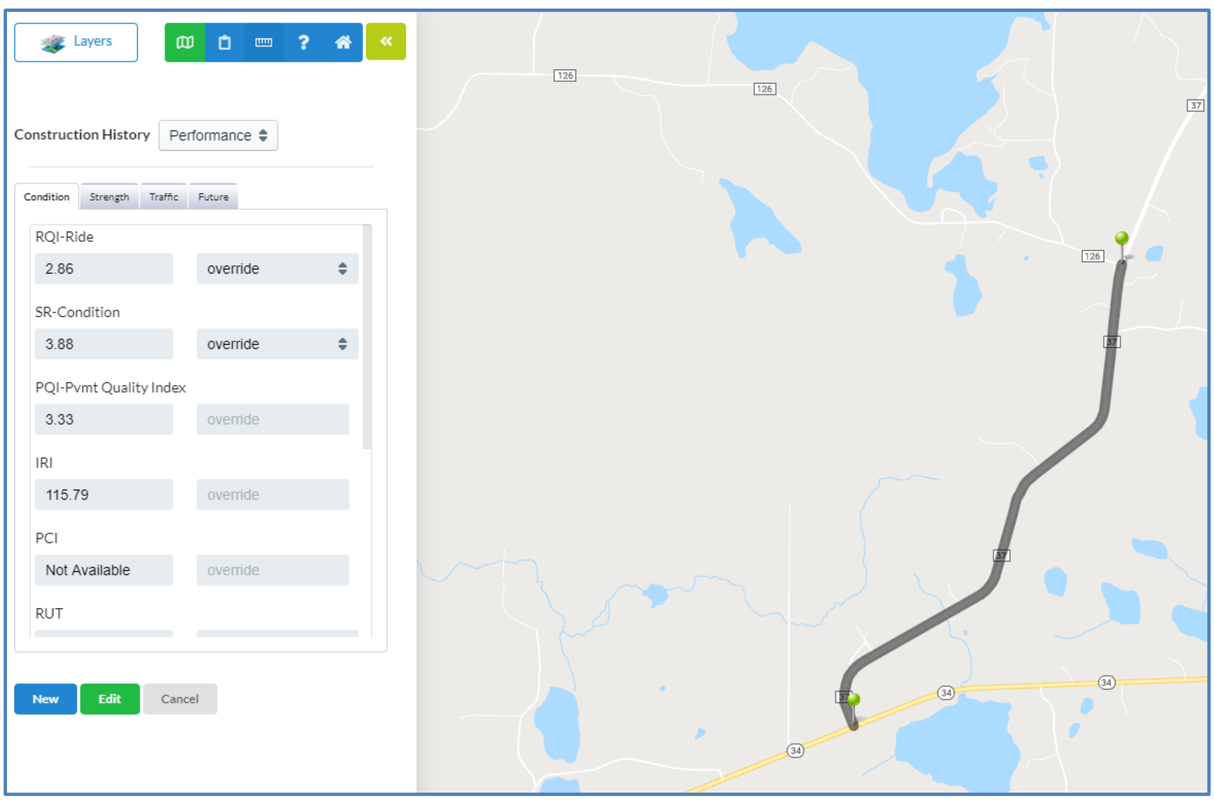

Figure 2.1 - Pavement Condition Tab

2.2 STRENGTH TAB

The Strength tab contains the calculated Structural Number (SN) as defined in the AASHTO 93 pavement design equation. The calculation requires the pavement thickness and pavement type along with base information.

This tab also includes the roadway section Gravel Equivalency (GE). Local governments and MnDOT commonly utilize GE during the pavement design process. GE is calculated based on structural roadway components including the roadway surface, base and subbase material, stabilized material, and material separation devices. Each of these structural components are assigned a GE factor. All of the component factors are combined to calculate the section GE.

The roadway section resilient modulus is also located under this tab and is directly transferred from within the GRIT inventory data. The GRIT program was modified to allow users to specify soil factor, R-value, or California Bearing Ratio (CBR) and a script was developed to convert this data back to resilient modulus.

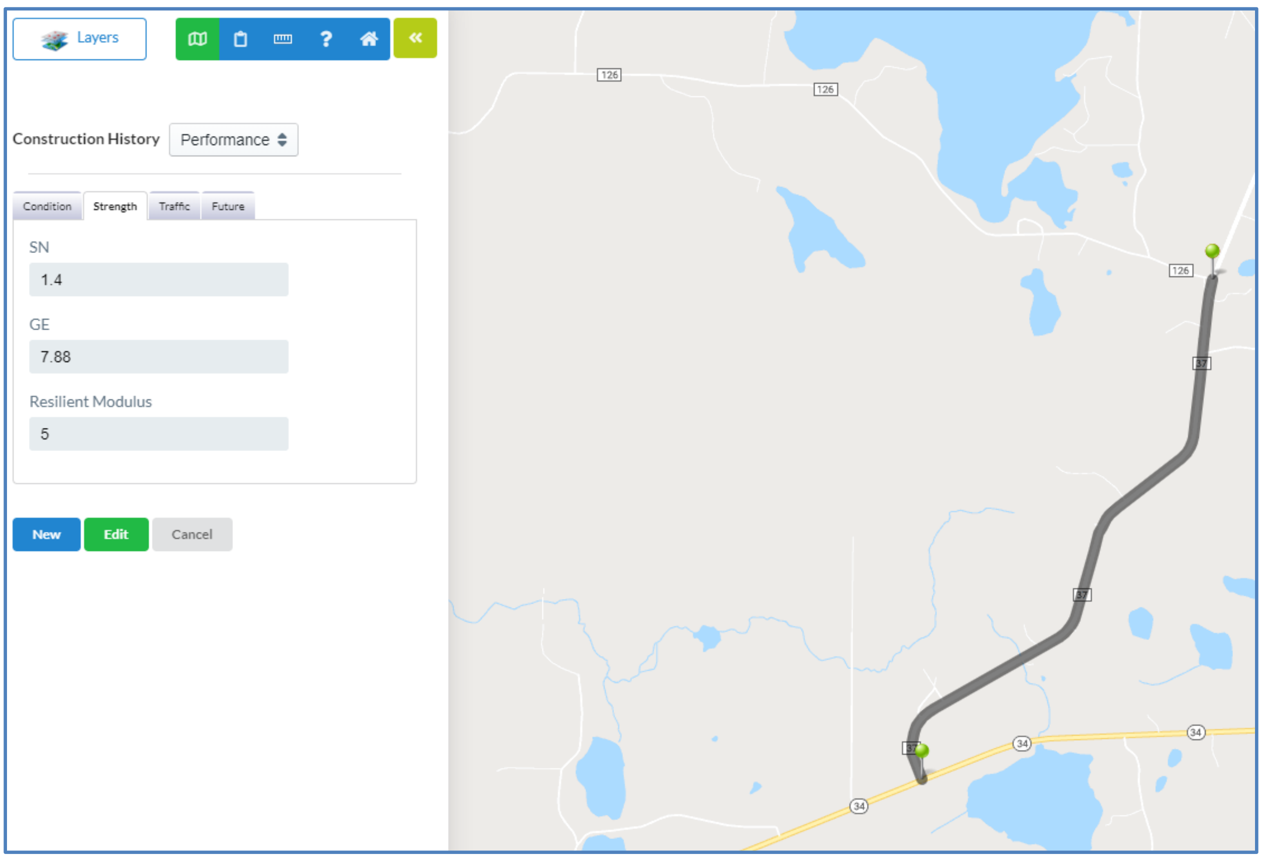

Figure 2.2 - Strength Tab

2.3 TRAFFIC TAB

The Traffic tab includes the current year and 20-year forecast for AADT, truck AADT, calculated ESALs, projection factor percentage. Chapter 1.5 provides an explanation regarding computation of these parameters. For both the AADT and project factor percentage, the tab includes an override input box which allows for the user to fill in missing data or incorrect information which will be used to calculate other program values that utilize these parameters.

The override might be used if the local agency has a more updated traffic count for a segment of roadway. In addition, override buttons are available for the truck AADT to allow the user to manually adjust the vehicle class count percentages. The program utilized the default truck percentages that were available within the most current MnDOT ESAL Calculator. Currently, any user overrides are stored with the construction history layer that is being edited. The ability of the program to store countywide specific vehicle class percentages might be an option for future program versions.

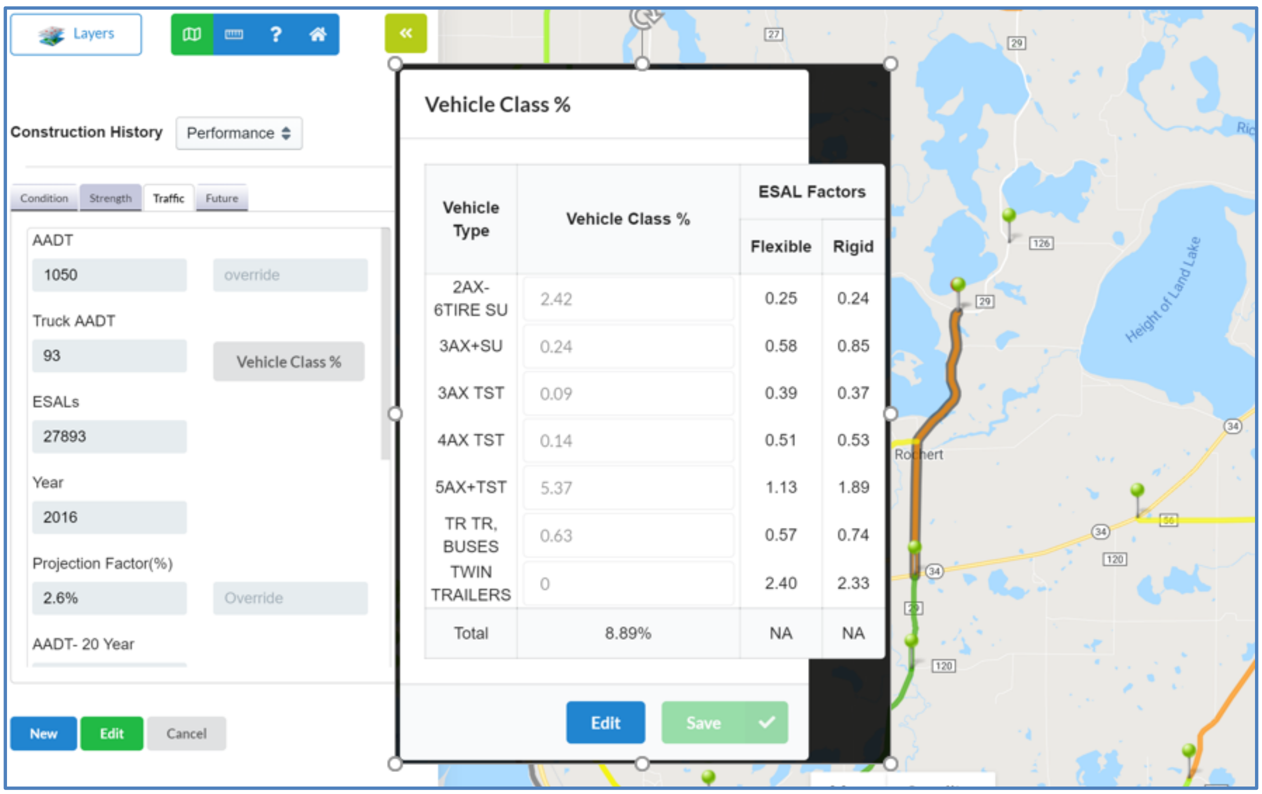

Figure 2.3 - Traffic Tab

2.4 FUTURE TAB

In the future tab the user has the ability to select the analysis year which begins with the current year and extends for 35 years. After the user selects the appropriate year, the PQI, pavement age, AADT, ESALs, and cumulative ESAL's are updated in the fields for that year. This data is stored in a database for all segments for all 35 analysis years which are used in the GIS maps and reports. The PQI is calculated based on the pavement forecast model as described in section 4.

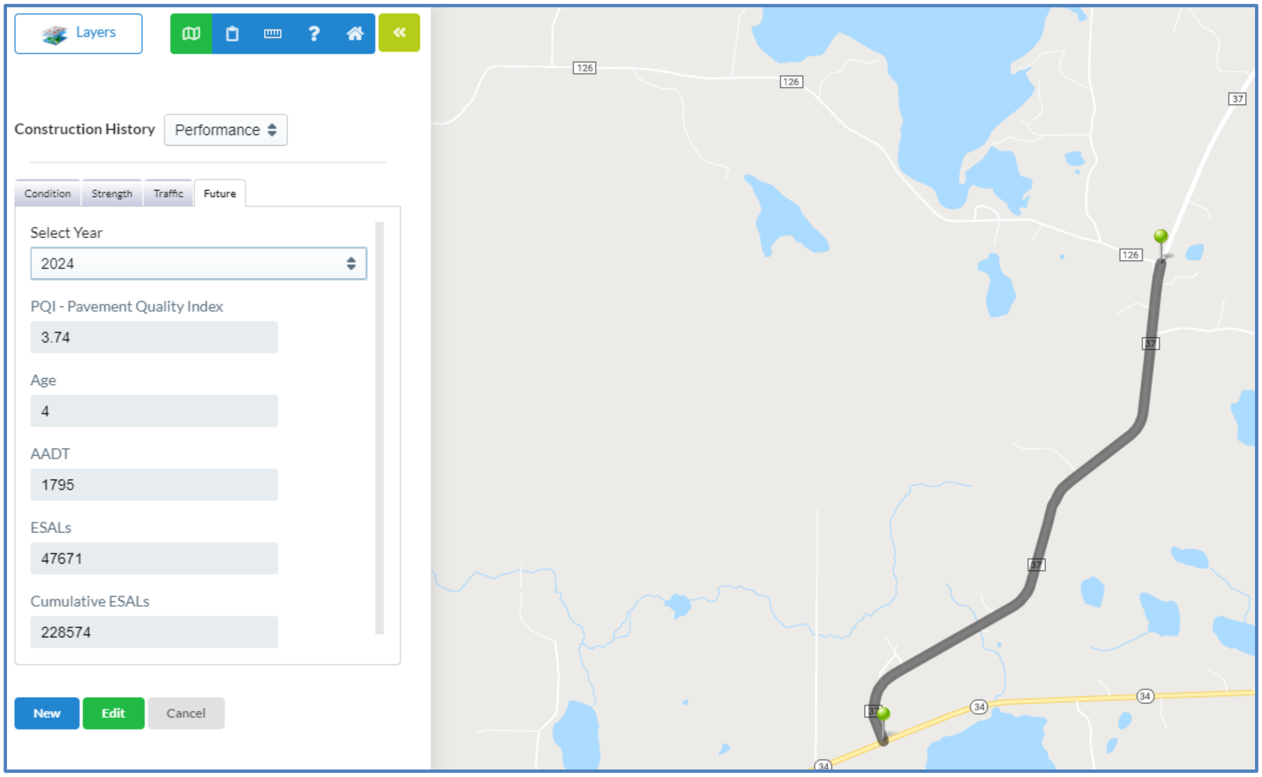

Figure 2.4 - Future Condition Tab

2.5 SYSTEM PERFORMANCE TOOLS

Based on input from the TAP members at the first review of the performance forecasting tool, the following enhancements were made to help evaluate system performance.

Pavement condition and age background maps by year

GRIT has a background layer button which shows color coded maps for various inventory items such as pavement age, shoulder width, planned construction projects etc. This background layer function was used to add layers for the future pavement condition and age of all roads in the County. A dropdown menu was added to select any year extending 35 years into the future. This background layer can be used while editing or viewing any of the four GRIT layers. This is especially helpful to have on when editing or adding projects to the construction planning layer.

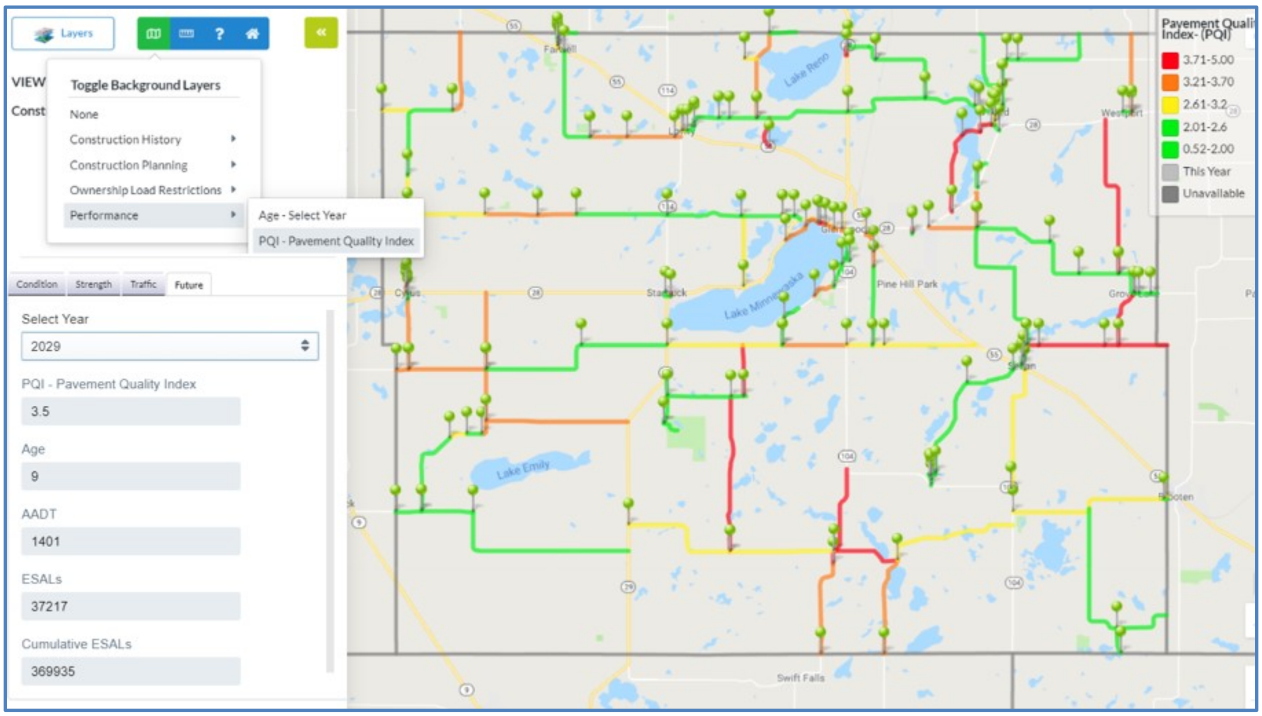

Figure 2.5 - Future Condition Background Layer

System Performance Report

A new button was added to GRIT for allow for various types of reporting. This report section was then used to produce graphs for pavement condition and age system performance. These graphs extend 10 years into the future and include bars representing the percentage of miles in three ranges of PQI and pavement age.

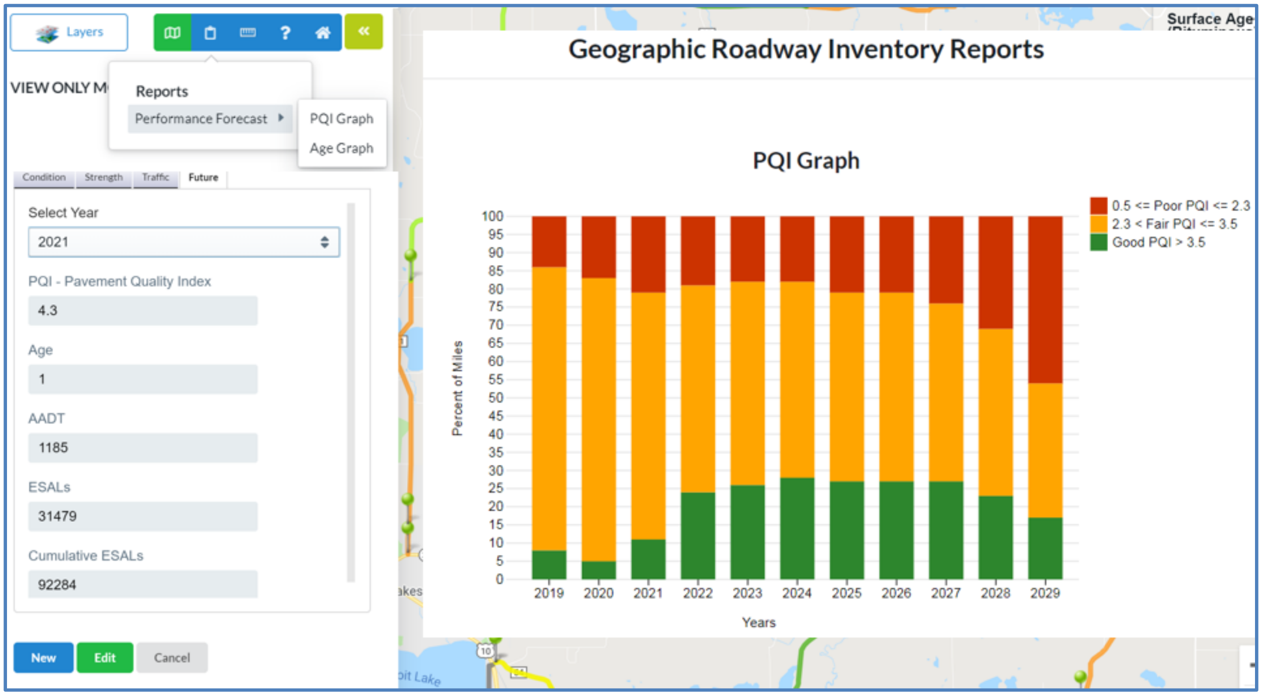

Figure 2.6 - System Performance Graph

CHAPTER 3: PAVEMENT CONDITION FORECASTING MODEL

The pavement condition forecasting model used in this project was developed by Dr. Denver Tolliver of the Upper Great Plains Transportation Institute. The following sections, including Pavement Performance, Predictive Equation, Reliability, and Pavement Deterioration Model, are taken directly from his report to the 63rd North Dakota Legislative Assembly titled *An Assessment of County and Local Road Infrastructure Needs*. Noted that the predictive equations below refer to PSR which is the pavement serviceability rating from the original AASHO road test and is a 0 to 5 scale rating of ride quality performed by a panel of raters. This was later transitioned into PSI which is the pavement serviceability index and correlates the panel rating to various physical and mechanical pavement measurements including pavement distresses and profile variance(ride) in the same 0 to 5 scale rating system. The pavement condition data for this project collected by MnDOT is processed similarly into a 0 to 4.5 scale referred to as PQI or pavement quality index. With the similar scale and correlation, we have used PQI as a substitute for all PSR calculations in the predictive model equations below (PSR = PQI).

3.1 PAVEMENT PERFORMANCE

The performance of a pavement is measured through its serviceability (or condition) and the number of axle loads it can sustain before being resurfaced or improved. The condition at which a pavement must be resurfaced or rehabilitated is called “terminal serviceability” (t), which effectively marks the end of a pavement’s useful life. Below this level, user and maintenance costs increase rapidly.

A pavement is designed for a performance period (T) based on a projected traffic load and environmental factors. Twenty years is often cited as the design-performance period for asphalt or flexible pavements. However, the period can be shorter or longer depending upon budgetary constraints, maintenance, and environmental factors.

The actual traffic load that will be experienced during the design period is unknown at the time the pavement is built and must be projected from historical data or traffic forecasting models. The traffic measure of greatest interest is the accumulated equivalent single-axle loads or ESALs. In particular, the total ESAL load that a pavement can endure before reaching terminal serviceability ($ESAL_t$) and the ESAL load accumulated during the design-performance period ($ESAL_T$) are of special interest. The design process is intended to ensure (with a high degree of probability) that the traffic actually experienced during the design-performance period is less than or equal to the traffic that would cause the pavement to deteriorate to its terminal serviceability level—i.e., the design period ESALs are less than or equal to the ESAL life of the pavement.

3.2 PREDICTIVE EQUATION

An equation for predicting the cumulative ESALs (or ESAL life) of a flexible pavement as a function of its structural number (SN), resilient modulus (MR), initial PSR (PSR_I), terminal PSR (PSR_t), and design reliability (R) is shown below.

$$(1) \quad \log_{10}(W_{18}) = R + A + \frac{G}{B} + M$$

Where:

$\log_{10}(W_{18})$ = The service life of the pavement in equivalent 18,000-lb single axle loads

$R = Z_R S_0$

Z_R = A standard normal deviate

S_0 = Standard deviation

$A = 9.36 \log_{10}\left(SN + \sqrt{6/SN}\right) - 0.2$

$G = \log_{10}\left(\frac{\Delta PSR_S}{\Delta PSR_L}\right)$

$B = 0.4 + \frac{1094}{\left(SN + \sqrt{6/SN}\right)^{5.19}}$

$M = 2.32 \log_{10}(MR) - 8.07$

$\Delta PSR_S = PSR_i - PSR_t$

PSR_i = Initial serviceability rating of the pavement

PSR_t = Terminal serviceability rating (e.g. when the pavement should be resurfaced)

$\Delta PSR_L = 2.7$

In Equation (1), ΔPSRS denotes the decline in PSR from its initial or design value (e.g., 4.5) to its terminal level (e.g., 2.5), while ΔPSRL represents the total decline in PSR until ultimate failure (2.7) as used during the AASHTO road test. In this study, ΔPSRS = 2.7.

3.3 RELIABILITY

There are many sources of uncertainty in pavement deign and performance. If a sample of pavements is designed using the same materials and thicknesses, many of these sections will reach terminal serviceability at different times because of variations in traffic, materials properties, and environmental and climatic conditions. The major sources of variation that affect pavement design and performance include: 1. Construction factors—e.g., layer thicknesses, material strengths, etc. 2. Environmental factors (e.g., soils and climate) 3. Traffic forecasts and projections 4. Prediction error: i.e., errors in performance prediction internal to Equation 1.

The reliability factor may be expressed as a percentage. For example, a reliability factor of 75% (which is used in this study) indicates a 75% likelihood that the pavement section will survive the design-performance period. The selection of a reliability factor involves several tradeoffs. The use of a higher reliability factor would increase the likelihood that the pavements would survive the predicted performance period. However, the use of higher reliability factors results in thicker pavements and significantly higher investment costs. Given the pros and cons, the 75% reliability factor is felt to be the most appropriate one for this study.

3.4 PAVEMENT DETERIORATION MODEL

With some extensions, the predictive model shown in Equation 1 can be used to predict the condition of a pavement each year of an analysis period using the cumulative ESAL load. In order to do so, Equation 1 must be solved for G (Equation 2).

$$(2)\quad G = B(\log_{10}(W_{18}) - R - A - M)$$

Substituting for G yields:

$$(3)\quad \log_{10}\left(\frac{\Delta PSR_S}{\Delta PSR_L}\right) = B(\log_{10}(W_{18}) - R - A - M)$$

An equivalent form of Equation 3 is:

$$(4)\quad \frac{\Delta PSR_S}{\Delta PSR_L} = 10^{B(\log_{10}(W_{18}) - R - A - M)}$$

Solving for ΔPSR_S and substituting yields:

$$(5)\quad PSR_i - PSR_t = \Delta PSR_L \times 10^{B(\log_{10}(W_{18}) - R - A - M)}$$

Instead of the terminal PSR (PSR_t), the model is used to predict the PSR at the end of each year (n) of the analysis period. Instead of using the ESAL load for the entire design period, the accumulated load at the end of each year ($\log_{10}(W_{18n})$) is forecast and used in the model. With these revisions, the pavement deterioration model is shown in Equation 6.

$$(6)\quad PSR_n = PSR_i - 2.7 \times 10^{B(\log_{10}(W_{18n}) - R - A - M)}$$

3.5 ENVIRONMENTAL-RELATED DETERIORATION

The environmental deterioration function is used to enforce a minimum rate of PSR loss per year, regardless of the level of traffic. Therefore, pavements with little or no truck traffic are still projected to deteriorate, but at a much slower rate than sections with heavy traffic.

For this project, deterioration rates were determined by considering the pavement age and most recent pavement condition ratings of all segments within the TAP counties. Deterioration rates were determined for various surface types including overlay projects less than and greater than 2 inches. They were further refined into three age categories of less than 10 years, 10 to 20 years, and greater than 20 years as observed deterioration rates varied within these age ranges.

3.6 FINAL PREDICTED PAVEMENT CONDITION

Finally, the PQI is calculated for the current year and 35 subsequent years using the lower calculated PSR from the truck/structural-based AASHTO calculation and the environmental-based calculation. There are certain situations where a high increase in ESALs on a roadway with lower SN or strength values can drop the truck-based calculated PQI to 0 within 1 year. As this is unrealistic, a maximum loss value of 0.3 PQI per year is applied to the truck-based calculations.

CHAPTER 4: IMPLEMENTATION AND CONCLUSION

4.1 PROJECT BENEFITS

The benefits of the proposed system include:

1) Improves roadway planning for local government agencies
2) Increases efficiency in managing and prioritizing projects
3) Provides those counties with highway staff who have limited IT and GIS experience access to pavement condition, traffic and inventory data in an easy-to-use GIS format.

The cost savings for each of these benefits are not quantifiable, but considering that the overall asset management program can be used by all 87 Minnesota counties, the potential cost-savings benefit is great.

4.1.1 IMPROVES PLANNING

One of the main benefits of the pavement condition forecasting tool is that it will significantly improve roadway planning. With the ability to see an estimated future pavement condition, local agencies can consider various scenarios and develop capital improvement plans that maximize their limited financial resources. In addition, GRIT will provide a tool that engineers can use to present and justify capital improvement plans to the public and decision-makers more effectively.

4.1.2 INCREASES EFFICIENCIES

The pavement condition forecasting tool will streamline the management and prioritization of roadway projects. By understanding how roadways will deteriorate in the future, engineers or road managers will be able to be more efficient with their monetary resources. The tool will aid in choosing a low-cost maintenance or improvement that will extend the life of a roadway, rather than result in a more expensive rebuild after deterioration. Studies show that a properly spent dollar on roadway maintenance saves $4 to $10 in expensive rebuilding cost later. This will allow for limited-budget entities such as counties to better use their dollars to maintain, rather than rebuild, their roadways. Cost-savings benefits come in the form of a more efficient roadway capital improvement plan for counties.

4.1.3 PROVIDES ACCESS TO DATA

As a result of this, project pavement condition and traffic data are automatically processed and made available through GIS services along with all the inventory and forecast data. This project eliminates the need for the county to provide trained GIS or technical staff to process and make this data available to the public and decision-makers. Counties often have difficulty hiring and retaining specialized IT or GIS technical staff.

4.2 IMPLEMENTATION PROCESS

The pavement condition forecast model was added and tested within GRIT, an existing asset management program developed by UGPTI. GRIT is available to all 53 counties in North Dakota and is currently being used by several Minnesota and South Dakota Counties. Participating TAP Counties have been responsible for inputting required inventory data such as pavement depth, age, and road base information to allow the program to properly calculate structural capacity of the roadway. Traffic data, which is collected by MnDOT, is automatically integrated into the forecast model in GRIT. Existing pavement condition information is automatically imported from MnDOT sources and spatially integrated with the project history segments. For the TAP counties of Pennington, Pope, Becker, Beltrami and Faribault, the results of this research project are implemented with their use and data entry in the GRIT program. Implementation for other counties in Minnesota can begin with the use of the GRIT program.

One of the more difficult data processing tasks involves obtaining the raw pavement condition data from Pathweb and recalculating the PQI on a 1000-foot basis for each county. This process would need to be performed each year when the data is uploaded from MnDOT to Pathweb Services. This process could be made more efficient and timelier if MnDOT Pavement Services would create the necessary 1000-foot interval PQI file when the data is initially processed from the data collection equipment. It is recommended that MnDOT develop a process to produce this file for each county and make the file available for download.

In addition, it is recommended that local agencies be encouraged to utilize GRIT or other asset management systems to inventory and maintain their assets. This pavement condition forecast tool will be included in future versions of the GRIT program and will be available to any local government with access.

4.3 CONCLUSION

The primary objective of this research project was to enable county engineers to access and use reliable future pavement condition and traffic data to simplify and enhance their development of performance-based capital improvement plans. This was to be accomplished without the need for expensive complicated software or specialized technical IT and GIS staff. The processes and programs developed through this research project demonstrated the feasibility of fulfilling this objective.

With the data and models in place and reliably forecasting the PQI 35 years into the future, the final objective was to provide this information to the county engineer, decision-makers, and the public in an easy-to-use web-based GIS format. GRIT was used and enhanced to provide GIS maps of pavement condition, age, traffic, and other data for any future year selected. System performance graphs were also developed to show the percentage of miles in the county at various age and condition levels. All pavement condition projections, maps and graphs are automatically updated as the user updates or changes the construction planning layer (long-range capital improvement plan).

The additional information contained in the pavement forecast system will allow county roadway managers to efficiently manage their systems and prioritize projects more effectively. This will allow them to more effectively use their limited budgets to deliver high-quality transportation systems by prioritizing projects that can benefit from lower-cost pavement preservation activities and understanding how long roadways can last before a high-cost reconstruction must take place. The online GIS output maps will also increase public visibility of the use of tax dollars, as the public can see what projects will be undertaken by the county on a yearly basis.

REFERENCES

AASHTO. (1993). *AASHTO Guide for Pavement Structures*. Washington, DC: American Association of State Highway Transportation Officials.

MnDOT. (2015) An Overview of Mn/DOT's Pavement Condition Rating Procedures and Indices. St. Paul, MN: MnDOT.

Tolliver, D., B. Wentz, A. Dybing, P. Lu, A. Bratlien, T. Horner, … & S. Shakya. (2012, September) *An Assessment of County and Local Road Infrastructure Needs in North Dakota*. Fargo, ND: Upper Great Plains Transportation Institute, North Dakota State University. Retrieved from https://www.ugpti.org/resources/reports/downloads/2012-09-county-and-local-roadway-needs.pdf