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Asset Management

PERFORMANCE-BASED TOOLS TO ENHANCE INVESTMENT DECISION MAKING: ASSESSING A REGIONAL BRIDGE NETWORK AND THE LONG-TERM CONSEQUENCES OF UNDERINVESTMENT

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A key challenge faced by transportation professionals is where and how best to allocate financial resources. This challenge is exacerbated in the current planning context given that revenue sources are not sufficient to meet infrastructure needs. Following the emergency closure of a primary bridge linking Rochester, NY to one of its suburbs, the Genesee Transportation Council (GTC) commissioned an analysis to determine the long-term consequences of underinvestment in its bridge network and what improvements would be possible with additional revenue support. The effort consisted of assessing the conditions of the nearly 1,600 bridges in the region and in developing two flexible, practical MS Excel-based tools to support more informed investment decisions to maximize the limited revenues expected to be available for bridge repairs and replacements.

The first tool – Bridge Asset Management Planning Tool – identifies a cost-effective balance between work types for bridges in the Region based on available revenues. It incorporates data on average annual daily traffic and annual daily truck traffic to emphasize the impacts of structural deficiency and functional obsolescence on bridge users, treating the users of the bridges as a critical prioritization factor rather than solely focusing on the number of deficient bridges. The tool deemphasizes a "worst first" approach to asset management and focuses on the customer and the broader system. The Bridge Asset Management Planning Tool selects work types based on the long-term economic optimization models from the National Bridge Investment Analysis System (NBIAS) and allows the user to conduct performance-based condition assessments. The tool revealed that attaining a State of Good Repair would require a doubling of annual investments in the Region's bridges over a ten year period, or a 60 percent increase in annual investments over a 25-year period.

The second tool – the Bridge Prioritization Screening Tool – provides a flexible approach to creating customized rankings of bridges based on user-defined criteria and identifying potential candidates for decommissioning if investment levels are not adequate to address future bridge preservation needs. Decommissioning a bridge has socioeconomic implications, but the versatility of the model assists the user in identifying bridge clusters to determine where traffic could potentially be diverted if a bridge is closed to reduce the impact to users and businesses. This tool provides an objective basis for discussions about investment priorities, enhancing but not replacing performance-driven project evaluation processes.

These tools provide cost-effective applications that small and medium-sized communities can consider developing to assess their specific bridge networks and enhance their capital programming processes. These tools provide an objective basis to assess and articulate the impacts of continued underinvestment in bridges and support performance-based, data-driven analysis to identify investment priorities.

PERFORMANCE-BASED TOOLS TO ENHANCE INVESTMENT DECISION MAKING: ASSESSING A REGIONAL BRIDGE NETWORK AND THE LONG-TERM CONSEQUENCES OF UNDERINVESTMENT

As in other parts of the country, the poor conditions of bridges in the nine-county Genesee-Finger Lakes Region (the Region) of New York have drawn their share of attention, if not resources. Due to the lack of adequate funding for bridge preservation and maintenance, the Genesee Transportation Council (GTC), the Metropolitan Planning Organization for the Region including the Rochester, New York metropolitan area, commissioned an analysis to determine the long-term consequences of underinvestment and what would be possible with adequate financial support.

The GTC retained Cambridge Systematics (the project team) to conduct a network level analysis to better understand how future bridge conditions (on a systemwide basis) will be affected under various levels of funding, as well as the funding necessary to meet performance targets. The network-level analysis supported the main purpose of the initiative, which was to develop a regional strategy and associated guidance for transportation agencies in the Region to consider when identifying requisite funding for bridges as part of their capital improvement program development activities.

In addition to the network level analysis, the project team also was tasked with creating two excel-based tools to support more informed investment decisions and maximize the limited revenues expected to be available. The first, a Bridge Asset Management Planning Tool, helps users identify a cost-effective balance between work types for bridges in the Region based on the amount available to be invested. The Bridge Asset Management Planning Tool can import the most recent data from the National Bridge Inventory (NBI) and relies on user-defined investment levels to recommend how much funding should be allocated to various work types – maintenance and rehabilitation, improvements, and replacements – to maximize return on investment over two horizon years: 2025 and 2040.

The second, a Bridge Prioritization Screening Tool enables users to create customized rankings of bridges based on various factors and provides the necessary data to assess if traffic currently using multiple bridges in close proximity to each other could be served by a single bridge if funding is insufficient to safely maintain all of the bridges currently in service.

The impetus for this initiative was the emergency closures of several bridges in the Region. As a result, all of the technical work was completed on an extremely expedited schedule (five months) to demonstrate that GTC was responsive to an issue negatively impacting the traveling public. This paper provides an overview of the methodology employed to assess regional bridge conditions and develop tools to further integrate performance management into the GTC capital programming process. It is important to note that, because the data used in this initiative comes from the NBI, the process is transferable and, with minor adjustments, so are the tools created.

BACKGROUND

Insufficient funding for bridges has consequences. Currently, one out of three bridges in the Region either has elements that are in poor condition that require repair (i.e., is Structurally Deficient) or does not meet current design standards (i.e., is Functionally Obsolete). Recent bridge closures have had significant impacts on mobility, accessibility, and economic activity in the Region. From 2010 to 2015, several bridges crossing the Erie Canal were closed abruptly as inspections revealed that the structures could no longer support the current posted weight limits. After a routine inspection in 2013 found deterioration in under-deck members of the steel truss supporting the bridge deck, the right hand lanes of the Irondequoit Bay Bridge (New York State Route 104, a Principal Arterial) were closed, and overweight and oversized trucks were banned for nearly six months between October 2013 and March 2014. Several large businesses in the Route 104 corridor were impacted as oversize and overweight trucks were forced to detour to alternate, slower routes around Irondequoit Bay.

The New York State Route 33A bridge over the Erie Canal, a critical connection between the City of Rochester and the Town of Gates, was closed abruptly on May 6, 2014 for emergency repairs due to issues discovered while preventive maintenance was being performed; the bridge carries over 16,000 vehicles per day. In the last five months of 2014 alone, while this study was conducted, seven bridges in the Region were closed or had weight restrictions put in place.

OVERVIEW OF BRIDGES IN THE GENESEE-FINGER LAKES REGION

The bridge inventory and condition data used in this initiative were from the 2013 National Bridge Inventory (NBI) data submitted by the New York State Department of Transportation (NYSDOT) to the Federal Highway Administration (FHWA) as part of the national bridge inspection program. The NBI database is a collection of information covering all of the nation's bridges over 20 feet in length that carry public roads, including Interstate Highways, U.S. highways, state, and county roads, as well as publicly accessible bridges on Federal lands. States are required to submit an annual summary analysis of the number, location, and general condition of the bridges in their respective state. Key statistics cited in this paper (e.g. annual average daily traffic, percentage trucks, condition data, etc.) were cross-checked against NYSDOT's Winbolts database for quality assurance purposes.

The Region has a total of 1,594 NBI structures. Of these, 214 are bridge culverts and 1,380 are bridges. The NYSDOT owns and maintains 790 bridges, approximately 50 percent of the regional total. The New York State Thruway Authority owns 103 bridges in the Region (6 percent), and 691 bridges (43 percent) are locally owned. Ten bridges (1 percent) are owned by other agencies. More than two out of five bridges in the Region are more than 50 years old (Figure 1).

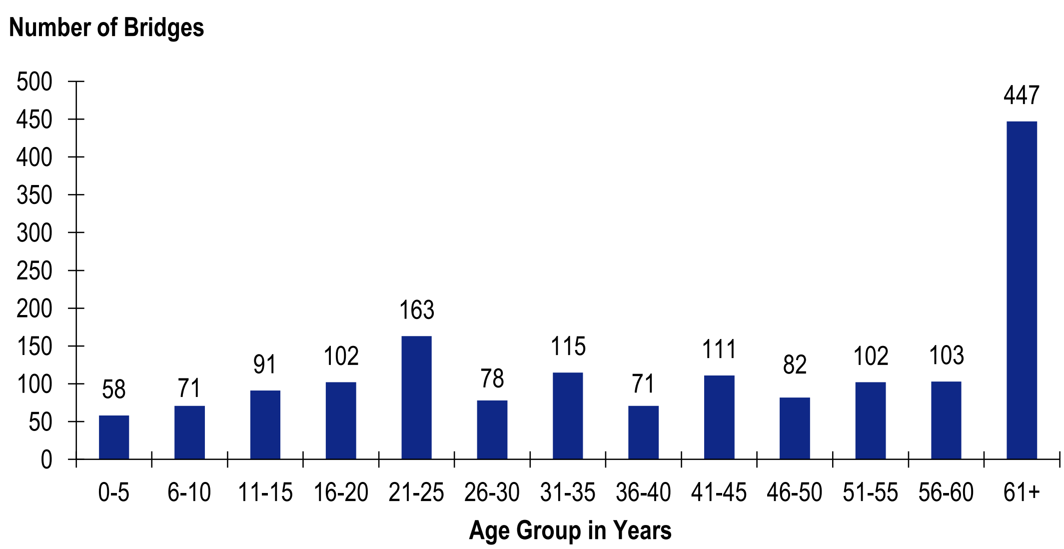

FIGURE 1. Distribution of the Bridges in the Genesee-Finger Lakes Region by Age Group

Regional Bridge Network Conditions

Per Federal inspection standards, bridges are assigned a rating that represents the general condition of the structure. Structural assessments, together with ratings of the physical condition of key bridge components, determine whether a bridge is classified as "Structurally Deficient" or "Functionally Obsolete." Bridges are considered Structurally Deficient if significant load carrying elements are found to be in poor condition due to deterioration and/or damage. A Structurally Deficient bridge requires significant maintenance and repairs to remain in service. The classification of a bridge as "Structurally Deficient" does not imply that it is unsafe for travel. A Functionally Obsolete bridge, by design, is no longer functionally adequate for its purposes (for example due to lack of compliance with current bridge design standards), although the bridge may be structurally sound.

Of the 1,594 structures in the Region, 13 percent are Structurally Deficient, 19 percent are Functionally Obsolete, and 68 percent are neither Structurally Deficient nor Functionally Obsolete (Figure 2). Bridges that are neither Structurally Deficient nor Functionally Obsolete carry approximately 7.9 million daily vehicles in aggregate. Functionally Obsolete bridges carry 4.3 million vehicles in aggregate, and Structurally Deficient bridges carry 1.4 million vehicles in aggregate (Figure 3). Bridges that are Structurally Deficient or Functionally Obsolete are spread relatively evenly across the Region, although certain roadways are carried by multiple Functionally Obsolete bridges, primarily due to the design standards in place when the bridges were built and/or increased traffic that exceeds the design capacity of the bridges in these corridors.

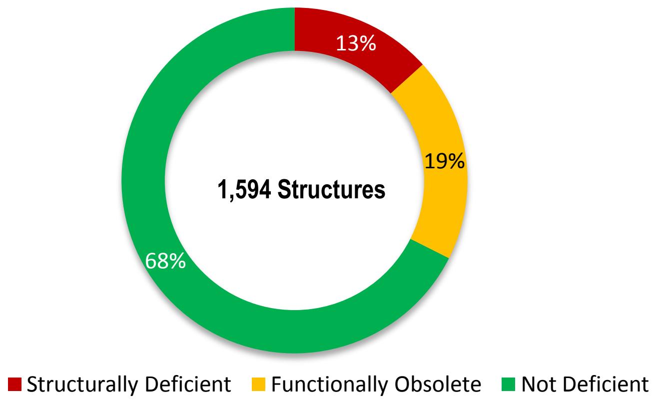

FIGURE 2. Summary of Current Bridge Network Conditions

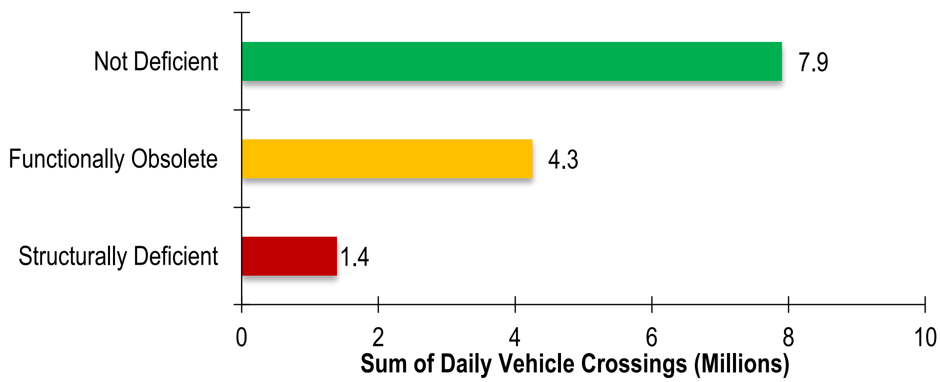

FIGURE 3. Sum of Daily Vehicle Crossings by Condition

IMPACTS OF INVESTMENT SCENARIOS ON FUTURE BRIDGE CONDITIONS

The project team developed performance-based condition assessments for three different scenarios to address current and future system deficiencies. The results of the analysis provide decision-makers with data-driven estimates of the funding needed for three scenarios of asset condition over two planning horizons (2025 and 2040).

Methodology

Future bridge network condition in the Region was forecasted using the FHWA's National Bridge Investment Analysis System (NBIAS) tool and the American Association of State Highway and Transportation Officials' (AASHTO) Pontis tool. NBIAS and Pontis are tools originally developed by Cambridge Systematics and others for the FHWA and are an essential decision support tool for analyzing policy and bridge investment needs by state departments of transportation and metropolitan planning organizations. Moreover, the FHWA uses NBIAS to provide Congress with a status report on the condition of the Nation's bridges every two to three years.

NBIAS and Pontis are based on the same analytical framework. Both bridge management systems incorporate economic forecasting analysis tools to project the multiyear funding needs required to meet user-selected performance metrics over the length of a user-specified performance period. At a minimum, the NBIAS tool is designed to work with bridge condition data as reported by the states for the national bridge inspection program and Pontis is designed to work with the commonly recognized (CoRe) elements defined by AASHTO. NBIAS uses a set of models called the Synthesis, Quantity, and Condition (SQC) models for translating NBI bridge level data into element-specific information.

NBIAS and Pontis consist of decision models to determine the optimal set of repair and rehabilitation actions to take for each bridge element based on the element's condition (rather than age). During the simulation process, preservation policies are applied to each bridge to determine bridge preservation work needed to minimize user and agency costs over time.

As previously stated, NBIAS mainly relies on NBI data and was used to model non-culvert bridge structures. To address the fact that NBIAS does not model culverts, the project team created a Pontis database for the 214 structures of this type in the Region. The project team imported the regional NBI file to Pontis to bring the basic inventory data (e.g., location, traffic, trucks traffic). Under the NBI inspection program, bridge components (e.g., deck, superstructure, and substructure) are rated based on a scale from 0 to 9, where 0 is the worst condition state and 9 is the best condition state. Pontis, however, looks at element condition in a scale from 1 to 5, where 1 is the best condition and 5 is the worst condition depending on the element. Culverts have 4 condition states. The project team developed correspondence tables to translate the NBI culvert condition ratings to Pontis condition states for this initiative.

Investment Scenarios

Funding levels were calculated to achieve three discrete future scenarios:

- **Maintain Existing Conditions.** The objective of this scenario is to maintain the existing network condition in the most cost-effective manner. This should not be interpreted as implying that stakeholders in the Region are satisfied with the existing conditions.
- **Achieve a State of Good Repair.** The objective of this scenario is to achieve the maximum performance level at which maintenance needs are cost-effectively addressed as intended in a bridge's life-cycle. Economic optimization analyses determine the maximum performance level relative to life-cycle costs to users and transportation agencies (i.e., benefit-cost ratio greater than 1).
- **Manage Declining Assets.** The objective of this scenario is to identify the performance level that would be achieved if the amount of funds invested from all sources were to remain at the current (or nominal) amount of $37 million in 2014 dollars and not be increased to keep up with projected rates of inflation for materials and labor.

Performance Measures

Future deficiencies were evaluated from the perspectives of both customers and the agencies responsible for ensuring bridges are safe and well-maintained. A total of eight measures were selected to evaluate the future performance and associated funding needs of the Regional bridge network:

- Number of regional bridges that are not classified as Structurally Deficient or Functionally Obsolete.
- Number of regional bridges that are not classified as Structurally Deficient.
- Number of state bridges that are not classified as Structurally Deficient or Functionally Obsolete.
- Number of local bridges that are not classified as Structurally Deficient or Functionally Obsolete.
- Percent of regional Average Annual Daily Traffic (AADT) on bridges that are not classified as Structurally Deficient or Functionally Obsolete.
- Percent of regional AADT on bridges that are not classified as Structurally Deficient.
- Percent of regional truck AADT on bridges that are not classified as Structurally Deficient or Functionally Obsolete.
- Percent of total deck area of bridges on the National Highway System that are not classified as Structurally Deficient.

Results of Scenario Analysis

To achieve a State of Good Repair in 10 years (by 2025), the Region would need to double its current investment in bridges, from $37 million dollars per year to $75 million dollars per year (all amounts in 2014 dollars, not accounting for future inflation). To maintain the current number of bridges that are neither Structurally Deficient nor Functionally Obsolete, the Region would need to invest $31 million per year over the next 10 years. However, the $31 million would have to be adjusted annually to account for inflation.

Over a longer planning horizon (to 2040), the Region would still need to invest considerably more in bridges to achieve and maintain a State of Good Repair. Annual investments would need to increase from $37 million per year to $59 million per year in 2014 dollars. To maintain the current number of bridges that are neither Structurally Deficient nor Functionally Obsolete, the Region would need to invest $31 million per year over the next 25 years, the same as the annual amount needed over the next 10 years.

From the perspective of the users of the bridges, the Region would need to invest approximately $22 million per year (in 2014 dollars, not accounting for inflation) to maintain the same percentage of regional traffic traveling on bridges that are not Structurally Deficient or Functionally Obsolete. This investment level would be needed over both the 10-year horizon and the 25-year horizon.

The scenario analysis process served as a valuable tool for regional stakeholders to understand the implications of various investment levels on the future performance of the bridge network. However, given that a potential investment scenario is one in which the current level of investment is the maximum that would be spent in any future year, the project team developed a set of projections for a “Manage Declining Assets” scenario. Under this scenario, investment levels for future years are set at $37 million dollars in year-of-expenditure dollars, with no annual adjustments for inflation. If inflation is assumed to be 2.7 per year through 2025 and 2.3 percent per year thereafter through 2040 (2), the purchasing power of a $37 million investment in 2014 falls to $27.6 million in 2025 and to $19.6 million in 2040. With these levels of investment, 44 more bridges in the Region will fall into disrepair by 2025, and an additional 196 (a total of 230) will fall into disrepair by 2040.

BRIDGE ASSET MANAGEMENT PLANNING TOOL

Faced with uncertainty around future levels of investment, the project team developed a Microsoft Excel-based Bridge Asset Management Planning Tool (BAMPT) to enable GTC to conduct performance-based condition assessments for the two horizon years of 2025 and 2040. As with the impacts of investment scenarios analysis discussed above, data from the 2013 NBI data as submitted by NYSDOT to Federal Highway Administration FHWA as part of the national bridge inspection program were used and future bridge network conditions were forecast using FHWA's NBIAS tool and AASHTO's Pontis tool.

The BAMPT allows the user to assess the system preservation needs for four different networks:

- The region as a whole;
- State-owned bridges;
- Locally-owned bridges; and
- Bridges on the National Highway System (NHS).

The BAMPT forecasts conditions for the same eight bridge-related performance measures considered in the impacts of investment scenarios analysis for the two horizon years based on the investment level inputted by the user. This enables users to explore the relationship between funding and performance and can help answer questions such as: What would the bridge network conditions in the Region be if the average annual investment level increases by X (e.g., 10, 15, 20) percent over the next 25 years? What if the average annual investment level decreases by a certain percentage?

The BAMPT is fully automated, allowing a user to navigate through the tool using a Control Panel. The user selects the performance measure of interest and will automatically be directed to a "Results" screen showing the corresponding 2025 and 2040 performance curves (Figure 7). On each Results screen, the user can input an assumed annual investment level in the cell shaded in yellow (or use a scroll bar) to see how the projected network condition changes for different annual budget levels. Projected network conditions are displayed as an orange dot on the graph. The value corresponding to the dot is displayed in a gray box above each graph in the units associated with that measure (e.g., number of bridges, percent deck area, or percentage of AADT).

To the right of each graph, a stacked bar graphs show how much funding should be allocated to various work types in order to maximize return on investment. All dollar amounts are expressed in constant 2014 dollars. The work types are:

1. **Improvements** – Examples of this type of work include (but are not limited to) deck widening, raising bridges to increase vertical clearances, and strengthening bridges to increase load-carrying capacity.
2. **Replacements** – Examples of this type of work include (but are not limited to) full replacement and replacement of decks, bearings, girders, stringers.
3. **Maintenance and Rehabilitation work (abbreviated "Maint. & Rehab")** – Examples of this type of work include (but are not limited to) pothole repairs, seal cracks and minor patching, overlays, deck spalls/delaminations, washing, painting, railing work, and rehabilitation of girders and stringers.

BRIDGE PRIORITIZATION SCREENING TOOL

The project team developed a Microsoft Excel-based Bridge Prioritization Screening Tool (BPST) to enable GTC to create customized rankings of bridges and identify potential candidates for decommissioning if investment levels are not adequate to address future bridge preservation needs. The Bridge Prioritization Screening Tool was developed specifically for the Region to prioritize bridges based on various factors and provide the necessary data to assess if traffic currently using multiple bridges in close proximity to each other could be served by a single bridge if funding is insufficient to safely maintain all of the bridges currently in service. The tool:

- **Ranks bridges based on user-defined criteria.** Bridges are scored on a scale from 0 to 100 and ranked in ascending order from the lowest numerical score to the highest. The higher the score, the more the bridge responds to the user-defined weighting of key factors such as number of vehicles carried, existing structural condition, ability to meet current geometric design standards, and whether transit vehicles use the bridge as part of their route, among others.

- **Identifies bridges that could be candidates for decommissioning and specific bridges to which their traffic could be diverted.** One or more bridges in close proximity to each other may need to be considered as a candidate for strategic divestment if investment in bridges drop below the level needed to maintain the current number of structures. This function of the tool provides the ability to determine if a nearby bridge could serve the needs of one or more of the bridges being considered for decommissioning, be maintained or repaired in a more cost-effective manner, and ensure connectivity across the network. Additional analysis to determine if a bridge serves a major employer, emergency management facility, or other critical civic function should be conducted as well.

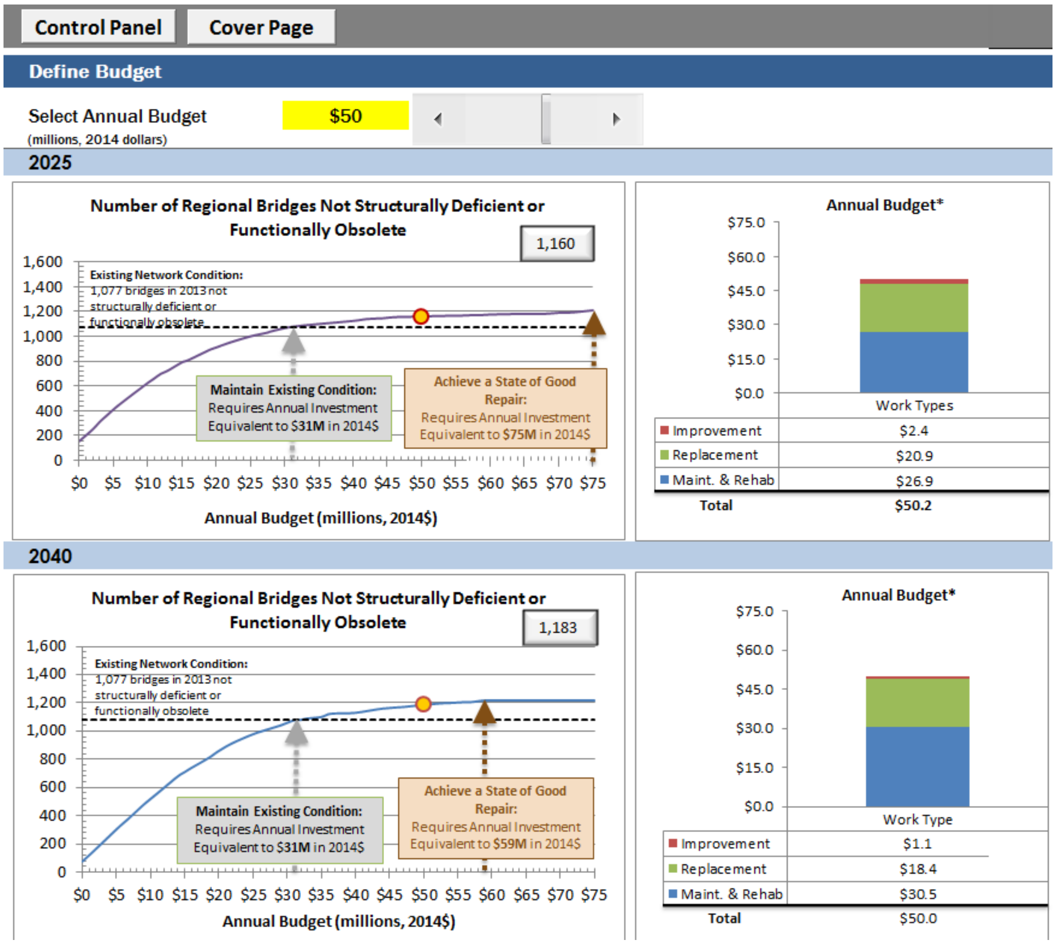

FIGURE 7. Example of Results from Bridge Asset Management Planning Tool's Performance-Based Condition Assessment

The BPST enhances the existing performance-driven Transportation Improvement Program project evaluation process. The BPST is not a performance-based prioritization tool. Bridge scores are based on current asset condition and operating characteristics. The development of the BPST consisted of four steps: (1) Selecting Prioritization Screening Criteria; (2) Calculating Individual Criteria Scores; (3) Calculating Composite Scores; and (4) Identifying Clusters of Bridges.

Selecting Prioritization Screening Criteria

The NBI database was the source of the data for all but one of the 14 criteria (the presence of the structure on a transit route was provided by GTC) selected by GTC staff and member agency representatives based on discussions and deliberations regarding the optimal set of factors to serve as the foundation for the BPST. Individual scores were grouped to calculate composite scores in three categories: Structural, Operating, and Functional (Table 1).

Calculating Individual Criteria Scores

- *Average Bridge Condition* – For structures other than culverts, the Average Bridge Condition Score was based on the average of the deck, superstructure, and substructure NBI condition ratings. The Average Bridge Condition Score for culverts was based on the composite condition rating for the culverts. The Average Bridge Condition Scores range from 1 to 5, where 1 represents a bridge that is in poor condition and 5 denotes a bridge that is in good condition.
- *Structural Evaluation Score* – Each bridge's Structural Evaluation Score was based on NBI item #67, which is an indication of the load level which can safely utilize the bridge. The Structural Evaluation Scores range from 1 to 5, where 1 represents a bridge that requires a corrective action (e.g., strengthening of components) or replacement and 5 denotes a bridge that meets or exceeds current structural design standards.
- *Fracture Critical Score* – A bridge in the NBI is identified as "fracture critical" if it has steel tension members whose failure would be expected to result in a partial or full collapse of the bridge. The classification of a bridge as fracture critical does not mean the structure is unsafe, but the bridge would require more frequent hands-on inspections and maintenance work to ensure it remains in service. A rating of 0 or 2 was selected for this criterion. A bridge with fracture critical elements received a score of 0; bridges that were not identified as fracture critical received a score of 2.
- *Detour Length Score* – The scores for detour length were determined based on the distribution of the detour lengths of all bridges in the Region. Bridges with detour lengths in the bottom quintile (less than 0.62 miles) were assigned a score of 1. Bridges with a detour length in the top quintile (longer than 5.5 miles) were assigned a score of 5.
- *Light-Duty Vehicle Average Annual Daily Traffic (AADT) Score* – The rating scale for light-duty vehicle annual average daily traffic was determined by splitting the bridges into five quintiles based on the light-duty AADT as calculated by subtracting NBI item #29 (total AADT) by the heavy-duty AADT (see below) . A score of 1 for AADT was assigned to a bridge with traffic levels in the bottom quintile (or bottom 20 percent), corresponding to 0-500 light-duty passenger vehicles per day. Conversely, a score of 5 represents a bridge that carries traffic levels in the top quintile (more than 12,000 light-duty passenger vehicles per day).
- *Heavy-Duty Vehicle Average Annual Daily Traffic (AADT) Score* – The rating scale for heavy-duty vehicle annual average daily traffic also was determined by splitting the bridges into five quintiles based on the truck AADT as calculated by multiplying NBI item #29 (total AADT) and NBI item #109 (percent trucks). A score of 1 for AADT was assigned to a bridge with truck traffic levels in the bottom quintile (or bottom 20 percent), corresponding to 0-30 heavy-duty vehicles per day. Conversely, a score of 5 represents a bridge that carries traffic levels in the top quintile (more than 800 heavy-duty vehicles per day).
- *Transit Route Score* – The Transit Route Score was determined based on needs for increasing the frequency of existing public transportation service in the Region. The project team used geographic information systems (GIS) to overlay the fixed-route public transportation network with the 13 place type categories (e.g., Regional Urban Core, Mature Suburb, Rural, Employment Center, etc.) identified in the current long range transportation plan for the Region (3). The long range transportation plan identified the transportation needs for each type of place through 2035 along with the corresponding degree of priority. Transit Route scores of 1, 2, and 3 represent the relative priority of increasing the frequency of public transportation based on minor, moderate, and major needs, respectively.
- *Lanes on Structure Score* – Bridges carrying 2 or more lanes received a score of 2. Other bridges received a score of 1.

- *Average Obsolescence Score* – An Average Obsolescence Score was calculated based on the average of the NBI appraisal ratings for deck geometry (NBI item #68), underclearance (NBI item #69), and approaching alignments (NBI item #72). A score of 1 was assigned to a bridge that does not meet current design standards from a geometric perspective, and a score of 5 was assigned to a bridge that meets current design standards.

TABLE 1. Summary of Prioritization Screening Criteria

Prioritization Screening Criteria	Corresponding NBI Data Item #
Components of Structural Score:	
Average Bridge Condition Score	
For bridge structures, average of:	
• *Deck condition rating*	58
• *Superstructure condition rating*	59
• *Substructure condition rating*	60
For culverts:	
• *Culvert rating*	62
Structural Evaluation Score	67
Fracture Critical Score	92A
Components of Operating Score:	
Detour Length Score	19
Light Duty Vehicle AADT Score	29
Heavy Duty Vehicle AADT Score	29 multiplied by 109
Transit Route Score	(not in NBI. Data provided by GTC.
Lanes on Structure Score	28A
Components of Functional Score:	
Average Obsolescence Score	
Average of:	
• *Deck geometry appraisal rating*	68
• *Vertical/Horizontal clearance appraisal rating*	69
• *Approach roadway alignment appraisal rating*	72

Calculating Composite Scores

The score of bridges is based on 3 components:

- **Composite Structural Score** – The Composite Structural Score is a function of the Average Bridge Condition Score (average of deck, superstructure, and substructure condition ratings for bridges or culvert condition rating for culverts); the Structural Evaluation Score; and the Fracture Critical Score:

$$= \frac{\text{bridge condition}}{5} * \text{weight} + \frac{\text{structural evaluation}}{5} * \text{weight} + \frac{\text{fracture critical}}{2} * \text{weight}$$

- **Composite Operating Score** – The Composite Operating Score is a function of the detour length score, light duty vehicle AADT score, truck AADT score, transit route score, and lanes on structure score.

$$= \frac{\text{detour length}}{5} * \text{weight} + \frac{\text{trucks AADT}}{5} * \text{weight} + \frac{\text{LDVs AADT}}{5} * \text{weight} + \frac{\text{transit route}}{3} * \text{weight} + \frac{\text{number of lanes}}{2} * \text{weight}$$

- **Composite Functional Score** – The Composite Functional Score is a function of the Average Obsolescence Score, which takes into account deck geometry, underclearances, and the approach roadway alignment.

$$\textbf{Functional Score} = \frac{\text{functional obsolescence}}{5}$$

The overall bridge score is determined by summing the scores of the 3 components, as shown in the following equation:

$$\textbf{Bridge Score} = \text{Structural score} * \text{weight} + \text{Operating score} * \text{weight} + \text{Functional score} * \text{weight}$$

The weights of each sub-component (i.e., individual criteria scores) and component (i.e., composite scores) can be adjusted based on modifications to the Region's strategic goals and desired emphasis for ranking.

Identify Clusters of Bridges

In addition to prioritizing bridges, the other objective of the BPST is to identify bridge clusters to further evaluate whether neighboring bridges could serve as alternatives and maintain the desired connectivity to reduce the potential negative impacts of decommissioning a bridge. The project team used the Great-Circle (a.k.a. orthodromic) distance formula to identify spatial clusters:

$$= 2arcsin\left[\sqrt{sin^2\left(\frac{latitude_1 - latitude_2}{2}\right) + cos(latitude_1)cos(latitude_2)sin^2\left(\frac{longitude_1 - longitude_2}{2}\right)}\right]$$

The latitude and longitude coordinates had to be converted to radians and the resulting distance was multiplied by 3,958.7392, which is the mean radius of the Earth in miles.

Additional Factors to Consider in Bridge Prioritization

The BPST was designed to identify bridges that could potentially be decommissioned using engineering factors and current operating characteristics collected from the NBI database. The tool considers the majority of critical factors for ranking bridges that should be evaluated by facility owners in their capital programming processes, and by GTC in its development of future Transportation Improvement Programs. Additional factors that go beyond the BPST and require deliberation and discussion by and among all affected stakeholders include:

- **Economic Costs** – The region's economic health depends on the efficient transport of goods and people. Decommissioning a bridge may disrupt important connections which may result in major economic ramifications on businesses and communities adjacent to or served by the structure. Even though bridges with low traffic volumes and relatively short detour lengths may score low in their respective categories, the traffic the bridge is carrying may be serving an important industry or a much needed community asset (e.g., hospital, fire/police station, etc.). The facility owner should evaluate how critical the initial list of bridges are to area businesses and how a link disruption would affect their profitability or ability to serve the community.

- **Increases in emergency response and evacuation time** – The current version of the tool does not measure the impact on travel patterns, emergency response, or evacuation times if a bridge is decommissioned. Similar to the Transit Route criteria, a GIS map of emergency response and evacuation routes could be superimposed with the roadway and bridge network to develop a rating scale; however, to measure impacts more precisely, a travel demand and microsimulation models should be used to quantify the additional travel time impacts on emergency response vehicles and the ability of the remaining bridges to accommodate traffic associated with an evacuation.
- **Travel costs to customers** – The current version of the BPST accounts for the potential driver detour length when prioritizing bridges. Shorter detour lengths indicate that if a bridge is decommissioned, an alternate route is available within a relatively close distance. However, the vehicle operating costs associated with the additional distance and travel time costs to detour around a closed bridge are not currently measured. To further evaluate the list of potential candidates for decommissioning, a regional travel demand model or a project evaluation spreadsheet could be used to evaluate the travel costs (disbenefits) of closing a bridge.
- **Mobility/System Connectivity –** Decommissioning a bridge involves diverting volumes of vehicles to alternate routes; however, these routes might not have been designed to carry additional capacity. As a follow-on activity when narrowing down the list of bridges, project participants need to consider future traffic growth when conducting vehicle carrying capacity analyses on alternate routes.
- **Bridge Condition** – The condition of the bridges that are candidates to receive traffic from a decommissioned bridge must be assessed to determine whether or not a nearby bridge is also in poor condition. If this is the case, the facility owner(s) need to determine which bridge is more worthy of investment.

CONCLUSIONS

Structurally-sound bridges that meet current design standards are absolutely critical to providing a safe, efficient, and reliable transportation system that supports economic development and quality of life for all. Insufficient funding for bridges has consequences. For the Region to attain a State of Good Repair, it would require a doubling of investments in bridges over a 10-year period, or a 60 percent increase in annual investments over a 25-year period. A commensurate increase in investment is likely for many communities across the country, and specifically those with harsher climates and older structures.

An emphasis on asset management and performance-based, data-driven capital programming has maximized GTC's return on investment. Currently, only 10 percent of traffic – both passenger and freight – travels on bridges that have elements that are in poor condition. The BAMPT and BPST have strengthened the GTC capital programming process and could do the same for other transportation agencies responsible for making the difficult decisions of where to invest resources that are clearly less than what is needed to make even modest improvements in performance.

The capacity to prioritize and select the most needed bridge maintenance, improvement, and replacement projects is a major step in the right direction but there are more steps to be taken to complete the journey of fully embedding performance-driven investment decision making in the capital programming process. The ability to conduct cross-asset evaluation is critical to maximizing the benefits and minimizing the negative impacts associated with insufficient resource levels. Moving forward, GTC expects to expand the capabilities gained through this initiative to other asset classes, including (at a minimum) pavements. True mode-neutral evaluation and assessment that provides the information necessary to transparently articulate accomplishments and shortcomings is paramount to solidifying public trust and gaining support for additional investment in transportation infrastructure and services.

REFERENCES

1. FHWA, Bridge Preservation Guide, August 2011.
2. New York State Department of Transportation Highway Cost Index Special Tabulations from IHS Global Insight, accessed August 2014.
3. *Long Range Transportation Plan for the Genesee-Finger Lakes Region 2035,* June 2011