Recovering from the 2010 Nashville Flood: Pavement Management as a Tool in Long Term Disaster Recovery

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ABSTRACT

In the spring of 2010, Nashville, Tennessee and surrounding Davidson County (commonly referred to as "Metro") was hit by a massive flood along the Cumberland River and its associated tributaries. This event broke nearly all flood-related records for the Nashville area and was identified as a 1,000-year flood by the National Weather Service. Damage to the transportation network was significant; flood related damages to pavement included major surface damage, washouts, and erosion of the soil that Metro's roads are built upon.

This paper is a case study of Metro's response to the 2010 flood with respect to its roadway network and the role the existing pavement management system played in the long-term recovery of Metro's pavements. It discusses the impacts of the flooding, how the system was used to identify repair areas, how the appropriate approach was determined for specific damaged areas, and how the results of repairs were tracked to ensure that they were both appropriate and effective. The development of new approaches used to address an event of this magnitude along with the impact to Metro's financial reporting and ability to issue bonds will also be discussed.

INTRODUCTION

All transportation agencies need to manage the result of natural disasters as a part of their operations. Many times, these events are localized (tornadoes, landslides, and similar events), have limited effects after the initial event, and can be managed as either a single repair project or a limited collection of repair projects. However, some disasters cause major, widespread damage and must be dealt with at the network level as most of the transportation network experiences some level of damage. On May 1st, 2010, record-breaking storms across the State of Tennessee began in the region which would lead to a 1,000 year flood in cities along the Cumberland River (1). At the conclusion of the storm, 13.57 inches (345 mm) were measured in Nashville alone; communities upstream of Nashville also saw rain totals between 10 and 16 inches (254 mm to 406 mm) over the two day period (2,3). This rain lead to massive damage of the pavement network with instances such as those shown in Figure 1 and Figure 2 occurring throughout the Nashville Metropolitan area.

While most roads were open to traffic (out of 1100 damaged areas, only 5 were still closed to traffic after May 9), the long term damage from this event is still being felt in 2014. A combination of base failures, potholes, and moderate to severe cracking continue to be systematically addressed through Metro's Pavement Management System (PMS).

PAVEMENT NETWORK DESCRIPTION

The Metropolitan Government of Nashville and Davidson County has operated as a combined government since 1963 and is most commonly referred to as "Metro". This means that the pavement network maintained by Metro Public Works (MPW) is a mixture of high-density urban, suburban, and rural pavements. Overall, the network is about 2,400 centerline miles (3,862 centerline kilometers) long and consists of approximately 397 million square feet (37 million square meters) of full-depth asphalt pavement.

FIGURE 1 Example of Pavement Damage Due to Severe Flooding.

FIGURE 2 Overview of Flooding Along the Cumberland River in Downtown Nashville.

EXISTING PAVEMENT MANAGEMENT SYSTEM

Metro put a new pavement management system in place in 2003 to systematically manage MPW's pavement assets. This system has a software component (as do all pavement management systems), but the objective was to install a complete system including regular data updates, business processes to update work and include new pavements accepted for maintenance, a systematic method to evaluate new rehabilitation methods, and a means to make the data contained within the PMS available to government users at large. This system is described in detail on Metro Paving's website (4).

The PMS uses three factors as a part of its Overall Condition Index (OCI): Surface Distress, Ride Quality, and Weathering. Surface distress is measured in accordance with ASTM D6433, which is commonly known as the Pavement Condition Index (PCI) or Paver methodology. PCI scores range between 100 and 0 with 100 representing a perfect surface. Ride quality is measured in accordance with the International Roughness Index (ASTM E1926) through the use of a high speed profiler and weathering is measured on a none/low/moderate/high scale. As weathering is evaluated through the measurement of mean texture depth and Metro uses open graded asphalt mixes for some of their paving, weathering is ignored in the OCI calculation for pavements that are less than five years old (5).

Pavement management conditions for Metro are evaluated through the use of a Digital Survey Vehicle (DSV) operated by Metro's pavement management consultant. An example of a DSV is shown in Figure 3. This vehicle contains the high-speed profilometer, lasers to automatically measure rutting and texture (which is used to determine weathering), and a set of digital cameras used in the identification of surface distresses. Data is collected annually on a biannual basis; this means that a given pavement segment will be evaluated once every two years. Both the digital photography and the evaluation data would be critical in the restoration of Metro's pavements.

FIGURE 3 An Example of a Digital Survey Vehicle.

As with most governments in the United States, Metro finances their non-maintenance paving operations through the use of public bonds. Government Accounting Standards Board Rule 34 (GASB-34) states that the value of infrastructure assets (such as pavements) funded through the use of municipal bonds must be reported to shareholders on an annual basis. There are several options available to governments regarding this reporting; Metro has decided to use the modified approach which means that the actual condition of assets needs to be reported and compared to Metro's baseline condition. In this case, that baseline is 70% of the pavements (by area) should have an OCI greater than 70. The pavement management system tracks compliance against this baseline. Obviously, as shown in Figure 4, this was a significant issue after the flood.

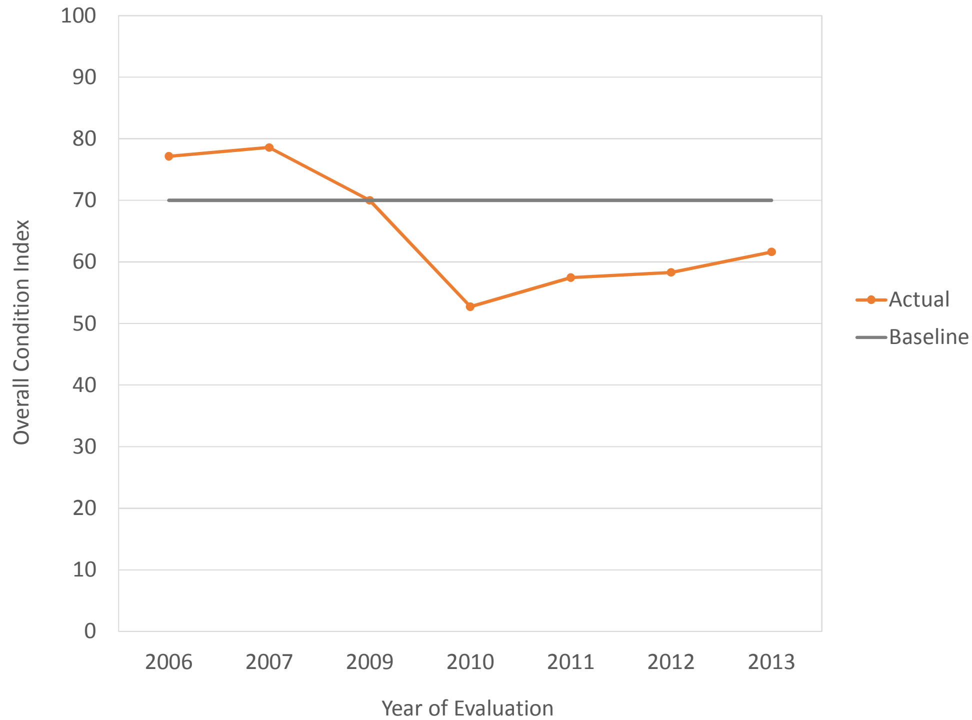

FIGURE 4 Overall Condition Index Over Last 7 Years.

EVALUATING THE PROBLEM

The first step, as mentioned above, was restoring transportation services to those homes without access to roads. The second step was to evaluate the system and determine the type of pavement damage caused by the flood. This was started by looking at the detailed data behind the pavement segments that experienced damage both in the most recent inspection and the prior inspection. Note that this meant more than just comparison of OCI; Metro in cooperation with its pavement management consultant looked at the individual distress quantities listed in the pavement management system to determine the types of distresses that were occurring on Metro's pavement network.

The result of this investigation was an observed increase in both potholes and patching, as shown in Tables 1 and 2. Upon further investigation of the new potholes (using both digital imagery and on-site visits), it was observed that the potholes were surface delamination: the loss of material from the top layer of pavement due to a failure in the bond between the top layer and lower layers of the pavement. The quantities were alarming, but not unexpected as resources normally allocated to routine maintenance were diverted to emergency repairs. The quantities shown in the two tables only represent the study area which was paving groups 1, 3, and 4 which is the pavement network on the west side of the Cumberland River including downtown Nashville. The investigation was limited to these areas as the 2010 survey was split around the flood (6). Note that patching severity decreased (even though the total area increased); this was due to the short-term repairs performed immediately after the flood.

TABLE 1 Number of potholes identified by year and severity in Paving Groups 1, 3, and 4.

Year	High	Moderate	Low	Total
2008	715	769	872	2271
2011	823	1790	1907	4520

TABLE 2 Amount of patching identified by year and severity in Paving Groups 1, 3, and 4.

Year	High	Moderate	Low	Total
2008	24,304 ft^2 / 2,258 m^2	130,093 ft^2 / 12,086 m^2	543,358 ft^2 / 50,478 m^2	697,755 ft^2 / 64,821 m^2
2011	17,656 ft^2 / 1,640 m^2	86,510 ft^2 / 8,037 m^2	701,933 ft^2 / 65,209 m^2	806,099 ft^2 / 74,887 m^2

In addition to an analysis of the numeric data in the pavement management system, Metro also looked at the images collected for each year's survey where there was a significant decrease in OCI to determine the exact nature of the problem. As expected, while the number of potholes (and their associated distresses) increased, these surface defects were still localized. From this information, Metro decided to approach the pavement repairs as localized repairs instead of repairing entire pavement segments. Without the digital imagery (for both years) it would have been difficult to make this decision.

SELECTING AND TRACKING REHABILITATION

At this point, it was possible for Metro to create a long-term plan to address the pothole and resultant patching issue in addition to the far less common base failures that occurred throughout the Metro area. While Metro decided to use a traditional full depth reconstruction in the base failure areas (an approach established prior to the pavement management system and confirmed during the implementation process), a new approach was called for to deal with the number of potholes in the road and the resulting patching that would occur should a traditional partial depth patch be used.

Metro Public Works had successfully used infrared patching technology to repair roads with 30% or less of the surface area affected by potholes and surface delamination as an alternative to the traditional overlay. The use of this treatment was already improving the life cycle cost of the Metro roadways. The technique involves using infrared heating equipment (such as the equipment shown in Figure 5) to soften the existing asphalt at the edges of each pothole. Once at the proper temperature, the heater is removed and a steel rake is used to scarify the pavement. Finally, new material is added and compacted to bring the pavement level with the existing roadway. The end product lacks the obvious sealed saw cuts that a traditional partial depth repair has which, in many cases, either eliminates the patch (the patch is indistinguishable from the original pavement) or maintains the patch at a low severity level as there are no edges to deteriorate.

At the time of the flood, the amount of pothole/surface delaminations were overwhelming. If infrared repair was going to be used on a large scale basis to improve the OCI, the results needed to be tracked to ensure that the treatment was performing as intended and that the treatment was leading to a higher average OCI. The minimum OCI of 70 is a requirement that Metro had to meet both for the requirements set by the Metro Government's management and by the requirements imposed by GASB-34.

FIGURE 5 Infrared Patching Equipment Example

To track the initial results of infrared patching, Metro conducted an additional inspection at each site where infrared patching was used immediately after the maintenance was performed. Follow-up surveys were also performed as a part of Metro's normal pavement condition inspection routine. The overall results (Figure 4), show an increase in the average OCI for the overall network. Based on initial results, Metro has increased its spending on infrared repairs to approximately $1 Million (US) per year. In 2013, that led to 1,660 individual repairs for a total of over 207,000 ft^2 (19,230 m^2). Figure 6 shows the increase in repairs since the start of the infrared program. Please note that the large increase in repairs shown in 2013 was due to additional funds that were made available to Metro Paving. As the repair needs were already identified in the pavement management system, Metro was able to quickly deploy their repair contractors to the appropriate areas and complete many additional repairs in 2013 with this additional funding.

The benefit that infrared technology offers is also shown by public feedback. This element is not yet a formal part of the pavement management program at Metro, but it is critical for both the Paving Department and the Metro Government in general. At the moment, all feedback comes into a central Metro Public Works Customer Service phone number that is widely advertised by the government. While the information from these customer service centers are usually complaints or service requests, this approach garnered positive public feedback both with respect to the time required to complete the repair (i.e., user delay) and the perceived quality of the repair. This is another indicator that the monitoring processes of the pavement management system are working properly and providing the correct conclusions.

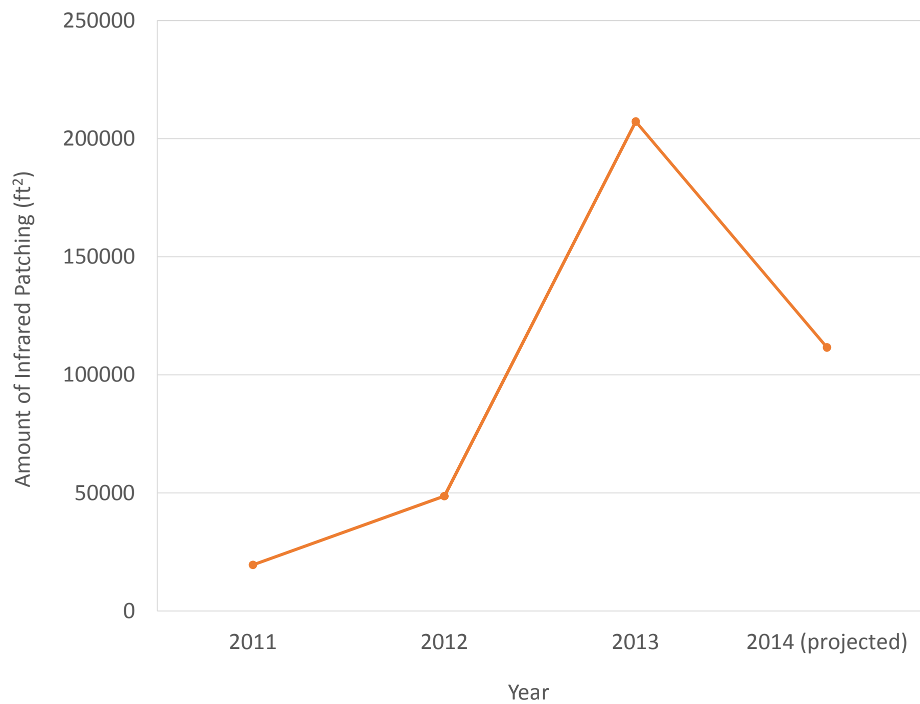

FIGURE 6 Amount of Infrared Patching Used since 2010 Flood.

The next step was to address the principal cause of potholes on the Metro network: delamination. An additional product that Metro Public Works has incorporated into their paving program after the 2010 flood was a new tack material. The major reasons for changing tack was to have the material cover the entire milled roadway surface and increase the bonding capacity between the milled surface and the new surface layer. This trackless tack product implemented by Metro Public Works has a 54% higher shear strength than the previous tack materials used in Metro's paving which should significantly reduce the number of potholes due to surface delamination in the future. Metro Public Works has incorporated the used of this tack material into their paving specifications. While the current product comes from a specific vendor, Metro is looking at tack materials from other vendors that would provide similar shear strength.

NEXT STEPS

Metro plans to continue the infrared patching program as a core part of their pavement management system. Currently, the actual patching is performed by contractors but Metro plans to acquire its own equipment and start doing in-house repairs in the near future based on the assumption that the pavement management system will continue to show that this pavement repair strategy is effective and applicable to the Metro pavement network in the future. In addition to infrared patching, other contractor-applied maintenance, such as crack sealing, is also being moved in-house; the expectation is that Metro Paving will be able to provide more maintenance capabilities for the same budget by doing the work themselves using existing staff in the early spring and late fall when they are not working on paving projects.

Based on both the pavement maintenance program (which, as stated previously, is currently spending about $1 Million per year) and general paving program (which has spent about $28 Million in repaving), Metro expects to meet its 70% over 70 goal in about 3 years based on its planned funding level. Unlike most pavement management analyses that look at multiple alternatives, due to the contractual nature of the pavement condition (considering Metro's agreement with its bondholders under GASB-34), the objective here is to return to the goal condition as quickly as possible to meet GASB requirements. Therefore, Metro is still looking for other ways to boost its funding for repaving and meeting this goal even more quickly.

Other plans for the expansion of the functionality of the pavement management system include providing mobile access to Metro employees for use in the field. While the system can be used in office at the moment, employees had to take either printed data or maps into the field. A new mobile system provides access to the pavement management data through Metro's mobile GIS portal, providing the required data on-demand. Further, Metro has improved the pavement management system's planning functions so that additional funding can be allocated quickly and effectively when it is made available; this was a key takeaway from the work performed in 2013.

CONCLUSIONS

Implementing a pavement management system and properly maintaining that system allows Metro to monitor its pavement network and make both the short-term and long-term decisions necessary after a massive disaster such as the Flood of 2010. The ability to use the system to not only effectively understand the details about pavement condition but to devise appropriate responses when needed is a critical part of what makes the pavement management system at Metro effective for both the Paving Department and Metro's citizens who end up funding the repairs necessary after the flood.

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