How Long Will Asphalt Pavement Last?

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**ABSTRACT**

The Georgia Department of Transportation (GDOT) has applied low-cost, preventive maintenance, including resurfacing, to preserve its 18,000+ centerline-mile (33,354 km) pavement system since 1986. However, due to funding shortfalls, an increasing number of GDOT’s resurfacing projects have been delayed, which could shorten pavement life and require more expensive treatments in the future. Thus, there is a need to study the effectiveness of pavement preservation and to explore the extent of pavement preservation delay in the actual operations because these studies are essential for life-cycle cost analysis, for developing a reliable forecasting model, and for establishing the framework for a pavement preservation delay impact study in order for state DOTs to scientifically justify the necessary pavement preservation funding. In response to this need, GDOT has sponsored the Georgia Institute of Technology to study the state’s pavement performance, using 22 years of pavement performance data. The results show that the average life of resurfaced pavements is about 9.4 years, but the actual average resurfacing project occurs at 11.4 years, a two-year lag. More than 67 percent of resurfacing projects are being delayed by more than one year, which is a serious pavement maintenance problem. This study reveals GDOT pavements’ actual performance and suggests the research necessary for dealing with the pavement maintenance problem.

**KEYWORDS**

Asphalt pavement life
INTRODUCTION

The Georgia Department of Transportation (GDOT) is one of the leading states applying low-cost, preventive maintenance, including resurfacing, to preserve pavements at the right timing (e.g. at a rating of 70). Having sufficient funds to perform the necessary activities is vital to the maintenance of a program such as pavement preservation. Thus, with consistent funding, a uniform and predictable schedule of these necessary pavement preservation activities can be maintained. It is hoped by GDOT that a pavement requires only resurfacing and that its major pavement structure can last forever with regular, early resurfacing. However, an increasing number of resurfacing projects have been delayed due to funding shortfalls which could potentially shorten the subsequent resurfacing life and require more expensive treatments.

There is a need to study the effectiveness of pavement preservation and to explore the extent of pavement preservation delay in the actual operations because these studies are essential for life-cycle cost analysis, for developing a reliable forecasting model, and for establishing the framework for a pavement preservation delay impact study in order for state DOTs to scientifically justify the necessary pavement preservation funding. For example, in the life cycle cost analysis of pavement design when comparing different pavement design alternatives (e.g. asphalt and concrete pavements), the expected pavement life is required. Due to lack of actual data, an assumption of the expected pavement life is often being made. Thus, there is a need to use the actual pavement performance data to conduct a more reliable life cycle cost analysis. The actual historical pavement performance data is also essential for developing a reliable long-term pavement performance forecasting model and to justify the pavement preservation need. This reliable model will provide a scientific and transparent framework for state DOTs to effectively communicate with their state legislature, state agencies and internally within their department. Although there are many forecasting models, developing a practical and reliable performance forecasting model still remains a challenge because of the lack of actual pavement performance data or because the data quality has not been quantified in a way that is useful due to such factors as weather, time of day effects and seasonal effects (Morian, Gibson, & Epps, 1998). In addition, this performance data is important for Mechanistic-Empirical (M-E) pavement design model calibration.

Many DOTS are impacted by insufficient funding resources to sustain their pavement condition survey program, and thus have very limited long term pavement performance data to use. Other reasons for not being able to sustain the pavement condition surveys may include lack of personnel, equipment, or database management, processing and analysis capability (Foundation of Pavement Preservation, 2001). GDOT has committed to collect its long-term pavement performance data so they can better prioritize pavement preservation projects and better understand the actual pavement performance. GDOT has performed its annual pavement condition evaluation on 18,000+ centerline miles (33,354 km) of state-maintained pavement system since 1986. As a first important step, data quality screening is applied to ensure that data used for analysis is meaningful. For example, the collected data may have gaps where the pavement condition survey data was not recorded or the survey was not performed in a particular year due to funding or manpower problems. Also, the pavement distress measurement may not be consistent from year to year which in turn causes fluctuations in the overall pavement rating which render the pavement rating information as questionable or unusable (Morian et al., 1998). A systematic approach has been developed to validate and to quantify the data quality. The detailed data quality quantification will be presented in a separate paper. This paper focuses on presenting the statistical analysis.

GDOT has sponsored Georgia Institute of Technology to conduct a large-scale statewide, long-term pavement performance study based on 22 years of actual pavement performance data collected on 18,000+ centerline miles (33,354 km) of highway system in Georgia (since 1986). Utilizing actual pavement performance
data, the effectiveness of pavement preservation is analyzed statistically in this paper and the extent of pave-
ment preservation delay in the actual operations is also analyzed to better understand the scale of the
problem and to support the future scientific study of quantifying the impact of pavement preservation delay.
Lack of reduction of treatment delay may be evident due to the lack of models addressing optimal treatment
timing (Peshkin, Hoerner, & Zimmerman, 2004). With this study, future research is further identified for
improving our understanding of actual pavement performance.

This paper is organized as follows: The need of critically assessing statewide pavement performance is pre-
sented in the first section and then followed by GDOT’s pavement preservation practice in the second section.
The third section presents the statistical analysis. Finally, conclusions and recommendations are made in the
fourth section.

**GDOT PAVEMENT PRESERVATION PRACTICES**

This section first presents GDOT pavement condition preservation practices and then defines pavement per-
formance information, including life of resurfacing effectiveness (LRE), pavement resurfacing life (RL), and
rating before resurfacing (RBR), to be studied.

**Asphalt Pavement Condition Evaluation**

In order to understand how data for use in pavement preservation is obtained by GDOT, the following
overview of GDOT’s pavement conditions survey system is provided. Within GDOT’s 18,000+ centerline-
mile roadway system (33,354 km), a logical division was created in the form of the project. Projects are defined
by GDOT for purposes of construction & maintenance (pavement preservation) and are approximately 10
miles (18.53 km) in length on average. Utilizing these project definitions, GDOT developed the COPACES in-
spection system to determine the amount and type of surface distress on the asphalt pavement associated with
a project. In order to quantify the pavement condition, definitions of ten distresses (Rutting, Load Cracking,
Block Cracking, Reflection Cracking, Patches & Potholes, Raveling, Edge Distress, Bleeding/Flushing, Corru-
gations/Pushing, and Loss of Section) and appropriate levels of severity were established. The COPACES
scheme requires that all visible pavement distresses be observed and documented for each one mile segment
of the roadway. This measurement process is facilitated by taking a 100 foot sample section that is the most
representative of the one mile segment under consideration. Proceeding with the COPACES process, a rating
(based on maximum score of 100) is established for the project by taking the average extent and predominant
severity level for each distress from the segments and determining the corresponding deduct values. These
deduct values are summed and the result is subtracted from 100 giving the project rating. The project rating
is established for every year.

The following discussion uses load cracking, one of the most common pavement distresses, to illustrate
the pavement distress data collection process and the distress deduct (used in determining the pavement rat-
ing) determination. The GDOT training documents contain images of real examples of load cracking with
four severity levels which allow the inspector to identify the distress in the field. As shown in Figure 1(a), load
cracking begins as simple longitudinal cracks in the wheel path of the pavement lane. The wheel path is usu-
ally around 3 feet (0.91 meters) wide. As time progresses, the cracks form polygons which become smaller until
pop outs occur. These advanced conditions as are illustrated as load cracking severity levels 2 – 4 in the GDOT
The measurement and quantification of load cracking is the next step and is necessary in order to determine the load cracking deduct that is used in the pavement rating calculation. Figure 1(b) illustrates the process of measuring level 1 load cracking. As illustrated in Figure 1(b), both lanes are evaluated and compared. As indicated, lane 2 has a higher percentage which is used to represent the 100 foot (30.5 meter) sample which in turn represents the segment which is averaged with other segment load cracking percentages to resolve the deduct for load cracking for the pavement project. Finally, the load cracking deduct is calculated. Figure 2 shows the deduct values for load cracking with different severity levels. The deduct chart was derived by GDOT
experimental study for reliably determining the projects requiring pavement preservation when the projects are at or below a rating of 70. Based on the deduct chart in Figure 2, the deduct for 60% of level 1 load cracking would be the maximum value of approximately 15 points. The deduct points for all different distresses are totaled and subtracted from 100 to determine the project rating. Therefore, the project rating ranges from 0 to 100. (A rating of 100 indicates that the pavement is in excellent condition.) The distress description, distress measurement, ways to compute project average for each distress, and examples to compute project rating are described in great detail in the user’s manual for PACES (GDOT, 1990).

**Figure 2. Load cracking deduct chart with different severity levels**

**Life of Resurfacing Effectiveness (LRE), Resurfacing Life (RL) and Rating before Resurfacing (RBR)**

To critically evaluate pavement performance, the historical data quality was quantified and filtered to generate the reliable historical data set for use in this analysis. Figure 3 shows the variables and abbreviations of the variables for evaluating the life of resurfacing effectiveness (LRE), the resurfacing life (RL), and the rating before resurfacing (RBR). The LRE is defined as the effectiveness of pavement preservation or the number of years required to reach a pavement rating of 70 (GDOT’s target rating for expected resurfacing timing). The RL is used to evaluate GDOT’s actual resurfacing timings. The RBR is used to evaluate the impact of initial pavement condition due to resurfacing delay on the subsequent pavement life. The RBR is the pavement project rating in the year before the Year End (YE). Since the project rating is established for every year, the graph of the rating for the year of inspection versus the year of inspection can be plotted and studied for examination of the behavior trend of the project rating and time span. A typical plot is provided in Figure 3.

A careful review of Figure 3 reveals a resurfacing life cycle where the yearly rating points for the Year Start (YS) to YE that can be defined as RL. With no detectable surface distress, a new pavement or a newly resurfaced pavement will have a rating of 100(or 105) at the start of its life. (Note, the rating of 105 indicates that
the pavement is under construction.) From this starting point, the pavement will continue to deteriorate until the point that resurfacing becomes necessary (unless a treatment or rehabilitation is performed). GDOT currently has a goal of resurfacing pavements whenever the project rating falls below 70. We have also defined the life of resurfacing effectiveness (LRE), as beginning at the YS and reaching a rating of 70 at the 70 Year (70Y) to provide a consistent performance measure. Thus, these life definitions are well defined in concept according to Figure 3. We can observe the deterioration trend in our manual evaluation of the Project Rating vs. Year chart and we have defined this trend as the Trend in the Middle (TM). These four variables, YS, YE, 70Y and TM are shown repetitively and were used to establish the quality of RL and LRE.

The total of approximately 9,713 projects based on 58,587 project-year records covering 18,000+ center line miles (33,354 km) of state-maintained highway system from 1986 to 2007 were screened and 455 projects were manually processed. Their data quality was also quantified. This paper focuses on presenting the statistical analysis and the detailed quantification of data quality of this data will be presented in a separate paper.

![Figure 3. Pavement resurfacing life (LRE, RL & RBR)](image)

**STATISTICAL STUDY**

The objective of statistical analysis is to evaluate the effectiveness of pavement preservation performance (e.g. life of resurfacing effectiveness) based on statewide data and to explore actual pavement preservation delay based on GDOT’s desired pavement preservation timing, (i.e., the number of years required to reach a pavement rating of 70). The actual GDOT pavement resurfacing practices are critically assessed in terms of resurfacing life. The actual pavement preservation delay is also assessed using the Rating before Resurfacing (RBR). Among 9,317 projects initially processed, 149 High Quality Projects were identified to perform the statistical analysis.
Analysis of Life of Resurfacing Effectiveness (LRE)

This subsection is provided to evaluate the effectiveness of pavement preservation performance using the life of resurfacing effectiveness (LRE). LRE is defined as the pavement life from the beginning of the resurfacing until a pavement rating of 70 (GDOT’s target rating for expected resurfacing timing) is reached. Based on the statistical analysis, it shows that an average life of resurfacing effectiveness is 9.4 years as shown in Figure 4. This indicates that the pavements last 9.4 years on average prior to reaching GDOT’s expected preservation timing. In fact, 9.4-year is very close to GDOT engineers’ 10-year resurfacing life estimate although it is slightly shorter. This actual LRE is important for GDOT. For example, in the life cycle cost analysis of pavement design, when comparing different pavement design alternatives (e.g. asphalt and concrete pavements), the expected resurfacing life is required for the life-cycle cost analysis. This statistical result lays a scientific foundation for the future life-cycle cost analysis.

Figure 4 shows a standard deviation of 2.9 years. This is a concern since the actual long-term preservation need forecasting model is complicated due to the number of potential causative factors. There is a need to minimize the standard deviation by further categorizing the data into homogeneous categories (e.g. functional class, traffic volume, etc.) in the future study. Certainly, it is a complicated process to study all factors (e.g. foundation, pavement design, construction quality, preservation timing, preservation methods, and traffic volume, etc.) that could potentially impact pavement performance. However, the outcome of this statistical analysis provides a very good input for the focused project-level study. For example, in Figure 4, there are some projects with very long and very short resurfacing lives (highlighted with red circles) which warrant an in-depth study of the factors impacting pavement resurfacing performance. Comparing the proposed project-level study with a network-level analysis, the project-level study on the selected projects (e.g. extremely short and long pavement life) identified at the network level statistical analysis will be the logic next step to perform in-depth study of analyzing the factors impacting pavement resurfacing performance.

Figure 4. Statistics of life of resurfacing effectiveness (LRE, based on a rating of 70)
Figure 5 shows the relationship of the LRE and the year. The purpose of this analysis is to explore if the LRE changes with time and could potentially be impacted by traffic volume increases, different pavement design & material applications, and different funding availability. The analysis required that the projects be defined by a 70 rating. The LRE of each of these projects was also determined and the projects were grouped according to the year that the 70 rating occurred. Then for each year, the LRE was averaged. The results show that the average LRE for 2006 is 8.3 years which is lower than GDOT’s estimation of 10 years. However, this lower number may be impacted by the fewer number of projects (7). The peak LRE occurred in 2002 with a value of 11.2 years and the LRE trend since then is declining. This analysis confirms the need for more detailed study and categorization by causative variables to determine why the LRE is decreasing. A review of the actual funding for resurfacing by year should also be included in the analysis to determine the progressive impact of the funding reduction.

![Figure 5. Average life of resurfacing effectiveness (LRE) by year](image)

**Analysis of Resurfacing Life**

This subsection is included to evaluate the actual pavement resurfacing life (RL). RL is defined as the resurfacing life cycle or the number of years between the YS (Year Start) and the YE (Year End). It reflects the actual GDOT resurfacing operation. Figure 6 shows the average resurfacing life is 11.4 years with a standard deviation of 2.6 years. Based on the results in Figures 4 and 6, it is implied that the actual resurfacing is 2 years (11.4 years – 9.4 years) later than the expected resurfacing timing. This may be due to the funding shortage. Figure 7 shows that there is limited historical data on the interstate highways. There are only 4 interstate projects available for analysis. Based on the 4 interstate projects, the average resurfacing life is 8.3 years with a standard deviation of 1.3 years. In the future, with the traffic volume increasing, it is expected that it will be even more difficult to collect pavement condition data on the multi-lane interstate highways. It is noted that interstate highways are crucial for determination of the states’ total Vehicle Miles Traveled (VMT) and therefore, it is desired to improve data availability and data quality. Therefore, there is an urgent need to develop automatic interstate condition assessment systems using remote sensing technology (non-contact and non-intrusive technology), including computer vision, laser technology and ground penetrating radar, with less interference on roadway traffic.
Analysis of Pavement Resurfacing Delay

This subsection gives the evaluation of the percentage of projects experiencing pavement resurfacing delay to better assess the actual pavement preservation operations carried out by GDOT. Figure 8 shows the difference in years between the RL and the LRE. Some projects apparently were resurfaced on schedule (right after dropping below a rating of 70) and have a lower RBR simply because of the high deterioration rate. Figure 8 also shows that there are more than 67% of projects that were not resurfaced at the expected timing which is the first year after the rating below 70.
Figure 9 shows that more than 46% of resurfacings were performed when the rating dropped to 65 or less. Funding shortages may be a key contributing factor. This result also indicates a serious problem for GDOT and other state DOTs because pavement will deteriorate faster and require costly treatment if the low-cost preservation like resurfacing cannot be applied in a timely manner. It is suggested to further quantify the resurfacing delay impact in a future study which includes temporal analysis so state DOTs can scientifically justify the pavement preservation need.
CONCLUSIONS AND RECOMMENDATIONS

The Georgia Department of Transportation (GDOT) is one of the leading states applying low-cost, preventive maintenance, including resurfacing, to preserve pavements. GDOT hopes that a pavement requires only resurfacing and that its major pavement structure can last forever with regular, early resurfacing. GDOT has performed its annual pavement condition evaluation on 18,000-centerline miles (33,354 km) of state-maintained pavement system since 1986. An increasing number of resurfacing projects have been delayed due to funding shortfalls and could potentially shorten the subsequent resurfacing life and require more expensive treatments. There is a need to study the effectiveness of pavement preservation and to explore the extent of pavement preservation delay in the actual operations because these studies are essential for life-cycle cost analysis, for developing a reliable forecasting model, and for establishing the framework for a pavement preservation delay impact study in order for state DOTs to scientifically justify the necessary pavement preservation funding. In response to this need, GDOT has sponsored Georgia Institute of Technology to conduct a large-scale statewide, long-term pavement performance study based on 22 years of actual pavement performance data collected on 18,000 centerline miles (33,354 km) of highway system in Georgia (since 1986). The objective of this paper is to present the important findings based upon analysis of the actual pavement performance and the extent of pavement preservation delay in the actual GDOT operations. The following summarizes the findings of this study:

1. More than 22 years of statewide historical pavement condition survey data have been comprehensively analyzed. The data quality of each project was quantified systematically and the high quality data was used to perform the analyses to ensure the quality of statistical outcomes. The preliminary studies analyzing the actual pavement performance and the actual pavement preservation delay are presented in this paper.

2. Based on statistical analysis, the results show that an average life of resurfacing effectiveness (LRE) is 9.4 years with a standard deviation of 2.9 years. It also indicates that the pavements last 9.4 years on average before reaching GDOT’s expected preservation timing (indicated by a rating of 70). This average LRE is very close to GDOT engineers’ 10-year pavement life estimate although it is slightly shorter.

3. The average resurfacing life for GDOT is 11.4 years with a standard deviation of 2.6 years. Based upon analyses of resurfacing life and the life of resurfacing effectiveness, there is an average of 2 years (11.4 – 9.4) of resurfacing delay in the actual GDOT pavement preservation operation.

4. Further pavement preservation delay study shows that more than more than 67% of pavement preservation projects have been delayed which reveal a serious problem for state DOTs.

The study has laid a good foundation for the subsequent research. The following list the recommended future research:

1. Future research can be conducted to minimize the standard deviation of pavement life (e.g. 2.9 years) by categorizing projects with homogenous road characteristics (e.g. functional class, AADT, etc.). This is important to improve our understanding of pavement performance and support development of a reliable performance forecasting model.

2. Utilizing the network-level statistical study, the pavements with extremely short or long pavement life can be identified for further study of the causal factors. Further, it makes sense to perform in-depth studies on the focused projects instead of studies of statewide projects that may not be feasible.

3. Having reliable pavement condition data is vital for establishing interstate highway pavement performance due to the difficulty in manually performing the pavement condition survey on the high traffic,
multi-lane interstate highways. Therefore, there is an urgent need to develop automatic interstate condition assessment systems using remote sensing technology (non-contact and non-intrusive technology), including computer vision, laser technology and ground penetrating radar, with less interference on roadway traffic.

4. There is a need to develop a scientific framework to quantify the pavement preservation delay impact in the future so that state DOTs can use this framework and calculations to scientifically justify the pavement preservation need. This research has laid an important ground for the future research on this subject.

5. Besides analyzing a composite rating in this study, the historical pavement condition data can also be used to analyze detailed distress information in the future. For example, users can analyze the predominant distress, pavement distress distribution and their propagation. The distress propagation can be used to support M-E pavement design model calibration.

REFERENCES


