Ongoing Research under CHAMPS

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Virginia Tech
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**Research Title:** Development of New Network-Level Optimization Model for Salem District Pavement Maintenance Programming

**Perfomed By:** Sercan Akyildiz

**Summary:**
The major challenge facing the state DOTs’ maintenance managers today is to preserve the road networks at an acceptable level of serviceability subject to stringent yearly maintenance and rehabilitation (M&R) budgets. Maintenance managers must allocate such limited budgets among competing alternatives; which makes the situation even more challenging. Absence of smart decision-making tools and accurate data exacerbates the matter. This research effort aims to develop and implement a network-level pavement maintenance optimization model that can be used by the maintenance managers as a decision-making tool to address the budget allocation issue.

The network-level optimization model is established with the application of linear programming algorithm and is subject to budget constraints and the agencies’ pavement performance goals in terms of total lane-miles in each pavement condition state. A smart decision-making tool is developed with Microsoft Office Excel. This decision-making tool can compute the optimal amount of investment for each pavement treatment type, shown in Figure 1, in a given funding period. Thus, the outcome of the model enables the maintenance managers in highway agencies to develop alternative network-level pavement maintenance strategies through an automated process.

![Figure 1: Relationship between Pavement Condition States & Highway Maintenance Activities (de la Garza and Krueger 2007)](image-url)
Research Title: An Investigation into Short Range RFID Tag Qualifications for Highway Asset Management

Performed By: Cecilia Arrington

Summary:

Virginia Tech has conducted broad research on short range and long range RFID technology. This research was an initial step to evaluate and determine the potential uses of RFID technology for interstate asset management in the field and how RFID technology could be employed to enhance the applications of stored data (Fedrowitz 2007). This current project will select short range RFID technology and present to VDOT a more in-depth understanding of the advantages and disadvantages for highway asset management. A series of experiments will be conducted over the next six months at the SMART Road to investigate short range RFID technology. Experiments include, but not limited to: tag attachment, weathering effects, and security protection methods as shown in Figure 2.

Prior research has concluded that the metal mile markers negatively affect the reading capabilities of the RFID tag. Therefore I will determine the best method of attaching the tag for the best long-term usage. To fundamentally keep the data in the field, it is important to test the tags for sustainability during the changing Virginian weather conditions. The tags will be monitored regular for any deterioration or defects. Most importantly, protecting the data and instruments from any unofficial access is essential for current security measures. External and internal protection methods will be tested to ensure all tags and data are safe in the field.

Figure 2: The Issues to consider for Short Range RFID Tags
Research Title: Adopting a Multiple Item Scale for Measuring Highway Maintenance Perceived Service Quality

Performed By: Adrian Burde

Summary:

The concept of involving the public in the development of transportation solutions was built in the Federal-Aid Highway Act of 1956, the legislation that authorized the construction of the Interstate Highway System. Better plans, transparent process, and public support are some of the benefits that road managers can obtain by educating and involving the general public. During the last two decades the volume of research performed related to the topic of customer-driven highway maintenance suggests an increasing level of interest in the field.

Most research concentrates on gathering information from road users to assess the performance level of highways. However, road users’ opinion can also be collected for measuring the quality of the service delivered by maintenance units. Product and service delivery performance are important measures for determining the overall performance of highway maintenance programs.

The main objective of the present study is to examine the relationship between road users' overall perception of the quality of highway maintenance services and the variables that define the highway maintenance service quality domain - reliability, assurance and tangibles - in order to support a reliable scale for measuring the perceived quality of highway maintenance services.

Next paragraphs briefly describe the key elements of the study:

- **Population of the Study**: The population of the study consisted of adult users of state maintained roads living in Montgomery County, Giles County, and Pulaski County. All these three counties are within the jurisdiction of VDOT Christiansburg residency.

- **Sample Size**: The sample size was calculated for the study as 120 responses. The sample size was dominated by the factor structure analysis. Other analyses taken into account for determining the sample size were: pair-wise correlation and multiple regression analyses. The sample frame contained 750 participants. The response rate was 45.8%, representing 343 completed surveys.

- **Measures for Service Quality**: The variables for measuring the perceived quality of highway maintenance service delivery have been adopted from the SERVQUAL multiple-item scale extensively used in the private sector for measuring service quality.

- **Survey Administration**: The questionnaire (shown in Figure 3 below) was mailed to each participant twice. In the first mail-out, a set of instructions accompanied the survey. In the second mail-out, a reminder note was attached to the questionnaire (see copy of the questionnaire on third page).

- **Data analysis**: The first two analyses on psychometric properties are pair-wise correlation and factor structure analysis. This analysis is followed by a verification of the internal consistency of variable items. The last analysis consists of a multiple regression analysis which is performed to determine the predictive power of the measurement.
### Figure 3: Questionnaire for Measuring Highway Maintenance Perceived Service Quality

**INSTRUCTIONS:** Based on your cumulative experience as a road user, please compare VDOT's actual performance with your expected level of performance for each of the activities listed below. If you feel that VDOT's performance is lower than expected, you would select 1 or 2. If you feel that VDOT's performance is as expected, you would select 3. If you feel that VDOT's performance is higher than expected, you would select 4 or 5.

Please, consider only state-maintained roads in Montgomery, Giles, and Pulaski counties. Examples of these roads are I-81 (Interstate), Route 8 (Primary), and Route 665, Prices Fork Rd (Secondary).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Much Lower</th>
<th>Same</th>
<th>Much Higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alerting road users when approached maintenance areas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employees wearing proper attire (e.g. hardhat, reflective vest, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating heavy equipment without frightening road users</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using clear indicators of maintenance activities (e.g. cones, barriers, signs, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guiding road users through well-defined maintenance areas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimizing travel delay through maintenance areas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making road users feel safe while driving through maintenance areas</td>
<td></td>
<td></td>
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<tr>
<td>Performing maintenance work when it appears to be needed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using equipment that looks well-maintained and in good working condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completing maintenance work within a reasonable time duration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performing maintenance during low traffic time periods</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keeping road users informed about the location and duration of maintenance work</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**How to mark your answer**

- 1 = Much lower
- 2 = Same
- 3 = Higher

**Please, return this survey to:**

Virginia Tech
Adrian Burde
200 Patton Hall (0105)
Blacksburg, VA 24061
(See enclosed stamped envelope)

**INSTRUCTIONS:** In the table on the right please select the options that best represent you in age, gender, and primary trip type, or most common reason for using the road network.

<table>
<thead>
<tr>
<th>Age</th>
<th>18 to 34</th>
<th>35 to 54</th>
<th>55 and over</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>Primary Trip Type</td>
<td>Commuting for/ to work/school</td>
<td>For Business</td>
<td>Shopping/Entertainment</td>
</tr>
</tbody>
</table>

**INSTRUCTIONS:** Based on your cumulative experience as a road user, please indicate your overall perception of the quality of the highway maintenance service delivered by VDOT in Montgomery, Giles, and Pulaski counties.

Please, consider all the highway maintenance service activities listed on the table as you answer this overall question.

**MY OVERALL PERCEPTION of the QUALITY of the HIGHWAY MAINTENANCE SERVICE is:**

- Poor
- Adequate
- Excellent

**ISN: 540001**

Department of Civil and Environmental Engineering
200 Patton Hall (0105)
Blacksburg, VA 24061
Research Title: Development of a Comprehensive Framework for the Efficiency Measurement of Road Maintenance Strategies using Data Envelopment Analysis

Performed By: Mehmet Egemen Ozbek

Summary:
Within the last two decades, the road maintenance concept has been gaining tremendous attention. This has brought about new institutional changes, predominant of which is the challenge for maintenance managers to achieve maximum performance from the existing road system. Such challenge makes it imperative to implement comprehensive systems that measure road maintenance performance. However, as pointed out by the Transportation Research Board (TRB) in 2006, even though the road maintenance performance measurement systems developed and implemented by the state departments of transportation (DOTs) elaborate on the level-of-service (i.e., effectiveness of the road maintenance), the fundamental relationships between the maintenance level-of-service and the budget requirements (i.e., efficiency of road maintenance) need more investigation (TRB 2006). This is mainly because not knowing how “efficient” state DOTs are in being “effective” can lead to excessive and unrealistic maintenance budget expectations.

To address the need mentioned above, this research aims to develop and implement a comprehensive framework that can measure the overall efficiency of road maintenance operations and that can also consider the effects of environmental and operational factors (both of which are beyond the control of the decision-maker, i.e., the maintenance manager) on such overall efficiency. This efficiency measurement framework, when implemented, will be able to identify: (i) the relative efficiency of different units in performing road maintenance services, (ii) the benchmarks (peers) and targets that pertain to the inefficient units (in an effort to inform the decision-makers within such units of possible efficiency improvements than can be secured in the future), and (iii) the effects of the environmental and operational factors on the road maintenance efficiency of units.

It is challenging to measure the overall efficiency of a process when such process is a multiple input-multiple output process and when such process is affected by multiple factors like the road maintenance process. To address this challenge, an innovative approach to efficiency measurement, Data Envelopment Analysis (DEA), is used in this research. The main idea of DEA is to construct a frontier of efficient decision making units (DMUs) representing the best practices. DMUs located on such frontier (i.e., efficient frontier) act as the benchmarks (peers) for the inefficient DMUs in the data set. The challenge is to find the position of the efficient frontier and then compute the distance from it to each inefficient DMU to identify the efficiency score of such DMU. The efficiency score is constrained to the interval of 0%-100% (de la Garza et al. 2005). Figure 4 presents the application of DEA for a process with two inputs and a single output. The DMUs, shown in dots, are plotted on an x-y plane by using the values for their inputs (x₁ and x₂) and output (y). Then, the efficient frontier, containing the DMUs with 100% efficiency score (relative to the other DMUs in the data set), is drawn by identifying the efficient pairs. Efficient pairs are identified by picking adjacent pairs of DMUs and connecting them with a line segment. If the line segment has a non-positive slope and none of the other DMUs lies between such line segment and the origin, then chosen DMUs are stated to be efficient and otherwise they are stated to be inefficient (Triantis 2005). Hence, according to Figure 4, DMUs represented by “E”, “D”, “C”, and “F” have an efficiency score of 100% and DMUs represented by “A” and “B” have efficiency scores that are between 0% and 100%. The efficiency score for
any inefficient DMU can be calculated by measuring its relative distance from the efficient frontier. For example, efficiency score of DMU B can be identified to be 63% by computing the ratio of $|OB'|$ to $|OB|$ as shown in Figure 4. As can be understood, DEA is a relative efficiency calculation technique as efficient frontier is not absolute but determined by the data set under investigation.

![Figure 4: DEA Model for a Process with Two Inputs and a Single Output](Adopted from Cooper et al. (Cooper et al. 1999, p.28))

The findings of the research outlined herein will contribute new knowledge to the asset management and performance measurement fields in the road maintenance domain by providing a framework that is able to differentiate effective and efficient maintenance strategies from effective and inefficient ones; as such, the impact of such framework will be broad, significant, and relevant to all transportation agencies.
**Research Title:** Furthered Implementation of Long-Range RFID Technology in Highway Asset Management

**Performed By:** Noah Yates

**Summary:**

The condition of the transportation infrastructure in the state of Virginia, as well as every other state in the United States, is constantly breaking down into a hazardous condition that poses more and more threats to the safety of the public as the condition worsens. The condition of a highway is not limited to the surface only, other assets that have to be maintained deal with drainage systems, bridges, signage, vegetation, and numerous others. In an effort to bring highway infrastructure to desired level of performance, the Virginia Department of Transportation (VDOT) monitors the maintenance contractors, and has retained the objectivity of Virginia Tech to assess the maintenance progress and efficiency with management of a database for the condition assessment data. While this information is very useful to VDOT, it is not located on-site where the inspections are performed; this situation limits the usefulness of the collected data from improving overall efficiency during inspection performance. To advance VDOT’s highway maintenance programs, Radio Frequency Identification (RFID) technology has previously been researched at Virginia Tech by Fedrowitz (Fedrowitz 2007). The use of RFID technology is being used by many industries for various purposes, such as monitoring inventory using the RFID tags to store and retrieve data. Two RFID systems, long-range and short-range, were found that showed potential usage and a pilot study was performed to show the basic performance of each system in similar inspection scenarios. Long-range RFID systems use tags that have identification numbers that can be read from a distance, while short-range RFID systems use tags that can hold information but can only be read from very short distances. This research will focus on the long-range RFID system (shown below in Figure 5) in order to expand in more detail upon implementation into highway asset management and maintenance. Objectives include establishing an interface with the information database, evaluating performance and durability of the long-range RFID tags in real-time scenarios, evaluating implementation of wireless technology and the short-range RFID system with the long-range RFID system, and performing a total cost analysis as part of a comprehensive report for VDOT.
Figure 5: Long-range RFID System
Research Title: Development of a Statistical Test for Random condition Assessment Quality Control

Performed By: Abdel-Salam G. Abdel-Salam (with the Department of Statistics at Virginia Tech)

Summary:

The Virginia Department of Transportation (VDOT) performs a random condition assessment (RCA) of the Virginia road network every two years. The purpose of the assessment is to establish a statewide inventory and condition of the network from a sampled population. The data collected by the RCA program is complemented with data from several other different sources within VDOT to develop the statewide annual maintenance budget. The indicator selected in the RCA program to report data reliability was the level of agreement between two independent raters, QA/QC field inspectors and regular surveying crews. I am trying to develop a statistical test. The statistical test is for determining the level of agreement between the raters.

The level of agreement between the surveying crew and the field inspector is determined from a sample agreement proportion (SAP), $\hat{\pi}$, and a percentage threshold, $\pi_0$. The SAP is calculated using Equation 1, where $y$ denotes the number of agreements within $n$ observations.

$$\text{SAP} = \frac{y}{n}$$

(Eq. 1)

The statistical test ($z = \frac{\hat{\pi} - \pi_0}{\sigma_{\hat{\pi}}}$) looks for sufficient statistical evidence to support the test hypothesis, $H_a$, and thereby reject the null hypothesis, $H_0$. The null hypothesis proposes that the SAP is less than or equal to the percentage threshold. Conversely, the test hypothesis proposes that the percentage of agreement is greater than the percentage threshold. If the null hypothesis is rejected then the statistical test concludes that the two raters are in a high level of agreement.

The second method is as follows: A given SAP that is greater than the LCL value implies that the data collected by the surveying crew is reliable.

$$\text{SAP} > \text{LCL} \Rightarrow \text{Data Reliable}$$

The LCL value can be considered as a threshold value and used for determining data reliability because all the data set SAP values that have been accepted during the 2006 RCA program as proof of data reliability.
References


