ASSET MANAGEMENT OF INTELLIGENT TRANSPORTATION SYSTEMS:
METHODOLOGY FOR SELECTING THE OPTIMAL PLATFORM FOR YOUR AGENCY

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ABSTRACT:

Intelligent Transportation System (ITS) enhances the performance of modern transportation systems by improving its efficiency, safety, and security. Because of these benefits, state departments of transportation and other transportation agencies have been increasingly deploying these tools since the mid 1990’s. Because ITS often includes technologically sophisticated devices, computer hardware and software, and communications infrastructure; traditional asset management tools are not always appropriate. Recently, many public agencies have expressed a need to manage their ITS systems more efficiently, yet ITS asset management is new to many. Thus, there is a need to evaluate different asset management systems for their potential efficacy for supporting transportation agency’s ITS needs. Establishing a method and identifying measures of effectiveness to evaluate such systems is the primary contribution of this paper. The method and requirements presented were identified through a nationwide survey of public transportation agencies and demonstrated through a case study in South Carolina.
INTRODUCTION

Intelligent Transportation System (ITS) enhances the performance of modern transportation systems through improved reliability in travel times, improved safety, and reduced environmental impacts (1). ITS consists of field devices, including telecommunication and information systems, and various subsystems. These subsystems consist of large complex cable networks, electronics and communication devices, wireless networks, radar, cameras (close circuit television known as CCTV) and other field devices. Because system upgrades and expansion is an inevitability of such systems, large regional ITS infrastructure systems require the proper management and integration among the subsystems, to maintain effective and efficient performance. Otherwise, the quality of the ITS system might be substantially degraded, requiring more time to troubleshoot the system, increasing the frequency of interruptions and raising operating costs. ITS asset management can help system managers and operations engineers at state departments of transportation (DOTs) and other transportation agencies to expand and rearrange their ITS system’s while maintaining performance at desired levels, all while minimizing operational costs.

Indeed the continued expansion of ITS infrastructure has brought to light the need to manage these assets. ITS asset management differs from traditional asset management applications in its features and characteristics, specifically with the inclusion of electronic devices and communication systems. Traditional transportation asset management includes assets such as highways, pavements, bridges, etc and these systems are not capable of managing the diverse and technologically-focused assets that support most ITS systems; therefore, there is a need for a customized asset management system that can serve ITS operations and maintenance and can be integrated with other asset management systems (2), particularly those currently used for road and bridge assets. Many transportation agencies have been proactive in identifying or adopting an effective asset management system that will accommodate existing infrastructure and manage their planned ITS infrastructure expansion.

Currently, three categories of asset management tools are available to agencies operating ITS systems. These include 1) ITS customized systems, 2) enterprise-based GIS systems, and 3) typical database management software. ITS customized systems are typically those systems that are specially designed to address ITS components where as enterprise-based GIS systems are basic GIS systems with enterprise capability. GIS-based system can be modified according to need to address ITS components and integrate with other transportation assets such pavements and bridge structures. Typical database system such as Microsoft access, excel etc. have been traditionally used to keep record of these assets. Further, within each category, there are multiple software and service vendors that offer such products. To assist state DOTs and other transportation agencies with their selection of appropriate ITS asset management tools, the authors present a method for evaluating these categories of tools to identify the most appropriate tool for a particular transportation agency.

Important characteristics of ITS asset management systems include visualization capability, data management ability, user interface quality, remote access ability, enterprise capability, and training required. The following paragraphs will describe the importance of each of these characteristics.

The ability to display assets graphically, also known as visualization, is one of the most important factors for ITS asset management. It plays an important role in decision making through visual observation and interpretation of a scenario, particularly for those more familiar with asset management of more traditional and visible infrastructure. The visualization
capability could include map viewing, visual representation of spatial queries, visualization of fiber optic cable locations and connectivity, customization for enhanced ITS visualization, and wireless network visualization. An example is shown in Figure 1.

![Figure 1 Example of ITS Asset Visualization (3)](image)

Data management is also an important issue to ITS asset management, particularly the ability to allow a single administrator control. The capability of having a single administrator who validates all the field updates before they become final might also be important if there is a concern that database changes from field users or technicians might not be always correct. Therefore, an administrator is responsible for validating the updates before they become permanent. Additionally, researchers evaluated the need of transportation agencies to recover and retrieve data to protect against system failures of the data storage components.

It is important for the user interface of an asset management system to be easy to use. This ease of use of the software, or user-friendliness, can be measured as how efficiently users could manage ITS assets assuming proficiency with the asset management tool. Because customization is also important to manage the diverse ITS systems deployed throughout the United States and the world, customization was also considered in user-friendliness. In particular, user friendliness is important when importing data files from other software in different formats such as shape files and/or as-built drawings from AutoCAD/Micro Station, without having to reformat the database. Each system should be judged based on their capability to import and support different types of files that are common to transportation engineering and information technology.

The ability for remote or web-based access is critical due to the amount of field reporting that must be entered into any asset management system. A web-based asset management system will be most effective, as it will allow instantaneous access to the database. It will also allow immediate updates of the database and reduce the need for redundant paperwork. ITS facilities require an asset management system which will compile information regarding the entire network’s assets. This compiling will help in managing the assets, maintaining and operating the system, and will support decision making about expansion and rearrangement.
Another possible requirement for the asset management tool is its capability for deployment in the enterprise-wide environment. Enterprise capability is the capability of a system to support multiple users at the same time and allow simultaneous access to the database that is saved in a central location. Most agencies need this flexibility for their system as they often need concurrent access to the same database for planning and decision making purposes. Lastly, because software training can be time-consuming and costly to agencies, the amount of training required is also a significant factor. Careful consideration should be given to required amount of training for database and field personnel, when selecting the appropriate ITS asset management tool for any agency.

There is no doubt that an asset management system is an obvious requirement for expanding ITS systems. The support of an expanding and changing ITS infrastructure requires the selection of an appropriate asset management system that satisfies users’ requirements, however; it is unclear how transportation agencies value these different user requirements. An evaluation of available ITS asset management systems would facilitate the adoption of appropriate tools by public agencies.

The focus of this paper is to present requirements valuable in evaluating an ITS asset management system and a method of evaluating which type of asset management tool is most appropriate. This paper presents a survey of DOTs in the US, identifying those requirements and their relative importance. The authors then illustrate the entire method with a case study for the South Carolina Department of Transportation.

RELATED WORK
Asset management for ITS is still a new concept in the transportation industry. Within a short time ITS has played a significant role in the improvement of the overall performance of transportation operations with higher efficiency and safety. Due to the dynamic nature of ITS and the variety of system components, asset management for ITS is gaining importance and attention from public agencies. Despite this fact, few studies have been conducted addressing ITS asset management systems.

Most notably, the Florida Department of Transportation (FDOT), evaluated three ITS customized systems supporting asset management for ITS including OSPInSight (4), FiberTrak (5) and Fiber management tool for ITS (FMT-ITS). Subsequently, FMT-ITS was renamed as NexusWorx (6). The study determined that the NexusWorx fiber management tool for intelligent transportation systems (FMT-ITS) would best serve their need for managing the ITS features for FDOT. NexusWorx software was first introduced as a geospatial solution for the telecommunications and utility industries, and was later customized for the ITS asset management. This software was found to have more capabilities than the other two applications to support ITS asset management (7).

Although an ITS customized asset management system was most appropriate for FDOT, there is a need to evaluate NexusWorx as a representative of customized ITS asset management systems for its suitability in the enterprise-based environment in contrast to enterprise-based GIS systems and general data management systems such as Microsoft Access. Enterprise-based GIS with some plug-ins to support ITS asset management could be a viable alternative to customized ITS asset management systems as most agencies already have deployed enterprise-based GIS tools for managing other infrastructure assets. Microsoft Access, or similar, could serve as a data management system when only data inventory is of sole interest. Although other research has
compared types of asset management software (8), their emphasis was on municipal infrastructure and not specifically on either transportation or ITS.

Other work has focused on asset management of traffic operations systems such as traffic signals, finding “the importance of taking a broader view of asset management techniques to reflect electronic system components rather than physical infrastructure elements such as those constituting pavements and bridges (9).” This study concluded that agencies will need to combine their knowledge to identify best courses for managing such transportation assets.

The transportation system is complex and has various functional divisions to fulfill the need for travel. As the system continues to grow, the components became so numerous that an appropriate management system becomes essential. The system requires very different divisions between the various assets because they all need different approaches for management. Over time, asset management systems have developed for each type of asset, including pavements, bridges and roads. Many methodologies have evolved for proper management of these various assets as well as the integration between management systems; however, ITS is unique due to its variety of components and technology-focus, which makes asset management for ITS even more critical. Also, with a number categories of ITS asset management systems available, it is difficult to select the right one and the decision making becomes even more challenging with non-quantifiable requirements. Multi-criteria decision analysis has the potential to identify more appropriate tools by providing the flexibility to consider quantifiable as well as non-quantifiable requirements.

METHOD OF EVALUATING ITS ASSET MANAGEMENT SYSTEMS

The requirements for an ITS asset management system were identified from a thorough review of previous work including: AASHTO 20011 (10), Gao and Zhang 2008 (11), FDOT 2006 (7), Hall et al. 2005 (12), Larson et al. 2000 (13), Small 2000 (2), and Gharaibeh et al. 1999 (14). After the project team reviewed the available literature and developed the foundation of approaching ITS asset management requirements, officials from the South Carolina Department of Transportation (SCDOT) were interviewed including traffic engineers and management center operators. These engineers and operators also provided the research team with thorough review of the ITS assets that could be managed and what assets could include in the future. This information led the research team to select measures of effectiveness (MOEs) for evaluating ITS asset management systems and classify them into two categories. FIGURE 2 shows these categories and how each category was broken down based on information from the literature and interviews.
Researchers created, conducted, and received responses from a nationwide survey from Virginia, Tennessee, Minnesota, North Carolina, South Carolina, and Wisconsin DOTs. These surveys asked DOTs to rate the importance of these MOEs, as defined in the introduction section, on a scale from one to ten, where ten was the most important.

Based on the survey responses, the researchers computed utilities for each MOE for two different scenarios. In one scenario, only system capabilities of selected ITS asset management system were included, neglecting asset management system cost. The researchers also evaluated a second scenario where the cost of the license, operation and maintenance of selected ITS asset management systems was included. The utility related to these factors were also calibrated so they too, added to one. Note that these utilities can be used for multiple forms of optimization analyses and the values represent how important each characteristic was to survey respondents, where a higher value indicated more importance.

Although the identified utilities can be used to evaluate ITS asset management systems using different optimization methods, the researchers chose a multi-attribute utility analysis for the case study. To apply this method, the research team conducted interviews with experts in and users of asset management systems, intelligent transportation systems and geographical information systems. These experts were selected from South Carolina DOT and Clemson University. The evaluation team reviewed the capabilities of an example ITS customized system (NexusWorx (6)), an enterprise-based GIS system, and a typical database management software.

For each MOE, team members were asked to rate each system either zero (does not have the capability), one (has the capability but not very good), two, (satisfactory), three (good), four (very good), or five (excellent capabilities).
Because the cost of the systems did not directly lend themselves for inclusion into a multi-attribute utility analysis, the research team took a linear approach to assigning ranking numbers. TABLE 1 shows the annual costs of ITS asset management systems in 2009 US dollars, including licensing, fees, maintenance, and 20 users for five years. Although these rankings were specific to the case study conducted in South Carolina, similar ranges are likely appropriate for other states in the US.

<table>
<thead>
<tr>
<th>Cost (2009 US $)</th>
<th>Relative Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10,000</td>
<td>5</td>
</tr>
<tr>
<td>10,000-29,999</td>
<td>4</td>
</tr>
<tr>
<td>30,000-49,999</td>
<td>3</td>
</tr>
<tr>
<td>50,000-69,999</td>
<td>2</td>
</tr>
<tr>
<td>&gt;70,000</td>
<td>1</td>
</tr>
</tbody>
</table>

After the data was collected from the evaluation team, utilities were calculated using equation one (without considering costs) and equation two (including costs).

\[
MUA_a = U_1 a PR_1 + U_2 a PR_2 + U_3 a PR_3 + U_4 a PR_4 + U_5 a PR_5 + U_6 a PR_6 + U_7 a PR_7 + U_8 a PR_8 + U_9 a PR_9 + U_{10 a} PR_{10} + U_{11 a} PR_{11} + U_{12 a} PR_{12} + U_{13 a} PR_{13} + U_{14 a} PR_{14}
\]  

EQUATION 1

\[
MUA_b = U_1 b PR_1 + U_2 b PR_2 + U_3 b PR_3 + U_4 b PR_4 + U_5 b PR_5 + U_6 b PR_6 + U_7 b PR_7 + U_8 b PR_8 + U_9 b PR_9 + U_{10 b} PR_{10} + U_{11 b} PR_{11} + U_{12 b} PR_{12} + U_{13 b} PR_{13} + U_{14 b} PR_{14} + U_{15 b} PR_{15} + U_{16 b} PR_{16} + U_{17 b} PR_{17}
\]  

EQUATION 2

The following defines the variables in equations one and two.

- \( PR_1 \) = Performance Rating of Visualization Quality of Map Viewing Capability
- \( PR_2 \) = Performance Rating of Visualization Quality of Spatial Query
- \( PR_3 \) = Performance Rating of Visualization Quality of fiber trace and connectivity of the fibers
- \( PR_4 \) = Performance Rating of Visualization Quality of Customized ITS Symbology Quality for Enhanced Visualization
- \( PR_5 \) = Performance Rating of Visualization Quality of Wireless Network Depiction
- \( PR_6 \) = Performance Rating of the Quality of Data Recovery and Retrieval System
- \( PR_7 \) = Performance Rating of the Quality of Single Administrator Control
- \( PR_8 \) = Performance Rating of the Quality of Ease of Use of the Software
- \( PR_9 \) = Performance Rating of the Quality of Customized Import Functionality (straight out of the box)
- \( PR_{10} \) = Performance Rating of the Quality of Customized Import Functionality (supporting user specific customization)
- \( PR_{11} \) = Performance Rating of the Capability to Support the Web Based Application
- \( PR_{12} \) = Performance Rating of the Capability to Support Field Updates/Usage
Based on the utilities generated, where a higher utility indicates a more-preferable alternative, information can be drawn to support decision makers in their selection to manage ITS assets within a state or agency.

FINDINGS AND DISCUSSION:
This section presents the findings from the nation-wide survey, suggesting utilities that can be used when evaluating asset management systems for US transportation agencies. Next, the authors detail the ratings of experts at the evaluation workshop and present the findings of the South Carolina case study.

Findings from the survey indicate that cost is a significant factor when considering the optimum tool for ITS asset management. The ability for users to customize such software tools and the ability to visualize wireless networks were rated the lowest value to transportation agencies. The utilities for scenario a, where no cost was considered, and scenario b, including cost, is presented in TABLE 2.
The authors conducted a least squared difference analyses to identify if survey respondents perceived any MOEs significantly more important than the rest. Although the results did not show any significant difference between the utility ratings of the different MOEs, an inspection of the residuals validated the data set by demonstrating no significant systematic errors were present as shown in FIGURE 3.
Data from the evaluation workshop provided strong evidence that standard database software does not have the capabilities required to manage the assets included in South Carolina ITS systems. The relative ratings suggested that ITS customized systems and enterprise-based GIS systems were similar in their performance, as shown in TABLE 3.
TABLE 3: Relative Ratings for User Friendliness and ITS Suitability

<table>
<thead>
<tr>
<th>MOE</th>
<th>Relative Rating</th>
<th></th>
<th>ITSCustomized System</th>
<th>Enterprise-based GIS System</th>
<th>Standard Database System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visualization</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Map Viewing Capability</td>
<td>3</td>
<td>5</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Spatial Query</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Fiber Trace and Connectivity of the Fibers</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customized ITS Symbology</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wireless Network Visualization</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data Management and Applicability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Recovery and Retrieve</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Administrator Control</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>User Symbology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of Use of the Software</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customized Import Functionality&lt;sup&gt;1&lt;/sup&gt;</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customized Import Functionality&lt;sup&gt;2&lt;/sup&gt;</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Remote Access</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Web Based</td>
<td>5</td>
<td>3</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Field Updating/Usage</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Restricted Data Access Capability</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Enterprise Capability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple User Supporting Capability</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>(Straight out of the box)

<sup>2</sup>(Supporting user specific customization)

Due to the unique nature of the cost element, the ratings of these MOEs are shown separately. The primary difference was that ITS customized systems could be either hosted by the vendor or set up on a transportation agency’s computer servers. On the contrary, an enterprise-based GIS system would normally be installed on an agency’s computers/servers, but could either be installed new or added onto an existing enterprise-based asset management system. These findings are presented in TABLE 4.
TABLE 4 Relative Rating for Costs of Alternative Software

<table>
<thead>
<tr>
<th>Relative Rating</th>
<th>ITS Customized System</th>
<th>Enterprise-based GIS</th>
<th>Microsoft Access</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Vendor Hosting)</td>
<td>(Client Server Setup)</td>
<td>(New Setup)</td>
</tr>
<tr>
<td>Personnel</td>
<td>5</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>Software Licensing</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Combining the performance ratings and the utilities via equations one and two provides information that can support the selection of a particular type (not brand) of asset management system. The utility ratings found are displayed in FIGURE 2, where a higher rating indicates a better choice. When neglecting cost, enterprise-based GIS was a better option; however, when considering cost, ITS customized system was slightly preferable.

FIGURE 4 Summary of Multi-Attribute Utility Analysis Findings
When selecting an alternative between such similar choices, consideration of existing asset management tools and practices in the transportation agency. For example, does an agency already use enterprise-based GIS to manage pavements, bridges, or other assets. Although there is no significant cost saving towards adding onto an existing asset management system, employee training can be considerably reduced.

CONCLUSIONS AND RECOMMENDATIONS

The researchers conducted a study wherein they developed a method for transportation agencies to evaluate asset management systems for intelligent transportation systems assets. Results from a nationwide survey of transportation agencies guided researchers to develop utilities that represent the importance of primary measures of effectiveness for ITS asset management tools. These ratings can be used by any transportation agency with a variety of optimization methods for selecting appropriate ITS asset management tools for their specific agency.

To demonstrate the use of these utilities, the authors presented a case study evaluating three asset management platforms for the South Carolina Department of Transportation. The findings indicated that standard database software lack the capabilities to manage standard ITS assets. In addition, enterprise-based and ITS customized platforms were found to be similarly capable. The study results suggested that if an agency already operated enterprise-based GIS to manage other assets, the best option would be to extend its use for ITS applications rather than implementing new software; however, because this transition may take time, ITS customized platforms may be a feasible option if a transportation agency would like to implement a system in the short term. Future work might investigate the return on investment for employing ITS asset management systems and report best practices during implementation of such tools.

ACKNOWLEDGEMENTS:

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