DEVELOPMENT OF THE ROAD CONSTRUCTION DATABASE (RECORD) SYSTEM

by

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(Under the direction of Dr. Stephan A. Durham)

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1.0 INTRODUCTION

1.1 Overview

In order for humanity to continue to advance as a society, people must learn from past successes and failures. This not only includes their own successes and failures, but those of others around them. Methodology or approach patterns will yield successes and failures. To take advantage of this information, people must be afforded the opportunity to learn this information and integrate in such a way that aids in the decision making process. Optimization of this process should include an organized system that teaches lessons assembled from a variety of sources given that the content is still applicable to the individuals trying to learn it. Learning from the experiences of others forgoes the need to learn everything by trial error, which can be costly. There is no need to reinvent the wheel with each new incoming challenge obstacle.

In a structured setting, this organized system is known as Lessons Learned Information Systems (LLIS) or Lessons Learned Programs (LLP). In the construction industry, there is an arising need for the use of these programs. With substantial growth in the construction sector in recent years, there is an opportunity for valuable information and experiences to be collected from successful and failed projects. LLPs will help to properly capture and record this information. Furthermore, it can more appropriately organize and disseminate the information, known as "lessons", in an efficient manner through the use of an organized database.

The Georgia Department of Transportation (GDOT) requests the development of a construction lessons learned database to store project-related information from its past, current, and future construction projects. GDOT intends to use this construction database to not only document information from its projects, but allow those working in all aspects of a project (concept, preliminary design, final design, programing and scheduling, and construction) to access information that may benefit a specific aspect of the project. The Road ConstRuction Database (ReCORD) system that will be created as a product of this study will benefit GDOT and those working with the agency by providing information that is not only easily accessible, but pertinent and useful. The lessons learned database will benefit and improve the quality current and future projects..

This study includes an extensive literature review examining the use of various LLPs and common practices within the construction industry in order to efficiently design and develop the construction LLPs database. Furthermore, a survey was sent to each state Department of Transportation (DOT) to solicit ideas and feedback from potential users of the system. Additionally, database attributes such as GIS capability allowing for the lessons learned to have a spatial link across the state, photo/video capture and storage, and user communication were explored through this study.

The primary objective of this study was to create a two-way construction database to be used as an LLP and implement within GDOT's standard practice. This study provides recommendations for implementing the LLP as well as training on its long-term use and maintenance. Overall, the potential benefit of implementing an LLP to a large scale organization such as GDOT is very high. In consideration of the number of construction projects GDOT manages, using an LLP to track important and relevant information will greatly increase both time and financial efficiency for future projects. Figure 1, below, depicts the process by which a new lesson is entered into the ReCORD system. It defines the three major phases: submission of the new information, curation and refinement of the information, and finally the publication of the lesson learned.

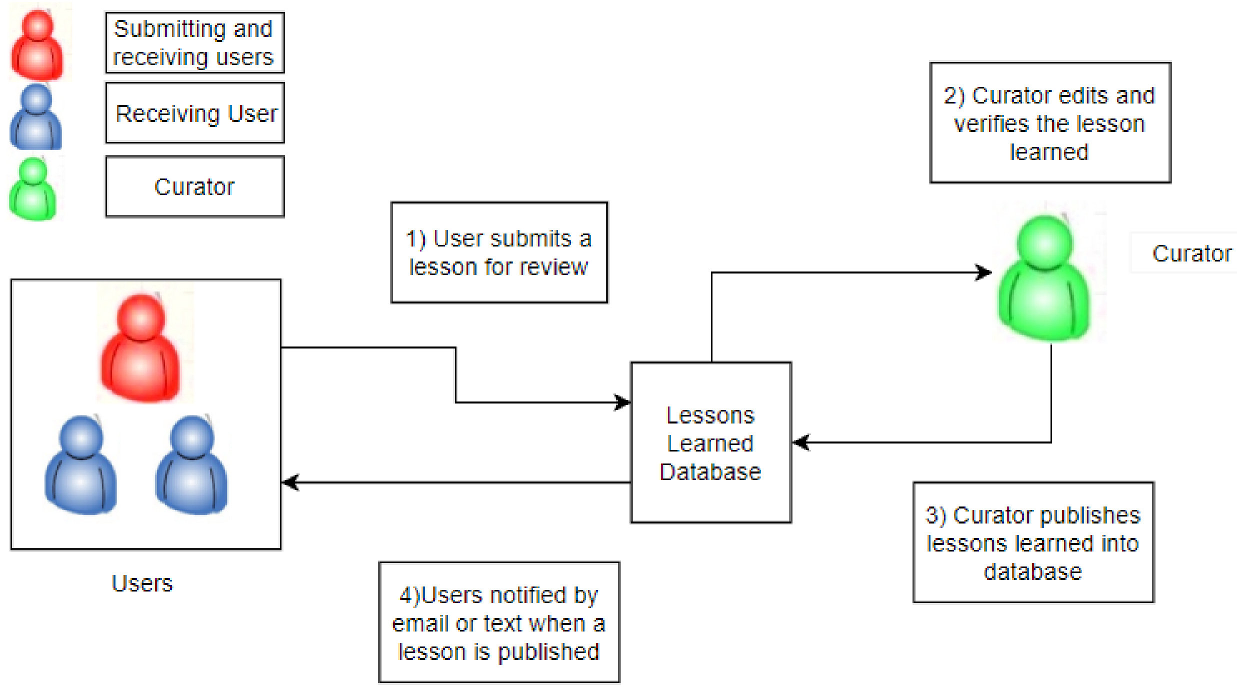


Figure 1 - Diagram for a Notification Based Lessons Learned Program

1.2 Research Scope

A national survey was conducted with responses from state DOTs. Chapter 2 includes the results and analysis of the responses from the survey and how this information is applicable in informing the database creation. A thorough review of previous research related to lessons learned programs including benefits, challenges, and applications are included in Chapter 3. Chapter 4 documents the need for a lessons learned construction database by stating the research study objectives and expectations. The design methodology for creating the lessons learned database is well documented within Chapter 5 of this thesis. This chapter discusses the lessons learned program process and database capabilities. Chapter 6 presents the outcomes of database development by documenting the specific details related to database functionality, structure, operation, and maintenance. Chapter 7 provides findings from the trial implementation of the lessons learned database through the examination of example lessons learned. Conclusions and recommendations are included in Chapter 8.

2.0 BACKGROUND

The following section investigates case studies of other lessons learned reports and construction failures that yielded lessons learns. They aim to provide an idea of what potential lessons learned would include.

2.1 Lessons Learned Case Studies

2.1.1 CDOT's US 36 Express Lanes

Colorado Department of Transportation (CDOT) oversaw the construction of its US 36 Express Lanes project, carried out by Ames Granite Joint Venture. This project was split into two phases, with a budget of $317 million and $180 million, respectively. Phase 1 took three years to complete, and it yielded valuable lessons learned. This phase included an 11 mile stretch of roadway reconstruction.

Phase 1 required the construction of 18 detention ponds and the replacement of 8 irrigation crossings in total. Additionally, the construction site included three different Federal Emergency Management Agency (FEMA) classified floodplains which were critical areas of design and construction.

Temporary drainage became an issue because the contractors did not properly document where the temporary drains were as the project progressed. The drains were either forgotten about or intentionally abandoned after the project was completed and permanent drains were installed. The contractor was installing the drains, using them temporarily, and then abandoning them when they were no longer needed. This lesson learned prompted a change in the outset of the project, within the Request for Proposal (RFP). New requirements added to the future RFP's required contractors to document the location of all temporary drains and include the location within the as-built plans. Additionally, it also required the contractor to properly dispose of the temporary drains at the project closing.

The RFP did not include a strict schedule or specific plan for temporary drainage plans. The lack of direction in the matter yielded issues that brought forth new lessons learned. In the future, the temporary drainage plans are to be tied in with the Maintenance of Traffic (MOT) plans to provide a clear strategy for temporary drainage until the permanent drainage is operational. Additionally, the construction of temporary drains needed to the scheduled throughout the life of the project to avoid last minute construction on all drains (CDOT, 2016).

2.1.2 Boston's Big Dig Tunnel Collapse

Boston's Big Dig was a mega-project designed to transform the road transportation system in Boston, MA. The project was spurred by the sheer number of cars that traveled through the Central Artery, a large interstate that ran through the center of downtown Boston, that resulted in significant traffic delays for up to 16 hours each day. The project was completed in 2006 and included a 7.8 mile long road consisting of 8-10 lanes of which half of the roadways traveled through underground tunnels (MassDot).

A construction failure did not occur during construction, but rather after the road was already in use. A large tunnel ceiling panel fell on a car resulting in the death of an individual. After an indepth investigation, the cause of the failure was determined to be result of creep in the epoxy anchor adhesive used to hold the ceiling panel. The weight of the ceiling tiles caused the adhesive to deform resulting in the weakening of the bond strength over time. Inevitably the bolts were unable to hold the weight of the ceiling panel and the bond failed causing the ceiling tile to collapse onto the traffic below. The investigation of the incident concluded that numerous tunnel ceiling panels were on the verge of failing due to the creep in the adhesive. Fortunately, this issue was identified early enough to prevent any further damages or catastrophes. The engineers had failed to account that the polymer adhesive was susceptible to creep and therefore should not have been used for long term loading.

Creep is defined as the deformation of a material under sustained loading. In the case of the Big Dig Project, the self-weight of the ceiling tile was the sustained loading on the epoxy adhesive. Epoxy adhesives are by nature viscoelastic and therefore susceptible to creep. Viscoelastic materials are exhibit properties of a solid in cold temperature and properties of a liquid in warmer temperatures. Naturally, materials that have more liquid-like properties tend to flow and deform more easily. Thus, when the ceiling tile load was applied, deformation of the epoxy graduatlly increaed over time. The deformation continued until inevitable failure. Figures 2 and 3 show the damage caused by the falling ceiling tile.

Figure 2 - Aftermath of Big Dig Collapse (NY Times 2017)

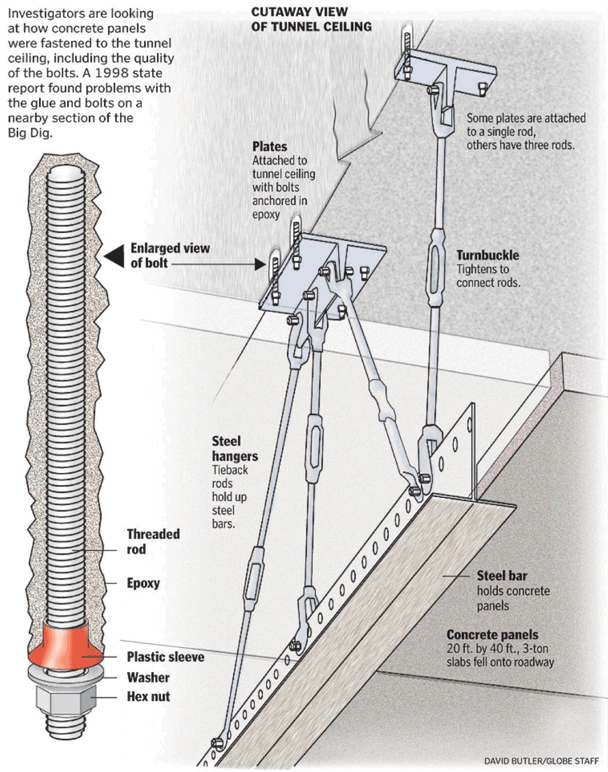


Figure 3 - Schematic of Ceiling Tile (Construction Equiv. to Financial Audit, 2006)

The following lessons learned were concluded:

- The Massachusetts Turnpike Authority should have regularly inspected the tunnel ceiling panels for structural integrity.
- Ultimate load tests should have been performed on the adhesive anchors prior to installation.
- Installing adhesive anchors in an overhead application is problematic. This process makes it likely that voids will enter the bonding area significantly reducing the tensile capacity of the epoxy.
- New materials that are introduced to different applications most likely have properties that are not fully understood or addressed correctly. In this case, it added a new failure mode that resulted in tragedy.

2.2 State DOT Survey

While GDOT has expressed interest in lessons learned in past years, the agency has not implemented a formal program that captures and disseminates lessons learned. In the past, GDOT had used a spreadsheet to track their project successes and failures; however, it was neither widely used nor effective. Upon request, the author could not retrieve the spreadsheet. Therefore, a national survey of state DOTs was conducted to better understand how other agencies use LLPs and their perceptions about the use of LLPs. In addition, the survey respondents' responses were analyzed through a statistical analysis was performed to validate the importance of an LLP among the transportation construction community.

2.2.1 Survey Overview

A questionnaire was developed to investigate how state DOT's nationally view LLPs. Additionally, the survey gathered information on states' LLP systems, if applicable. The survey intended to discover a plethora of valuable information pertaining to data management, the transfer of information, and potential areas for increasing efficiency. Ultimately, information received from the survey can be applied in the creation of the ReCORD system. The survey was designed to be short, simple, and concise in order to keep it user-friendly to maximize the potential number of responses generated. A web-based tool called Qualtrics (https://www.qualtrics.com/) was used to formulate the questionnaire and analyze the responses. The responses to this survey were expected to provide valuable information for use in this study and in developing an effective LLP system for use by GDOT. The respondents of the survey were state DOT employees who are members on the Committee on Construction, through AASHTO. These respondents are expected to be the head of their departments or high-ranking employees within their department at their state DOT.

2.2.2 Survey Findings

Survey responses were received from 27 of the 50 states and the District of Columbia, for a 55% return rate. See Figure 4. In all, a total of 32 responses were received from the survey, with some state DOTs having multiple respondents. Two responses were received from the states of California, Kansas, Ohio, and Vermont.

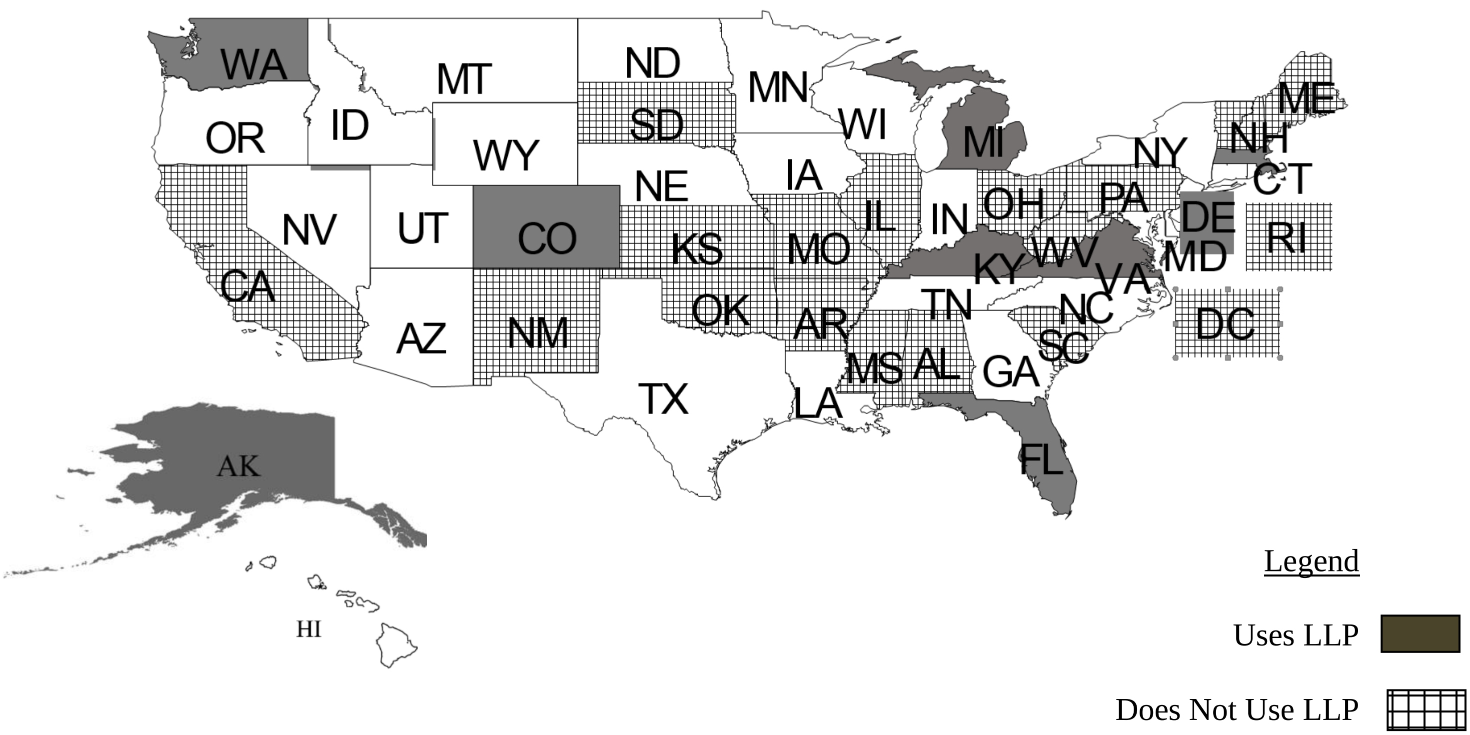


Figure 4 - Dot Respondents Map

The states of South Dakota and Oklahoma did not complete the survey, but responded via email that their DOT did not use an LLP. The Kentucky Transportation Cabinet responded via email that they did use an LLP; however, the database is not accessible by the public.

Question 1 was designed to inquire whether the DOTs responding to the survey utilized a LLP in their construction operations. A total of 9 (32%) states replied that their DOT utilized a LLP. As shown in Figure 4, Alaska, Colorado, Connecticut, Delaware, Florida, Kentucky, Virginia, and Washington were states that have implemented a LLP system. Additional questions were asked of these states (DOTs utilizing a LLP). Questions included:

- How is the LLP managed (excel spreadsheets, software, etc…)? Explain.
- How often and to what degree is the LLP used?
- Is the LLP system freely available both internally and externally within the DOT?

The Michigan Department of Transportation (MDOT) responded that they have meetings with project stakeholders including the designer, construction engineer, prime contractor and any subcontractors. MDOT creates and catalogs meeting minutes within their document storage system ProjectWise. The meetings are required for all projects that have plan sets developed and it is freely accessable to individuals with ProjectWise access. The results of this process allow for designers to provide input and retrieve information from the database. The Virginia Department of Transportation (VDOT) uses a Sharepoint Database with access restricted to only responsible charge engineers. Thus, the VDOT LLP is only an internal process. Florida Department of Transportation's (FDOT) LLP is in the form of Process Reviews as PowerPoint Deliverables. FDOT's LLP process is separated into different specialty areas such as structures, pavement, materials, and geotechnical. FDOT's LLP has been active for two years and available internally via Sharepoint. The Colorado Department of Transportation (CDOT) uses a questionnaire in MS. Word (.doc) but have not been using it regularly. It is available both internally and externally; however, the awareness for the program is substantial. Washington State's Department of

Transportation (WSDOT) LLP is utilized in the form of a FileMaker database. WSDOT state that the use of the database has declined over the past five years. Currently, WSDOT is in the process of revitalizing the database and updating processes. While the database is currently internal only, it was previously available to external users. Alaska's Department of Transportation and Public Facilities uses a Microsoft Access Database that was developed in house. At the end of each construction season a top ten list of lessons learned is generated and presented w/ design squad leaders. In addition, small group meetings are held with the Department of Revenue and design management team. Alaska's LLP process is partially internal and external. The Delaware Department of Transportation (DelDOT) utilize spreadsheets with sporadic usage. Currently, the DelDOT spreadsheets are only available internally. The Massachusetts Department of Transportation (MassDOT) recently initiated a post construction meeting process in order to capture the successes and challenges encountered on projects and to provide feedback on lessons learned that could be used on future projects. A SharePoint site has been developed to track the information developed at the meetings. MassDOT are requiring district offices to select a minimum of 5 projects each year for this process. The SharePoint site is only available internally.

To further understand the accessibility of users to input and retrieve lessons learned, the survey asked respondents additional questions. Specifically, which individuals of their organization are able to input lessons and retrieve information from the database. As Figure 5 illustrates, individuals working as engineers, inspectors, or construction/project managers are most likely to have access to inputting lessons learned in a DOT's database. Though fewer, other responses included maintenance personnel and contractor reps. FDOT stated that their Central Office Specialty Engineers and to an extent district construction engineers have access to input lessons learned. Further, DelDOT stated that the agency's Performance Management Section has complete control over the entries and frequency of reporting. Figure 6 provides the responses to the survey question asking DOT respondents which agency employees are capable of receiving and viewing the lessons learned. The responses to this question are similar to those with access of inputting lessons learned with the respondents stating that engineers, inspectors, and construction managers have the majority of access. FDOT indicated that FHWA and their agency's executive team have access to retrieve lessons learned. Similarl to the previous question, DelDOT indicated their Performance Management Section has the ability to receive and view the lessons learned.

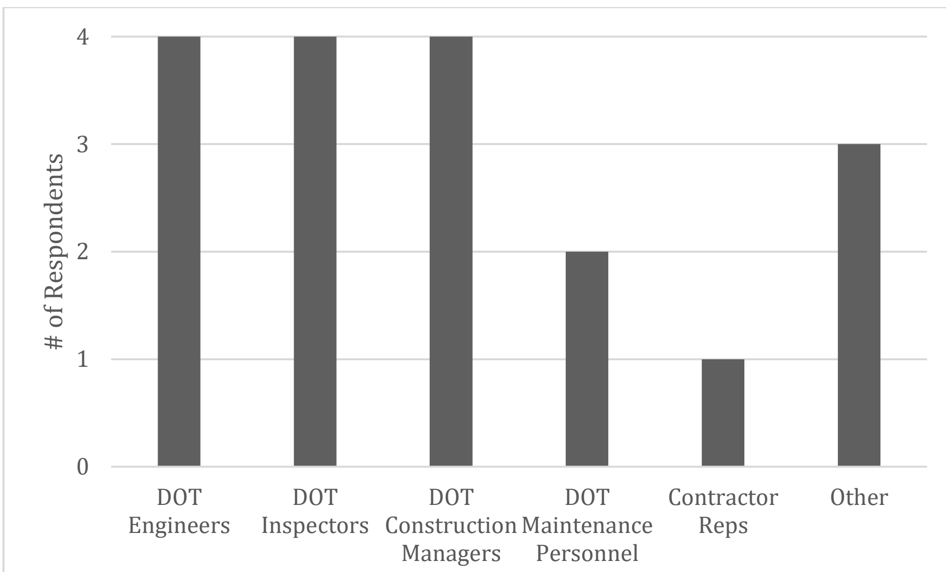


Figure 5 - Individuals with Access to Input Lessons Learned

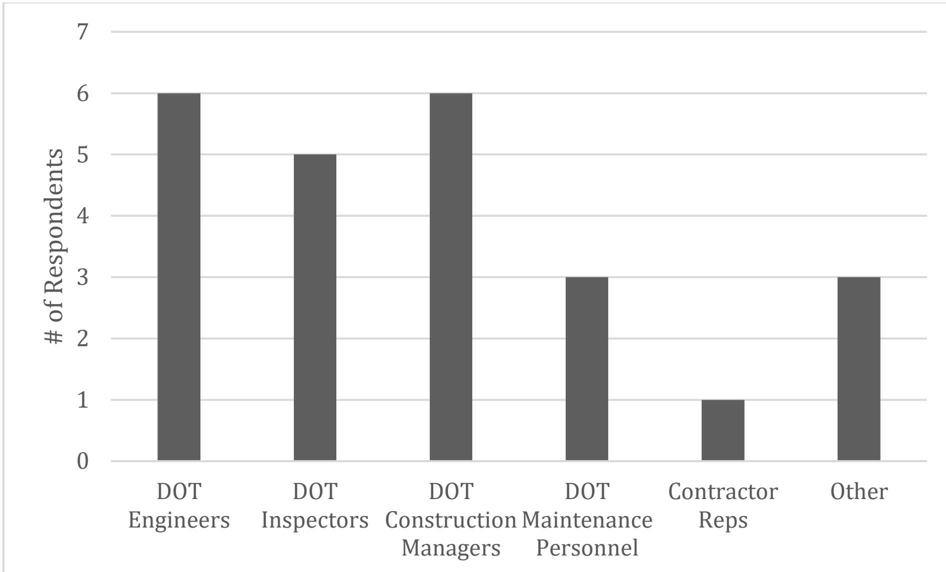


Figure 6 - Individuals with Access to Retrieve Lessons Learned

Questions 2 through 5 of the survey asked respondents to rate their level of agreement on statements related to the effectiveness, benefits, and challenges of utilizing LLPs within DOTs. Survey question 2 asked whether "an LLP is effective in facilitation and improving the construction process." The responses, shown in Figure 7, were overwhelmingly positive with 28 of the 32 (88%) respondents agreeing that an LLP is an effective means to improve the construction process. The balance of respondents indicated that they neither agreed nor disagreed.

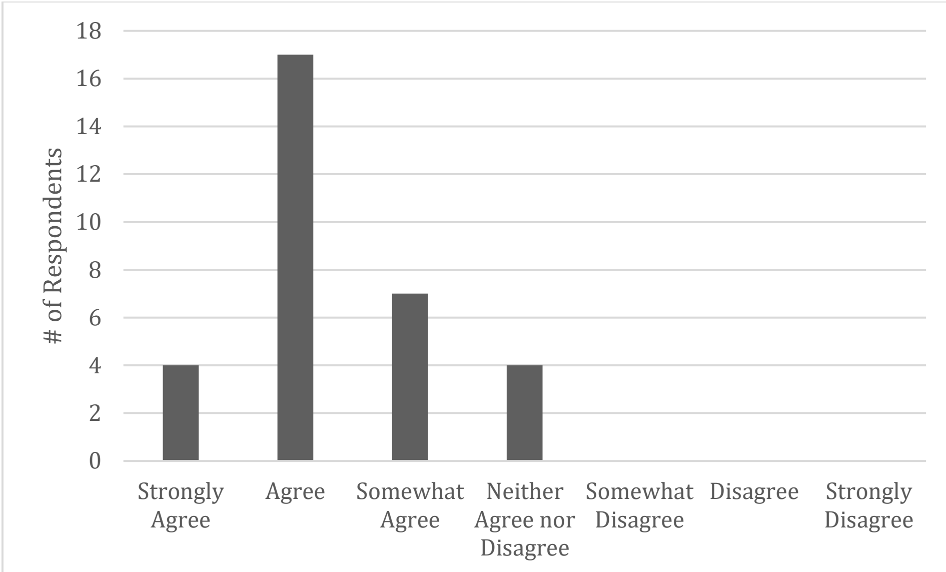


Figure 7 - LLPs Effectiveness in Improving the Construction Process

Survey question 3 asked respondents if “an LLP in the form of an archivable construction database would benefit my organization and the work of my office or division.” Similar to question 2, respondents agreed that LLPs would provide great benefit to their agency. Shown in Figure 8, 28 of the 32 (88%) agreed with the statement while only 4 (12%) respondents were indifferent. Respondents were asked whether “the general contractors that my DOT typically works with would be receptive to regularly submitting “lessons” into the construction database” in question 4. Responses to this question were much more varied than others. Illustrated in Figure 9, 14 (44%) indicated they agreed with the statement while 7 (22%) disagreed. Eleven (34%) respondents neither agreed nor disagreed that contractors would be receptive to inputting lessons into the database.

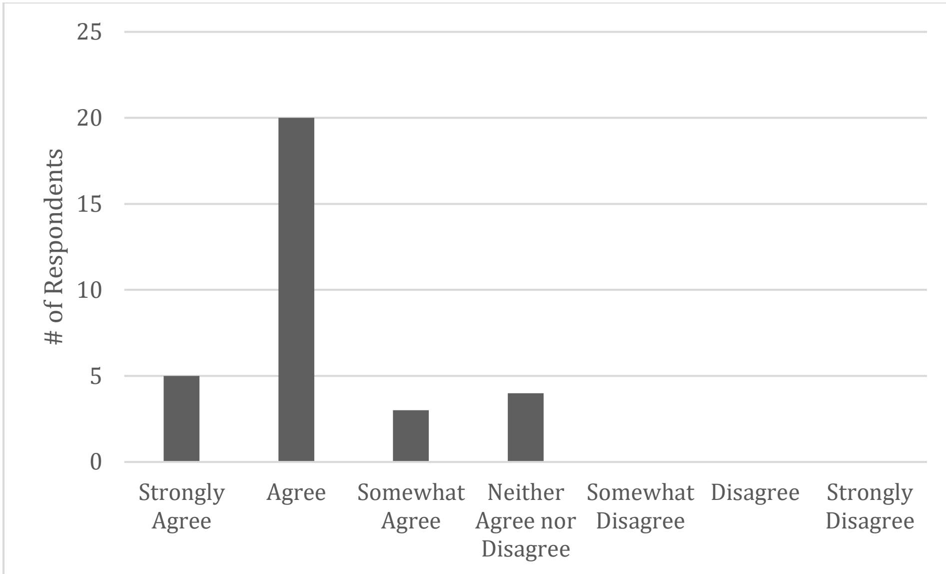


Figure 8 - LLPs Benefit to the DOT and Office/Divisions

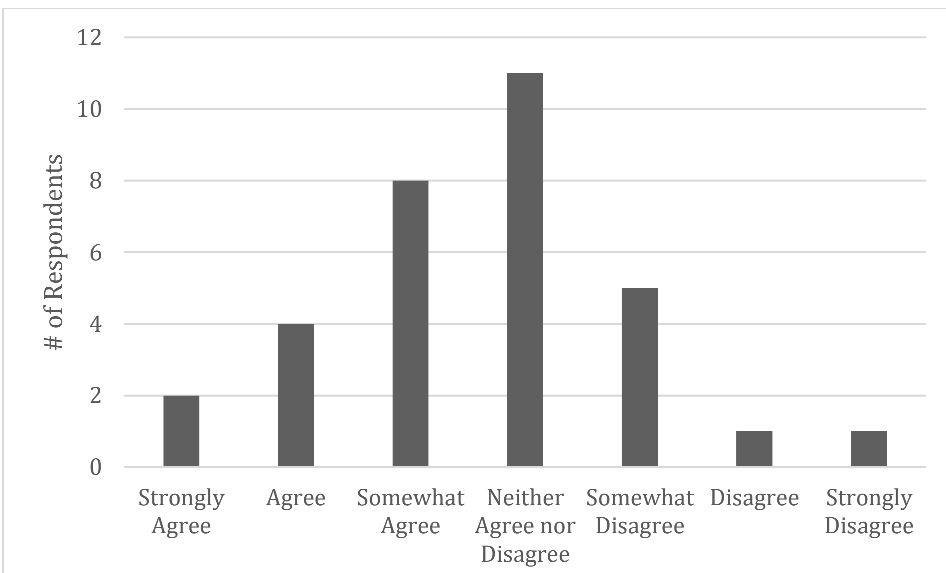


Figure 9 - Receptiveness of Contractors to Inputting Lessons into the Database

Survey question 5 sought to understand whether mistakes from previous construction projects (materials or procedures), which may occur due to a change in personnel or a lack of documentation, were often repeated. Reinforcing the need for an LLP construction database, 24 (75%) of the respondents indicated they believed their agency made repeated mistakes as a result of a change in personnel or lack of documentation. See Figure 10. Smaller percentages of the respondents, 4 (12%) and 4 (12%), indicated that they neither agreed nor disagreed or somewhat disagreed with the statement, respectively.

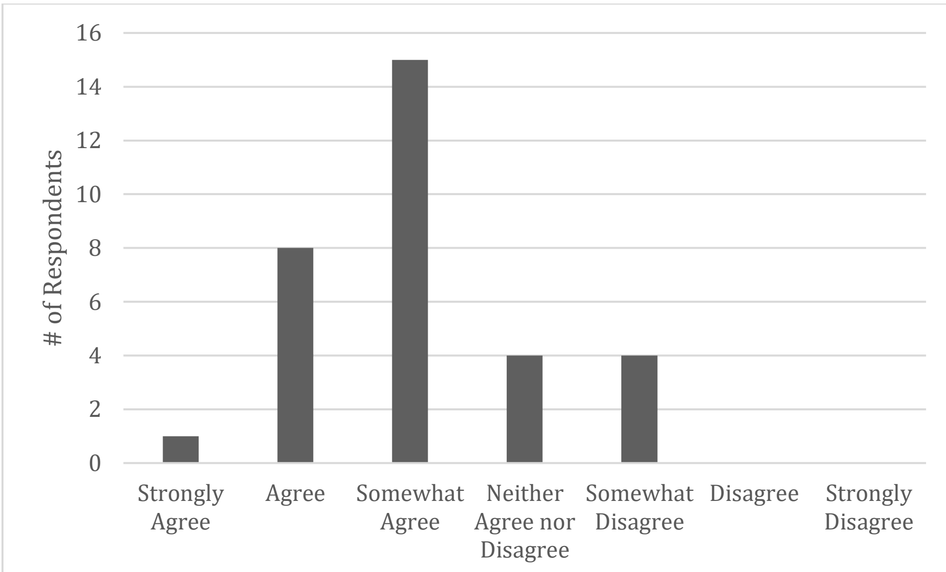


Figure 10 - Mistakes are Repeated Due to Change in Personnel or Lack of Documentation

Understanding an agency's challenges with adopting an LLP is important. Survey question 6 asked respondents "what challenges would your organization have in implementing an LLP for construction?" Results are shown in Figure 11. Respondents could select multiple challenges as a part of the question. Forgetfulness of using the LLP was selected by most respondents (17 of 32, 53%). Other responses, in descending order, included skepticism of using the LLP, lack of project similarities to relate lessons learned, lack of LLP effectiveness, informing DOT personnel of the LLP implementation, and personnel with the inability to operate the mobile app. Additional responses were provided that included:

- "Not sure we are discussing apples to apples on this question. Ours is not an app or a queried database;"

- “They have many responsibilities and adding more may not yield beneficial results;”
- “Turf wars over ownership of the procedures and giving direction based on the outcomes of findings.”

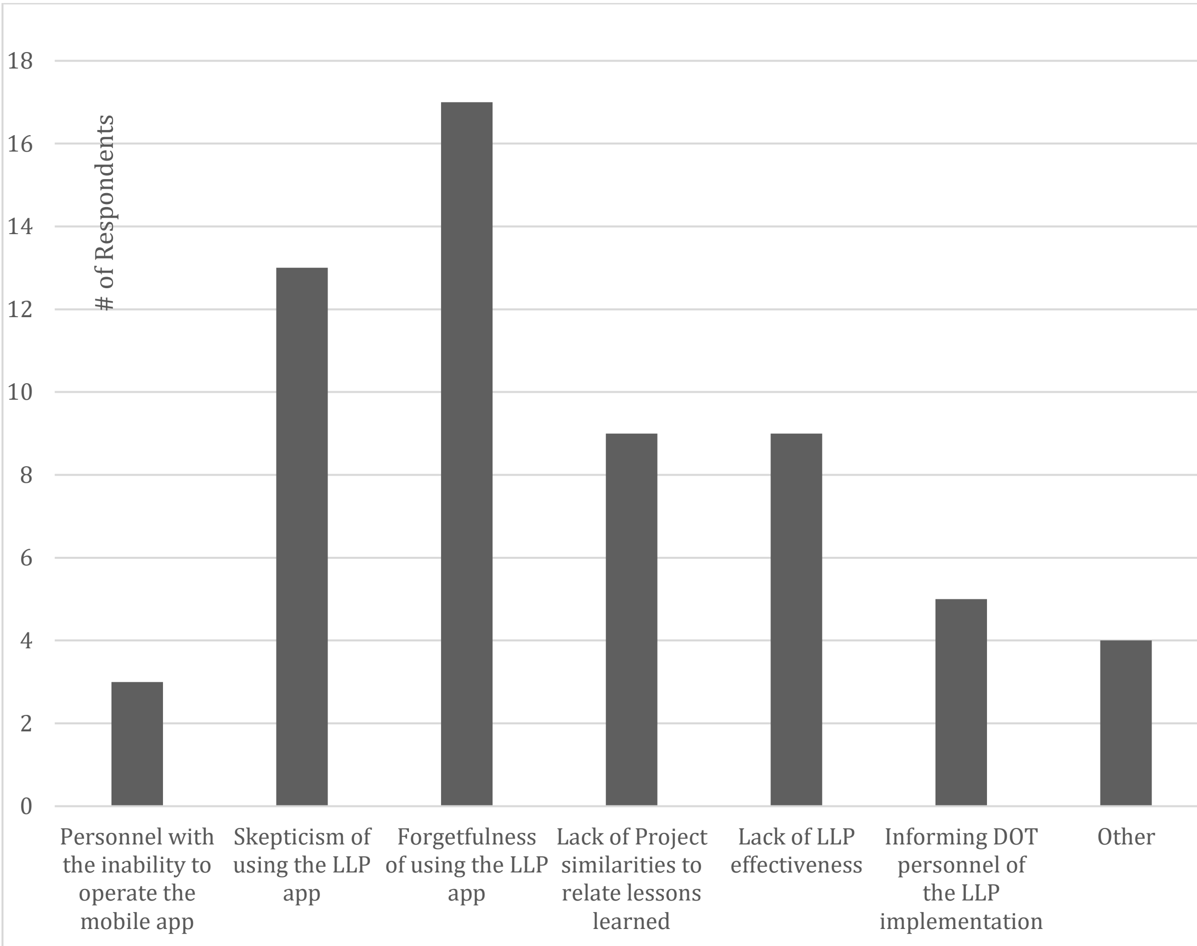


Figure 11 - Challenges in Adopting an LLP

Survey questions 7 through 11 examined the respondents level of agreement regarding LLP database capabilities such as notifications, GPS, uploading and storage of photos and videos, and mobile/cloud computing. Question 7 investigated how lessons should be documented. Specifically, would the most effective form of documenting information for input into the database be in increments throughout the project life cycle? Shown in Figure 12, respondents positively agreed (23 out of 32, 72%) that having information related to lessons documented throughout project life cycle would be most effective. Only two individuals disagreed with the statement.

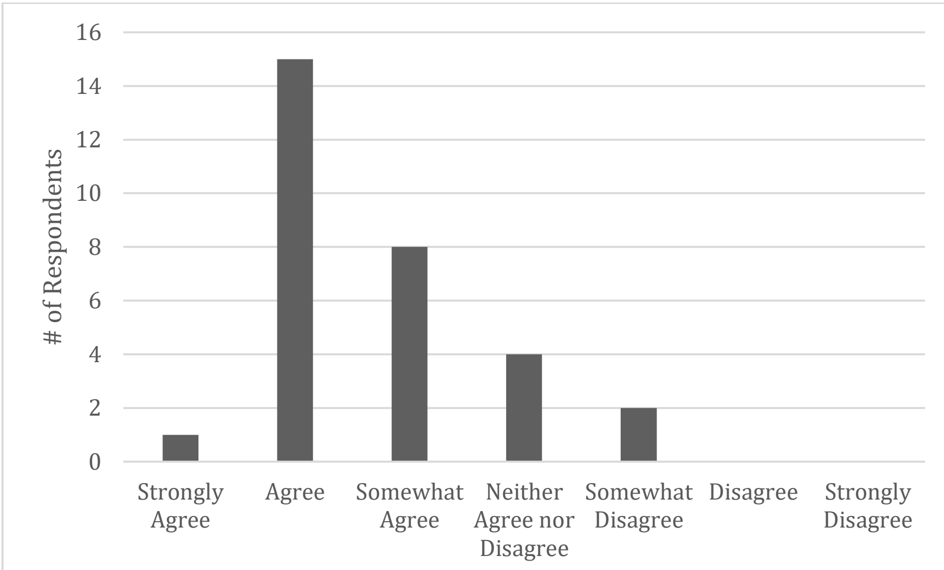


Figure 12 - Documenting Lessons Learned Throughout the Project Lifecycle

Survey question 8 related to the database having the capability for push notification. This would allow users of the database to be notified when lessons learned specific to the individual's interest are entered into the system. When answering the question "it would be useful for each user of the database to have a profile with specific field interests such that they can be notified when a relevant "Lesson" is entered into the system," 23 (72%) respondents agreed. See Figure 13. In addition, 4 (12%) respondents neither agreed nor disagreed while 3 (9%) respondents somewhat disagreed.

Because of GDOT's e-Construction initiative, field engineers have the ability to complete more site specific documentation via mobile devices. Question 9 investigated the usefulness of having the LLP accessible through mobile application technology and cloud computing such that field personnel are able to access it on the construction site. As illustrated in Figure 14, 24 (75%)

of the respondents indicated that mobile application technology and cloud computing would be beneficial to the usage of the LLP database. Only 3 (9%) of the respondents somewhat disagreed.

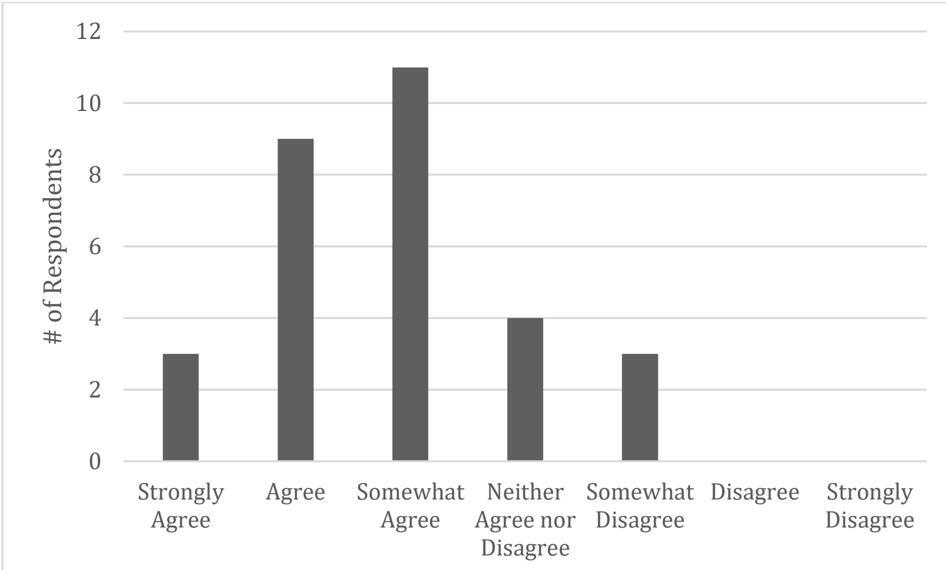


Figure 13 - LLP Database Capability for Push Notification for Users

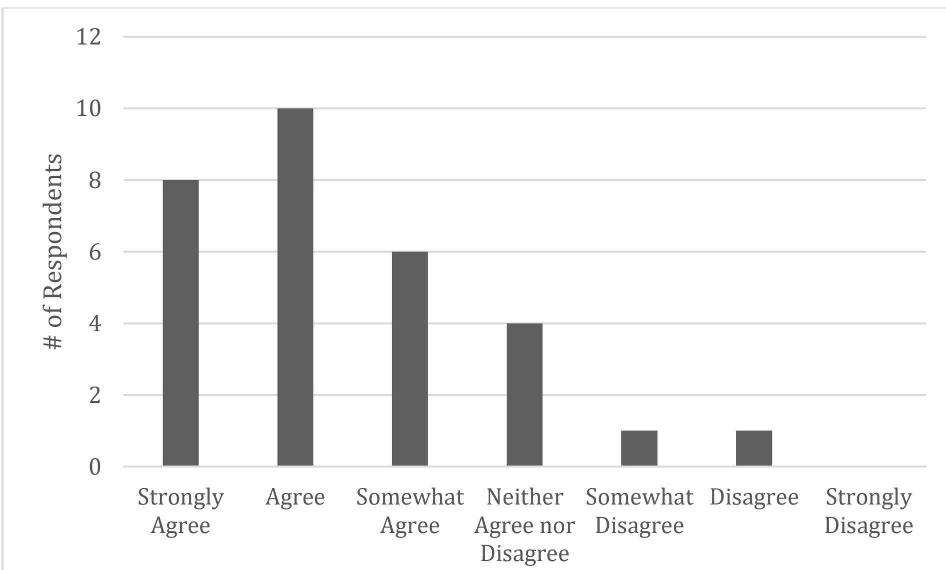


Figure 14 - Need for Mobile Application Technology and Cloud Computing

The author recognizes the need for photographic of video evidence to document the lesson learned. Question 10 of the survey examined the perceived usefulness of the LLP database having the ability of uploading and cataloging photographs of the lessons learned. Most all respondents indicated they agreed with the need to have photo/video uploading capabilities with 29 (91%) positives responses. See Figure 15. No respondents disagreed with the need for the database to have such capabilities.

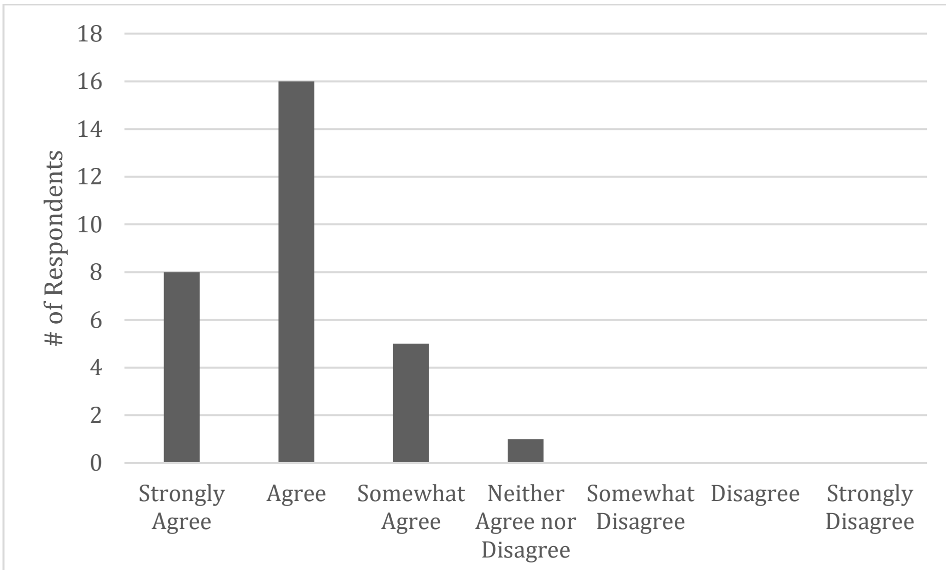


Figure 15 - Need for LLP Database to have Ability to Upload and Catalog Photos/Videos

Survey question 11 asked the respondents their agreement regarding the usefulness of the LLP database having Global Positioning System (GPS) capabilities in order to identify project locations for the lessons learned. Results are shown in Figure 16.

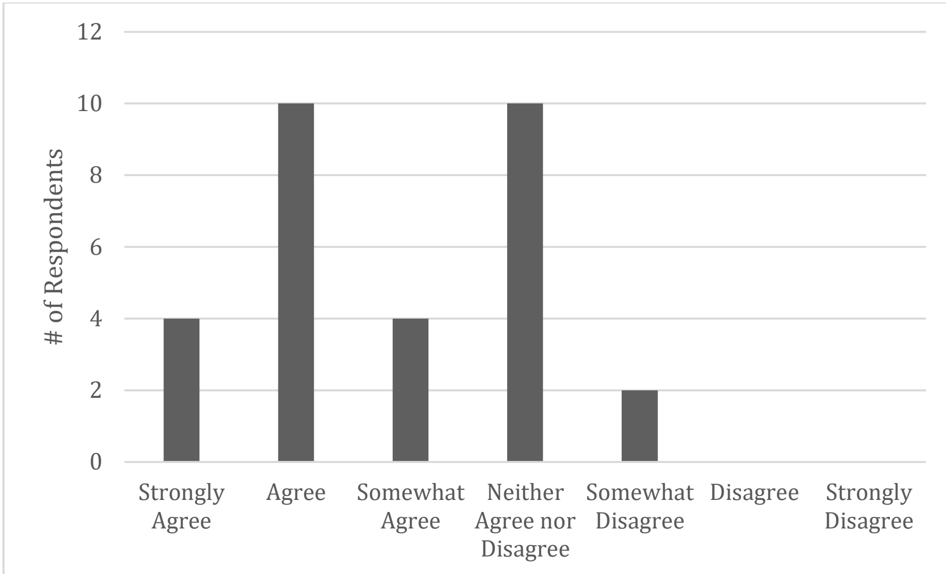


Figure 16 - Need for the LLP Database to have GPS Capabilities

Responses to the question were mixed. Eighteen (56%) of the respondents believed the use of GPS would be beneficial to the LLP database; however, 10 (31%) neither agreed nor disagreed with its use while 2 (6%) of the respondents disagreed. As a result of the breadth of work that is completed through transportation construction projects, terminology was identified as being a potential challenge. Survey question 12 asked respondents whether the grouping of terms of similar or exact meaning for the input and the retrieval process would be useful. Specifically, the question read:

"Considering LLPs will be used by individuals from various regions, differing terminology may become an issue during the entering/retrieval process. For example, a process or piece of equipment could be referred to by multiple terms. As a user looking to retrieve information from the database, this can cause problems while searching key terms. Would it be useful if the LLP system grouped terms of similar or exact meaning for both input and retrieval processes? (For example, searches for “mesh” would also show results for “welded wire reinforcement” and “welded wire fabric”).”

Results are illustrated in Figure 17. Similar to past questions, an overwhelmingly positive response was observed for the use of terminology commonality. In total, 28 (88%) of the respondents felt it would be useful to group terms with common meanings. Only 4 (12%) were in different with the question. Question 13 asked respondents for additional input regarding terminology in LLP systems. Suggestions included:

- Who would maintain this list? Maybe tie to pay items (CDOT);
- The system is currently designed to require all submittals by reviewed and approved by an administrator, who coordinates with subject matter experts and the Attorney General's office if required prior to posting. The administrator would review and make any final edits, this could help eliminate inconsistencies in terminology (WSDOT);
- Maybe allow for descriptors (District of Columbia).

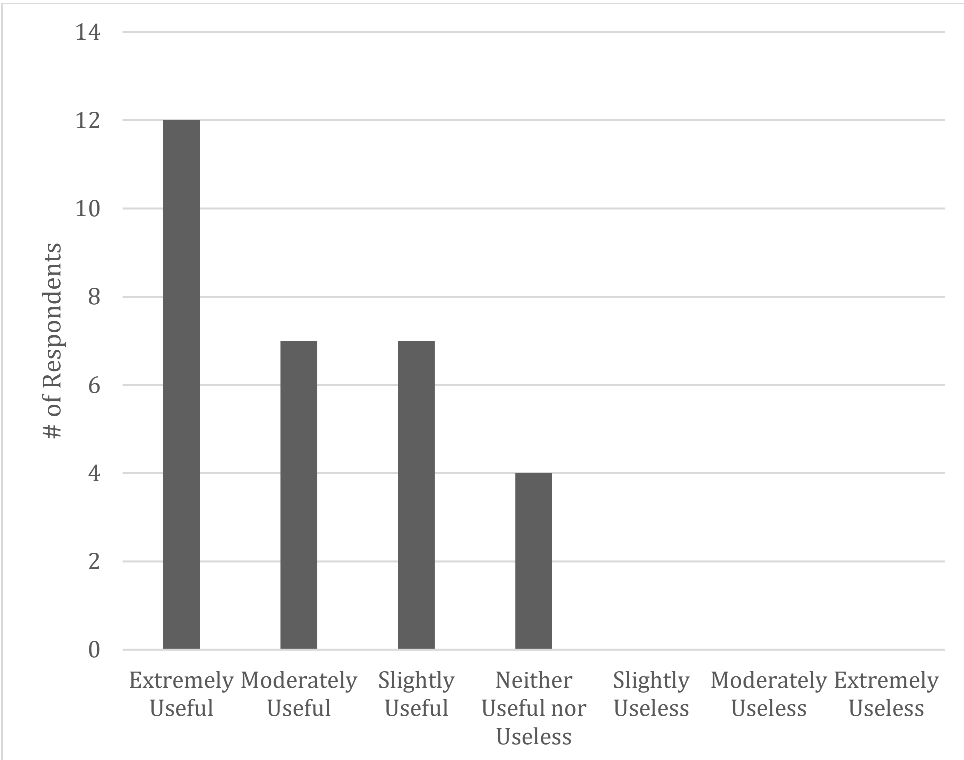


Figure 17 - Usefulness of Common Terminology

Question 14 asked respondents for additional information that may aid in the development of the ReCORD system for GDOT. Input was received from the Vermont Agency of Transportation (VTrans), District of Columbia Department of Transportation (DDT), Rhode Island Department of Transportation (RIDOT), Alaska Department of Transportation and Public Facilities, Delaware Department of Transportation (DelDOT), and Virginia Department of Transportation (VDOT). VTrans stated that LLPs would be most beneficial to their in-house design teams and their consultants. DDT recommended the use of visual aids, printables, pictures, and anything that would easily add value. RIDOT had attempted to utilize a Lessons Learned Program; however, the "buy in" of the value of Lessons Learned during planning and design was limited. The Alaska Department of Transportation and Public Facilities stated that LLP's are only useful if they are integrated in the design/construction process. They found that one on one post construction meetings with the design squad resulted in the process of sharing lesson learned information. DelDOT mentioned that navigating bureaucracy within a DOT is the most significant cause of recurring construction problems; consequently, finding the best use for the results is the most difficult part of getting something like this to work. Additionally, DelDOT believes that the most useful comments are well written paragraphs describing the exact situation. VDOT stated that they transitioned from a LLP to a scenario based guidance.

2.2.3 State DOT Response Summary and Conclusions

2.2.3.1 Current LLP Usage

The national survey of state DOTs resulted in a 56% (28 states) response rate. In total, 9 of the 28 states reported using an LLP while others did not actively use an LLP; however, some expressed some interest. The LLPs were primarily managed through Microsoft office software such as Sharepoint, Microsoft Access, and spreadsheets. MDOT uses the Bentley System, Projectwise, while WSDOT uses a FileMaker Database. The level of use varied from state to state with the majority respondents experiencing little use of LLPs. Overall, responses indicated the use of LLP as a newer process that is used inconsistently. Findings from the survey suggest that it would be beneficial to implement the LLP in such a way that conditions users to utilize the program frequently and consistently. Most of the LLPs are only available internally to DOT users. DOT Engineers, Inspectors, Construction Managers, and Maintenance Personnel were listed to be primary individuals allowed to input lessons into the database. The performance management section and the Central Office Specialty Engineers were able to input lessons into the LLP, for FDOT and DelDOT, respectively. DOT Engineers, Inspectors, Construction Managers, and Maintenance Personnel were the most common responses of the people allowed to retrieve lessons from the database. Two other responses indicated access to FHWA and DOT Executive Team as well as the performance management section for one of the DOTs.

2.2.3.2 LLP Challenges

Most of the responses were in general agreement that construction mistakes are repeated due to change in personnel or lack of documentation. This indicates room for improvement and the opportunity to reduce the number of repeated errors in the construction field. An effective LLP is certain to mitigate these errors. DOT respondents indicated that the biggest challenges to the effective use of an LLP are skepticism of the LLP, forgetting to use the LLP, and lack of LLP effectiveness. The majority of these issues are related to the implementation of the system. If properly implemented, the skepticism will fade and the people will habitually incorporate the LLP into their routine. As previously stated from the responses of survey question 4, another potential challenge is guaranteeing cooperation from the contractor. Another concern is the user’s perception that the extra time spent on the LLP is not worth the benefits. Most of the responses agreed that documenting information throughout the project life cycle was the best method to gather lesson learned information for the. This process of collecting information throughout the project lifecycle is expected to minimize the amount of important information lost in the confusion of other ongoing tasks.

Most states agreed that an LLP is effective in facilitating and improving the construction process. Only a couple of responses were indifferent about LLP usage. Similarly, there were positive responses from individuals who believed that an LLP would personally benefit them if applied to their office or division. There was a high variance in the responses regarding whether a contractor would be receptive of incorporating the LLP system into their routines and regularly submit lessons into the LLP. These results identify potential issues in implementing the LLP system. In addition, this suggests that a major potential challenge is finding a way to guarantee the contractor's cooperation.

2.2.3.3 LLP Attributes

A majority of responses agreed that a notification system for the LLP would be useful. A notification system should keep the users actively involved in the LLP. Further, this process will help to address the issue of people forgetting to use the LLP. Most responses agreed that mobile access to this LLP software would be useful. Convenient access of the LLP app would allow information to be incrementally input into the system rather than wait until the end of the project to add lessons into the LLP. Most of the DOTs agreed that the capability to add photographs would benefit the effectiveness of the LLP. Photographs would add another perspective on learning from the LLP that would help visual learners. Photographs are sometimes necessary in order to properly communicate information; as expected photograph capability should prove beneficial. A majority of responses neither agreed nor disagreed with the benefit of the LLP having GPS capability, but several DOTs were in favor of this database attribute. A majority of responses indicated that grouping similar or exact meaning terms would be helpful for both input and retrieval. This feature will simplify the LLP in such a manner to create a better experience for the users. A common complaint of LLPs is that the system is hard to use and complicated. The author expects that simplicity of the LLP will correlate to a higher rate of its usage.

Additional key comments regarding terminology were to have an administrator of the LLP review and finalize inputs into the LLP system and to use specific descriptions for terminology to avoid confusion. Lastly, several DOTs suggested that integration of the LLP within the project planning phase would be helpful in avoiding potential pitfalls.

The results from this survey were used to help design a construction LLP for GDOT. Ultimately, the survey was successful in finding a solid foundation of information from which to begin outlining the basis for the ReCORD system. In addition, it should be noted the use of an LLP would not only be useful GDOT, but many other state DOTs nationally.

Overall, there is much positive support for the use of LLPs. While only 9 of the 28 states that responding to the survey used an LLP, it seems that there is a future for LLP in state DOTs. The respondents recognize the opportunity for improvement. Mistakes were identified as being repeated during the construction process resulting in the loss of time and money. The DOTs are willing to try new systems and processes to help minimize repeated mistakes.

2.3 Statistical Analysis

2.3.1 Data Description

LLPs within the construction industry are databases where information from construction projects is compiled for use in future projects. GDOT does not currently employ an LLP for its construction operations. The information collected from over 50% of the state DOTs through a national survey was used in a statistical analysis to quantify the need and challenges of a construction LLP database. Calculations performed and figures illustrating the results in this section are generated with the program JMP Pro 13.

2.3.2 Research Questions

The following fundamental questions were sought to be answered:

- Do the majority of state DOT employees agree that an LLP is effective in facilitation and improving the construction process?
- Do the majority of state DOT employees agree that an LLP in the form of an archivable construction database would benefit the organization and the work of their office or division?
- Do the majority of state DOT employees agree that mistakes from previous construction projects are repeated?
- Do the majority of state DOT employees agree that the most effective form of documenting information for input into the database be in increments throughout the project life cycle?
- Do the majority of state DOT employees agree that it would be useful for each user of the database to have a profile with specific field interests such that they can be notified when a relevant "Lesson" is entered into the system?
- Do the majority of state DOT employees agree that it would be useful to have the LLP accessible through mobile application technology and cloud computing such that field personnel are able to access it on the construction site
- Do the majority of state DOT employees agree that it would be useful if the LLP database had the ability to upload and catalog photographs and videos of the lessons learned
- Do the majority of state DOT employees agree that it would be useful if the LLP system grouped terms of similar or exact meaning for both input and retrieval processes?
- Are the proportions of state DOT employees that either agree, neither agree nor disagree, or disagree if contractors will be willing to cooperate with the use of an LLP the same?

- Are the proportions of state DOT employees that either agree, neither agree nor disagree, or disagree if GPS capability would be useful the same?

2.3.3 Data Collection

Construction representatives from each of the DOTs nationally received the survey via email. Thirty-two responses (n = 32) were received from these state DOT employees. Two responses were received from 4 state DOTs. Two states chose not to respond to the last 5 questions of the survey.

2.3.4 Analysis

Each of the survey responses were analyzed by one of two tests. The first test is known as the hypothesis on one proportion test. The test uses a null hypothesis of $H_0 = .5$, an alternative hypothesis of $H_a > .5$, and a level of significance of .05. The results of these tests are shown below in Table 1.

Table 1- Hypothesis on One Proportion

Statistical Questions	Is the proportion significantly different enough to be considered the majority?	Magnitude of agreement
Do the majority of state DOT employees agree that an LLP is effective in improving the construction process?	Yes	28/32
Do the majority of state DOT employees agree that an LLP would benefit the DOT and its divisions?	Yes	28/32
Do the majority of state DOT employees agree that mistakes are repeated due to change in personnel or lack of documentation?	Yes	24/32

Do the majority of state DOT employees agree that lessons should be documented throughout the project life cycle?	Yes	24/30
Do the majority of state DOT employees agree that push notifications would be beneficial for users?	Yes	23/30
Do the majority of state DOT employees agree that there is a need for mobile application technology?	Yes	24/30
Do the majority of state DOT employees agree that there is a need for the LLP to have the ability to upload and catalog photos and videos	Yes	29/30
Do the majority of state DOT employees agree that it would be useful to have grouping based on common terminology?	Yes	26/30

The second conducted test was the goodness of fit test. The goodness of fit test was conducted on survey questions that yielded a high range of answers. This test classified the responses into three different categories: agree, neither agree nor disagree, and disagree. This test determines whether there is a significant difference between each of the response groups. These test results are shown below in Table 2.

Table 2- Goodness of Fit Test

Statistical Questions	Is there a significant difference in proportion at least two of response groups?	Magnitude (Agree/Neither Agree nor Disagree/Disagree)
How receptive will the contractor be to inputting lessons into the database?	There is not a significant difference in the proportion of GDOT employees that agree, disagree, and neither agree nor disagree with the statement	14/11/7
Would GPS capability be useful for the LLP?	There is a significant difference between the response groups of agree, disagree, and neither agree nor disagree.	18/10/2

See Appendix A.2 for a detailed analysis process.

2.3.5 Statistical Analysis Conclusion

The statistical analysis performed in this section confirms that an LLP construction database would benefit GDOT and other state DOTs. The state DOT employees believe that there is a need to improve the construction process because mistakes are being repeated. Additionally, the findings indicate that DOT employees believe that their office and the entirety of their DOT would benefit from the use of an effective LLP. The only discrepancies lie within how the LLP should be used. The DOT employees had varied responses on the usefulness of GPS capability and the level of contractor cooperation. The inclusion of GPS capability will not harm the effectiveness of the LLP; it can only improve or not affect its working capacity. However, the DOT should expect varying levels of contractor cooperation which have the potential to complicate the process. Ultimately, the information presented within this section confirms the need for contractor cooperation throughout and beyond the implementation phase of the LLP.

3.0 LITERATURE REVIEW

3.1 Overview of LLPs

3.1.1 Definition

A lesson learned is an experience gained by the success or failure of a specific task. When this occurs, knowledge is gained by the individual or group of individuals who worked on the task. Knowledge is defined as “a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information” (Davenport and Prusak, 1998).

Originally, lessons learned were understood to be guidelines, tips, or a checklist of what went right or wrong (Stewart, 1997). However, in a modern society, guidelines, tips and a checklist is not enough to shift an organization’s behavior and reprogram people to have the appropriate working habits and processes. Lessons learned systems have adopted an acceptance criteria for each lesson in order to validate its importance and effectiveness. In order to be effective, the results must be considered. Some authors make this point in distinguishing a lessons learned. A lesson learned could be defined as the change that results from successfully applying past knowledge (Bartlett, 1999). Others argue that stored lessons in a database are simply “identified lessons” (Siegel, 2000). The identified lessons are not lessons learned because they have yet to be applied. While the lessons have potential value, they are not worth real value until it can be successfully used in a future application. Bartlett (1999) and Siegel (2000) point to the fact that implementation is the real driver for an effective LLP.

The most complete definition of a lesson learned is: “A lesson learned is a knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative such as a mishap or failure. In addition, successes are considered sources of lessons learned. A lesson must be significant in that it has a real or assumed impact on operations; valid in that is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result" (Weber, 2001).

Overall a successful LLP will promote knowledge reuse, conversion, and sharing in an efficient manner. LLPs have been implemented to serve many purposes; some of which are to avoid wasting resources (Air Force Combat Command Center), protecting the safety of employees/ clients (Department of Energy), and survive and learn (Center for Army Lessons Learned). Regardless, LLPs are used to refine an organizations' operations in order to help achieve the organization's goal.

3.1.2 Distinguishing LLPs from Other Knowledge Artifacts

Knowledge artifacts are sources of information that are used solely for individuals or dispersed throughout a large group, organization, or industry. Common knowledge artifacts are lessons learned, incident reports, alerts, corporate memories, and best practices. These knowledge artifacts are compared in Table 2. Incident reports describe an unsuccessful experience that is used as a manner of documenting safety and accident investigations. It does not provide suggestions or recommendations for improvement. Alerts are similar to incident reports in that they are used to report negative occurrences. However, alerts are used specifically to bring attention to a specific technology or area of technologies that is problematic. Corporate memories do not have a "set in stone" definition. These could be understood to be a repository of different types of knowledge artifacts that all contribute to the understanding and level of knowledge for a specific organization. Best practices are knowledge artifacts only described as positive experiences with the goals improve specific activities within an industry. Best practices are the golden standard to which all processes and tasks should be held to.

Table 3: Types of Knowledge Artifacts (Fisher, 1998)

Knowledge artifacts	Originates from experiences?	Describes a complete process?	Describes failures?	Describes successes?	Orientation
Lessons learned	Yes	No	Yes	Yes	Organization
Incident reports	Yes	No	Yes	No	Organization
Alerts	Yes	No	Yes	No	Industry
Corporate memories	Possibly	Possibly	Yes	Yes	Organization
Best practices	Possibly	Yes	No	Yes	Industry

Some lessons learned systems mix different knowledge artifacts as input lessons into the database. From the perspective of the user, a mixture of different knowledge artifacts is detrimental as it results in confusion and makes it tougher to locate relevant information. Naturally, the solution is to only allow inputs into the LLP in the form of a lessons learned. This formatting consistency will allow users to more quickly familiarize themselves with the thought process of the lessons learned and expedite the learning process.

Additionally, for the ease of verification, each input to the LLP should only have one clear lesson to convey. An input with multiple lessons will not only be complicated to verify and input into the system, but can result in unnecessary confusion. If two lessons are closely tied together, they should be input separately, but have a hyperlink within the file to other closely related lessons. (Fisher, 1998)

3.2 Operations of LLPs

3.2.1 Psychological Aspect

Decisions that are made on a day to day basis are habitually made rather than deliberate decisions. According to the book The Power of Habit, 40% of the actions that individuals make are ascribed to habits (Shedd, 2013). In order for a LLP to work effectively, it must be used continuously. In other words, its use must become habitual. Once an organization continuously uses an effective LLP, then positive results will be realized and accumulate over time.

3.2.1.1 Internalization of Information by Repetition

In terms of an LLP, a stimulus is an event that evokes a specific functional reaction. In other words, the stimulus is the incident from which a lesson learned can be synthesized. Repetition of stimulus plays a dual role in the internalization of knowledge. Repeated exposure to the same stimulus maintains the information in the primary (short term) memory as well as storing the information in the secondary (long term memory). This knowledge concludes that exposure time of information within the primary memory correlates to the internalization of information into the secondary long term memory (Chabot et al. 1976). As it relates to the current study, not only can the ReCORD system become beneficial to the users that retrieves infromation from it, but it can be helpful to those individuals who are submitting the lessons for review. When a significant success or mistake is made on the jobsite, it is mentally noted and inputted into an individual's primary memory. In the proposed process for the ReCORD system, the mistake is to be physically documented and inputted into the database system. The old adage "learn from your mistakes" holds a great deal of wisdom. In order to learn from mistakes, it must first be necessary to admit that a mistake has occurred. When the lesson submitter documents his or her mistake, it is the first step in admitting an error. The process of documenting the mistake provides for a prolonged exposure to the stimulus of information. This process facilitates the transfer of information from the primary memory into the secondary memory of the lesson's submitter. Similarly, when a new process or idea is successfully implemented in the field, it shall be documented within the primary memory of the individual and input into the ReCORD system. As the physical documentation for the ReCORD system occurs, the individual is subjected to a prolonged exposure to the stimulus of information, allowing the information to transfer to the secondary memory. Additionally, the information will later be transferred to the hands of others for their benefit as well.

3.2.1.2 Information Types

Memory is split into two broad, distinct categories: declarative memory and nondeclarative memory (procedural memory). Declarative memory is the conscious memory that allows individuals to deliberately recall information, whereas nondeclarative memory is much more subtle. Nondeclarative memory is accessed without consciousness, such as the use of motor skills that have been indoctrinated into muscle memory (Curran et al. 2014). By nature, the information that is committed into nondeclarative memory has a higher retention than declarative memory. For example, an indivudal is more likely to forget a person's name or phone number rather than forgetting how to tie their shoes or how to ride a bicycle.

Regarding the application of the memory attributes discussed above to LLPs, two types of information critical to the use and effectiveness of LLPs is tacit knowledge and explicit knowledge (Dixon 2000; Inkpen 1996; Polayni 1996; Nonaka & Takeuchi 1995; Von Krogh et al, 2000). Explicit knowledge is straightforward information that is easily transferred or understood such as a name or phone number. The explicit knowledge is easily transferred between people. Tacit knowledge is a more emotional and intuition based state of awareness. Further, it is linked to personal perspective, experiences, and values. Tacit knowledge is more challenging to articulate or communicate to others.

The challenging demand of any effective LLP system is the requirement of the capability to convert knowledge from one form to another (tacit to explicit and vice versa) while distributing the information to multiple parties. Table 3 depicts the methods of knowledge conversion. (Mohammad Nazir Ahmad Sharif et al. 2004)

Table 4: Types of Knowledge Conversion

To / From	Tacit	Explicit
Tacit	Socialization (Collect)	Externalization (Verify & Store)
Explicit	Internalization (Reuse)	Combination (Disseminate)

Based upon the theory presented in Table 3, there are four types of knowledge transfer. These include socialization, externalization, internalization, and a combination of methods. Socialization is the method of knowledge transfer that allows for communication of tacit knowledge from person to person. By nature, this is the most difficult of the four methods of knowledge transfer. Tacit knowledge requires time to accumulate and truly understand what is being learned. Thus, it is a challenge to transfer the internalized knowledge of one party and implant it into another. The transfer of knowledge requires the process of socialization; the parties must adequately communicate their tacit knowledge in a specific and detailed manner in order for the information to be properly understand and learned as tacit knowledge.

Externalization is the method of knowledge transfer that converts tacit knowledge into explicit knowledge. The conversion happens within an individual or organization before it can be shared with others. If the knowledge being converted is already tacit knowledge, the conversion process is as simple as vocalizing the knowledge or information. The process must be a deliberate one.. Conversion of tacit to explicit knowledge will require introspection of some degree in order to deliberately externalize the implicit knowledge into tangible facts and figures. Once the knowledge is externalized into explicit knowledge, it becomes easier to transfer to other parties.

Internalization is the process of converting knowledge from explicit to tacit knowledge. The knowledge must already be possessed as explicit knowledge. Internalization requires a process such as implementation and application of the knowledge. This process is a critical aspect to the type of knowledge conversion that the ReCORD database plants to promote and facilitate.

Combination refers to a multitude of communication avenues to convey a message. Since this method includes the transfer of explicit knowledge from one party to another, it is the simpliest process. A prime example of combination is the sharing of a phone number or name with another individual. The sharing of this information occurs in a multitude of manners such as face to face meetings, email, text, phone, and other means. The most effective LLP is capable of promoting all types of information conversion and transfer. The input system of the ReCORD system is configured in a way to all for the ease of transfer of explicit knowledge and also promotes two way knowledge conversion through its documentation process.

3.2.2 Benefits

The use of lessons learned databases must be incorporated into a regular and routinely used system of operation for maximum efficiency. In many cases, the lessons learned system is not regularly utilized and falls out of favor. In these instances, it is unlikely that the lessons learned will be of much value and decreases the likelyhood of the program being brought back into routine use. However, if the lessons learned system is used regularly, it can provide desirable results such as increased working efficiency and a reduction in resources such as money and manpower. Other performance-based benefits include improved productivity, cost, quality, and overall performance.

3.2.3 Challenges

The Construction Industry Institute's (CII) modeling lessons learned research team conducted a study of 2400 organizations and their use of an LLP. Fifty distinct LLP types were identified, from this study. CII selected 25 organizations to perform a more detailed investigation. None of the 2400 LL systems examined in the study used any type of process that proactively "pushed" existing lessons to users who would potentially find them helpful (Fisher et al., 1998). The most reasonable explanations are that either software unable to reinforce the process, the newly found lessons were input into a best practice manual and became untraceable from there, or that the lessons were only presented back to those who made mistakes in the first place. Regardless of the reason, the ability for an LLP to send push notification gives it a much higher chance of success.

In general LLPs will fall short of their full potential due to two distinct reasons. First, the quality of the lessons within the system are not satisfactory. This usually occurs because the lesson learned does not adequately describe the situations to which it can be applied. Secondly, the LLP is often not integrated into the organization's decision making process. In order for an LLP to be effective, it must be capable of changing the habitual patterns of the organization as a whole. This is only performed at the "root" of the organization. The performance of an LLP is strongly linked to its degree of integration with the decision making process. (Aha, Becerra- Fernandez, Maurer, & MunÄoz-Avila, 1999; Reimer, 1998).

Secutor Solutions is a company that creates Lessons Learned Programs for its clients. According to Bill Brown, the blogger for Secutor Solutions, the three main reasons that LLPs fail are lack of content, poor lessons quality, and inability to efficiently retrieve information. If the

LLP does not have a sufficient amount of relevant information archived, it will not consistently be able to supply its users with the appropriate information. After repeat occurrences, users believe the program is useless and a waste of time resulting in a lack of desire to use the program again. If the quality of lessons in the system is not high quality, the system will not serve a purpose. Even if the system is able to effectively convey the message to the right people, the lesson itself will provide little value. A successful lessons learned system must have an efficient method for retrieving the appropriate data. Individuals will wish to retrieve data in different manners (complex searches using Boolean logic, browsing topics/ categories, timeline, etc). Thus, it is important to have multiple search methods in order for each user to have a method that is convenient to them. (Brown 2016)

In 2006, a survey was conducted by Ernst and Young of 130 members for the Project Management Institute about their views on LLPs (Marlin, 2008). 91% of the respondents believed that leasons learned are important to the development of the organization; however, only 13% stated that LLPs were used within their organization. Additionally, only 8% replied to the survey stating that the point of the LLP reviewing was to understand potential benefits and improvements that would help the company grow.

The literature confirms the trend that most people believe LLPs to be useful. However, why are LLPs not more commonly used? A major reason for this trend lies within the implementation of the LLP. There are numerous barriers that contribute to the hindrance of an effective LLP implementation. Barriers include:

- Being unable to find relevant information within the database;

- The user's belief that using the LLP is a waste of time because it does not directly contribute to their project;
- The belief that an LLP is just a "blame game;"
- The belief that the LLP process is more trouble that it is worth (too complicated to use, wastes too much time);
- The belief that the LLP is too ideal, something that management only talks about, but is never able to execute.

3.2.4 Implementation

The ability for an LLP to efficiently locate and retrieve information that is relevant to the user's interest lies with the program administration. Once the user is accustomed to the LLP database, the database should be simple to search and find the desired information. However, it is the administrator's responsibility to create a simplified system for the users. How intuitive the program's user interface is to the employees contriubtes in large part to the success of the LLP. For ease of use, the user interface should be made as intuitive as possible. During the development stages of the database, the creaters of the LLP databse are encouraged to examine programs that the employees are already using and establish similar features for the LLP. This will shorten the learning curve due to user familiarity. The ReCORD system will have proactive features that are designed to bring newly input lessons to the user. Each user will have their own profile that will contain "tags" for their specialty area. Similarly, when a lesson is input into the LLP, it will contain tags for relevant fields. Users with the same tag as the newly input lesson will receive a notification to alert them of the lesson, thereby saving the user time by eliminating the need to search for LLs themselves.

Leadership is a critical aspect of instituting an effective LLP. “The lack of leadership involvement in and commitment to the learning process is the most critical barrier” (Dressler, 2007). Leadership is required to change the attitude of workers and foster the understanding of the LLP users that it is not only acceptable to admit mistakes, but encouraged to do so. This philosophy allows for a more direct method of communication and shortens the path to identifying the issue. This in turns, expedites the problem solving process. The implementation process is improved if management utilizes a reward system or other incentive program for admitting mistakes. People are often reluctant to admit mistakes; it makes them vulnerable to criticism and puts their pride, reputation and quite possibly their career at risk. However, a committed leadership team has the potential to reshape the attitude paradigm of the employees to a more open and transparent outlook.

With the importance placed on creating a simplistic LLP, literature recommends that an input into the ReCORD system only contains a single lesson. If a situation arises that produces multiple lessons learned, then multiple entries should be submitted to the database. If a single entry contained multiple lessons, the plethora of information and multiple issues may overwhelm the user. Arguments are made against this idea of keeping each lesson separate from each other by claiming that it will create too many lessons that results in a onerous process for the user. However, the ReCORD system will be organized in such a manner that the additional number of lessons will not be a concern. Further, this process reduces the risk of the LLP being too complicated for users. Separating the lessons from one another ensures the best chance of the lessons clearly communicating its core message.

3.3 Applications of LLPs

3.3.1 LL Systems

The organizations discussed in the following sections have an established LLP. These LLPs in size from the federal level down to the state level and are used for different purposes

3.3.1.1 NASA

The National Aeronautics and Space Administration (NASA) has a lessons learned database known as the Lessons Learned Information System (LLIS) that is mostly accessible by the public. Access to some files are reserved for only NASA employees. The LLIS is a centralized compilation of reviewed and edited lessons learned that have been submitted by departments across NASA divisions and other organizations. This centralized database is used at all 10 NASA's centers across the nation. The LLIS was originally established to avoid safety mishaps. GDOT has the same motive for creating the ReCORD database. (Hoffpauir, 2015)

3.3.1.2 US Army

The US Army's Center for Army Lessons Learned (CALL) offers a five day course for army officers. The course covers information that has been validated through experience and testing. CALL defines lessons learned as validated knowledge and experience derived from observations and the historical study of military training, exercises, and combat operations that has led to a change in behavior at either the tactical, operational, strategic level or in one or more of the Army's DOTMLPF (Doctrine, Organization, Training, Material, Leadership and Education, Personnel, and Facilities) domains." (Global Security 2009)

3.3.1.3 US Department of Transportation

Currently, the US Department of Transportation (US DOT) is revising their Lessons Learned Program. The most notable aspect about the US DOT's process is the lessons are written by a third party. The US DOT process begins with the project information being submitted through regular progress reports and end of project reviews. Next, a team known as "scourers" search the end of project reviews and compile lessons for the database after project completion (Greer, 2018). Because of this process, there is likely a disconnect between the individuals who experienced the lesson firsthand and those summarizing the lessons for entry into the database. This disconnect should be mitigated by extracting specific details about the lesson from those who experienced the firsthand. It is recommended that GDOT not follow this model, but instead have indivdials involved with the project submit lessons directly to the database and curator.

3.3.1.4 Kentucky's LLP

The Kentucky Transportation Center, known as KyTC, is currently using a lessons learned database. Their database emphasizes the importance of a curation of lessons, a centralized system, and integration with the planning process at the outset of construction. In 2003, KyTC conducted a study to formulate and build their Lessons Learned Database. The lessons learned process that was developed is shown below in Figure 18. An important lesson that KyTC learned from other LLPs is to keep the lesson learned process as simple as possible. If a complicated and in depth lessons learned system is implemented, it has to potential to produce outstanding results, but the process is risky. Another possibility is that the process overwhelms the users and completely turns them away from the system. At this point, all of the work and resources invested into the system would be in vain. It is recommended that the process be kept as simple as possible to target high user retention. (Goodrum et. al 2003)

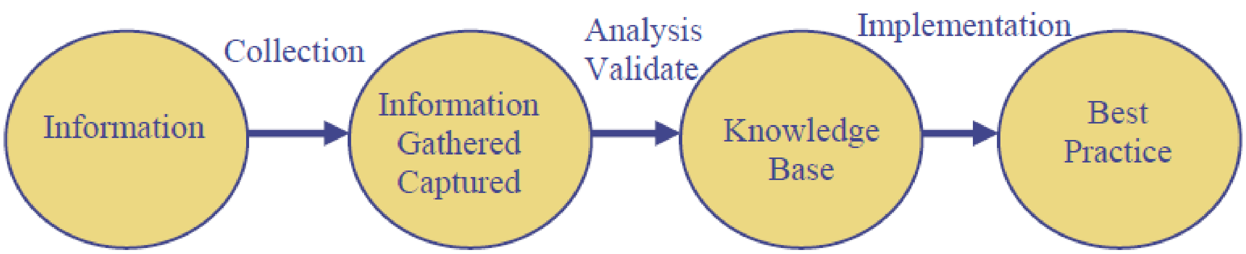


Figure 18 - KyTC's LLP Process (Goodrum et. al 2003)

KyTC had 4 objectives for their study, listed below.

1) Identify lessons learned systems currently used by other transportation organizations and other industry organizations
2) Define the desired functional capabilities of a lessons learned system for KyTC
3) Develop a system design for a lessons learned system
4) Recommend a lessons learned system for integration into the KyTC's design and construction process

The process that KyTC used to develop their LLP system was applied to the creation of the ReCORD system. Each of the objectives was met by the ReCORD system project as well as the creation, testing, and evaluation of the system. Below in Figure 19, a more detailed conceptual design of the KyTC lessons learned process is shown.

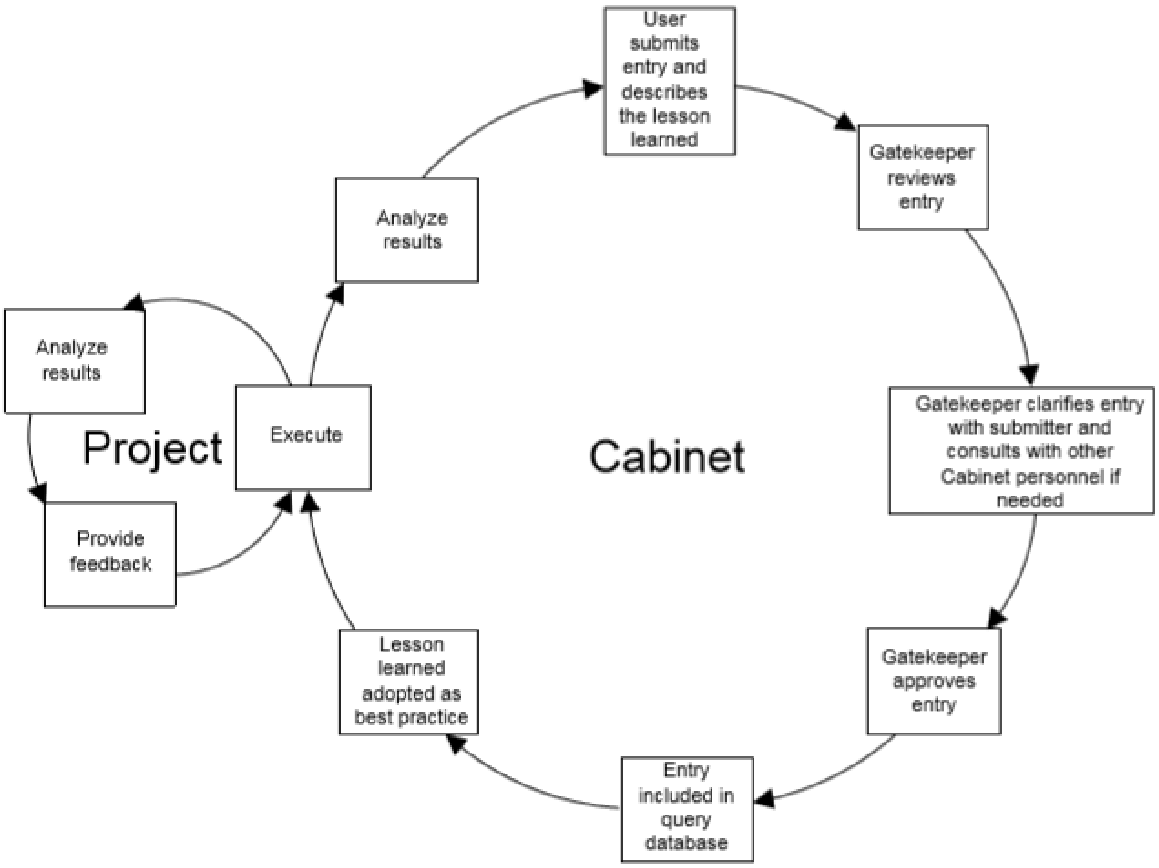


Figure 19 – KyTC's Lessons Learned Process

3.3.1.4.1 Database Selection

KyTC used MS Access as the database language due to convenience. The software was already installed on the KyTC and the University of Kentucky's computers, since it came pre-installed with the other MS products. Additionally, KyTC already used MS Access to store and display post-construction reviews conducted by on its projects. The team decided to choose MS FrontPage to work as the front-end of the database in terms of displaying information. This had an added bonus of making the database internet based, reducing the database access requirement down to only having internet access.

3.3.1.4.2 Curation

Once a lesson is submitted to the database, the gatekeeper is notified. The gatekeeper decides which lessons are worthy of being displayed in the database. The duty of the gatekeeper involves editing the submitted lesson until it is ready to be put on display in the database. The gatekeeper has the ability to solicit help from the cabinet members to aid in the verification of the lesson. The gatekeeper may make changes to the lesson before its publication into the system.

3.4 Lesson Learned From LLPs

3.4.2 CDOT's T-REX Mega-Project

CDOT oversaw a huge transportation expansion project, carried out by Kiewit, known as the T-REX Mega project. The project started in 2001 and was completed in 2006; it included 17 miles of reconstructed interstate highway, 19 miles of double-track rail transit with 13 stations, and construction/ reconstruction of 61 roadway bridges (I-25 T-REX Project, n.d). The massively successful project was attributed to a handful of "keys to success". These keys are listed below:

1) Remember: "project comes first"
2) Develop a well-defined contract
3) Develop and focus on project goals from the outset- update at the start of major phases.

The major key in the success of the project was the attitude of the team and their positive work environment. This allowed them to prioritize the project over an individual. Their motto was "One Team, One Voice". It helped the team think in a unified manner that led to mutual respect among themselves. Furthermore, the team co-located all of the T-REX project team members.

Another key to success was attributed to a well-defined contract. In order to develop a well-defined contract, the team invested time and resources into researching other similar projects and incorporating their lessons learned. This research allowed the team to avoid the mistakes of others while capitalizing on the methods and procedures that worked well. A well-defined contract must also set proper expectations for the contractors and the client. Realistic expectations from both parties eliminate miscommunication down the line as well as lay out a standard that can be strived for.

Similar to having a well-defined contract, clear project goals keep the project moving in a positive direction. More importantly, the goals were updated at the start of major phases. Updating the project goals as it progresses ensures that the entire team is on the same page. Situations arise on projects that can significantly restrict or complicate the tasks at hand. When this happens, the goals should be updated appropriately to keep the team members on the same track (Federal Transit Administration, 2007).

3.4.3 VDOT's 3P Program

On April 23, 2009, Thomas Pelnik, P.E. delivered a presentation that took an introspective view on the Virginia Department of Transportation's (VDOT) past projects. The presentation eventually made recommendations for moving forward with VDOT's construction projects:

1) Begin at the beginning,
2) Focus on what you want at the end

"Begin at the beginning" refers to having a clear idea of what needs to be done and planning out the tasks. The policy objectives must be noted and taken into consideration of the design and construction. Additionally, the planning process must consider the cost/benefit of the project, potential risks, and project delivery method.

Focusing on the end goal does not only refer to the completion of the project. More importantly, it includes the long-term performance, much later than just the project closeout. This includes accounting for the project's life cycle, operation, and maintenance. Current construction practices separate construction and maintenance, yet the two are so closely related and dependent upon each other. Maintenance is just as important as the construction itself, otherwise the construction effort would soon go to waste (Pelnik, 2009).

3.4.4 Other Interactive Systems

The Pennsylvania Department of Transportation (PennDOT) has an interactive map that marks locations of both ongoing and future construction projects (PennDOT, 2018). When a marker is clicked, a new page is opened that provides project specific information such as contrator name and contact information, type of work being performed, and cost. The interactive map is a simple and effective way to convey spatial information for locations that have experienced lessons learned. The ReCORD system adapts these features into its own interface.

3.5 Summary of LLPs

LLPs have the potential to help an organization improve its processes and tasks in order to increase efficiency by saving money, ensuring worker safety, reduce training times, etc. The most complete knowledge artifact to learn and gain experience from is an LLP. LLPs are effective because it emphasizes internalization by repetition as well as promoting multiple types of knowledge conversion and transfer. Many LLPs in the past have failed due to:

- Poor lesson quality/ lack of content;

- Inability to recall lesson properly (during input);
- Lack of integration of LLP into decision making process;
- Lack of cooperation from users or lack of the users' belief in the system;
- Poor administration (curating of lessons);
- Misuse or lack of overall habitual use;
- Overly complicated input, verification/validation, or retrieval system.

A successful LLP requires exceptional leadership and implementation. Workers must feel safe enough to openly admit mistakes. NASA's LLIS is an excellent model for the ReCORD database because it utilizes push notifications as well as features effective methods of organizing and curating lessons learned.

4.0 PROBLEM STATEMENT

4.1 Research Significance

LLPs have been implemented by large and successful publicly funded agencies such as the U.S. Army, U.S. DOT, Environmental Protection Agency (EPA), and NASA. The LLPs created and maintained by these organizations typically include database platforms that allow individuals to both store and access information relating to a specific field of interest within their industry. The storage of valuable lesson learned information in an easily accessible database is convenient and advantageous. The process allows for future users of the database to access the data in order to learn from the successes and mistakes of projects in advance, which results in the saving of time, money, and other resources. LLPs allow users to grasp the lessons stored in the database and ideally avoid the same mistakes while implementing successful practices in order to optimize the work being performed.

The Construction Industry Institute (CII) describes LLPs as “essential to the construction industry”. As the more experienced professionals retire from the workforce and job turnover continues, documentation of worker expertise is even more valuable. If the information is not recorded or documented, then it is essentially being lost, and the newer workers in the industry will have to begin with little knowledge to go on. However, when the information is documented, it can serve as priceless guidelines for newer, less experienced workers. Additionally, in a modern age, large scale integration along with the growth in public-private partnerships creating an ever changing construction industry makes this an opportune time to establish the ReCORD system for GDOT.

4.2 Research Objectives

GDOT has never had a formalized LLP. Previously, GDOT utilized a spreadsheet to keep track of project data; however, it was not widely used nor effective. The development of the ReCORD system will help to unify GDOT's large workforce and footprint throughout the state of Georgia under one system for capturing and reporting of lessons learned. The system will have a systematic and effective method of curating and retrieving lessons learned. As with the adoption of any new method, it is expected that a well thought out and strategic implementation plan should be created to provide support and guidance for the curating and long-term management of the database system. Furthermore, the implementation must illustrate the significance and benefit of the system to its users. The ReCORD system will facilitate the essential task of retaining and dispersing knowledge throughout GDOT, leading to improved design and construction related decisions being made by employees, thereby, leading to higher working efficiencies throughout the life cycle of projects and organization.

5.0 EXPERIMENTAL PLAN

The framework for the ReCORD system was established through the integration of information collected from the national survey of state DOTs, comprehensive literature review, personal interviews with curators of other industry-based LLPs, and recommendations from GDOT. The development and implementation plan for the ReCORD system consisted of process development, conceptual design, and product development, trial implementation, and adoption. A major aspect of this plan is the trial implementation phase that involves the overseeing the use of the ReCORD system with several lessons learned to verify the LLP is operating correctly and producing the results expected by GDOT.

5.1 Preliminary Planning (process development phase)

5.1.1 GDOT Pre-Planning Meeting

On March 9, 2018, a meeting was held with GDOT to discuss the launch of Phase 2 of the ReCORD system project. Phase 2 marked the end of the preliminary information acquisition and transitioned into building the framework of the ReCORD system. John Hancock, Beau Quarles, and Binh Bui attended the meeting. The group held an open discussion on potential features that the ReCORD system would use. GDOT strongly agreed with the use of the notification system and the use of a ReCORD system app for mobile devices. Additionally, the group briefly reviewed NASA's LLIS system and decided that more information was needed. A meeting was scheduled with Michael Bell, the system curator, see section 3.3.1. GDOT recommended to solicit feedback from potential ReCORD users, other GDOT employees. A meeting was scheduled with the GDOT District 1 field engineers to discuss and refine operations and features of the ReCORD system. See section 5.1.2 for more information about the meeting with NASA LLIS curator, Michael Bell.

5.1.2 NASA Interview

The LLIS utilizes topic tags to organize its lessons learned. For example, several of the topic tags include: fire protection, ground operations, and pressure vessels. Furthermore, a wide range of topics are categorized within each of the topic tags. This process allows for a more efficient method of organizing the multitude of lessons stored within the database. NASA's LLIS curator, Mr. Michael Bell, stated that the list of topic tags is still fluid and capable of ,being regularly redefined by new terminology (Bell, 2018). Naturally, a user can use these tags to search/retrieve lessons from within the database for viewing.

NASA recommends its LLIS users to gradually input information as the project progresses, rather than all the information at the end. The desire with this process is that it will minimize the amount of information lost between the realization of the lesson and its formal documentation. In addition, NASA allows for repeat lessons to be input into the system if the situations differ substantially. For example, this could help to illustrate that a specific problem is not confined to one situation, but could arise within other circumstances as well. While the lessons themselves may not differ much, having both lessons documented and presented to the users will help in the understanding of the issue in a more complex or comprehensive manner.

The NASA Lessons Learned Steering Committee (LLSC), and more specifically the system curator, manages the content (Bell, 2018). The curator acts as the administrator for the LLP, reviewing, editing, and helping to validate the lessons prior to entry into the system. Before each lesson is validated and input into the system for distribution, the lesson entry requires committee approval. In the NASA LLIS, lessons have different committees for approval due to the nature of the different topics that are covered with the lessons. The time required to verify each lesson varies from lesson to lesson due to the differing levels of complexity.

The LLIS features a method of receiving feedback from its users. Users have the opportunity to rate the lesson on its usefulness, applicability, coherence, among other lesson atributes. As a result, the curator reviews the comments and makes edits to the lesson, if necessary. Additionally, NASA currently monitors the number of times each lesson and topic is viewed. This serves as a indicator of how users view the LLIS. High viewership suggests that the lessons and the system overall are operating in a manner that is accommodating to the users and effective.

Formal training for the usage of the LLIS does not yet exist, but users have access to a handbook that discusses the procedure for capturing a lessons learned and submitting it to the LLIS. When Mr. Bell was asked about changes that could have been made to the LLIS in recent years, he responded with three primary suggestions (Bell, 2018):

1) Keep it more simple;
2) Think long term;
3) Continued promotion of the system.

NASA's LLIS is a great model for the framework of the ReCORD system. This is particularly due to its use of the proactive push notification technology to notify users of pre-registered topics tags associated with the entered lessons. The ReCORD system aims to use a similar feature by associating lessons with topic tags. Further, other features that NASA uses within its LLIS will be adapted and put to practice within the ReCORD system.

5.1.3 District 1 GDOT Meeting

The GDOT District 1 meeting was held on April 18, 2018; roughly 30 GDOT employees were in attendance. After a productive discussion, new features were incorporated into the framework of the ReCORD system. These features included anonymous submission, inclusion of links to other suggested lessons while viewing a lesson, and an opportunity for the users to provide feedback on lessons as well as the whole of the ReCORD system.

5.1.4 Project SR 316/ SR 81 Site Visit

In order to further confirm that the ReCORD system was being designed in a manner consistent with GDOT employee's needs, site visit was made to Project SR 316/ SR 81 in Barrow County, GA. The site visit occurred on July 2, 2018. The project is managed by Mr. Luiz Alvarez. State construction liaison, Mr. Todd Wood, was present on the day of the site visit. Mr. Wood's recommendation was to have the project manager be the individual to submit lessons learned into the ReCORD system. Further, Mr. Wood stated that district offices would be capable of contributing to the submission; however, the inception of the lesson would need to reside with the project manager. In this scenario, the project manager would have the knowledge to understand and document the incident. Further, the project manager is located on-site and experiencing the incident firsthand. This makes the project manager the ideal candidate for submitting new lessons learned in most cases. (Wood, 2018)

Currently, GDOT Project Managers use a Bentley Software, ProjectWise, to manager and store documentation throughout the life cycle of a project. ProjectWise systematically stores all files for all GDOT projects. Mr. Luiz Alvarez accesses ProjectWise approximately once a month to upload files in order to keep the database updated. The files are created outside of ProjectWise and then uploaded into the system at milestones (usually once a month). These files include both digital and hardcopy files. Paper documentation is scanned into the system. Project files typically include pictures and videos, thus the addition of such items into the ReCORD database would not be overly difficult. Mr. Alvarez agreed that the use of a ReCORD database mobile or tablet app would be helpful as a first entry point for the lessons learned system while on-site. Currently, Mr. Alvarez takes numerous pictures and videos from his phone. A mobile version of the system would facilitate the process of quickly recording the information while on-site and away from a computer. However, this application would be Mr. Alvarez's only use for the LLP app. He stated that a computer would be a more feasible method of finalizing the entry prior to submission. Mr. Alvarez recommends the development of a tutorial to inform new users how to operate the ReCORD system. The tutorial will assist in familiarizing potential users of the system and making it more likely for the employees to incorporate it into their working habits (Alvarez 2018).

5.1.5 Stakeholders

Three parties exist that will potentially interact with the ReCORD system. These individuals include are GDOT's offices of IT Application Support and IT Infrastructure, the ReCORD system users, and the system curator along with subject matter experts.

The offices of IT Application Support and IT Infrastructure play a major role in implementing the database and provides long-term technical support for the program. The long-term management of the program includes administrative issues such as updating the system and accessibility concerns.

The ReCORD database users include GDOT employees that are regularly involved in providing planning, design, and construction related support for projects. The users contribute to the lessons learned system by submitting new lessons, consuming published lessons, and providing feedback about the system. New lessons are realized by these users through their involvement on active projects. When an incident arises, it triggers the user to submit a form that will capture the lesson.

The curator and subject matter experts serve as a bridge for the information to be conveyed to users who are looking to retrieve information. They facilitate the knowledge transfer process by refining the raw information that is submitted by the users. The curator keeps track of the ReCORD database usage as well as the databases successes and shortcomings. The curator will be the first point of contact for questions or concerns regarding the ReCORD database.

5.2 Conceptual Design

A flowchart illustrating the input, curation, and notification/viewing processes of the proposed LLP is shown in Figure 20. The left-hand portion of the flowchart represents the raw data collection and its submission to the system curator. The central portion of the flowchart explains the refinement of the raw data through the use of the curation system. The right-hand portion of the flowchart depicts the notification and viewing process of a lesson learned once it has been published into the ReCORD system.

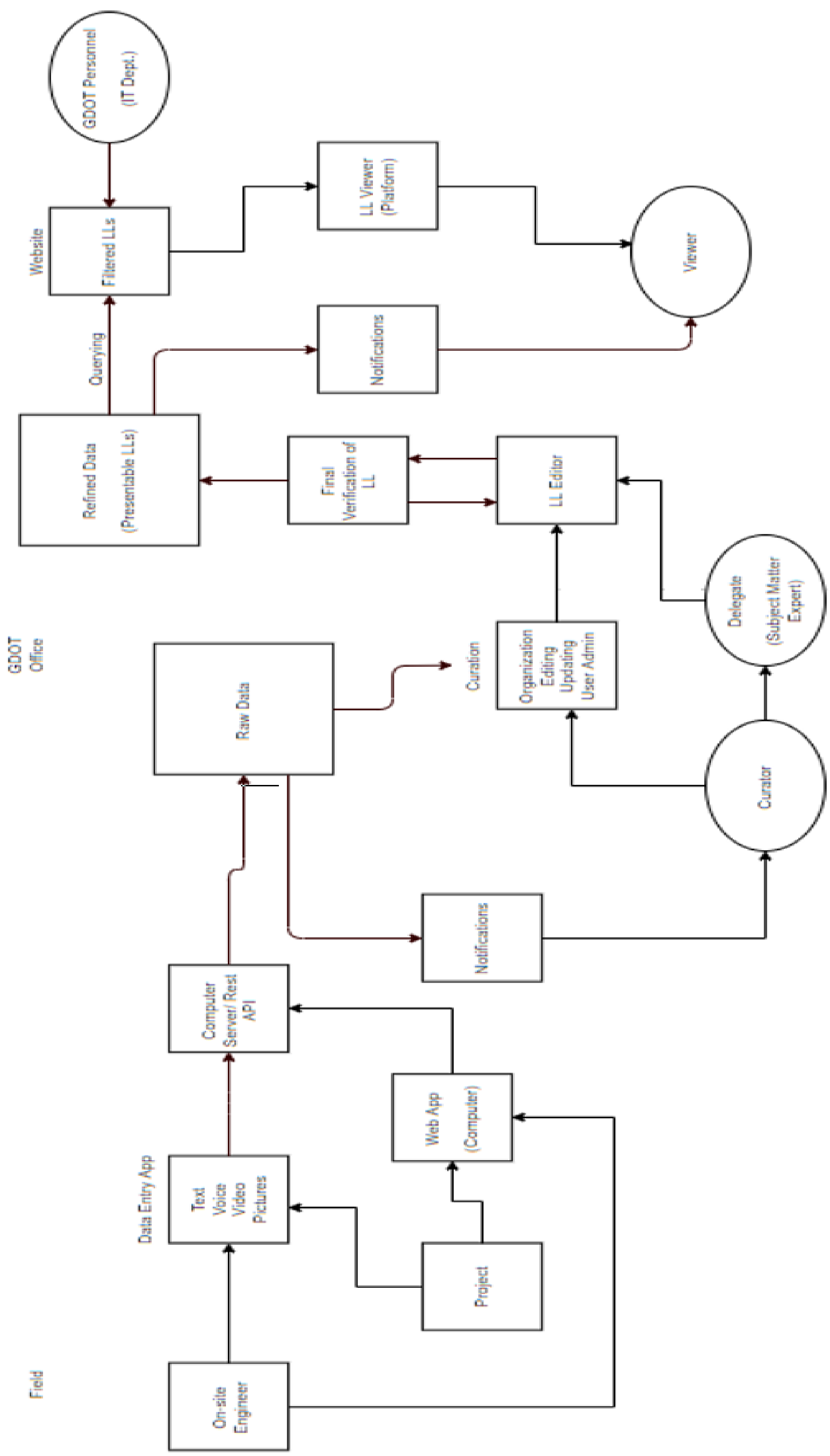


Figure 20 - LLP Flowchart

The raw data collection occurs on-site where the lesson is first encountered. This process is shown below in Figure 21. The lessons learned system process is initiated when the lesson is realized while on a project. The project engineer enters information related to the lesson learned into either the ReCORD system mobile app or computer. While the LLP app will likely be the first response to a lesson learned, the will perform final edits on the lessons learned submission via computer. The app will be integrated with capabilities to take and upload photos, videos, or record sound clips. It is expected that these capabilities will be the features most used on the LLP app because it is simplest method for inputting this type of information through a phone or tablet while on the jobsite where the engineer may or may not have convenient access to a computer. Note that it is possible to start creating a lesson learned submission from the app, but then continue and submit it on a computer.

During the initiation of a lesson learned submission, the user will be tasked with entering project information, incident description, lesson learned, and suggested topic tags. A list of verified topic tags will be available; however, the user will have the option to suggest additional tags not included in the system. As previously mentioned, the submitter has the opportunity to include photos, videos, or sound clips into the ReCORD system. Additionally, the submitter will be asked to provide the project and incident location(s). After the submission of the lesson learned, it will progress through the Representational State Transfer Application Programming Interface (Rest API). The Rest API functions as the "brain" of the database and is capable of receiving input and processing requests. Afterwards, the data within the submission form is considered to be raw data consisting of only the information compiled and submitted by the site engineer.

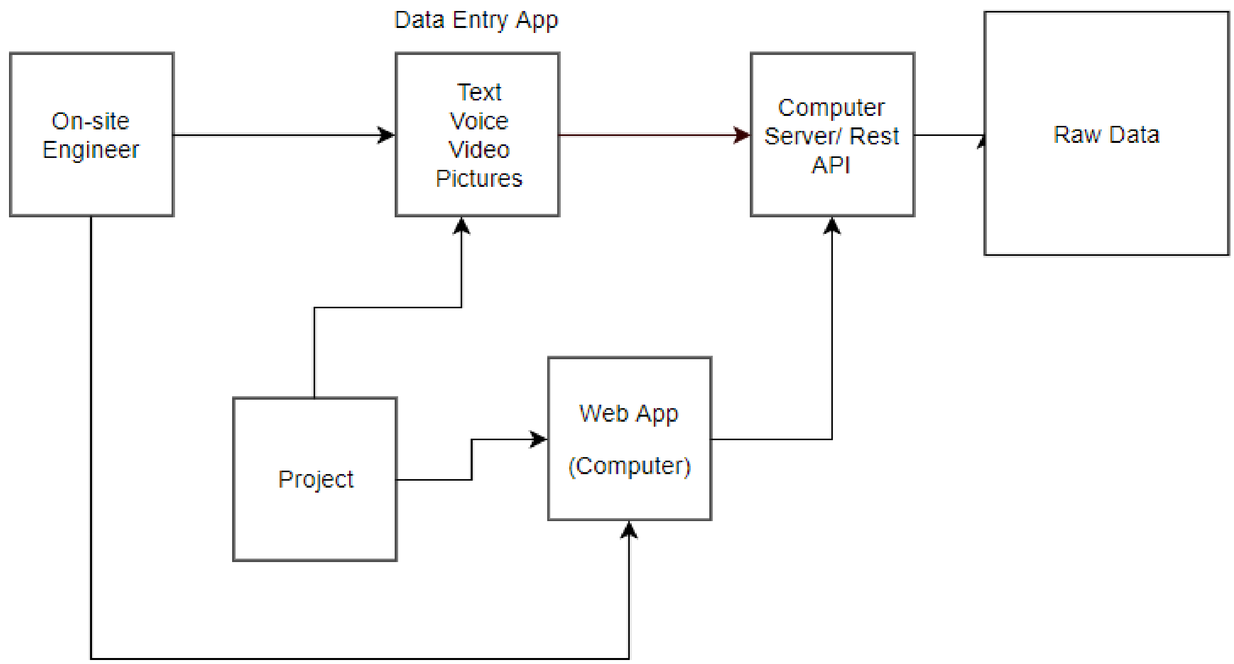


Figure 21 - Submission Process

Once the information is submitted by the user, the curator receives a notification of the newly submitted information and is given complete control to refine the raw data. Once the curator receives this information, the curation process begins. This is shown below in Figure 22. The curator is able to organize, edit, and update any information that they deem necessary. However, the curator is not alone in this task. There are subject matter experts (SMEs) to aid in this task. Each subject matter expert will have an area, or areas, of expertise for which the curator will consult his or her knowledge. Together, the subject matter experts and curator will refine the data by making the appropriate changes to the raw data within the LL editor until it is deemed fit for publication. Once the final edits are accepted, the lesson is now referred to as refined data and published into the ReCORD system. At this point it is viewable by all users of the ReCORD system.

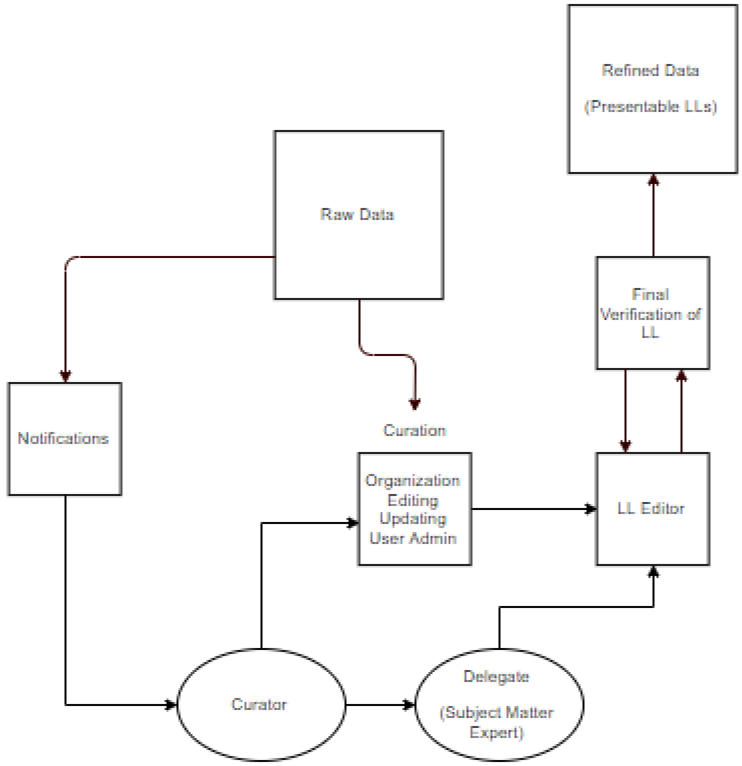


Figure 22 - Curation Process

Once the curation process is completed, the lesson is published into the database for viewing purposes. Upon publication, the notification system will take effect. This is shown in detail in Figure 23. The notification system is designed to proactively bring pertinent information to the viewer when a new lesson learned is available published into the system. Each ReCORD system user has a personalized profile that will include subscriptions to topic tags. When a user subscribes to a topic tags, they will be notified each time a new lesson with the associated topic tag is published. These notifications can be sent through email or text, depending on user preference. Additionally, the user has no limit to the number of topic tags that they can subscribe to. The notification will provide a convenient link that the user can utilize to directly access the newly published lesson learned within the lessons learned viewer.

The website is managed by the offices of IT Application Support and IT Infrastructure. This responsibility includes ensuring website is free of bugs and is running smoothly. At this time, the lesson will be accessible by all the users of the ReCORD system using the retrieval interface described in section 6.2.2.

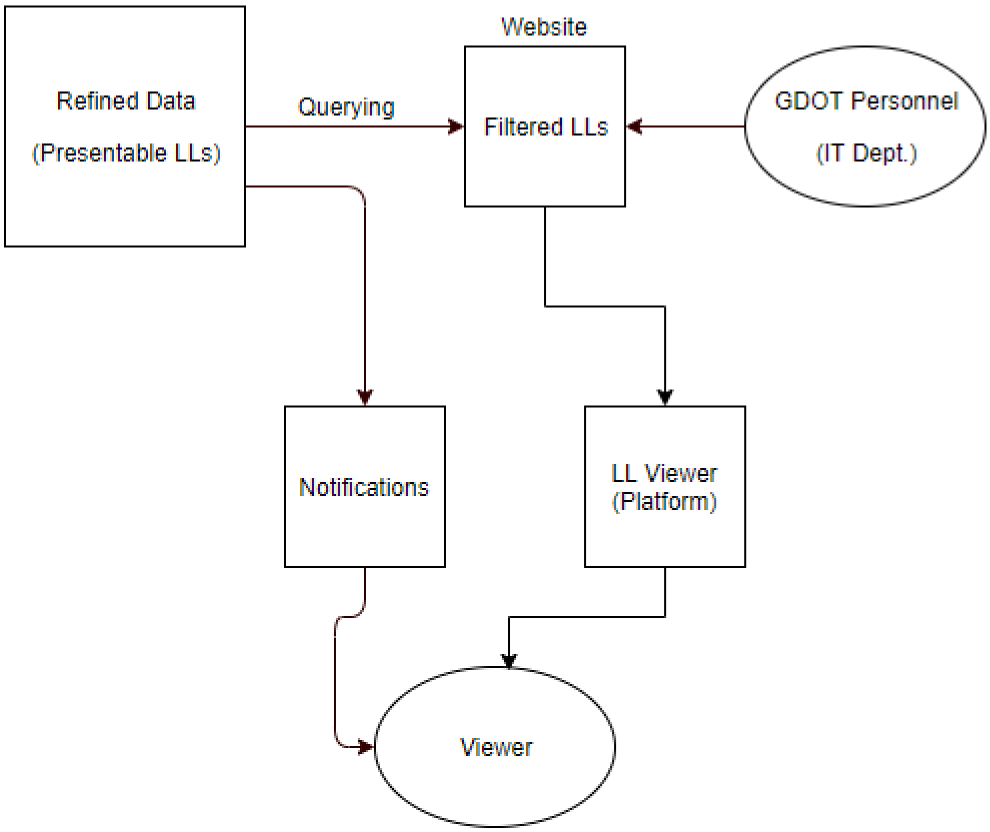


Figure 23 - Notifications and Viewing

5.3 Product Development

5.3.1 ReCORD Database Features

This section discusses the key features of the ReCORD system that will ensure its long-term use through effective documentation, storage, retrieval capabilities. The ReCORD system is designed to be user friendly in order to shorten the learning curve of the program.

5.3.2.1 Notification System

The major highlight of the ReCORD database is the use of a notification system that notifies system users when a new lesson related to their subject matter is entered into the system. Upon joining the ReCORD system, the user will subscribe to topic tags that are relevant to their field of work. When a lesson is newly published into the ReCORD database, the system users subscribed to the topic tag of a lesson and are notified through text or email such that the lesson can be viewed. Other users are able to search the newly published lesson in the database as well.

Each topic published within the ReCORD system will include at least one topic tag. As a result, the ReCORD database will send out notifications through email, text, or both, per the user's preference, regarding the availability of the newly published lesson. This attribute distinguishes the ReCORD system from other LLPs that have failed in the past due to a lack of consistent use. Notifications will keep users connected to the system and establish a habitual standard of practice for the LLP system which will in turn, will assist with the realization and implementation of lessons learned to support GDOT's decision making process at a project to project level.

5.3.2.2 Curation Process

The ReCORD system will be a living and interactive database that encouraging its users to submit new lessons to the program on a regular basis. This will enable the database to remain updated with common problems and successful solutions. However, not all lessons submitted to the database will be accepted. As described previously, a curation process will ensure that only lessons of high quality will be accepted into the ReCORD system. Each lesson will be individually reviewed and verified by the curator. In addition, a subject matter expert may be used for certain submissions requiring additional examination prior to publishing of the lesson. In the case of more complex lessons, a committee will be formed to aid the curator in the verification of the lesson. If the initial submission for the lesson does not meet the standard required for publication within the ReCORD system, the curator can send the submission back to the submitter asking for additional information or specific changes. This process is repeated until the curator determines that the lesson is acceptable or not for publication within the system.

5.3.2.3 GIS Capability

The ReCORD system has built in GIS capabilities that will be used to document the location of the lesson. The ReCORD database records both project location and location on the project site where the incident occurred (that triggered the lesson learned). Both locations are recorded in the case of large project sites that may result in substantially different conditions. The successes or failures of a method or procedure could be entirely dependent upon the location. For example, the soil conditions of Georgia vary significantly throughout the state. North Georgia is a mountainous region with steeper slopes and weak soils while south Georgia has characteristics of a coastal plain with more stable soil. Therefore, if a similar pavement project were designed and constructed in both north and south Georgia, a pavement performance issue may be encountered in north Georgia, whereas, no issue may exist in south Georgia. The ReCORD database's retrieval process features the use of an interactive Georgia map. This map will have layers for the counties in Georgia as well as the GDOT district boundaries. The user has the ability to toggle the layers on and off, based on preference.

5.3.2.4 Mobile Application

The ReCORD system will have app capabilities such that field personnel will be capable of entering lessons and information through their mobile devices. This process will help to eliminate the loss of information between the occurrence of the event that created the lesson and the when the information is recorded. The ReCORD system will have the capability to receive pictures, sound files, and video files to aid in the task of effectively communicating the lesson. The mobile app will be utilized as a first response tool to quickly document lesson learned information. The mobile app will have built in multimedia capabilities such as the capacity to record videos, audio clips, and take pictures. It is expected that the users will finalize their LL submission on computer, but the app is provides a first response, convenient method of instantly documenting information on site.

5.3.2.5 Miscellaneous Options

Additionally, the viewed lessons will have an associated cost estimate with links or reference to relevant codes or specifications that provide further guidelines on the subject matter. The cost estimate will help to quantify the importance of the specific lesson by illustrating the monetary value (savings or costs) associated with the lesson learned. Links to the relevant codes or specifications will include internal (GDOT) and external (AASHTO, other) sources. This attribute will add credibility to the lesson and further provide assistance to users in need of additional pertinent information. By connecting the ReCORD system with supporting information such as codes and specifications, to a degree the validation and accuracy of the lesson learned has occurred. Furthermore, links of other relevant lessons will be provided for the viewer to give the option of delving into more other similar information. This process is similar to Amazon's tactics of displaying items under the heading "Customers who bought this item also bought…".

5.3.2.6 Suggestions and Feedback

The ReCORD system will be a dynamic system allowing for the opportunity for future improvement. Each lesson will include a section for users to rate the validity and usefulness of the lesson with the option for the user to record comments and suggestions. Additionally, there will be a suggestion box for the ReCORD system. This suggestion box will be an anonymous submission that allows users to submit comments, recommendations, or concerns regarding the operation and functionality of the ReCORD system. The suggestion box use will encourage more people to use the system. Individuals are more likely to use a product if they feel like they have contributed to the improvement of its functionality. This feedback is reviewed and taken into consideration by the system curator. The ReCORD system is created for users, and therefore, the priority is to meet their needs.

5.4 Testing and Evaluation

After the ReCORD system was completely built, its performance was tested and evaluated. This testing and evaluation occurred in two phases: the University of Georgia (UGA) / Savannah State University (SSU) testing and evaluation and the GDOT testing and evaluation. The UGA/SSU testing phase occured first to ensure that the ReCORD system is performing up to GDOT standards. When the preliminary testing phase finished, the database was handed over for GDOT to do similar testing to evaluate and compare results.

5.4.1 Preliminary UGA/SSU Testing

11 Students participated in the UGA/SSU preliminary testing; 6 students from UGA and 5 students from SSU participated. This was a preliminary test that was performed with the

information readily available. All of the participants used the same CDOT drainage lesson learned from section 2.1 to evaluate the ReCORD system's performance. Along with personal login information, each of the participants was sent three files: A submission guide for draft lessons, the trial test sample information, and a JPG image. All of these files can be found in Appendix A.3: UGA/SSU Trial Testing. Note that the lesson address was input as a UGA building because the database was not made to accommodate locations outside of the state of Georgia. After the students completed the trial test, they were each asked to complete a survey through Qualtrics. This survey can be found in Appendix A.3.4: Qualtrics Survey. As the final step of the evaluation process, the students were asked to elaborate on their survey answers. The SSU students recorded their explanations in a word document while the UGA students were each personally interviewed. Note, Question #2 of the survey asks about the system's technical functionality. Technical functionality refers to how well the system works from a coding standpoint i.e. links are working correctly, the website is responsive, absence of technical errors or bugs, etc. Question #3 of the survey asks about the intuitive flow of process. This refers to the order in which the fields are listed. Question #4 of the survey asks about accessibility, referring to the location of system commands. If the commands are conveniently located and do not require an excessive amount of navigating to use, the system accessibility is considered satisfactory.

5.4.2 GDOT Trial Testing

The GDOT testing phase included a curator and a project manager from all 7 Georgia districts. Two professional engineers from GDOT's Office of Construction acted as the curator for the trial test. The project managers were each from a different GDOT district. Each of the project managers were tasked with inputting a lesson learned into the submission interface as well as finding and viewing it in the retrieval interface as well as testing the notification system. These lessons were real lessons that had occurred within each of the project manager's line of work, unique to each project manager. The project managers were given login information for the ReCORD system in order to receive notifications to test the retrieval portion of the system. The curator was given access to the ReCORD system after the projects were already submitted into the system. The curator was tasked with editing each of the projects and finalizing them for publication. This testing process occurred over the course of 3 weeks.

In order to properly capture the feedback from the project managers and curator, a survey was sent out. The survey requested information on how each individual believed each of the ReCORD system features were performing as well as an open-ended portion that requested additional feedback such as comments, recommendations, and concerns.

Work in Progress.

The aim of the GDOT testing phase was to optimize the simplicity of the ReCORD system for the sake of its users. The goal was to make processes as intuitive and as simple as possible to increase user retention. The importance of each contractor using their own unique project helped to analyze the effectiveness of the ReCORD system on a wider scale. The testing of these unique projects were expected to identify missing elements that were not brought to light by the UGA testing phase.

6.0 EXPERIMENTAL RESULTS

This section documents the products of the ReCORD system and its trial test results. It includes details regarding the system interfaces and its uses. The trial tests were conducted in order to verify the performance of the system's features and processes before implementation into GDOT's network.

6.1 Creation of ReCORD System

6.1.1 System Requirements

The programming platform of the ReCORD database was created through the use of Java and MySQL. JavaServer faces is responsible for the display of information while Java Servlet is the "back end" of the system. The term "back end" refers to the processor or "brain" of the system, and it is also the connection between JavaServer faces and MySQL. MySQL is used to store the data. The user only interacts with JavaServer faces and does not have access to Java Servlet or MySQL. For example, when a user inputs a search query, it will be submitted through JavaServer faces. JavaServer faces relays the message to Java Servlet which then retrieves the appropriate information from the MySQL database. Java Servlet then relays the information back to JavaServer faces, which displays the information to the user.

6.2 System Interfaces

Three different interfaces were designed for the ReCORD system. The submission interface was created to be used by individuals submitting a new lesson learned into the database. The retrieval interface was for users retrieving and viewing the lessons learned. The curator interface was developed to be used by the curator allowing for the collection of raw data. Furthermore, the curator will be able to edit the lessons learned before publication through this system interface.

6.2.1 Submission Interface

The submission interface is accessed by users to enter lessons into the ReCORD system. Users access this interface by either using the "submit new lesson" link on the GDOT website or by opening the ReCORD database itself and navigating to the tab "Creation" => "Create Draft Lesson". The first part of the interface is shown in Figure 24.

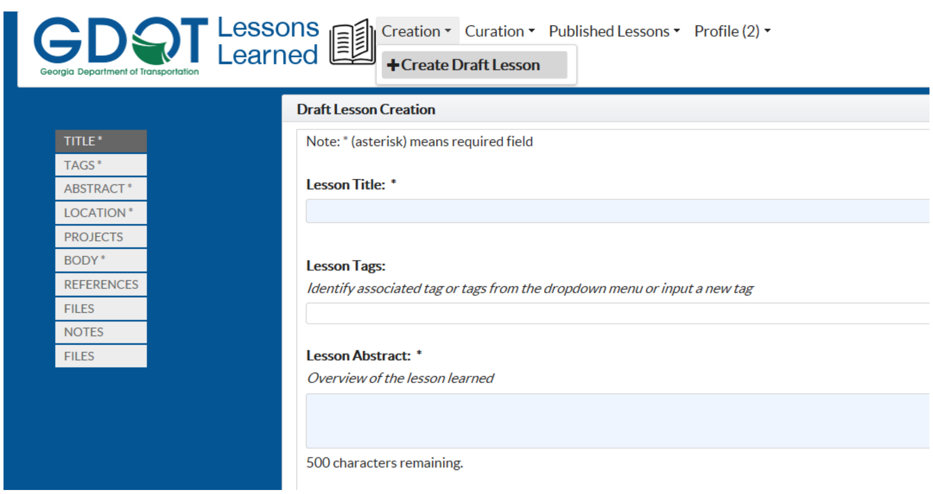


Figure 24 - Submission Form Interface I

This form includes a lesson title, lesson tags, lesson abstract, lesson location, the project/s to which the lesson is associated with, and the lesson learned. Fields that have an asterisk must be filled out before submission. The system user can utilize the navigation bar on the left-hand side of the screen to quickly navigate between fields. Once a field is completed, its tab on the navigation bar will turn green and a check mark will appear to confirm its completion.

The “Lesson Tags” section is the key to the organization and distribution of the lessons learned. These tags serve as convenient, searchable labels for the lessons learned. More importantly, the notification system is based upon the topic tags: users subscribe to topic tags and will get notifications when a lesson with their topic tag subscription is published. A list of topic tags will be managed by the curator. A submitter will be able to choose topic tags from the list during the submission process as well as manually type in a topic tag if it does not already exist in the system. If the curator sees fit, they will add the new topic tag to the list and it will become a suggested tag for future submitters.

The “Lesson Abstract” serves as a preview of the full lesson. The abstract will be an overall summary of the lesson learned that will help the database organize the lesson. The user is asked to write an abstract less than 500 characters, including spaces.

Figure 25 shows the “Lesson Location” and “Select Project to Associate” sections.

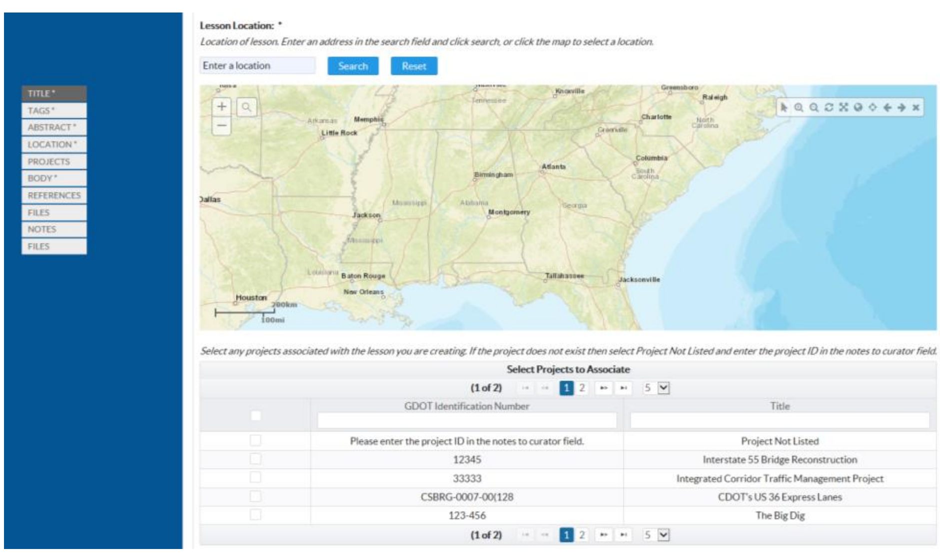


Figure 25 – Submission Form Interface II

The "Lesson Location" section asks the user to provide the location of the lesson. This is done by entering an address into the text field or by clicking on the location on the map. If the user chooses to enter an address, they will need to click "search" after the address is input. A green marker will appear on the map, confirming the location. If the user chooses to select the location on the map, they will pinpoint the location on the map and click it. An address will appear in the text field, confirming the location.

The "Select Projects to Associate" section is used to associate the lesson with a project; each lesson must be associated with one project. Associating a lesson with a project communicates to the ReCORD system which lesson occurred on which project. The system allows for multiple lessons to be associated with one project such that multiple lessons can be learned from a single project. However, it is important that users submit separate entries per project. Thus, only a single lesson is allowed per entry. Doing so will simplify the process by avoiding having an overwhelming number of lessons within an entry. If the user cannot find the project in the list, they are instructed to select "Project Not Listed".

Figure 26 shows the "Lesson Body" and "References" text fields.

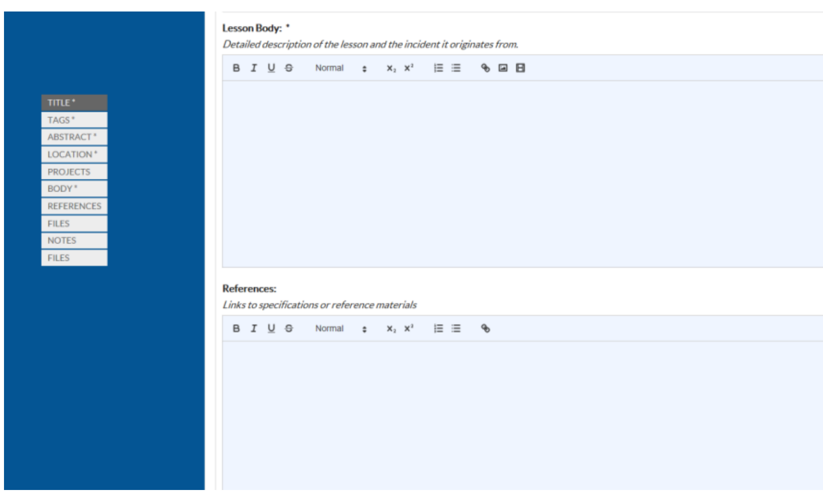


Figure 26 – Submission Form Interface III

The “Lesson Body” text field will include a description of the incident or incidents that triggered the lesson learned as well as a description of the lesson itself. The incident description allows readers to understand the circumstances leading up to the lesson learned, which potentially helps them identify similar situations in their own line of work.

The “References” text field allows the users to add links to more official guidelines and requirements such as a code, reference manual, or specification.

Figure 27 shows the “Notes to Curator” and “File Upload” sections

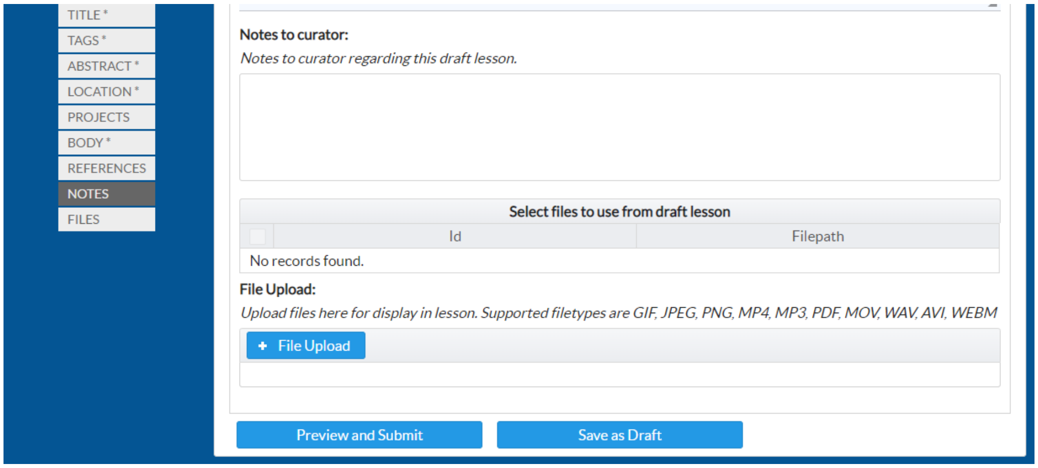


Figure 27 – Submission Form Interface IV

The “Notes to Curator” section allows the user to write any additional comments to the curator. If the user chose “Project not Listed” in the “Select Projects to Associate” section, this section must include the project name and description. The “File Upload” section allows the user to include any kind of media files with their lesson submission. This media could be in the form of JPEG, MP3, MP4, etc.

6.2.2 Retrieval Interface

The retrieval interface is for users who wish to view published lessons. ReCORD system users are able to learn of published lessons through four avenues:

1) Push notification via email or text. (Passive)
2) Recommended lessons feed/ Top lessons (Passive)
3) Text search of the database (Active)
4) Visual (geographic) search of the database through the use of the map (Active)

6.2.2.1 Push Notifications

Each user has the opportunity to subscribe to lessons tags. When a user is subscribed to a lesson tag, they will receive push notifications when a lesson is published with the associated tag. The user has the option of receiving these push notifications through text message, email, or both. The push notification will include a link that will ask for login information, then gives the user direct access to the newly published lesson. This is a passive way that a user will be exposed to newly published lessons.

6.2.2.2 Lesson Feed

Another passive method of exposure is through the personalized lesson feed and the feed of most viewed lessons. **<u>Work in progress</u>**

6.2.2.3 Text Searching

Alternatively, users will be able to access a publish lesson by actively performing a text searching for it. A user will navigate to the "Published Lessons" tab and select "Search/View Published Lessons". This will bring up the text search interface. **<u>Work in progress.</u>**

6.2.2.4 Visual Search

Another form of active searching is a visual search. A user accesses this search function by navigating to the "Published Lessons" tab and select "Published Lessons Map". A Georgia map, including counties and GDOT districts is included within the retrieval interface. See Figure 28. These counties and district layers are toggled on and off by clicking under "show layers" on the left-hand side page. A viewing toolbar, located at the top right of the page, provides the user tools for panning, zooming, and general tools for controlling the view of the map. The map includes dropped pins for each published lesson within the ReCORD database. When a pin is clicked on, it shows a brief lesson description such that the user can determine whether the lesson is relevant to them. If so, the user may select to view the full lesson by clicking on a link. The user has the ability to filter lessons by county or GDOT district. These filters are accessed on the left-hand side of the interface.

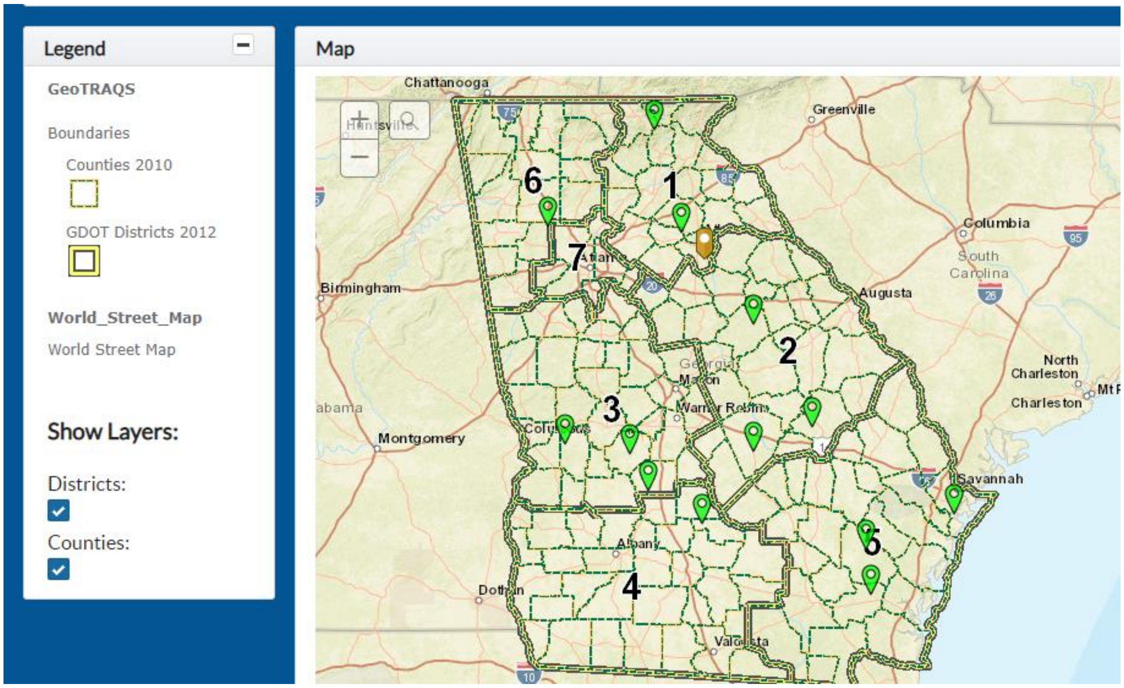


Figure 28 – Visual Search Interface

6.2.3 Curator Interface

The curator serves as the reviewer of the submitted raw data and approver for the published lessons learned to the ReCORD system. The curator is the bridge between the submitter's raw draft lessons and the published lessons for the lesson viewers. Therefore, the curator has complete access to all components and interfaces of the system in order to refine the raw data until it is suitable for publication.

6.2.3.1 Tag Approval

Lesson tags are important keywords that identify the lesson topic, and each lesson has at least one lesson tag. The primary function of the lesson tags is organization: the database archives the lessons based upon its lesson tags. These tags are also the basis of the push notification system.

The list of lesson tags is a dynamic list that the curator can edit at any time. The "Tag Approval" page is accessed by selecting "Curation" => "Tag Approval", as seen below in Figure 29.

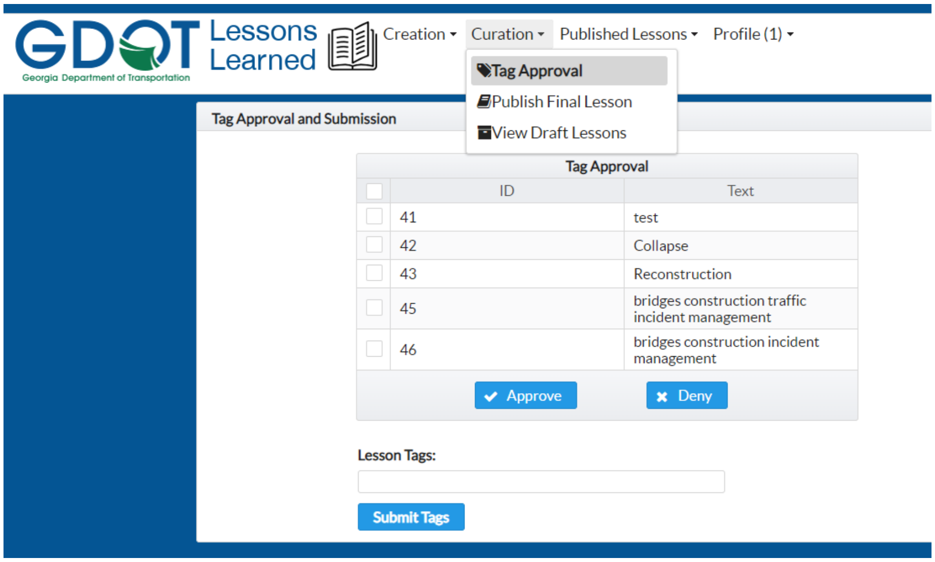


Figure 29 – Tag Approval

The table in the figure shows new lesson tags that have been submitted with draft lessons. The curator can click the checkbox to the left of each new tag and approve or deny it. If the curator chooses to approve the tag, it is added to the list of lesson tags and will be a suggested tag for users submitting new draft lessons. If the curator denies the tag, it is not added to the list. Below the table, the field titled "Lesson Tags" allows the curator to add new lesson tags to the list by clicking "Submit Tags".

6.2.3.2 Publish Final Lessons

This page is accessed by selecting "Curation" => "Publish Final Lessons". The curator uses this page make edits to the submitted draft lessons prior to publication. The page is shown below in Figure 30.

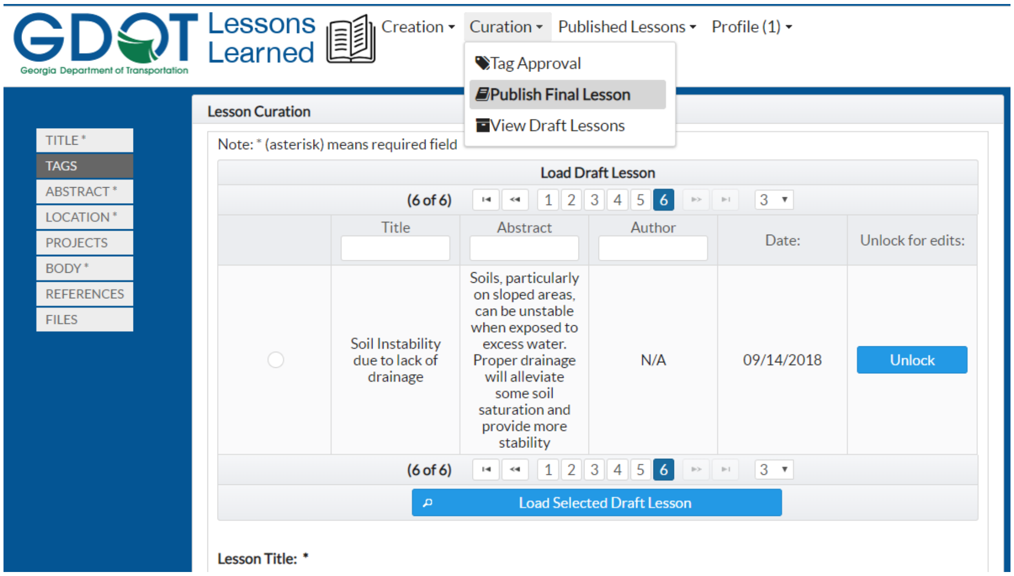


Figure 30 – Publish Final Lesson

The submitted draft lessons are shown in the table at the top of the page. Below the table is the same submission interface from 6.2.1. When the curator is editing or published a draft lesson, they will first select the draft lesson that they want to edit by selecting the checkbox next to the lesson. When the curator clicks on “Load Selected Draft Lesson”, the database will populate the below fields with the draft lesson that the user submitted. The curator can freely edit all the information. When the curator is finished editing the lesson, they will select the “Preview and Submit” option at the bottom of the page. After the curator confirms that the information is finalized, the final submission will publish the lesson into the database. At this point, users subscribed to the lesson’s lesson tags as well as the original submitter will be notified that the new lesson is available for viewing.

6.2.3.3 View Draft Lessons

The curator can access the “View Draft Lessons” page by navigating to “Curation” => “View Draft Lessons” as shown below in Figure 31.

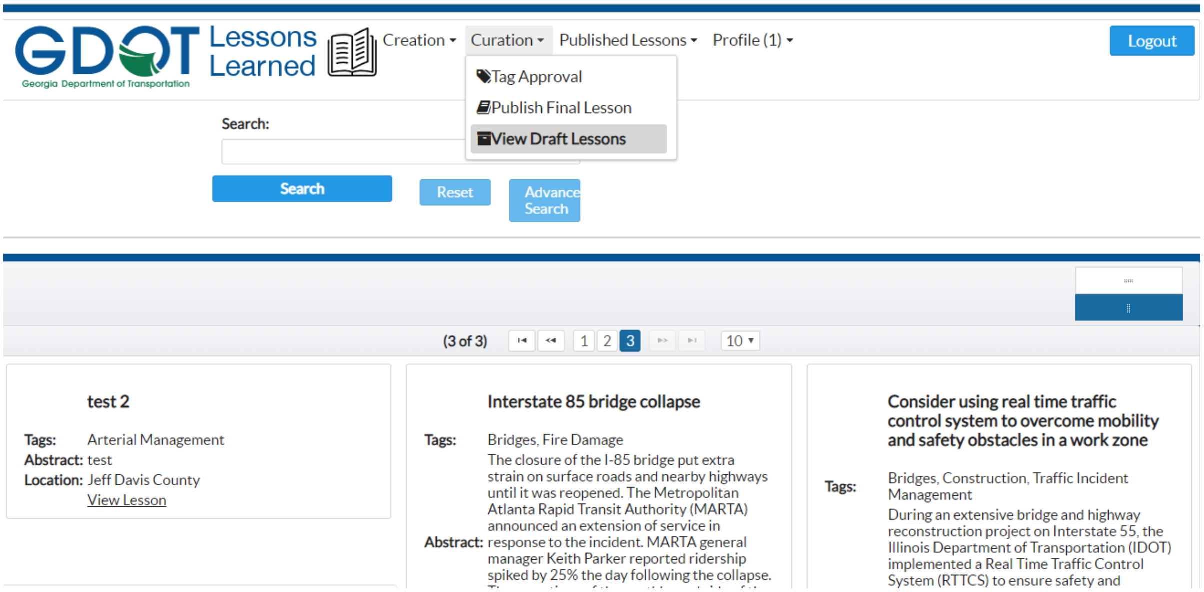


Figure 31 – View Draft Lessons

The curator uses this page to view submitted draft lessons. The search bar is used to search for specific keywords or phrases within the lessons. Alternatively, all of the submitted draft lessons are displayed below the search bar. The curator has the option to change the lesson viewer to compact view by toggling the options on the right-hand side of the screen, as shown in the image above. In order to see a lesson in its entirety, the curator will click "View Lesson" underneath the lesson that they wish to view. This will load a new tab wherein the lesson can be viewed.

6.2.4 Profile Interface

The profile interface houses all the personal user settings and customizations as well as tracking profile activity. Each user has their own personal profile, while the curator will have a unique profile interface.

6.2.4.1 User Profile

The user profile can be accessed by clicking the "Profile" tab, as shown in Figure 32.

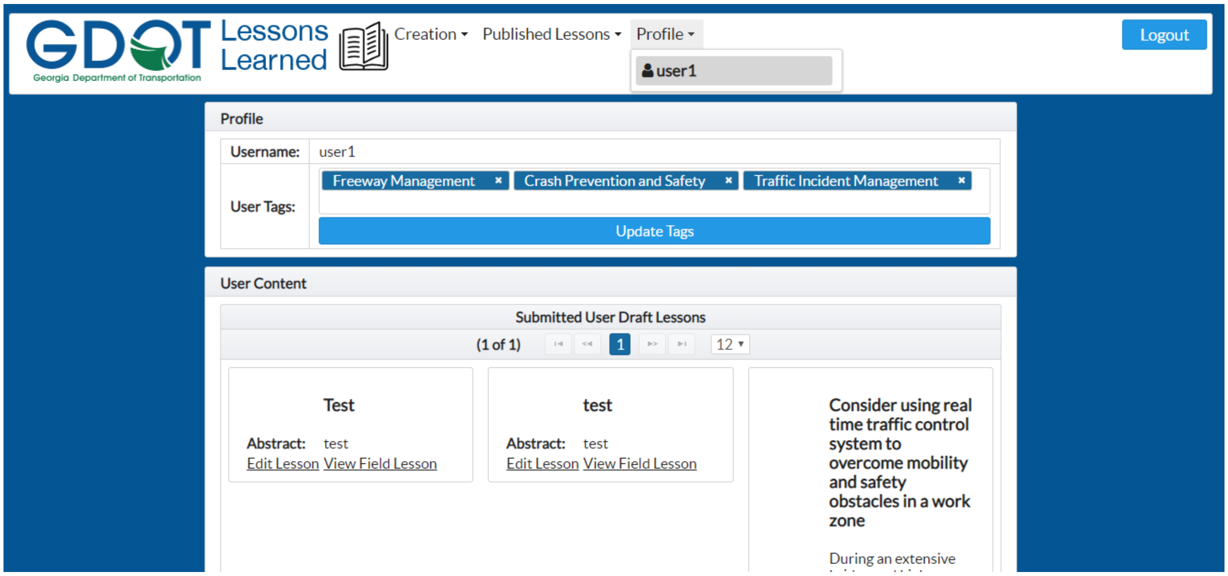


Figure 32 – User Profile

The user profile will include:

1) Editable list of the user's lessons tag subscriptions
2) View-only copies of draft lessons that the user has submitted
3) The user's submitted lessons that the curator has already published
4) Notifications for successful publications, messages from curator
5) Personalized feed of recommended published lessons based upon subscriptions

The field title "Lesson Tag Subscriptions" **(Work in Progress)** records all of the user's tag subscriptions. Whenever a lesson is published by the curator, push notifications are sent out to all users that have the same tag subscriptions as the new lesson. The user may add tags by typing in field, and the system will suggest existing tags. Alternatively, the user may unsubscribe to lesson tags by clicking the X next to the tag they wish to unsubscribe from. The user must click "Update Tags" to finalize the changes. Additionally, the user profile shows draft lessons that the user has submitted, published lessons that the user has submitted, notifications from the curator, and a personalized feed of recommended published lessons. **Work in Progress.**

6.2.4.2 Curator Profile

The curator's profile is accessed by navigating to the "Profile" tab, as shown in Figure 33.

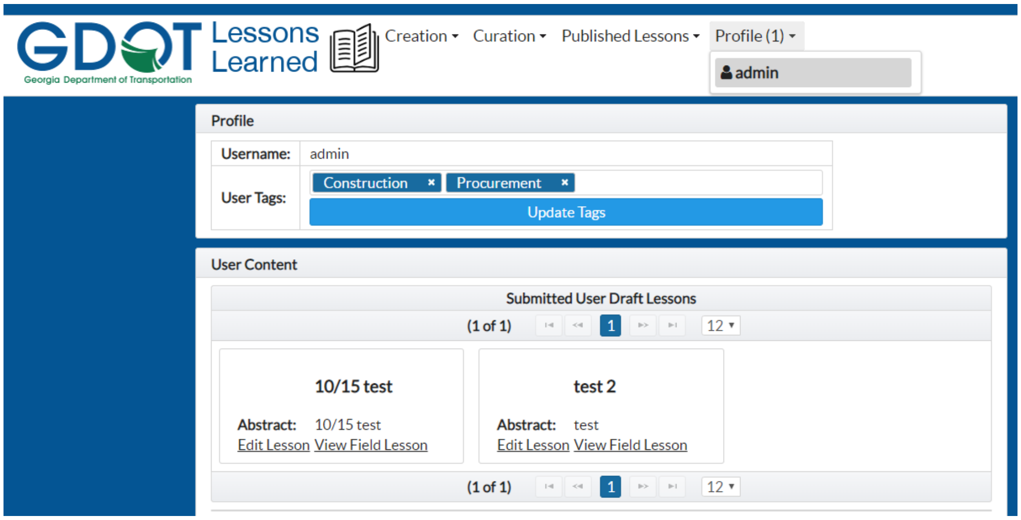


Figure 33 – Curator Profile

This profile page shows newly submitted draft lessons, notifying the curator that there are new lessons to edit and publish. **Work in Progress.**

6.3 Trial Testing Results

6.3.1 UGA/SSU Trial Testing

Figure 34, below, shows the results of the trial test survey.

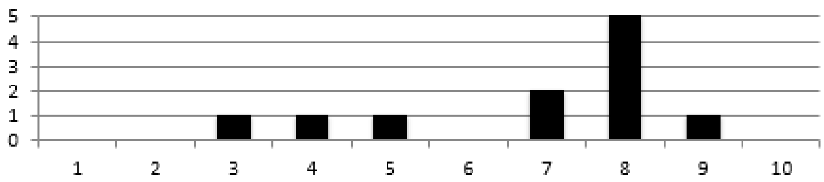
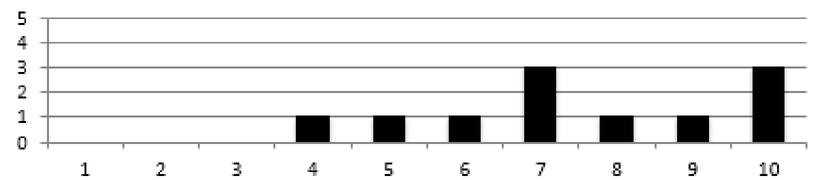
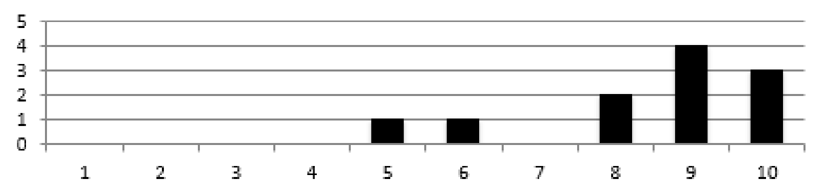
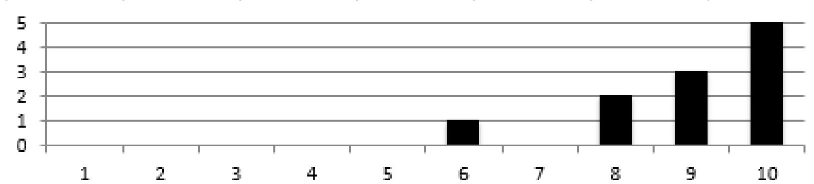
Item	N	Mean	Rating
Appearance	11	6.8	
Technical Functionality	11	7.5	
Intuitiveness	11	8.5	
Accessibility	11	9.0	

Figure 34 – UGA/SSU Survey Results

6.3.1.1 Visual Appeal

Key feedback regarding the visual appeal of the database included:

1) The textboxes are too wide and disproportionate, so it does not look appealing

2) Do not include all of the information on a single page. Each page should only include one field; this will give users a sense of progression and minimize the risk of the user accidentally skipping over a field.
3) Add a picture or any kind of visual to grab the user's attention
4) here is too much white space. Add a pictureThe interface needs contrast between the background and the textboxes

After evaluation of the suggestions, the follow changes were made per each suggestion:

1) The textboxes were centered and shortened width-wise.
2) No changes were made. Creating a different page for each field is too much work for the user to go through, and the user not have a sense of how much more is left to do.
3) The GDOT logo and an image of a book were added to the top of each page.
4) Images were added, See #3)
5) The textbox backgrounds now have a blue-grey tint.

6.3.1.2 Technical Functionality

Key feedback regarding the technical functionality of the database included:

1) The "Lesson Tags" did not allow for copy and pasting
2) Unable to access a saved draft lesson
3) No confirmation of a successful submission

After evaluation of the suggestions, the follow changes were made per each suggestion:

1) No changes were made. In this case, multiple tags were pasted into the field at the same time. The database cannot distinguish the end of one tag and the beginning of another.

However, this issue would not arise in practice because users will be typing in one lesson tag at a time.

2) A system bug did allow the users to access their saved draft lessons. This bug has been fixed
3) The database does confirm that a submission is successful, however the notification icon is not very noticeable. A successful submission will now load a new page that clearly confirms the submission.

6.3.1.3 Intuitive Flow

Key feedback regarding the intuitive flow of the database included:

1) The incident summary should be listed before the lesson abstract.

After evaluation of the suggestions, the follow changes were made per each suggestion:

1) The incident summary field was removed entirely. It was decided that the field was unnecessary and only served to confuse users. Instead, the user is asked to include the incident summary within the "Lessons Body" section.

6.3.1.4 Accessibility

Key feedback regarding the accessibility of the database included:

1) Separate links can be added to help the user navigate the submission interface

After evaluation of the suggestions, the follow changes were made per each suggestion:

1) Links for each field were added on the left-hand side of the screen. The user can use these links to quickly and conveniently navigate the submission interface. Additionally, the links will confirm the completion of each field. For example, when the user

completes the “Lesson Title” field, a green checkmark will appear beside the “Lesson Title” link on the left-hand side of the screen.

6.3.1.5 Navigation of Retrieval Interface

The final question of the survey asked the participant to navigate the retrieval interface to locate a specific published lesson. Then, the users were asked to find the latitude and longitude of the lesson. Every single participant correctly input these coordinates except for one student. There is adequate reasoning to believe that this was a typing mistake. The student correctly identified the latitude, but mistakenly changed a single digit of the longitude.

6.3.1.6 Additional Comments

Key feedback of the additional comments included:

1) In the “Lesson Location” section, the map should auto zoom to the location once the user inputs the address.
2) Under the field “lesson abstract” there is a character limit. The character limit includes spaces, this is not consistent with a word document, so it has the potential to cause problems.
3) This system will only work if the users are educated about it. They should be taught how to best absorb and utilize the lessons learned

After evaluation of the suggestions, the follow changes were made per each suggestion:

1) **<u>Work in Progress.</u>**
2) The comment is invalid. Word also has an option to count spaces as characters.
3) This is a true statement. Moving forward, this will be kept in mind.

6.3.2 GDOT Trial Testing

Work in Progress

7.0 DOT IMPLEMENTATION PLAN

The users of the ReCORD system must understand the expectations of the program. A GDOT employee is not expected to have no more than three new lesson learned entries a year. One or two new lessons learned each year is average. The system is not designed to be onerous for the submitters or users. Ultimately, the ReCORD system is meant to be a convenient and efficient resource for users. The ReCORD system implementation provides major benefits that will accumulate over time. Visibility of these benefits to system users will only reinforce the LLPs use and increase participation among its users. In part, the system benefits are based on the "pay it forward" mentality, where the work of past user submissions will serve to aid the work of those in the present. Similarly, the work that the users submit now will help those in the future. Potentially, this LLP may help to reduce future training as the lessons learned are readily available anytime, anywhere, to all departmental personnel limiting the need to provide specialized workshops on specific failures or successes.

When the users of the ReCORD system realize the benefits, they will be more willing to invest time and effort back into the system. Therefore, the key to a successful implementation is ensuring users are aware of the ReCORD system capabilities and the support it provides its users. Although, the ReCORD system will be widely available to its users, the system must be properly introduced through initial training. This training will provide a thorough understanding regarding how the database functions with the desire that its users implement the program into their daily routine.

ReCORD database orientation sessions will introduce and provide training on the system. Initially, training sessions could occur throughout the department (headquarters and district officers) to inform current employees on the database and its functionality. Additional training will be incorporated into GDOT's new employee training program. The sessions will serve to familiarize users with the system interface and demonstrate operations. Continually raising awareness and promoting the system will ensure the system remains visible to its users and continual use. In most cases, the system curator will lead the database training sessions. The ReCORD system works only as well as its use from participants. Thus, a clear and effective implementation will be critical.

8.0 CONCLUSIONS AND RECOMMENDATIONS

This study researched the development of a lesson learned database, known as the ReCORD system, to be used by GDOT. Other LLPs were studied in order to build the framework of the database, particularly NASA's lessons learned information system. Additionally, a state DOT survey gathered feedback from 33 state DOTs about the usage of LLPs for DOT construction. The database was programmed on Java and web-based. During literature review, it was found that most LLPs failed or lacked effectiveness due to lack of consistent use. In order to address the issue, the ReCORD system was built with an automated push notification system that notifies users of newly published lessons that involve a topic relevant to the user. Other LLPs failed due to poor lesson quality; users do not want to view poorly written lessons or useless lessons. In order to ensure that only high-quality lessons are published, the ReCORD system will have a curator review and edit lessons prior to publication. In order to evaluate the effectiveness of the ReCORD system, a two-part trial test was conducted. The first part of the trial test was conducted with students from UGA and SSU. These results suggested that the ReCORD system needed to be visually reworked. The second part of the trial test was with GDOT; project managers from varying GDOT field districts participated in the trial test, submitting draft lessons. GDOT also trial tested the curator interface by reviewing, editing, and publishing lessons. Each of the trial test participants completed a feedback survey and gave an interview. The feedback was evaluated and used to make modifications to the ReCORD system.

8.1 Recommendations

Based upon the results from the study, the ReCORD system will be most effective if there is continued promotion and education about the system and if the system is kept simple. A measure of success of the database is usage, especially long-term usage. In order for people to use the system, they must first understand how the system works and how it can benefit them. This will be done through the use of orientation sessions wherein the users are introduced to the system, shown the system's capabilities, and taught how to use it. These sessions will most likely be headed by the system curator, or individuals who are experienced in using the system. The orientation participants must understand the expectations and benefits. It is projected that any given user will not submit more than three draft lessons a year. Additionally, the users must understand that by submitting draft lessons, they are contributing to a huge pool of effectively organized information that will greatly benefit the community. Taking opportunity cost into consideration, the GDOT employees will not use the system, regardless of the benefits, if too much effort is required to use it. Therefore, another recommendation, moving forward, is to keep the processes as simple as possible. Generally, users do not want to learn complex system that will only be used on occasion. Concerning future changes and updates to the system, the users must be the priority. System capabilities must be designed in a way to cater to the users; as long as the users understand the benefits of the ReCORD system and are willing to put in the time to properly use it, the ReCORD system will flourish.

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10.0 APPENDIX

A.1: State DOT Survey Form

UNIVERSITY OF GEORGIA

The Georgia Department of Transportation (GDOT) in partnership with the University of Georgia College of Engineering is conducting research for the creation of a construction lessons learned expert system. The primary goal of this study is to create a versatile Road COnstRuction Database (ReCORD) system that enables GDOT to catalog past and current construction experiences and lessons learned through mobile application technology and cloud computing, such that designers and contractors may readily access information to better address construction-related issues. ReCORD is expected to operate as an entry/retrieval system whereby each user will have the capability of being notified of new entries that match their expertise or work area.

This survey is being conducted in order to gain a better understanding of how state DOTs use lessons learned programs, if any. We appreciate your time in completing the survey and input that may help us further this project. The survey should take no longer than 5-10 minutes to complete. If you have any questions, you may contact the project's principal investigator, Stephan A. Durham, Ph.D., P.E. at (303) 803-8031 or sdurham@uga.edu.

→

UNIVERSITY OF GEORGIA

YOUR DOT's USE OF LLPs

1) Does your Department of Transportation utilize a Lessons Learned Program (LLP) for construction?

Yes

No

1a) How is the LLP managed (excel spreadsheets, software, etc…)? Explain.

1b) How often and to what degree is the LLP used?

1c) Is the LLP system freely available both internally and externally within your DOT?

1d) Please select the individuals that are able to input Lessons Learned into the database.

- DOT Engineers
- DOT Inspectors
- DOT Construction Managers
- DOT Maintenance Personnel
- Contractor Reps
- Other

1e) Please select the individuals that are able to retrieve and view Lessons Learned from the database.

- DOT Engineers
- DOT Inspectors
- DOT Construction Managers
- DOT Maintenance Personnel
- Contractor Reps
- Other

Utilization of LLPs

For questions 2 through 5, rate your organization's level of agreement with the following statements:

2) An LLP is effective in facilitating and improving the construction process.

- Strongly Agree
- Agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Disagree
- Strongly disagree

3) An LLP in the form of an archivable construction database would benefit my organization and the work of my office or division.

- Strongly Agree
- Agree
- Somewhat agree

Neither agree nor disagree

Somewhat disagree

Disagree

Strongly disagree

4) The general contractors that my DOT typically works with would be receptive to regularly submitting "Lessons" into the construction database.

Strongly Agree

Agree

Somewhat agree

Neither agree nor disagree

Somewhat disagree

Disagree

Strongly disagree

5) Mistakes from previous construction (materials or procedures), which may occur due to a change in personnel or a lack of documentation, are often repeated.

Strongly Agree

Agree

Somewhat agree

Neither agree nor disagree

Somewhat disagree

Disagree

Strongly disagree

←

→

LLP Implementation

6) What challenges would your organization have in implementing an LLP for construction?

- Personnel with the inability to operate a mobile app
- Skepticism of using the LLP app
- Forgetfulness of using the LLP app
- Lack of project similarities to relate lessons learned
- Lack of LLP effectiveness
- Informing DOT personnel of the LLP implementation
- Other

← →

LLP Database Structure

For questions 7 through 11, rate your organization's level of agreement with the following statements.

---

7) The most effective form of documenting information for input into the database would be in increments throughout the project life cycle.

- Strongly Agree
- Agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Disagree
- Strongly disagree

---

8) It would be useful for each user of the database to have a profile with specific field interests such that they can be notified when a relevant "Lesson" is entered into the system.

- Strongly agree
- Agree

Somewhat agree

Neither agree nor disagree

Somewhat disagree

Disagree

Strongly disagree

---

9) It would be useful if the LLP database was accessible through mobile application technology and cloud computing such that field personnel are able to access it on the construction site.

Strongly agree

Agree

Somewhat agree

Neither agree nor disagree

Somewhat disagree

Disagree

Strongly disagree

10) It would be useful if the LLP database had capabilities of uploading and cataloging photographs of the lessons learned.

- Strongly agree
- Agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Disagree
- Strongly disagree

---

11) It would be useful if the LLP database had capabilities of identifying project locations using GPS.

- Strongly agree
- Agree
- Somewhat agree
- Neither agree nor disagree

Somewhat disagree

Disagree

Strongly disagree

---

12) Considering LLPs will be used by individuals from various regions, differing terminology may become an issue during the entering/retrieval process. For example, a process or piece of equipment could be referred to by multiple terms. As a user looking to retrieve information from the database, this can cause programs while searching key terms.

Would it be useful if the LLP system grouped terms of similar or exact meaning for both input and retrieval processes? (For example, searches for “mesh” would also show results for “welded wire reinforcement” and "welded wire fabric”).

Extremely useful

Moderately useful

Slightly useful

Neither useful nor useless

Slightly useless

Moderately useless

Extremely useless

13) Please provide any additional comments regarding LLPs terminology.

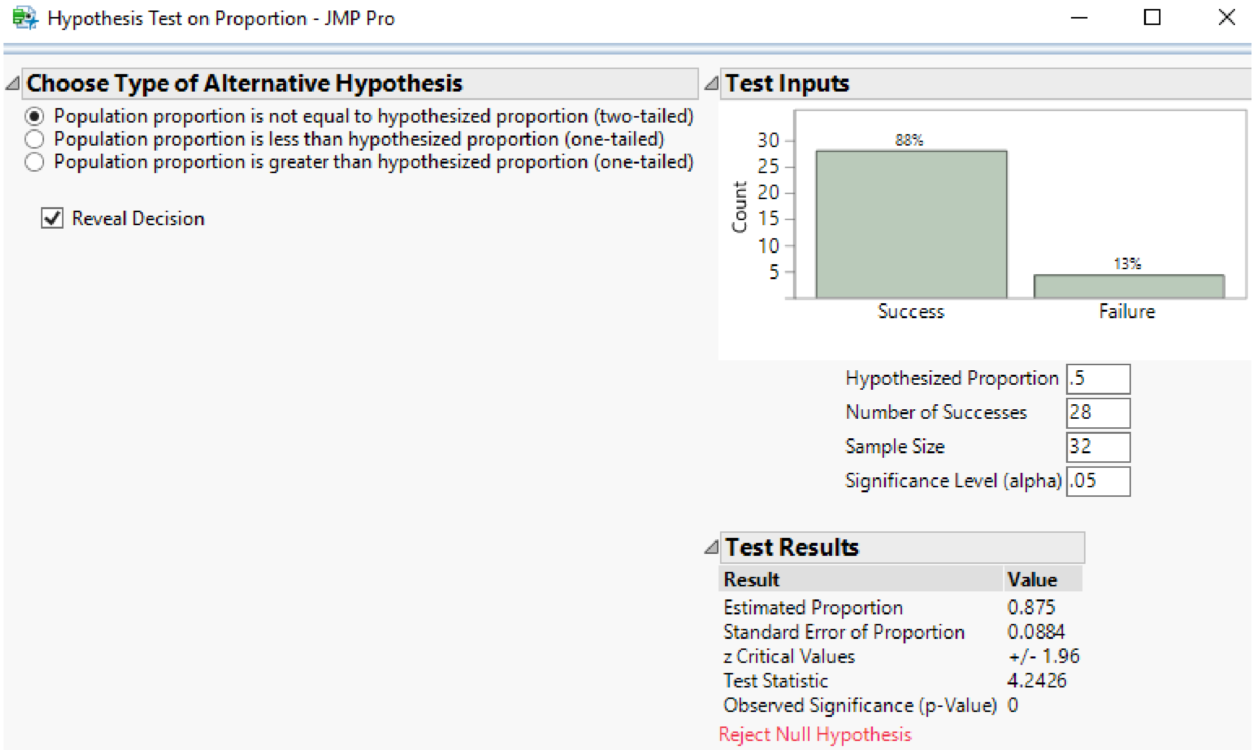
14) Please provide any additional comments that may be beneficial to our evaluation of LLPs in construction.

←

→

A.2: Statistical Analysis

Survey Figure 5 - LLP effectiveness in improving construction process



Survey Figure 6- LLP benefit to DOT and division

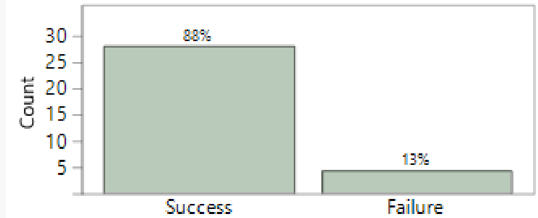
Hypothesis Test on Proportion - JMP Pro

Choose Type of Alternative Hypothesis

- (●) Population proportion is not equal to hypothesized proportion (two-tailed)
- ( ) Population proportion is less than hypothesized proportion (one-tailed)
- ( ) Population proportion is greater than hypothesized proportion (one-tailed)

☑ Reveal Decision

Test Inputs



Hypothesized Proportion	.5
Number of Successes	28
Sample Size	32
Significance Level (alpha)	.05

Test Results

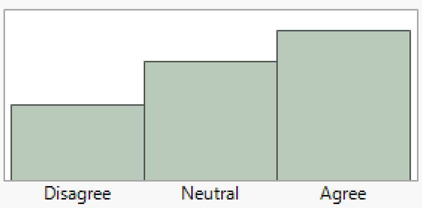
Result	Value
Estimated Proportion	0.875
Standard Error of Proportion	0.0884
z Critical Values	+/- 1.96
Test Statistic	4.2426
Observed Significance (p-Value)	0

Reject Null Hypothesis

Survey Figure 7- Level of Contractor receptiveness

Distributions

Column 1



Frequencies

Level	Count	Prob
Disagree	7	0.21875
Neutral	11	0.34375
Agree	14	0.43750
Total	32	1.00000

N Missing 0

3 Levels

Test Probabilities

Level	Estim Prob	Hypoth Prob
Disagree	0.21875	0.33333
Neutral	0.34375	0.33333
Agree	0.43750	0.33333

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	2.3941	2	0.3021
Pearson	2.3125	2	0.3147

Method: Fix hypothesized values, rescale omitted

Note: Hypothesized probabilities did not sum to 1. Probabilities have been rescaled.

Survey Figure 8- Are mistakes repeated?

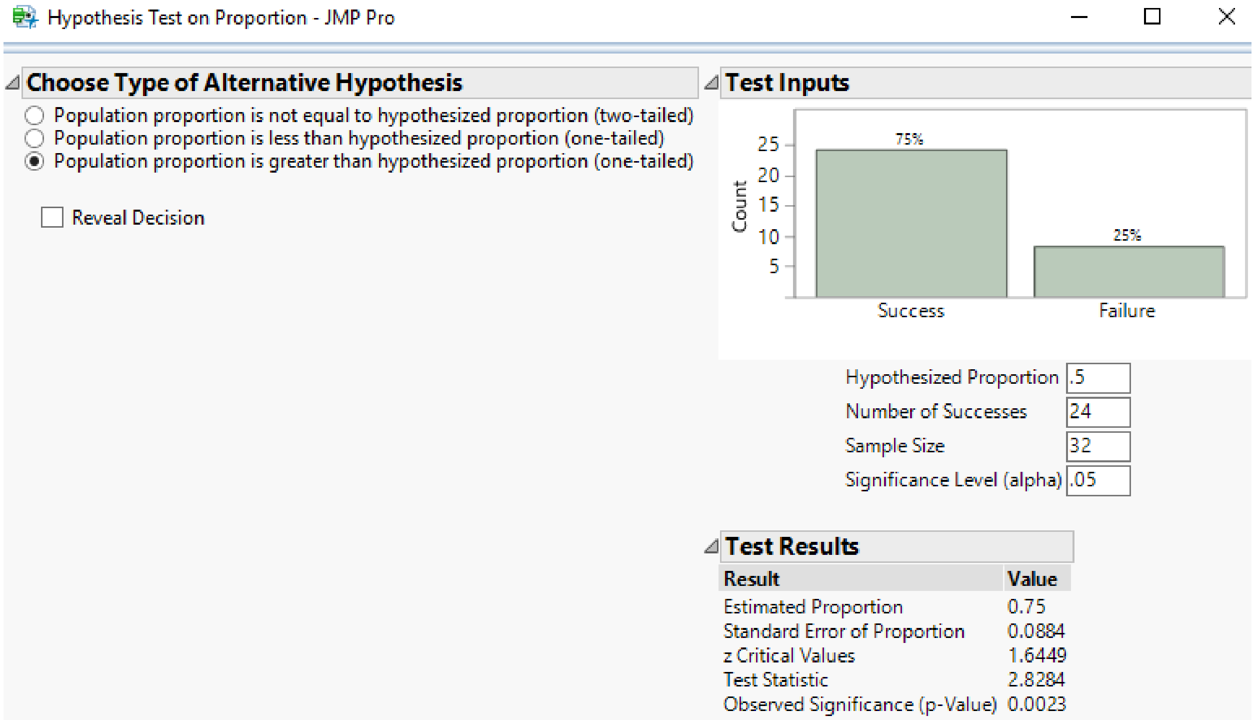


Figure 10- Documenting throughout life cycle

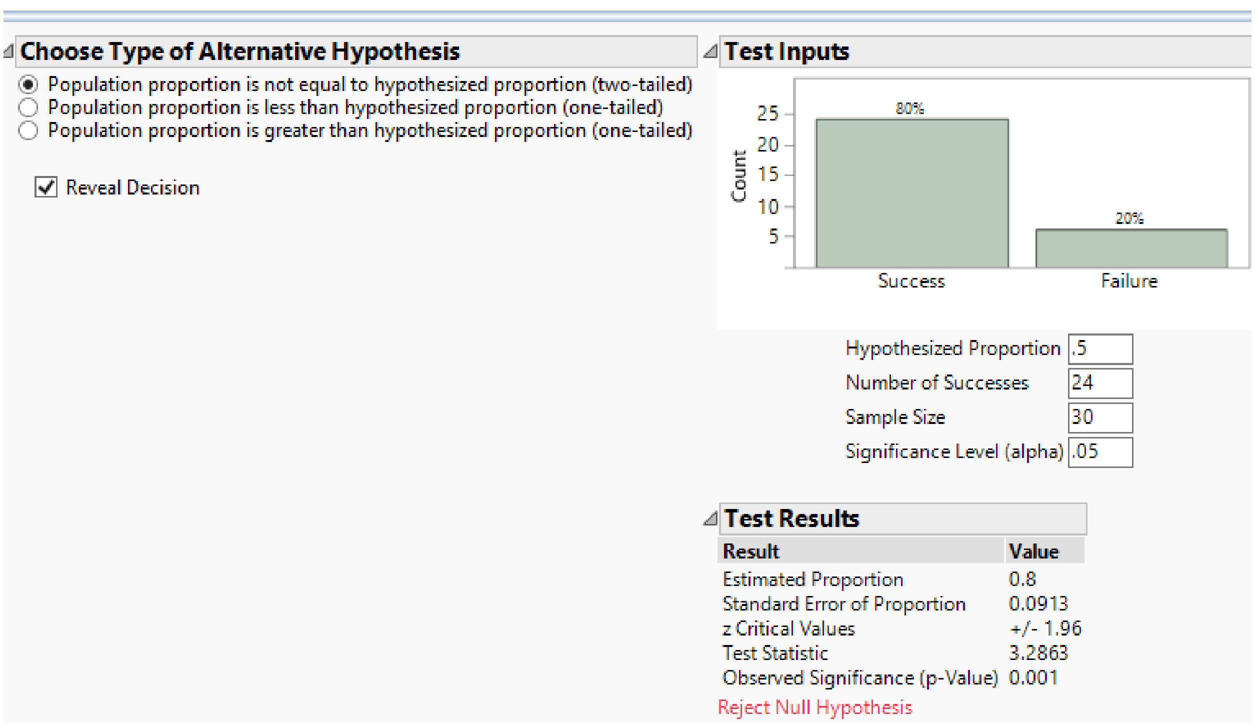


Figure 11- Usefulness of Push notifications

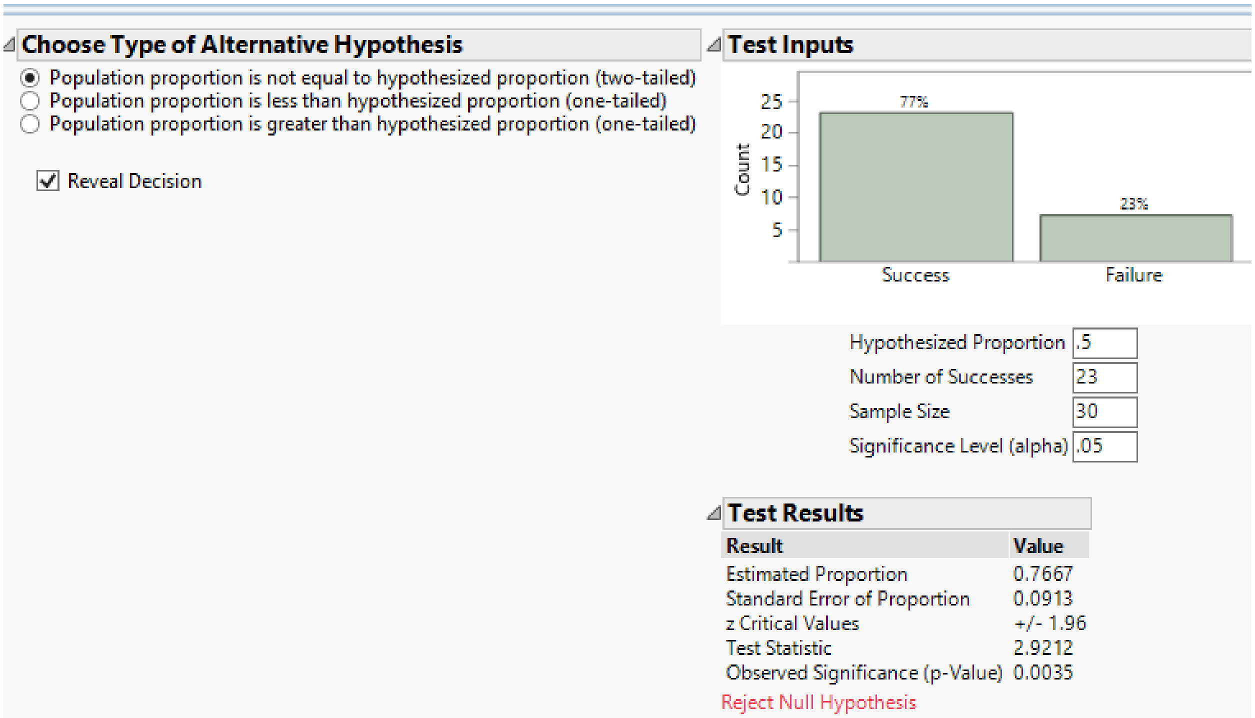


Figure 12- usefulness of mobile app technology

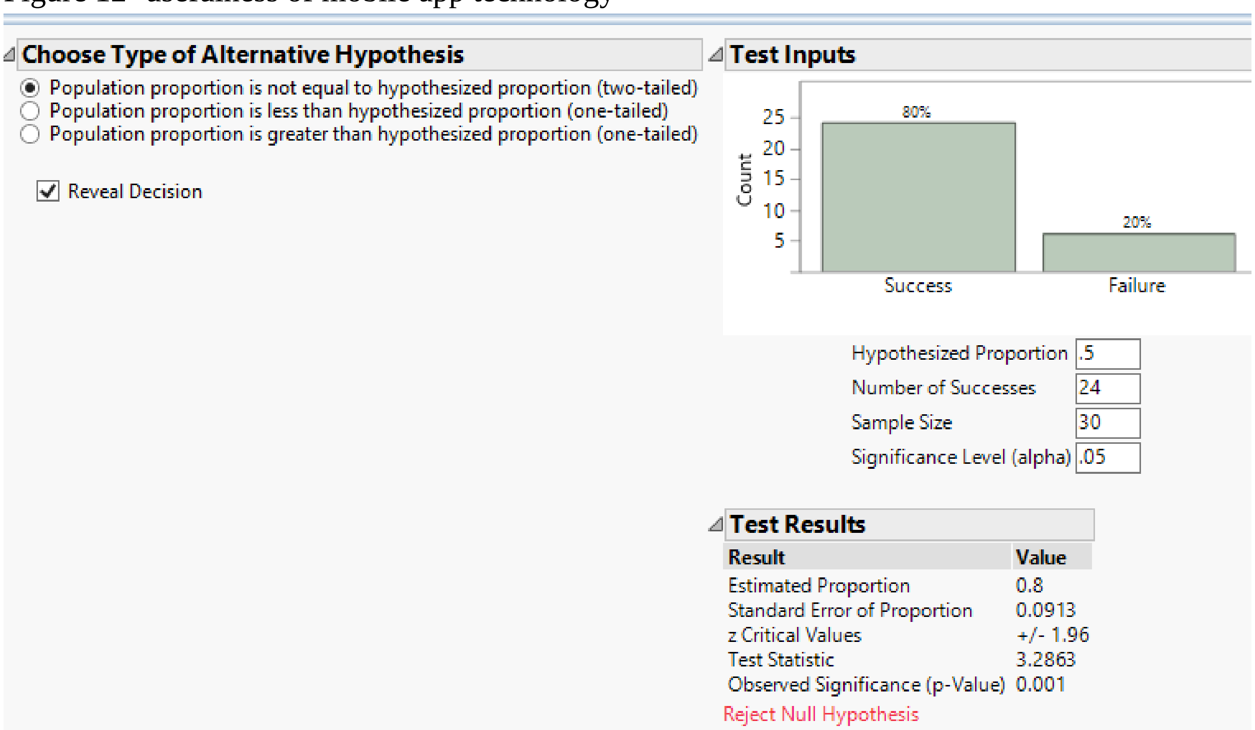


Figure 13- ability to upload and catalog photos and videos

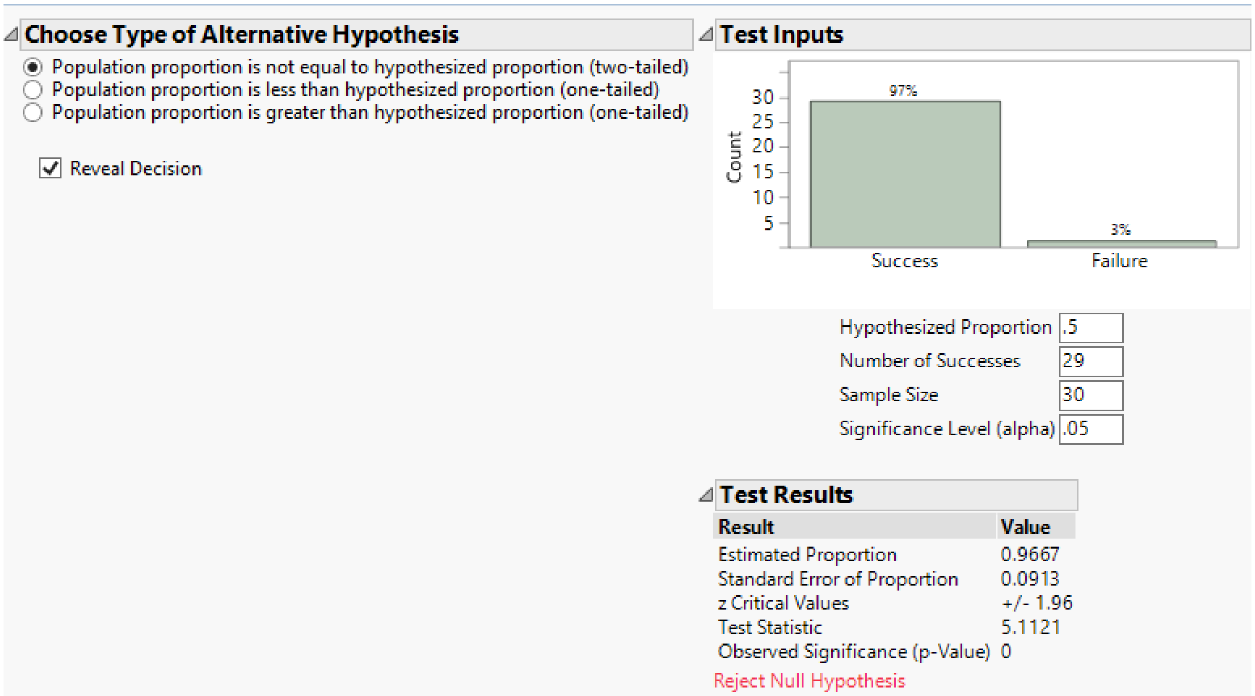


Figure 14- GPS capability

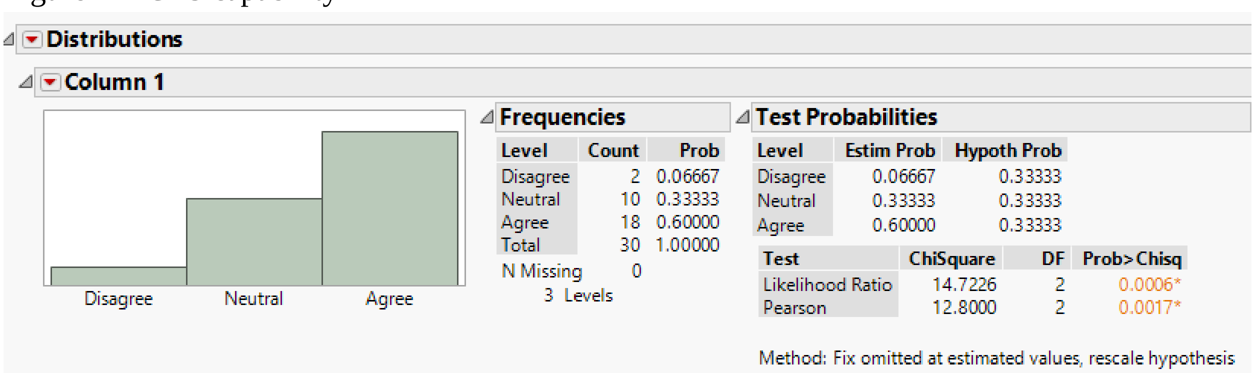


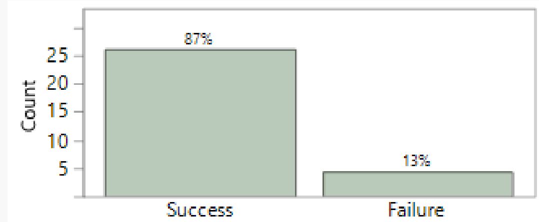
Figure 15- usefulness of common terminology

Choose Type of Alternative Hypothesis

- (•) Population proportion is not equal to hypothesized proportion (two-tailed)
- ( ) Population proportion is less than hypothesized proportion (one-tailed)
- ( ) Population proportion is greater than hypothesized proportion (one-tailed)

☑ Reveal Decision

Test Inputs



Hypothesized Proportion	.5
Number of Successes	26
Sample Size	30
Significance Level (alpha)	.05

Test Results

Result	Value
Estimated Proportion	0.8667
Standard Error of Proportion	0.0913
z Critical Values	+/- 1.96
Test Statistic	4.0166
Observed Significance (p-Value)	0.0001

Reject Null Hypothesis

A.3: Trial Testing

A.3.1: Submission Guide for Draft Lessons

Submission Guide for Draft Lessons

Your role as a submitter is to create and submit a draft lesson associated with a current or past project. This guide explains the steps you must complete to create a draft lesson in the GDOT Lessons Learned Database. Once you have created and edited a draft lesson, you will submit it to the system curator for review and approval. Once the curator has approved the lesson, it will be sent back to you for final review before it is published to the database system.

Procedure to Submit a Draft Lesson

Step #1 - Go to https://www.kpgoff.tech/GDOTLLP and log in with your GDOT credentials.

Step #2 - Use the **Creation** tab and select **Create Draft Lesson** (Figure 1).

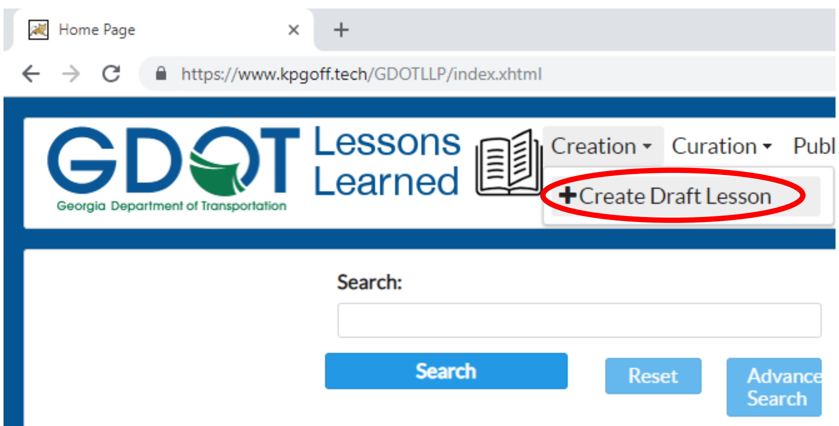


Figure 1 - Step #2 - Create Draft Lesson

Step #3 - Provide the following lesson information. Please note that all fields marked with an asterisk (*) are required.

a. **Lesson Title * -** Include a concise and descriptive title for the lesson learned.
b. **Lesson Tags** – Lesson Tags serve to identify the lessons related fields. Tags are the basis of the notification system and serve as an easy way to search for lessons. You can select tags from the dropdown menu or begin typing a tag name in the textbox. The system has an autocomplete function that will suggest tags that are already existing in the system. If a

tag does not exist, then you have the option of submitting a new tag. The curator will review your tag after submission of the draft lesson (Figure 2).

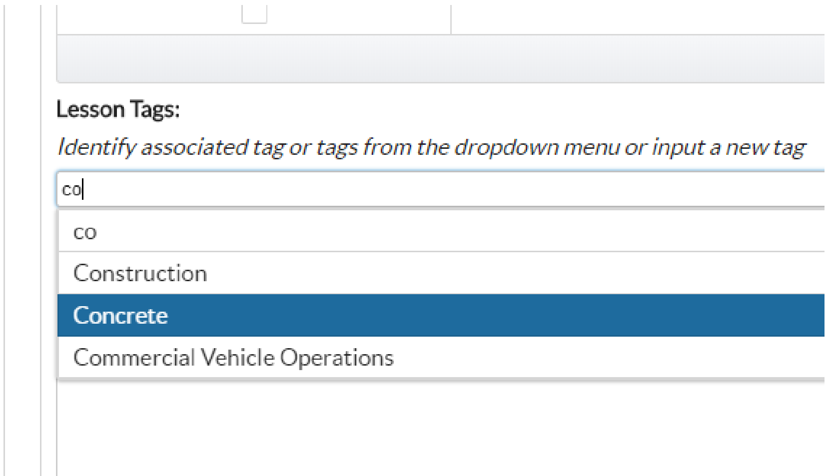


Figure 2 - Step #3b – Lesson Tags

c. **Lesson Abstract** * - In 500 characters or less, provide a description of the lesson learned.

d. **Lesson Location *** – The lesson location can be specified by inputting an address into the text box or by using the cursor to select a location on the map. The features on the right-hand side of the map may be used to navigate (Figure 3).

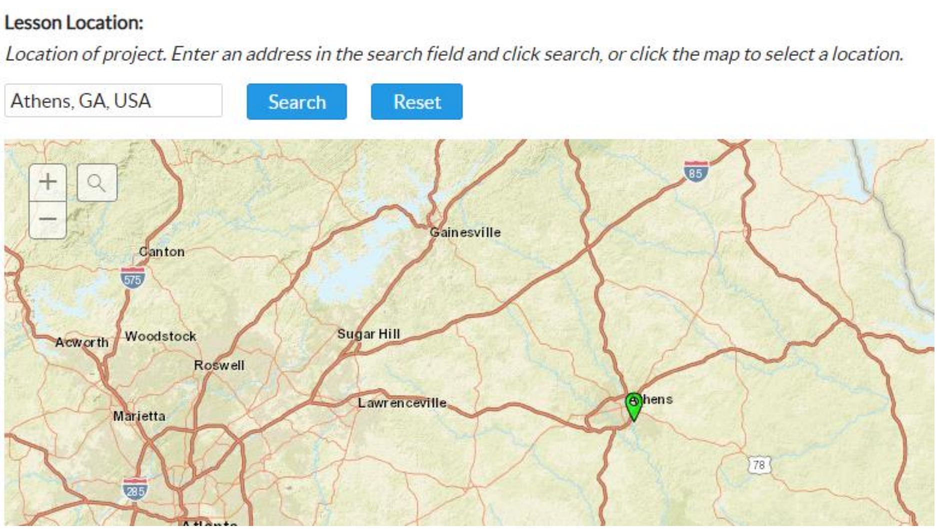


Figure 3 - Step #3d – Lesson Location Entry

e. **Select Projects to Associate** * - Select the project for which the lesson is associated. This is the project that the lesson originated from. Projects can be searched for by entering its GDOT Project Identification number or the project title. Project association is designated by clicking the check box to the left of the project ID. This will link the lesson with project information within the database. If the project does not have a GDOT Project Identification number, select "other" and use the **Note to Curator** field to inform the curator of the project title.

f. **Lesson Body** * - Describe the event or series of events that triggered the lesson. This will inform users of the circumstances leading up to the lesson. Provide detailed information on the lesson learned from the incident. Be specific! You can also provide photos, videos, or audio clips in the next section.

g. **References** – Relevant GDOT specifications or codes that address the issues discussed within this lesson should be entered in this section. Text and website links can be added in this section.

h. **Notes to Curator:** Use this field to provide the project information if your project did not appear in the "Select Projects to Associate" list from above.

i. **Upload** – Reports, pictures, videos, voice recordings, drawings, and other project related files may be uploaded to support the lesson summary. Files may be uploaded by clicking on File Upload. Then, click Upload to finalize the media upload (Figure 4).

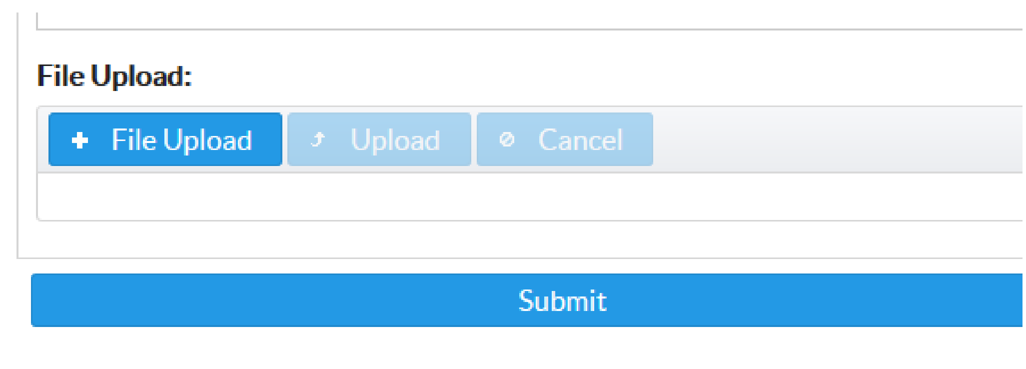


Figure 4 - Step #3h – File Upload

Step #4 - Submit the Draft Lesson.

Step #5 – After the initial submission, the curator will review and make edits. Once finished, you will be notified and given 2 business days to approve or request changes before the lesson is automatically published.

Step #6 – Submission Process Complete!

A.3.2: Trial Test Sample Information

Disclaimer: The information in this document is for the purpose of testing only. Most of the information is imported from legitimate sources, but some of the information is simplified for the purpose of convenience or system trial testing.

Thank you for your willingness to participate in this trial test. The research team appreciates your valuable time and intends to make the most of it. Please follow the instructions in the "Submission Guide for Draft Lessons" document and use the following information to fill out the fields. (You are welcome to copy and paste, if that is convenient for you)

Lesson Title: Consider using real time traffic control system to overcome mobility and safety obstacles in a work zone.

Lesson Tags: Bridges, Construction, Traffic Incident Management

Lesson Abstract: During an extensive bridge and highway reconstruction project on Interstate 55, the Illinois Department of Transportation (IDOT) implemented a Real Time Traffic Control System (RTTCS) to ensure safety and mobility during construction. The system successfully monitored traffic along the busy interstate between Springfield (the state capital) and St. Louis, the location of a busy airport serving southern Illinois and eastern Missouri.

Incident Summary: Due to significant traffic backups and higher than average rates of traffic violations during the Interstate 55 bridge reconstruction project, the need for an extra safety measure was required.

Lesson Location: 45 Baxter St, Athens, GA 30602

Select Projects to Associate: Interstate 55 Bridge Reconstruction

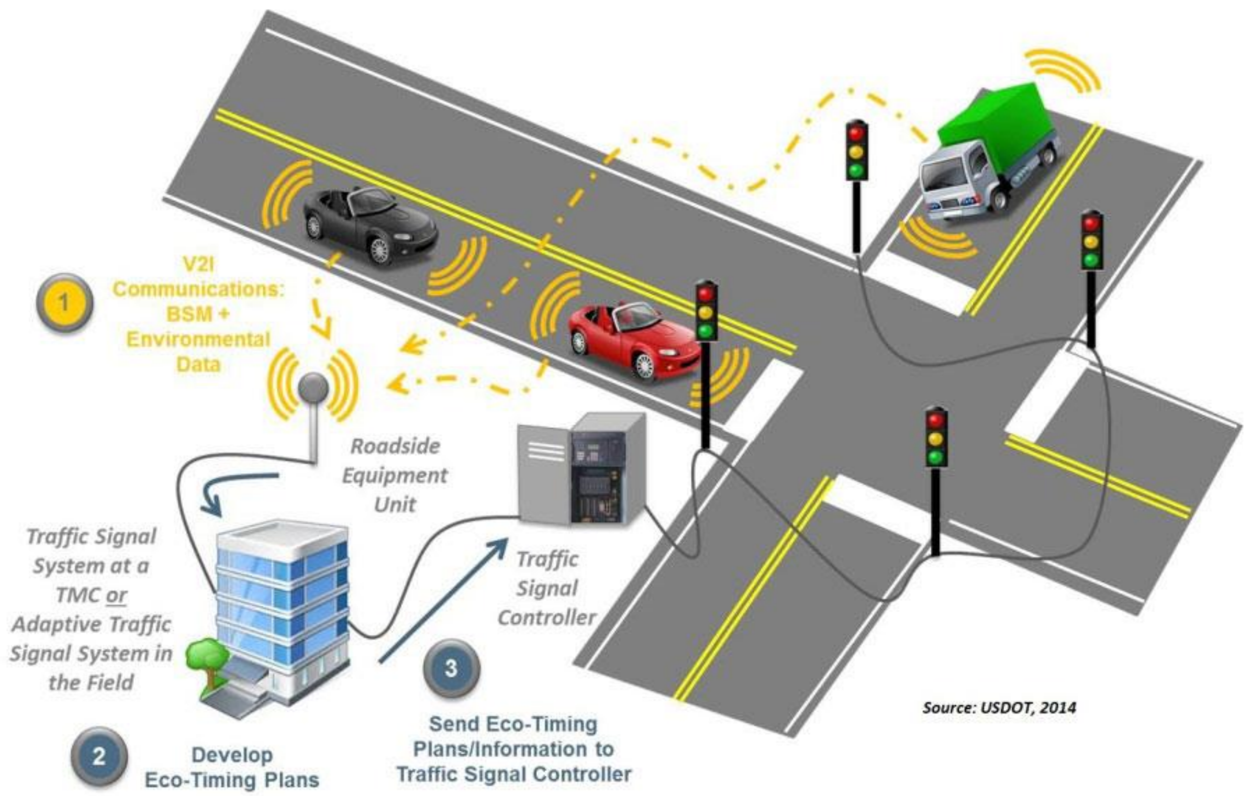
Lesson Body: IDOT reported that the system performed well, with little downtime. In addition, IDOT staff stated that they would utilize this type of system again in a similar project. The IDOT shares the following experiences with other implementers that may choose to utilize ITS in a work zone.

- **Involve agencies responsible for 911 and other emergency response operations during system planning and design.** This effort can help facilitate a coordinated response to incidents during the roadwork.
- **Use a proactive approach to building public awareness of the project.** Successful techniques include holding press conferences, issuing news releases, and keeping local media up to date.
- **Assess when it is appropriate to use a work zone ITS application and what type of system best meets the site-specific needs.**
- **Ensure that software/systems engineers and transportation engineers use common terminology during the requirements definition process.**
- **Include the vendor's engineering staff, in addition to vendor marketing staff, in early discussions of vendor capabilities.**
- **Allow significant time for system calibration during initial implementation of queue-length detection systems.** The calibration process will likely take longer than the best estimate of the time required. The implementation of this system required system calibration that was complicated by the absence of significant traffic congestion. Consequently, the initial deployment phase lasted longer than anticipated.
- **Expect the need to recalibrate detection systems during the course of the project.** IDOT required that the system be deployed on I-55 and tested two weeks prior to initiation of reconstruction activities. The only difficulty encountered was that there was no significant congestion prior to the start of the reconstruction project, which prevented complete calibration of the traffic detection system. Consequently, recalibration of the system was required after the work zone was in place.

IDOT staff identified several benefit areas for the RTTCS system used in this project. The staff reported benefits in both mobility and safety. Despite the work zone location on a busy interstate, the IDOT staff reported no significant traffic backups while the RTTCS system was in place. For the duration of the construction project, only two crashes occurred which were attributed to other causes than the work zone. In addition, there was a significant downtrend in traffic violations after DMSs started notifying drivers approaching the work zone of the number of citations issued in the work zone. This lesson suggests that using ITS in work zones, such as the RTTCS, can be very successful in ensuring safety and mobility within the work zone.

References: https://ops.fhwa.dot.gov/publications/fhwahop17056/fhwahop17056.pdf
Notes to Curator: Please write your first and last name and any comments you have.
File Upload: (Please upload the JPG file attached in the email)

A.3.3: JPG File



A.3.4: Trial Test Survey

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1785

UGA Trial Testing Survey

Thank you for participating in this trial test. Please give your honest feedback; your input is important.

What is the username that you used to log into the system? (i.e. user5)

On a scale of 1 to 10, how visually appealing is the database?

Terrible		Poor		Average			Good		Excellent
1	2	3	4	5	6	7	8	9	10

On a scale of 1 to 10, how well does the system work, from a technical point of view? Are there any bugs? At any point did you feel like the system did not work as intended?

Terrible		Poor		Average			Good		Excellent
1	2	3	4	5	6	7	8	9	10

On a scale of 1 to 10, how intuitive is the submission process? Does the order in which the information is entered make sense?

Terrible		Poor		Average			Good		Excellent
1	2	3	4	5	6	7	8	9	10

On a scale of 1 to 10, how accessible were the commands and data entry fields?

Terrible		Poor		Average			Good		Excellent
1	2	3	4	5	6	7	8	9	10

At the top of the page in the database, click on Published Lessons -> View Published Lessons. Search for the term "drainage" and view the lesson titled "Drainage Issues". Scroll down to the lesson map and click on the green pin in the map. What are the latitude and longitude coordinates of this location? (Round to the nearest integer)

Latitude

Longitude

Do you have any additional comments, concerns, advice to improve the system?

Thank you for completing the survey! Please submit your feedback and notify Justin.

→