

Exercitation of Knowledge Translation and Implementation Science: Transportation Engineering Case Study.

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Abstract: The prolific utilization of research results has become of paramount importance in Engineering as well as other organizations. There is an abundance of publications on implementation science and knowledge translation in the health care industry, perhaps more so than in Engineering. In this article, the authors briefly summarized knowledge translation methods from several organizations including the Louisiana Transportation Research Center (LTRC). They also introduced methods from the fields of psychology, persuasion, and marketing that can be beneficial to knowledge translation. Finally, the methodology utilized in the successful implementation of an LTRC transportation research project were presented. Regardless of which agency an individual works for, knowledge brokering (marketing) of research results (knowledge) is paramount. In many cases, researchers have had nil to minimal training in the art and science of persuasion; however, they are required or strongly urged to have knowledge users accept and employ the research results (new knowledge). Persuasion and rapport methods were introduced. The process to gain rapport through mirroring/matching, pacing, and emotional empathizing between the knowledge broker and knowledge user were expounded upon. The authors provided a detailed description of the steps utilized for a successful knowledge translation project (GIS software) at LTRC. The user friendly software provided knowledge users with quick access to knowledge that in turn increased their productivity. Successful knowledge translation is as significant in this day and age as is the production of robust research results. It is paramount that the researcher utilize some form of a knowledge translation system, regardless of the type, to ensure that the research results (knowledge) is adopted by the user. When researchers themselves are expected to be knowledge brokers, either they should receive training in persuasion, influence, and marketing, or professional knowledge brokers (marketing, sales, etc.) should be contracted so as to maximize the chance of adoption of the research product (knowledge) by the knowledge user. This maximizes the return on investment of the research process.

Keywords: Implementation Science, Knowledge Management, Knowledge translation, Engineering Implementation, Persuasion skills, Engineering Management, GIS web applications, Knowledge Broker

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I. Background

The prolific utilization of research results has become of paramount importance in engineering as well as other organizations [1]. There is an abundance of publications on implementation science and knowledge translation in the health care industry, perhaps more so than in Engineering [2-8]. Implementation, knowledge translation, knowledge transfer, knowledge exchange, research utilization, dissemination, and diffusion have been used interchangeably on many occasions. The lack of a specific grammar with structured semantics in the arena of knowledge translation causes difficulties for sharing of knowledge across disciplines such as health care, engineering, management, marketing, to name a few. In this article, the authors will begin by briefly summarizing knowledge translation methods from several organizations including the Louisiana Transportation Research Center (LTRC) [9]. The authors will also introduce some methods from the fields of psychology, persuasion, and marketing that can be beneficial to knowledge translation as well as present the methodology utilized in the successful implementation of an LTRC transportation research project [10-12].

Transportation Research Board

Meyers and Meyers has provided an excellent summary of successful research implementation in the transportation research arena [1]. They begin by first describing three risk impediments during the research process: limited resources, operational priorities, and dual failure possibilities. Dwindling budgets almost

unilaterally across agencies was the major topic cited regarding limited resources. Operational priorities referred mainly to the cynical restraint exhibited by many agencies due the uncertainty in the long term performance of new processes or products emerging from research projects. Dual failure possibilities were the time-lag between prototypes and completed research as well as temporal uncertainty between prototypes and its network wide utilization.

Improvements in the transportation research process were narrowed down to six topics, 1) Structure the research, 2) Involve stakeholders, 3) Disseminate research outcomes, 4) Mitigate systemic impediments, 5) Manage the double-edge swords (accelerators and impediments), and 6) Track research and implementation over the long term.

Subtopics for each of the six listed above are outlined as follows:

Structure the research

1. Distinctively detail objectives
2. Map out implementation strategies
3. Conduct pilot tests and/or demonstration projects
4. Incentives for researchers

Involve stakeholders

1. Enhance stakeholder-researcher interactions
2. Search for key stakeholders
3. Attempt to merge stakeholder capital
4. Grasp stakeholder-researcher relationship impediments

Disseminate research results

1. Use multi-tiered communication methods
2. Build trust amongst professional associates
3. Educate individuals new to the engineering field

Mitigate systemic impediments

1. Revise low bid procurement policies
2. Change policy barriers
3. Develop a systems approach to research and implementation
4. Harmonize with the pace of external change
5. Scale of implementation should be proportional to the size of the transportation system

Manage the double-edge swords (accelerators and impediments)

1. Standards (some provide certainty while others inhibit innovation)
2. Intellectual property rights (can inhibit the sharing of information)

Track research and implementation over the long term

1. Obtain the correct data
2. Duration of research should be similar to life span of implementation
3. Calculate Return on investment (ROI) on the research process not the research project itself

Details on how to accomplish the topics and subtopics ranged from slightly specific to ambiguous which follows other industries on the subject of knowledge translation or implementation. Reasons for this varies from the nearly infinite variety of projects across disciplines, the fast pace of technological development and the lack of knowledge brokers or marketing experts on the knowledge translation team.

Canadian Institutes of Health Research

The Canadian Institutes of Health Research (CIHR) has developed over time a robust system for knowledge translation planning [2-8]. Knowledge translation (KT) has become paramount amongst research agencies. It is imperative that knowledge users other than the researchers themselves become aware of the latest innovations whether its new medications, medical surgical procedures, or medical technology such as new diagnostic equipment. Furthermore, funding agencies, whether public or private, also desire that the outcomes of research make it to the market place in order to maximize their return on investment (ROI). CIHR has developed an integrated-knowledge-translation (IKT) system consisting of two major phases: knowledge translation (KT1) and end-of-grant knowledge translation (EKT).

Knowledge translation (KT1)

In this phase, CIHR is primarily concerned with the identification of the problem to be solved and the conduct of the research though it may also include components of EKT, to be described later. CIHR has four categories for KT1:

1. **Research question:** The users of the knowledge define the project intent, objectives, and scope.
2. **Research approach:** A research proposal is developed which addresses the items in the research question and includes a detailed methodology on how the research is to be conducted. The proposal should contain the knowledge users participating in the development of the research project as well as all known targeted audiences.
3. **Feasibility:** Risks to utilizing research outcomes should be identified. Potential risks are knowledge users changing positions, influencing management to utilize research results, disputes between researchers and knowledge users, and available resources to match the scope of the project.
4. **Outcomes:** If successfully completed, the probable conclusions of the project are listed. For instance, how will practices or policies be affected?

End-of-Grant knowledge translation (EKT)

In this phase of the IKT process, emphasis is placed on informing knowledge users of the research results. This may be accomplished through dissemination, diffusion, and/or workshops, to name a few. EKT has five categories.

1. **Goals:** The two major objectives of this portion of the EKT process are becoming cognizant of research results and adopting them.
2. **Knowledge user audience (other than project participants):** In this section, researchers should conduct an in-depth analysis to discover the individuals and groups who will use the research as well as any individuals or groups that can assist in the discovery of knowledge users.
3. **Strategies:** After the key messages have been identified, the appropriate knowledge translation will occur through diffusion, dissemination, and application.
4. **Expertise:** The appropriate knowledge users and the requirements to communicate the knowledge to them are identified. For instance, knowledge brokers, IT experts, and videographers may be used to create formats that are appealing to the knowledge users.
5. **Resources:** The researchers are required to demonstrate that the appropriate resources such as funding for research and knowledge translation have been identified.

Louisiana Transportation Research Center

LTRC's research manual provides its employees and contract researchers with guidelines and policies for the conduct of research [9]. LTRC was first established in 1986 by the Louisiana legislature as cooperative research entity merging the resources of the Louisiana Department of Transportation and Development (DOTD) and Louisiana State University (LSU).

LTRC has a highly structured format to develop its annual work program as presented in Figure 1. The cycle begins with the biennial solicitation of problem statements (research topic or question). Anyone may submit transportation related problem statements during the allocated period. In some cycles as many as 200 problem statements have been submitted. From there the problem statements are stratified into related topics and distributed to the appropriate research problem identification committee (RPIC). Here topics that are considered valid for research are prioritized and sent to the research advisory committee (RAC). The RAC members review the problem statements and based upon available funding determine which ones will be funded. Unfunded projects may be considered again during the next RPIC cycle. Problem statements that are not considered research topics or that may be accomplished by other means are handled internally by LTRC staff (LTRC disposition of problem statements).

LTRC management reviews the prioritized problem statement list from the RAC and decides whether to conduct the research internally or by contract. Research problems may also be obtained from other sources such as unsolicited problem statements, internally generated problem statements, emerging technology issues, or from current project review committees (PRC), discussed later. Once LTRC management has selected which projects will be funded, then its annual work program (AWP) is developed. From there it must be approved by both the LTRC Policy committee and the Federal Highway Administration (FHWA).

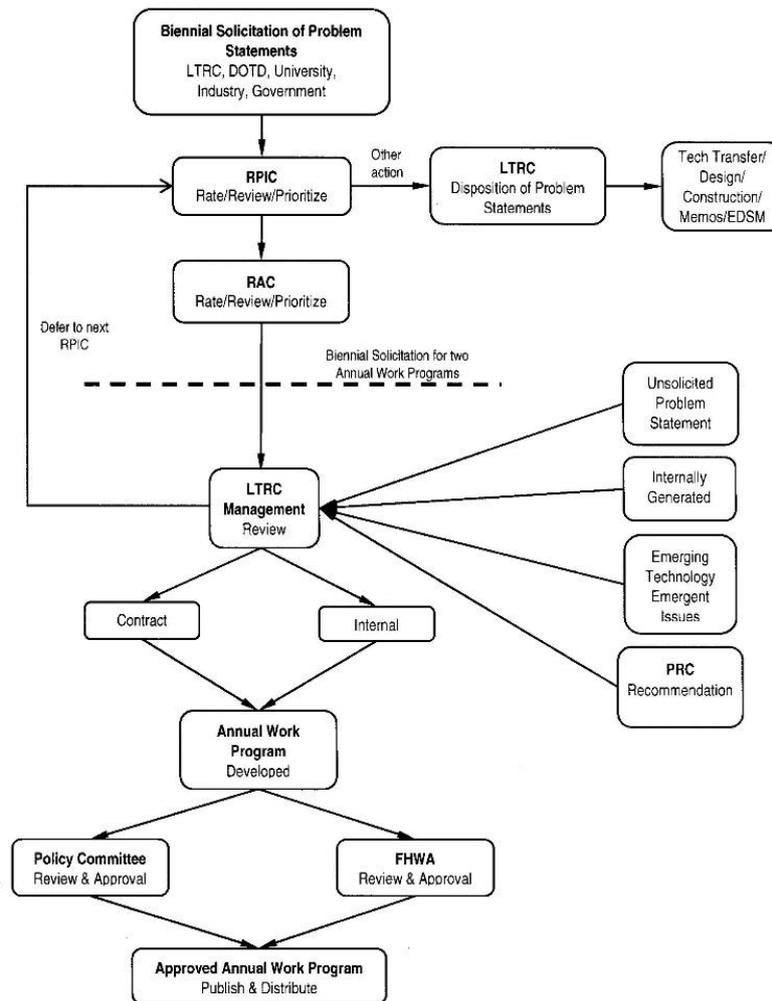


Figure 1: LTRC Publication review and approval process [9]

Once the AWP is completed and accepted, then a project review committee (PRC) is established as presented in Figure 2 [9]. If the work is to be conducted by LTRC staff then a proposal is developed by the appointed LTRC researcher. The PRC reviews and approves the proposal prior to any work beginning. If the work is to be conducted by contract, then a referendum for proposals (RFP) is advertised and the PRC selects the ‘best’ proposal to conduct the work. Regardless of whether the project is contract work or LTRC staff work, the PRC guides the researcher, and reviews/approves the work during the course of the project. The final report contains the results of the research project and acquires approval from the PRC and the LTRC Director of Research.

Once the final report has been accepted, it is published and implementation begins. The authors have divided the implementation process into two methods: passive and active. Passive methods include publications (paper or electronic) such as the final report and technical summary. The LTRC and DOTD communities are made aware of these publications by email. The active process can be broken down into two subcategories: mandatory and optional. Here mandatory refers to processes developed by the research which were turned into specifications and policies that now all DOTD staff must abide by [10]. For instance, if a new asphaltic concrete mix design was developed by a research project and adopted by DOTD, then all contractors must abide by those specifications when that particular asphaltic concrete mixture is used. With the optional subcategory, products or processes have been developed and are available, but it is not mandatory that DOTD employees (knowledge users) or contractors adopt them. For example, if a software package was developed in conjunction with a new analysis method, the knowledge users may still elect to conduct the analysis as they have been doing. It is in this subcategory that person(s) in charge of implementation must employ strategies to convince the knowledge users to utilize the software.

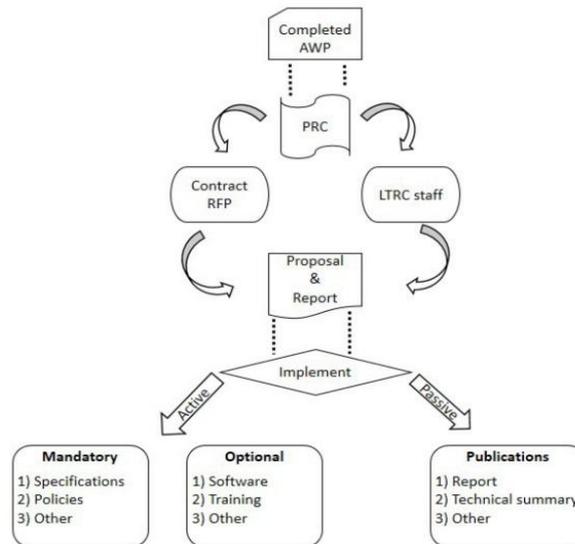


Figure 2: Conduct of Research and Implementation

LTRC has identified common obstacles during the implementation process. They are 1) resistance to change, 2) lack of management support, 3) existing institutional policies/laws, 4) perceived need, 5) political, 6) tools, 7) economics, 8), communication, and 9) incomplete results.

Persuasion Skills for Knowledge Brokers

Regardless of which agency an individual works for, knowledge brokering (marketing) of research results (knowledge) is paramount [1], [2], [9]. In many cases, researchers have had nil to minimal training in the art and science of persuasion; however, they are required or strongly urged to have knowledge users accept and employ the research results (new knowledge). While there are well formed models showing the path to knowledge translation such as the three previously presented in this article, for all practical purposes, there is no interpersonal relationship skills mapped out to carry out the deployment of the new knowledge. It's as if researchers are assumed to know how to be an expert knowledge broker because they are an expert in their field of practice. The authors propose that this is a major reason why it takes so long for research results to make it into practice if results even make it at all. In some instances, there may be a 15 year lag between the completion of research and its deployment into practice [14]. Obviously, this creates huge challenges as well as very low ROIs. One of the first steps in persuading knowledge users to accept and adopt new processes is to first gain rapport [11-13]. "Like Attracts Like," is a major supposition in rapport. Rapport can be accomplished by mirroring/matching, and pacing. In mirroring/matching, we attempt to harmonize our body language, voice tone, word choices, and emotional state with theirs. An example of body language mirroring is if the person you are communicating with has their weight shifted to the left leg, leans forward slightly, breathes quickly, and raises their eye brows while you are in communication with them, then you subtly mirror their posture. If they speak fast and use a lot of visual predicates (**I see, looks bright, picture this**, etc.), then you do the same. It is important that mirroring/matching be accomplished without the other person being conscious of it, else they may take offense and rapport is lost.

Emotional state mirroring/matching would be empathizing and genuinely listening to the knowledge user. For instance, if there were recent layoffs in their company so that each staff member is having to do the work of two people, you would be supportive of their feelings and hardships regarding this. You may even bring up examples of hardships in your own organization, thus establishing a commonality between the two of you.

Pacing is when you have gained rapport through mirroring/matching after which you lead them -while maintaining rapport - towards what you desire, such as adopting the research results. **You must pace before you lead!**In rapport, it is about the knowledge broker adapting to the knowledge user, otherwise rapport is lost, and resistance emerges. The references in this article may serve as resources for knowledge brokers to enhance their skills as well as lead them to trainings in the arenas of rapport, persuasion, and influence [11-13].

It is preferable, that the rapport process with knowledge users begin during the proposal development phase. By carefully listening to the needs of the knowledge users, the researchers develop a product that the knowledge users desire and therefore adopt with little or no resistance. However, in the case of large national or international organizations those who helped build the initial proposal may be upper level management and not the actual users of the product. So when the product is developed, other members of the organization are now presented with a new product or process of which they are resistant to using in their day to day activities [15], [16].

II. Methodology

Project description

In this section the authors will present a brief background description of the research project that produced the research translation tool. After which, the development of the knowledge tool (computer visualization software) and its successful adoption of the primary and secondary knowledge users will be expounded upon.

Pavement surface and embankment distresses due to seasonal moisture variation in the base course, subgrade, foreslope, ditches, and backslope are both a national and international issue existing since the first hard surfaced pavements were constructed [17], [18]. Clay soils, which are prevalent in some regions of Louisiana, can be particularly vulnerable to changes in moisture content, shrinking during drying (desiccation) and swelling during wetting (absorption). Volume changes and/or tension cracks can be accelerated or increased when trees are present, since they extract water from the soil, which in turn increases the suction stresses in the soil [17], [18].

In Louisiana, longitudinal cracks, meandering cracks, and subsidence in the pavement surface have occurred at isolated locations in rural areas, typically with unpaved shoulders. Trees are usually adjacent to the roadway when this occurs as presented in Figure 3. Those distresses have led to pavement service life reduction, costly maintenance repairs, and numerous complaints from the public. The purpose of this research project was to 1) determine the factors contributing to these distresses, 2) develop cost effective mitigation strategies, 3) construct a geographic information systems (GIS) map of the roadway locations that are currently showing signs of distress accentuated by trees, and 4) catalogue the soil types at those locations.

In this article, the steps necessary to complete items 3 and 4 will be expounded upon later. Figure 4 presents a schematic flowchart of the steps used to develop the GIS map and determine the soils present at those locations.



Figure 3: Pavement distresses [Source DOTD]

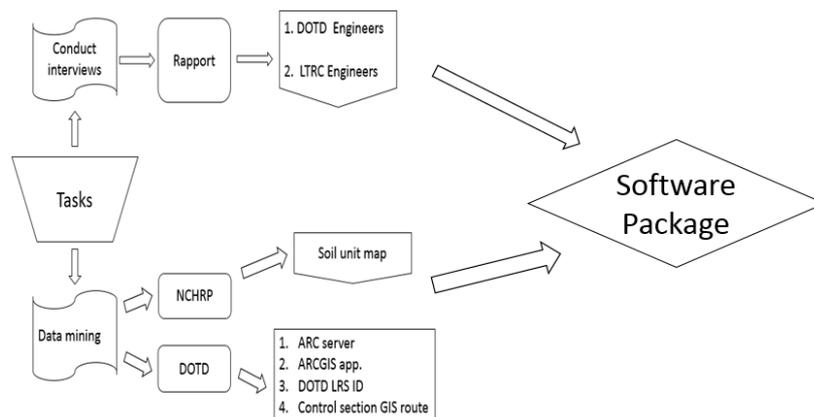


Figure 4: Schematic map of software development

In order to construct the GIS map, a survey of all the pertinent DOTD engineers was performed so as to determine the locations of DOTD roadway distresses presumed to be caused by trees throughout Louisiana. Roadways owned and maintained by other agencies such as counties and cities were not part of the survey. Once the survey was complete, the information was properly geo-referenced so that it may be imported into ArcGIS software by ESRI [19]. The research team discovered during the literature review that a comprehensive geo-reference soil map for the state of Louisiana was available from the National Highway Cooperative Research Program (NCHRP) [20]. It contained pertinent soil property information that would be valuable for preliminary roadway design as well as determine the type of soil at each site.

At this stage of the software development, the authors proceeded to determine who the knowledge users were. Two primary knowledge users were targeted and interviewed. The primary knowledge users were identified as DOTD's District Administrators, Assistant District Administrators, Area Engineers and Project Engineers. Additional primary users were LTRC's research engineers. Interviews and surveys with them revealed what features were first necessary, and second preferable for their use. Interviews were also conducted with LTRC engineers of all levels from administrators to student workers. The authors were mindful of the rapport process at all times during the interviews. Secondary users for the software were identified as DOTD Pavement/Geotechnical Engineers and Pavement Preservation Engineers. Their needs discovered during past interactions and interviews were taken into consideration as well.

Having completed the interviews and establishing rapport with the targeted knowledge users, the authors proceeded with the development of the software. Multiple data sources were mined. From NCHRP, soil unit maps were obtained. From DOTD two GIS databases were data mined, DOTD LRS ID, and Control section route. The use of ESRI Arcserver software and ArcGIS online licenses were necessary. The proper authorization for use of all maps, databases, and licenses were obtained from the appropriate parties.

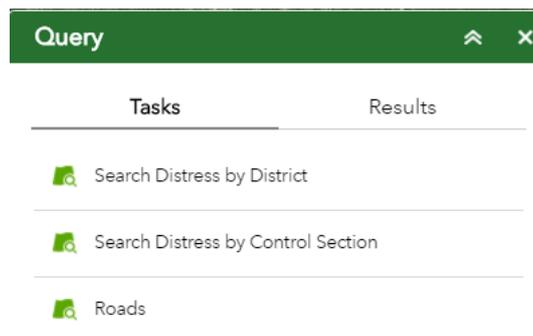
With the appropriate databases, maps, and software packages identified, the LTRC principle investigator (Kevin Gaspard) and project manager (Doc Zhang) provided guidance to the computer analyst (Adele Lee) for the development of the research product which was an GIS web application, entitled "Louisiana Roadway Tree Distress"[21]. Once a beta version was developed, it was shared with several knowledge users in order to obtain feedback. After addressing the feedback from the knowledge users it was published and made public through the internet [21].

GIS web application

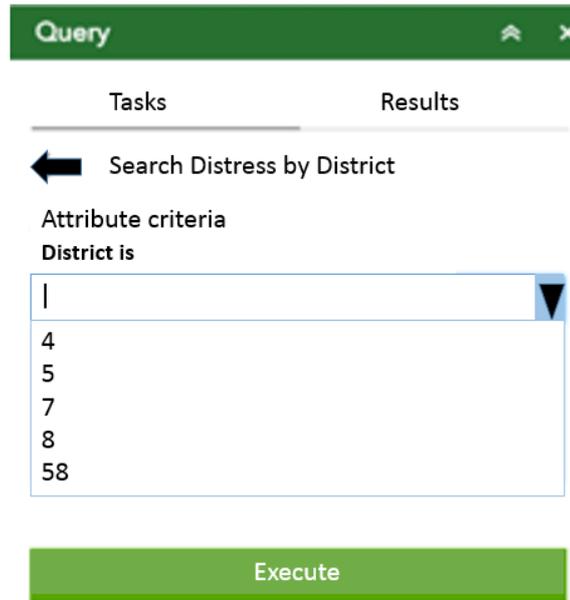
The user interface was designed so that the knowledge user could obtain the desired information with relative ease. At DOTD, roadway locations can be referred to in numerous ways. Below are the available query options in this software.

1. Control section number (e.g., 036-01)
2. Roadway name (e.g. LA 1)
3. District (District 08)

For example, take the case where the user wishes to know the roadway locations in Louisiana's District 8 where tree distresses have been identified. The user begins by clicking the web link to the application. Once there the user is shown a map of Louisiana along with a Query box on the right hand side as presented in Figure 5a. The user clicks on the first level identifier "Search Distress by District" after which the "Attribute criteria" location identifier box appears and the user selects "8" as presented in Figure 5b.



5(a)



5(b)

Figure 5: 5(a) First level identifier, 5(b) Location identifier

Once the location identifier has been selected, the map zooms and the locations where tree related distresses exist are highlighted in red as presented in figure 6; additionally, information specific to each roadway is displayed in the Query results box as presented in Figure 7.



Figure 6: Roadway locations with tree distress (highlighted in red)

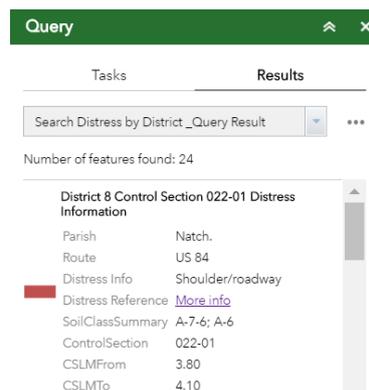


Figure 7: Query results for all roadways in District 8

At this stage the user has three options to obtain information on an individual roadway. With the first option, the user may click on any of the highlighted red areas on the map (Figure 6) which results in that roadway segment alone being displayed on the screen as presented in Figure 8. The second option that the user has is to click anywhere in the dialogue box (Figure 7) which in turn produces the same display (Figure 8) as the first option. The third option the user has is to click on a tab at the bottom of the web page which will cause all the information available for that roadway to be displayed in table form, a portion of which is presented in Figure 9. It should be noted that the user guide contains full details of the content available in the program.

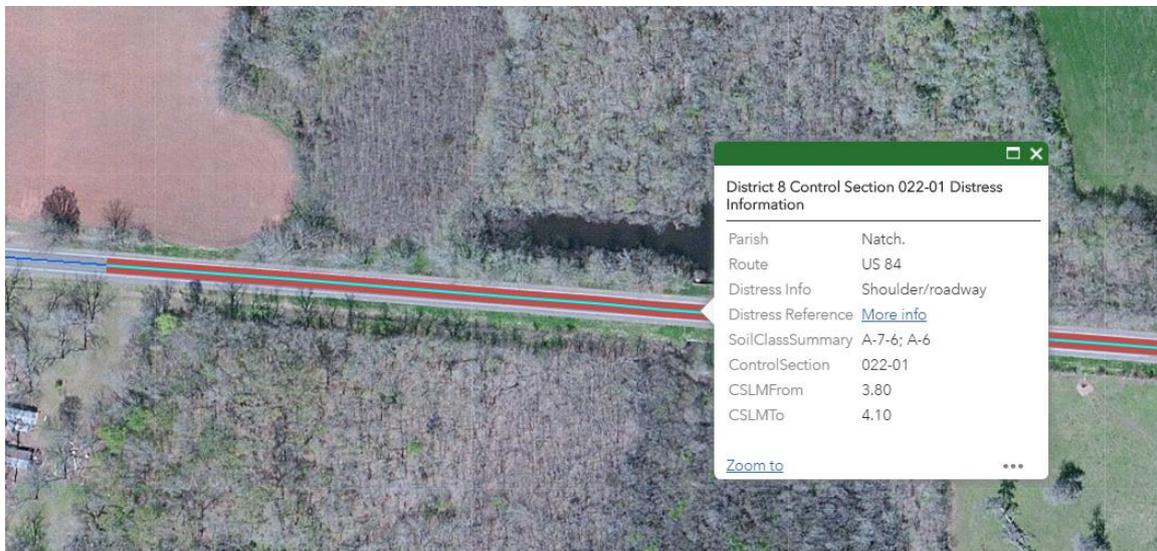


Figure 8: Location of tree distressed roadway

Roadway_Distress_Trees_20161219							
Options Filter by Map Extent Zoom to Clear Selection Refresh							
Distress Info	CSLMFrom	CSLMTo	District	Parish	Route	RuralUrban	RoadwaySurface
Shoulder/roadwa	3.80	4.10	8	Natch.	US 84	R	AC

Figure 9: Detailed information for selected roadway

Successful knowledge translation is as significant in this day and age as is the production of robust research results as was the case with the GIS web application previously discussed [21]. The authors have received favorable comments from primary and secondary knowledge users and have also recently published another software package which was adopted by the appropriate knowledge users in their design process [22]. To illustrate the crossover knowledge translation steps between different agencies, we will outline the steps used in the GIS web application in terms of CIHR’s end-of-grant methodology [2].

- 1) Goals: The authors’ objective was to inform knowledge users of the research results and secure their adoption of the process.
- 2) Audience: Primary and secondary users were discovered through interviews with several DOTD sections and suggestions from the Project Review Committee.
- 3) Strategies: Computer software was designed to meet the needs of the knowledge users. The content of the research results (knowledge) was designed so that the knowledge users could obtain the information quickly and easily.
- 4) Expertise: The researchers utilized the services of LTRC’s computer analyst and DOTD’s GIS manager to develop a web application for the knowledge users.
- 5) Resources: Funding for the project was provided by LTRC. Databases, servers, and software licenses from DOTD were utilized as well to create geo-databases and publish the GIS web application.

It is important that the researcher utilize some form of knowledge translation system, regardless of the type, to ensure that the research results (knowledge) is adopted by the user assuming that the knowledge is appropriate for them. We have demonstrated here that the steps to knowledge translation of a transportation related topic (Louisiana roadway tree distress) can fit into the end-of-grant knowledge translation model even though it is not a health care related research topic [2], [21]. Both researchers and agencies would benefit greatly by studying the knowledge translation methods of different agencies including those outside of their field of research.

III. Conclusions

This article summarizes three knowledge translation methodologies from the fields of healthcare and engineering. The adoption and usage of research results (knowledge) is at the forefront of research projects. Funding agencies expect to realize a return on their investment from the research process.

While there is a plethora of information on the science of implementation (knowledge translation), there is little published on specifics of “how to” influence or persuade knowledge users to adopt the research results. In many cases, the researchers (knowledge brokers) on the project are not experts in the fields of persuasion or marketing, yet are expected to persuade knowledge users to adopt the knowledge. The authors’ introduced rapport techniques which include mirroring/matching, pacing, and emotional state empathizing. In rapport, it’s about the knowledge broker adapting their state to that of the knowledge user, otherwise rapport is lost. These simple tools can enhance knowledge brokering and increase the rate of knowledge adoption.

The authors provided a detailed description of the steps utilized for a successful knowledge translation project at LTRC. The methods employed for developing a GIS web application (knowledge translation) were described. We have produced several software packages from various research projects which were adopted and still in use today. The user friendly software provides knowledge users with quick access to knowledge that in turn increases their productivity.

To illustrate the potential overlap between knowledge translation systems/strategies, the authors described the LTRC knowledge translation process utilized for the software development in terms of the end-of-grant process used by CIHR.

Successful knowledge translation is as significant this day and age as is the production of robust research results. It is important that the researcher utilize some form of a knowledge translation system, regardless of the type to ensure that the research results (knowledge) is adopted by the user. When researchers themselves are expected to be knowledge brokers, either they should receive training in persuasion, influence, and marketing, or professional knowledge brokers (marketing, sales, etc.) should be contracted so as to maximize the chance of adoption of the research product (knowledge) by the knowledge user. This maximizes the return on investment of the research process.

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