FY2022 Call for Research Proposals

Administration

Construction & Structures

Environment & Planning

Pavement & Maintenance

Traffic & Safety

Research Request for Proposal

Title: TDOT Critical Knowledge Gaps, Existing Knowledge Management Practices and Cultural Readiness

RRFP Number: 1

Problem Statement:

As of July 30, 2021, nearly 43% of TDOT's full time employees had less than 5 years' experience with the State of Tennessee. An additional 18% are currently eligible for retirement. A robust knowledge management (KM) program is needed to collect and transfer workforce knowledge and best practices from experienced staff to new staff. The goals of knowledge management are to retain and advance existing knowledge and to decrease the amount of time needed for new staff to get to a working state.

Knowledge management programs are recognized for stimulating innovation, enhancing decision-making, inspiring perpetual learning, standardizing work, and encouraging communication across the organization. This research will help TDOT understand where best to focus resources as we develop and implement a KM framework, thus reducing the likelihood that critical knowledge will be lost due to retirement, resignation, attrition or inability to maintain organizational bench strength. By developing and implementing a KM framework based on this research's findings, TDOT will be better prepared to quickly instill competence and more efficiently spread knowledge throughout the organization in the face of changing workforce resources.

Research Objectives:

This research should lead to a prioritized list of at-risk critical knowledge areas. This list can be utilized to assist TDOT as we select areas to pursue for piloting a KM Framework and for maintaining strong knowledge management practices through continuous improvement tools such as maturity models. This research should include the following objectives:

1. Identification of critical knowledge areas for organization – this should include an assessment of the strategic knowledge areas necessary for competency and delivery of operational strategies. An assessment should also be made on the current state of strategic knowledge areas where TDOT has a lack of competency depth, coverage of key positions may be at risk, and/or there is a hesitancy to share information.
2. Inventory of current knowledge management practices in each division – this should include identification and assessment of knowledge, knowledge management practices, and knowledge resources that are currently available and not available (gaps).
    a. This should not be limited to explicit knowledge and may include information about implicit and tacit knowledge that specific individuals possess.
3. Evaluation of cultural readiness for each division – this could include an assessment of dimensions such as open vs. defensive, learner vs. knower, need to know vs. need to share, collaborative vs. competitive, and pursuit of excellence vs. complacency regarding Division

capabilities to embed a knowledge management system into workflow.

Research Deliverables:

Deliverables should at minimum include:

- A baseline inventory and analysis of knowledge resources/practices for each of the divisions. Should include, but not be limited to:
    - Critical knowledge areas and gaps
    - External agencies and/or knowledge resources that can or do provide tacit knowledge required for TDOT functions
- A culture audit in relation to knowledge management receptiveness and current knowledge sharing behaviors in each division. The scope of cultural readiness should involve TDOT divisions, the senior leadership of each respective division, and the primary knowledge holders/sharers of each respective division (the primary knowledge holders/sharers may or may not be senior leadership). This audit should include, but not be limited to:
    - Areas of resistance and corresponding barriers to acceptance
    - Knowledge management allies and level of interest in piloting a knowledge management framework
- An assessment based on available employee turnover rates and how knowledge management may affect or may improve those rates.
- A diagrammatic representation of knowledge flows. Should include, but not be limited to:
    - TDOT divisions, functional units, and regions
    - Any frequently used external representatives critical to TDOT functions and knowledge management
- A final report and research results presentation that summarizes the research findings and potential implications.

Benefits and Implementation:

On an organizational level, this research will move TDOT closer to obtaining the vision of "Commitment to excellence in managing and improving the state's transportation system, promoting the success of our employees, and strengthening the trust of our customers" with particular emphasis on ensuring employees have the information necessary to do their best work while improving on the ideas of others. This research also underpins TDOT's values of Development (we continually grow and share our knowledge, expertise, and experience) and Collaboration (we work together internally and with our partners to share ideas, skills, and insights to get the best results.)

On a programmatic level, TDOT will eventually be working to develop a KM framework that seeks to understand the intersection between people, processes, technology and governance with how knowledge is discussed, documented, synthesized, found and maintained.

Findings from this research will help to inform the framework and assist TDOT in prioritizing at-risk knowledge to pursue in the initial stages of the knowledge management program. It is hoped that the deliverables will provide a good overview to evaluate where critical knowledge is being held, documented, and shared freely vs. those areas where critical knowledge may be retained by certain

individuals and groups. This information will help TDOT identify potential pilot areas for KM as well as identify specific interventions and knowledge tools to promote sharing.

Research findings may be of interest to other states through the American Association of State Highway Transportation Officials Committee on Knowledge Management and the Transportation Research Board's Information and Knowledge Management Committee.

Research Team Requirements:

Specific expertise beneficial to this research could include backgrounds in library sciences, business or public organization, education, human resources, information systems, and organizational psychology. Any graduate assistants involved in this research project should also have backgrounds in the fields of study listed above.

TDOT Assistance:

TDOT can aid in scheduling interviews with key TDOT staff, utilizing video conferencing technologies, and facilitating access to specific knowledge assets.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $200,000.00

Special Note:

Due to the sensitive nature of the information that may be provided by TDOT, some information may be considered private and may not be readily shareable academically. Any deliverables or publications will be given extra scrutiny as a result and may be redacted from publications for privacy reasons.

Research Request for Proposal

Title: **Risk Assessment Tool (associated with cost)**

RRFP Number: **2**

Problem Statement:

While all projects, regardless of size and/or complexity, have a risk component, it is difficult to monetarily quantify cost associated with risk. The Department has various opportunities to delay project development, but what is the cost of those delays? As cost of a project increases, it impacts delivery of itself or a neighboring project. How are these decisions quantified? How does the Department determine risk associated with these cost impacts? This request for research is requested by our Executive Leadership to assist in a reliable, quantifiable decision-making tool. This will help understand how each risk impacts the cost of a project and if the project still holds the original importance over a neighboring project.

The Department is continuously looking to improve cost estimates and quantifying additional project cost directly related to identified risk is a constant battle. For example, there are times that projects are delayed 1-year or more due to Right-of-Way (ROW) acquisition. However, sometimes, when we receive an updated estimate during this delay, we receive a "Nothing has changed" update in which additional inflation costs are still applied. Or, we have to avoid a particular area or purchase additional ROW in order to not avoid. In these cases, we need better cost estimates for the design delay or ROW delay.

These costs are misleading to TDOT decision makers when programing funds, or budgeting project phases; additionally, we share this information to our external partners, so they see this misleading information.

Research Objectives:

The objective of this research is to provide/allow for a continuous opportunity to improve project cost estimates based on different project risks, including cost of the:

- Risk of delay
- Risk mitigation
- Risk avoidance
  - Etc.

The project will also seek to develop a reliable and transferable tool with which to provide more accurate cost estimations as it relates to the project risks described above. Lastly, the project should seek to disseminate this information in a timely and transferrable manner to other DOTs or local transportation agencies.

This research should plan on these costs being included in the latest/scheduled estimate submittal.

Research Deliverables:

Overall, the Department seeks quantifiable results for delays in projects (e.g., 1-year equates to X-amount of dollars), changing cross-sections/alignments/walls/structures to avoid a Risk (equates to X-amount of dollars). Deliverables should at minimum include:

- Review of appropriate financial methods for determining cost overruns and concurrent project comparisons
- A shareable tool to calculate these cost (software/program)
- Any applicable workshop(s) to DOT employees that may benefit from the tool and/or research during the life of the contract

It should be noted that TDOT has reached out to several State DOTs for similar examples, but at this time there isn't anyone doing this. Several are interested and would like to see what TDOT develops, so there are no examples for this request.

Benefits and Implementation:

The benefit of this research comes to the Department, MPOs, RPOs, Local Officials and the citizens of Tennessee by providing more realistic cost estimates. More realistic cost estimates can help ensure efficient spending of funds and increase public trust in fund expenditure.

This tool could be shared with other DOTs and our local partners to improve their estimating process as well.

Research Team Requirements:

Applicants should have experience in transportation project budget estimation and project development.

TDOT Assistance:

TDOT may be able to provide access to estimates, staff expertise, PPRM, and other critical information as needed.

Estimated Cost and Project Duration:

Project Duration: 12 months

Estimated Cost: $150,000.00

Due to the critical nature of this research, duration should be expedited. Therefore, greater time commitments are expected by staff researchers over graduate assistants.

Special Note:

Due to the potentially sensitive nature of the information that may be provided by TDOT, some information may be considered private and may not be readily shareable academically. Any deliverables or publications will be given extra scrutiny as a result and may be redacted from publications for privacy reasons.

Title: Automatic Tools for Quick and Accurate Construction Cost Estimation for Retaining Walls

RRFP Number: 3

Problem Statement:

Rapid and accurate construction cost estimation of important assets, such as retaining walls, is important for TDOT to develop accurate engineers estimates, plan construction activities, control budgets and costs, meet schedules, and ensure construction quality. Inaccurate cost estimations could result in problems during the construction phase, resulting in change orders to the contract. Outsourcing cost estimation is also costly and may not be feasible. Therefore, there is a need to develop automated/semi-automated tools to help TDOT professionals to quickly and accurately estimate the construction costs and time (production rates) to construct important infrastructure assets, such as retaining walls prior to the bid letting.

Significance of this research includes:

1) Developing accurate engineering estimates for retaining walls, which are subject to a variety of factors and uncertainties such as allowable wall types, wall heights, and required ground improvements when included in the bid price for the contractor to design and build. With ever-increasing construction volumes projected, it is important to develop an easy-to-implement toolset for TDOT professionals to conduct cost estimation prior to bid letting to determine the most appropriate wall type in a timely and accurate manner.
2) Providing TDOT with semi-automated tools for quick and accurate construction cost estimation that will help TDOT keep up the pace with the projected high volume of construction activities, reduce errors in cost estimation, facilitate the award of the contract, and construction.

Research Objectives:

This RRFP seeks research to develop tools such as application(s) or spreadsheet(s) and provide the associated workflow that: 1) considers construction processes and activities including estimated productivity and unit price information reflected in costs; 2) provides flexibility for TDOT professionals to adjust the estimate based on different site conditions and relevant factors. Factors to be considered include, but are not limited to, wall heights, wall lengths, preferred wall types, required ground improvements (for global stability), moment slabs and other required fixtures, etc.; 3) integrates the automated toolset and emerging technologies to help streamline the estimation process of retaining wall construction. 4) establishes standard pay items and their implementation and use for estimate and bid consistency.

Research Deliverables:

Deliverables should at minimum include:

1) An application, or spreadsheet, and the associated workflow that considers the construction processes of retaining wall structures and activities with estimated productivity and unit price information to accurately estimate the costs of construction for the appropriate types of retaining walls.
2) Training materials and workshops to help TDOT personnel familiarizing the estimation toolsets developed through this research.
3) Final report and research results presentation.

Benefits and Implementation:

Benefits:

1) Easy-to-use semi-automated tools for TDOT to estimate construction costs of important infrastructure assets efficiently and accurately, such as retaining walls, which can help the budgeting and construction cost control processes.
2) Streamline the data collection and cost estimation process with TDOT in-house staff which will not require additional efforts and interventions (extra effort by TDOT or third-parties).

TDOT expects to implement the outcome of this research into the current estimation practice:

1) The developed tool(s) should be easily integrated with the current construction cost estimation process at TDOT.
2) The developed tool(s) should be user-friendly, easy-to-use, compatible with current TDOT information technology infrastructure and current design and construction provisions.
3) The developed tool(s) can be easily updated with new available information such as any periodically updated unit price information to suit TDOT's needs for more accurate estimation in the future.

Research Team Requirements:

The research team is expected to have expertise in construction cost estimation, automation in construction, construction productivity assessment, construction engineering, project control, and geotechnical materials and to have technical background in different types of retaining wall design and construction. In addition, the research team should also have capability in developing applications, information technologies, automated toolsets to estimate construction site conditions and assess construction productivity for more accurate cost estimation.

TDOT Assistance:

TDOT will provide the research team access to relevant engineering designs, cost data from past constructions, and current estimation documents and practice.

Estimated Cost and Project Duration:

Project Duration: 18 months

Estimated Cost: $150,000.00

Research Request for Proposal

Title: Best Practices for Bridges with Pipe Piles

RRFP Number: 4

Problem Statement:

Pipe piles (PP) and concrete-filled steel tubes (CFST) have been used on bridge projects in Tennessee for decades. Parameters defining PP/CFST installations include:

(a) piling material, (b) fill material, (c) connection details, (d) installation procedures, (e) design criteria, and (f) corrosion protection measures.

These six parameters have varied greatly from project to project and there is no standardized process whereby the most suitable parameters may be established for a particular project. Seismic design parameters need to be standardized within Division of Structures design policy for both consultant and in-house design. Additionally, local buckling of pipe piles is not properly addressed in current design specifications.

Research Objectives:

Objectives should include:

- Develop a systematic method of selecting the most appropriate system. Currently the piling systems vary between design groups or the design consultant's preferences. A unified policy to determine the use of pipe piles in both abutments and bents is desirable.
- Derive recommended structural analysis techniques to satisfy AASHTO requirements in the LRFD Bridge Design Specification and the Guide Specification for LRFD Seismic Bridge Design.

These objectives will be accomplished through an assessed comprehensive synthesis of construction techniques, and advanced structural modeling of example bridge structures to include the use of (a) Hollow steel pipe piles with no connection to the cap (b) Hollow steel pipe piles with a dowel connection to the cap (c) CFST with the tube embedded in cap (d) CFST with gap between pile and cap.

Research Deliverables:

Deliverables should at minimum include:

(1) A comprehensive report detailing their recommended systematic method for determining when to utilize steel pipe pile piling systems and what type of steel pipe pile connections would be applicable.
(2) A recommended calculations method to address local buckling of pipe piles.
(3) Recommendations for specifying connection details, installation procedures and corrosion protection measures.
(4) These reports and presentations shall include method of analysis, software used for analysis and all pertinent datasets used to derive their presentation.

(5) A final report and research results presentation will be presented to the Division of Structures.
(6) Policy language that can be readily integrated into the Structures Division's current policies.

Benefits and Implementation:

TDOT anticipates the research findings to benefit the Department and our partners by the following points:

- This research will solidify a uniform approach to the design and utilization of steel pipe foundation support systems and clarify the design method to analyze local buckling in steel pipe piles.
- This research will benefit TDOT with improved Division efficiency in the use and subsequent design of steel pipe pile foundation support systems.
- TDOT hopes to implement the findings of with this research with updated design policy and procedures for steel pipe pile foundations.
- TDOT anticipates using the results of this research to update our published design policy for bridge foundation systems
- Consultants and other state DOT's could benefit from this research as a design reference for steel pipe pile foundation systems.

Research Team Requirements:

The research team shall have detailed knowledge of the use of steel pipe piles in bridge substructures – abutments and bents – and be well versed in the application of AASHTO requirements in the LRFD Bridge Design Specification and the Guide Specification for LRFD Seismic Bridge Design. The research team will also have knowledge of readily available inventory of steel pipe piles from TDOT's preferred fabricators.

TDOT Assistance:

TDOT will be able to provide access to prior steel pipe pile foundation calculations and example plans and details.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $165,000.00

Research Request for Proposal

Title: **Design and Application of Stormwater Conveyance from Bridge Decks**

RRFP Number: **5**

Problem Statement:

TDOT has long used large catch basins at the end of bridge rails to gather runoff from bridge decks. (See STD-1-6 through STD-1-13.) These are located on the bridge approach pavement and may be contributing to fill settlement under bridge approaches resulting in bumps at the end of bridges.

As part of an initiative to minimize or eliminate the bump at the end of the bridge, TDOT has moved away from these catch basins and instituted a new standard with an open channel riprap lined flume at the end of the bridge. See STD-10-3 for details.

For this standard, research is required to determine the most accurate way to calculate capacity to intercept flow along the bridge rail and to calculate the capacity of flow conveyed down the roadway embankment without erosion damage. Calculation is specific to individual bridge sites with variable longitudinal and cross roadway slopes. Determining the best location for the flume and integration with safety guardrails is a concern.

This research is necessary to facilitate conveyance of stormwater away from bridge decks. Inadequate conveyance facilities may contribute to standing water puddles on roadways, an immediate safety hazard that can lead to hydroplaning. It may also lead to erosion on roadway embankment slopes and around bridge substructures and safety guardrail components which presents a long-term safety hazard and maintenance expense.

Note, this research does **NOT** have a water quality component.

Research Objectives:

The primary goal of this research is to (1) evaluate the existing TDOT standard end of bridge flume in STD-10-3 and validate current calculation methods or recommend a reliable method for TDOT designers to calculate flow interception and conveyance capacity of the flume and spread width at upstream end. This evaluation may include physical and/or advanced numerical modeling using computational flood dynamics. (2) A calculation method developed will consider site-specific requirements such as roadway longitudinal slope, roadway cross-slope, and roadway width. This method should be as compatible as possible with existing TDOT design procedure which is based on methodology in Chapter 4 of FHWA's Hydraulic Engineering Circular 22: Urban Drainage Design. (3) Research shall evaluate placement and configuration of flume inlet and outlet with respect to end of bridge guard rails, as well as methods for evaluation and maintenance of flumes and any site limitations for using this standard.

The secondary goal of this research is to (4) complete a literature review of methods used by state DOTs and other transportation agencies, depth and breadth of the literature review can be determined in consultation with TDOT staff.

Research Deliverables:

Deliverables should at minimum include:

- While quarterly progress reports are required, one should specifically include a summary of the literature review when completed.
- Datasets for physical or numerical modelling should be provided at request of TDOT staff.
- The federally required final report will include an adapted digital version of TDOT's existing drain calculation spreadsheet with calculation method developed for end of bridge drainage flume. Recommendations for adapting applicable methods and technologies from other states and transportation agencies will be included as well. The report should also estimate the potential cost savings of safety improvements.
- The presentation of the final report to TDOT design staff provided should discuss implementing the new calculation method.
- A demonstration of modifications to TDOT's drain calculation spreadsheet will be provided if deemed necessary. Recommendations for adapting applicable methods and technologies from other states and transportation agencies should be included as well.

Benefits and Implementation:

This research is anticipated to modify current drainage practices at the end of TDOT bridges, a topic of increasing importance as Tennessee bridges are getting wider to accommodate more traffic using additional, wider, travel lanes and shoulders. Improving drainage will contribute to increased safety of the traveling public by conveying as much stormwater as possible away from travel lanes as quickly and efficiently as possible to avoid hydroplaning hazards. This will also decrease long term maintenance problems with bumps at the end of bridges and erosion under and around bridge abutments and roadway slopes by decreasing bypass flow from bridge ends.

Research will be implemented through changes to TDOT's current bridge drainage spreadsheet and procedures as well as proposed changes to standard drawing STD-10-3. Research may also recommend additional methods or technologies for increased drainage capacity around bridge ends.

This research will also be beneficial to local governments throughout Tennessee as they design and implement their own bridge projects using TDOT standards.

Research Team Requirements:

Principal Investigator (PI) should be knowledgeable in the topic of open channel hydraulics and experienced in design of open channels. Experience in use of open channels in a roadway environment is preferrable. PI should have a support team with similar knowledge sizable enough to complete the research plan and may require occasional consultation with a roadway design engineer and a geotechnical engineer.

Specialized facilities will be required for physical or CFD numerical modelling as proposed by the research plan.

TDOT Assistance:

The research team will be provided access to staff knowledgeable in current TDOT design methodology as relevant to the research and a copy of the current TDOT spreadsheet used for end of bridge drainage design.

TDOT staff will assist the research team in finding examples of field installations of the current standard design flume. Note, this is a new standard and field examples may not be available at commencement of research project. As field installations are constructed their locations will be provided.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $125,000.00 to $175,000.00

Project budgets and justifications should reflect modelling choices and reasoning for better proposal comparison.

Research Request for Proposal

Title: Influencing Mode Shift through Behavioral Change Strategies

RRFP Number: 6

Problem Statement:

It is evident that single occupant vehicles (SOVs) are the predominant mode of transportation in TN. The latest census data (CTPP) estimates roughly 84% of the state's commuter population travel to and from work alone in their vehicles. As our nation begins to emerge from the pandemic, traffic volumes and congestion have started to increase. For many years, state and regional planning agencies have demonstrated the many benefits of eliminating vehicles from the road through ridesharing, telework, and transit both environmentally and for quality of life. So what influences are making Tennessee drivers still so reliant on our personal vehicles to get around? Is it convenience? Is it the lack of multi-modal infrastructure? And, ultimately, what would it take to influence commuters to consider different modes of transportation and choose an alternative mode over their personal vehicle? How can people be inspired to use SOVs less for commuting?

Research Objectives:

This research project will explore the human element of travel behavior in Tennessee and begin to uncover the many factors that influence our modal decision-making. This research project should:

(1) Develop specific strategies and approaches that have proven to nudge commuters toward sustainable mobility alternatives.
(2) Determine probable influences of travel behavior including (but not limited to):
    - Geography (urban, suburban, and rural)
    - Convenience of access (including place, time, and usability)
    - Cultural/social perceptions of SOVs and alternative modes
(3) Provide case studies of successful modal shifts from the US or significantly similar cases around the globe.

Research Deliverables:

Deliverables should at minimum include:

- Final report and research results presentation
- Appendix
- Maps as they might be applicable to clustered behaviors and perceptions.
- Survey tools for potential use by TDOT, MPOs, and RPOs for future comparison data.
    - There is potential for repeatable surveys to determine behavior change on an annual or multi-annual basis. As such, the methodology developed should also be usable and convenient for other parties to learn and replicate in a public capacity.
- Additional assistance in updating policies for the Transportation Demand Management (TDM) will also be highly valuable.

- Brief forecast of potential congestion and capacity-building reductions throughout the State.

Benefits and Implementation:

This research project should provide a better understanding of how the general public considers their travel options and what TDOT and our partners can do to help encourage and sustain the shift to alternative travel modes. The results of this research project will be incorporated into our statewide TDM program and can also be used as material when discussing the many benefits of TDM. In addition to improving the quality and reliability of the state's transportation system, other potential long-term benefits of this research project include reduction in congestion levels that can potentially slow the rate of spending on expensive capacity-building projects.

Research Team Requirements:

The successful research team should be well-versed in the field of behavioural science and have an understanding of the current transportation climate in Tennessee. Those with experience in TDM and TDM programming will also be preferred.

TDOT Assistance:

It is assumed that most of this research effort would involve external data collection and peer interviews. However, if it is determined that an engagement tool is necessary, TDOT can provide MetroQuest or Microsoft Forms applications. If other tools or research materials are suggested, it is recommended the proposer reach out to TDOT to inquire on the availability prior to procuring.

Estimated Cost and Project Duration:

Project Duration: 18 months

Estimated Cost: $150,000.00

Research Request for Proposal

Title: More Effective Use of Tennessee Waterways to Account for Competing Uses and Address Freight Congestion

RRFP Number: 7

Problem Statement:

This project focuses on developing and understanding the role the inland waterway network in Tennessee has and can play in freight movements and overall infrastructure resilience for Tennessee. TDOT needs to identify and quantify the stressors on the freight system, such as development or closures of terminals, and also the federal level investments that may impede or improve the performance of the system to connect with other modes in critical areas. Both are issues pertaining to increasing last mile and lengthening trips for less efficient freight vehicles such as trucks.

Through a state-level review of the inland system and connectivity, redundancies, and operations; opportunities may also be identified for investment to protect or leverage the navigable waterways of the state to reduce highway traffic and increase resiliency. This would involve a robust analysis of both public and private ports and terminals, key city and urban area development plans along the waterways, and development of metrics to assist in evaluating and prioritizing the importance of specific inland waterway infrastructure assets. A key aspect of the research would also examine how other states are leveraging and managing inland waterway systems and associated infrastructure to optimize freight system performance and increase resilience. If TDOT does not undertake this research, the state could miss vital ways to properly develop our waterway assets and divert freight to this mode where it is currently underutilized.

Research Objectives:

The research project should provide information to TDOT through the following objectives:

- Conduct a literature and best practices review of other inland waterway programs.
- Conduct a state-level review of the inland waterway system, connectivity, redundancies, and operations.
- Analyze all public and private ports and terminals and key city and urban area development along Tennessee's inland waterways.
- Volumes with tonnage of current commodities on the waterway system for the past five years will be tabulated with state origin and destination.
- Identify and quantify the stressors on the freight system such as development or closures of terminals.
- Develop metrics to assist in evaluating and prioritizing the importance of specific inland waterway infrastructure assets.

- Provide potential areas of new inland waterway development based on evaluation metrics.

Researchers can also propose other objectives, as well, to further elaborate on the research.

Research Deliverables:

Deliverables should at minimum include:

- A separate report on Tennessee's inland waterway system, including a list of all public and private ports and terminals in Tennessee. This report should include maps of these assets.
- Evaluation metrics spreadsheet.
- Volumes with tonnage of current commodities on the waterway system for the past five years will be tabulated with state origin and destination.
- A final report and research results presentation including:
    - Some broad analysis on rough economic benefits and jobs that a port brings to a community.
    - Catalogue of best practices on state water programs regarding inland waterways from other states. (could also be a separate deliverable)

Benefits and Implementation:

TDOT envisions that this research and its implementation will benefit the state in the following ways:

- This research will help TDOT formulate a potential waterway development program, similar to other states.
- This research will help TDOT implement projects that will shift freight to other modes and help take more trucks off the highways or railroads. Indirect benefits of modal diversion will benefit congestion, improve air quality, and help lower maintenance costs of highways.
- TDOT potentially could create a grant program through water transportation equity funds that could give grants to communities that would benefit from inland waterway development.
- Based on research deliverables, TDOT could partner with the Tennessee Department of Economic and Community Development and Department of Agriculture on future development of inland waterways to spur economic growth and development.
- Projected future growth will be studied to see about potential sustainability of the commodities to the areas to accommodate future growth in Tennessee
- With the short-term completion of the Kentucky Lock and Chickamauga Lock, the Division can look at expected commodity and terminal growth potential in Tennessee.
- With the new Infrastructure bill over the next 5 years and a few programs related to inland waterways and PIDP, a potential matching funds to federal funds would leverage state dollars and bring additional business and industry to Tennessee.

Research Team Requirements:

Preferred qualifications from research staff would include expertise in transportation planning, freight planning, advanced knowledge about all freight modes, specific knowledge about waterway

freight transport, knowledge of freight commodity flows, and potential economic development partners.

TDOT Assistance:

For the duration of the project, TDOT can provide support and interaction to the research team to ensure the research is moving in the right direction. TDOT may also be able to provide access to datasets, such as Transearch commodity flow data, disaggregated FAF data, and freight volume data on other freight modes such as highway and rail.

Estimated Cost and Project Duration:

Project Duration: 18 months

Estimated Cost: $150,000.00

Research Request for Proposal

Title: **Pollinator Habitat**

RRFP Number: **8**

Problem Statement:

Tennessee's native roadside vegetation, which support a wide variety of threatened and endangered pollinator species, is under stress from numerous types of encroaching invasive plants, over-mowing, and misguided herbicide application techniques.

This leads TDOT to ask the following questions:

- What are best training practices and resources for TDOT Operations staff and supporting contractors to become educated about the importance of proper mowing and herbicide application techniques?
- How can TDOT utilize native plantings to reduce mowing and maintenance of sloped surfaces? Describe the types of native plantings and their establishment practices and demonstrate which are most beneficial for preventing erosion.
- How are Environmentally Sensitive Areas, which have been identified along TDOT rights-of-way, beneficial to pollinator species? Do high quality sites such as grassland remnants and solid stands of milkweed, provide a greater ecological benefit, contribute to greater pollinator movement, and impact higher populations of pollinator species?
- What are the best ways to demonstrate TDOT's pollinator research and habitat conservation practices to the public?

Research Objectives:

Objectives include:

1. Further TDOT's understanding of why appropriate mowing and herbicide application techniques are beneficial to populations of pollinator species.
2. Determine best practices for the selection, preparation, installation, and maintenance of native plantings along sloped surfaces.
3. Evaluate how proper maintenance and high quality Environmentally Sensitive Areas provide ecological benefits to populations of pollinator species.
4. Test plots and physical beds, of native plantings, serving as a basis for planting on TDOT rights-of-way. Sloped conditions should be present.
5. Develop a curriculum for a teaching series and disseminatable training resources about this subject matter and findings from the research.

Research Deliverables:

Deliverables should at minimum include:

- Multi-language training resources (i.e., printed resources, guides for website publication, video tutorials) for TDOT Operations personnel and support contractors. These are to be disseminated annually in conjunction with mowing and herbicide application trainings and workshops.
- A formalized spec, including test plots and physical beds, of native plantings, serving as a basis for planting on TDOT rights-of-way. Sloped conditions should be present.
- Reporting on high-quality Environmentally Sensitive Areas and their benefits to pollinator species. Rationale listed in the final report should include whether high quality sites offer greater ecological benefit and contribute to greater pollinator movement among populations of pollinator species?
- Virtual attendance at quarterly meetings of TDOT's Pollinator Working Group. This includes a final report and research results presentation to the group.

Benefits and Implementation:

Departmental benefits include a greater application and understanding among front-line operations staff of threats facing pollinators and the need for habitat conservation. Additionally, the department will increase safety, reduce carbon emissions, and benefit financially from having a native vegetation alternative to maintaining sloped surfaces on rights-of-way. The project will also aid in protecting multiple ecologically critical pollinator species in Tennessee, several of whom are classified as "threatened" by the U.S. Fish & Wildlife Service.

Generally, recent federal support of pollinator projects has increased. A June 2014 Presidential Memorandum directed the USDOT to evaluate resources and identify opportunities to increase pollinator habitat along roadways, and to promote pollinator friendly practices and corridors. As a result, Section 1415 of the FAST Act amends 23 U.S.C. 319 and directs FHWA, when carrying out any program under title 23 to encourage: (1) integrated vegetation management practices on roadsides and other transportation right-of-way, including reduced mowing; and (2) the development of habitat and forage for Monarch butterflies, other native pollinators, and honey bees through plantings of native forms (e.g., flowering plants_ and grasses, including non-invasive native milkweed species that can serve as migratory way stations for butterflies and facilitate migrations of other pollinators.

Research Team Requirements:

The research team should include extensive expertise in the regional horticultural of Tennessee, as well as expertise in the maintenance practices of utility and transportation rights-of-way.

TDOT Assistance:

TDOT Staff can provide access to the following to assist in the research:

- Right-of-way locations statewide (so as coordinated through Highway Beautification staff and a local TDOT District Office)
- GIS records, 2019 research findings, site observation reporting, and other historic resources of the TDOT Pollinator Working Group.

- Contracted creative design services and community relations assistance provided by Highway Beautification staff.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $175,000.00

Research Request for Proposal

Title: Evaluating Transit Accessibility to Food, Education, Recreation, and Other Essential Services in Tennessee

RRFP Number: 9

Problem Statement:

Disadvantaged populations, particularly low-income populations, often rely on public transit for their transportation needs. Numerous prior studies, including the TDOT project numbered RES2021-08, have evaluated transit accessibility to job opportunities, particularly for low-wage workers. However, although providing access to jobs in an important function of public transit, other travelers use transit to get to grocery stores, health services, schools, or outdoor recreational areas, which are not typically considered in transit accessibility analyses. These critical destinations are essential for independence, health, and quality of life. Research is needed to evaluate the transit accessibility to food, education, recreation, and other essential services for low-income populations in Tennessee in helping to better determine the value of transit for riders.

Research Objectives:

To better understand how current transit services meet the needs of disadvantaged groups, especially low-income groups across the state (both urban and rural), it is necessary to analyze spatiotemporal transit accessibility to different essential services like food stores, health services, schools, and parks. To analyze this, the research team should (1) compile data from various sources, such as transit service data, demographics, and the locations of food stores, hospitals, parks, and/or other essential services in Tennessee, (2) determine transit accessibility from low income housing units and/or neighborhoods with predominantly low income populations should be measured and evaluated, and (3) analyze methods for fixed route transit services in the larger urban areas and suburban areas, as well as demand-response services in rural areas.

Research Deliverables:

Deliverable should at minimum include:

1) maps & shapefiles illustrating transit accessibility levels from low-income housing and/or predominantly low-income neighborhoods to the locations of essential services;
2) a list/spreadsheet of areas with limited amenities (e.g., food deserts) and/or limited transit access; and
3) a list of recommendations of transit service improvements that can increase access to essential services. Service recommendations should include low-cost recommendations that can be implemented in the short-term as well as more extensive recommendations and relative costs.

Benefits and Implementation:

This research is needed to evaluate if equitable access is provided to essential services for disadvantaged populations. It is anticipated that the results will provide two key deliverables that can be used to guide implementation of the research results. First, a list of areas with limited amenities (e.g., food desserts) and/or limited transit access will be compiled; this list can then be used by local stakeholders (e.g., city planning departments, transit agencies, developers) as well as TDOT to identify areas with the greatest need for improvements. Second, a list of specific recommendations of transit service improvements that can increase access to essential services will be compiled; this list can be provided to local transit service operators to consider for future implementation, and to TDOT for project evaluation and planning.

Research Team Requirements:

The research team will need an understanding of multimodal travel and specific expertise in public transit, as well as the ability to form connections with public transit providers in Tennessee. Those with extensive planning expertise will be helpful for developing recommendations for interested MPOs or RPOs.

TDOT Assistance:

It is not expected that TDOT can provide specific assistance other than that of the Lead Staff and any Technical Advisory Committee members as this research does not have dedicated or federally required data collection.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $150,000.00

Research Request for Proposal

Title: Identification of Simulation Calibration Parameters using Urban Freeway Data

RRFP Number: 10

Problem Statement:

The purpose of this research is to identify calibration parameters for microsimulation software, specifically PTV VISSIM. The Tennessee Department of Transportation (TDOT) is beginning to use PTV VISSIM more frequently in-house for traffic analysis but lacks state calibration factors that could enable a more accurate representation of actual traffic flow. A simulation training and user manual on PTV VISSIM, and to some extent SYNCHRO+SIMTRAFFIC, is currently being developed for use in-house and would contain suggested calibration parameters. However, these calibration parameters are determined based on best practices from Departments of Transportation (DOT) manuals developed by other states and practical experience with VISSIM projects in Tennessee. Data-driven calibration parameters would be beneficial in enhancing TDOT's model development and reliability of simulation results along urban freeways in Tennessee. While TDOT can continue to develop microsimulation models, it is critical to incorporate Tennessee-specific calibration parameters in our PTV VISSIM training and user manual to have more robust microsimulation models and reliable traffic analysis results for the preliminary engineering decision-making process.

Research Objectives:

The research objectives that will drive the research methodology are listed below.

- Utilize existing TDOT ITS urban freeway data to identify calibration parameters for microsimulation software, specifically PTV VISSIM.
- Identify limitations in ITS urban freeway data and provide recommendations and enhancements, if any, to the ITS data collection sensors and cameras that are installed along urban freeways in Tennessee. If it is determined in the early stages of the research project that data limitations are present, further data collection may be required in order to obtain more accurate results specific to Tennessee.
- Identify the distribution of freeway free flow speed, speed limits, and number of lanes in one direction across highly populated cities in Tennessee for direct input into future microsimulation models.
- Determine the distribution of speed-at-capacity and the associated flow-at-capacity for freeways and state routes.
- Specify network settings used in the analysis.
- Determine calibration metrics (i.e., lane change parameters, speed distributions, driving behavior, conflict areas, and priority rules) that are required for developing microsimulation models and how they differ across multiple cities in Tennessee.

- Determine guidelines for calibration parameters along freeways and ramp terminals for both peak hour timing and off-peak timing.
- Specify the methodology and practical procedures for validating microsimulation models and the measures of effectiveness required for reporting from a project development standpoint.

Research Deliverables:

The researcher is expected to provide TDOT Strategic Transportation Investments Division (STID) the deliverables listed below during or at the conclusion of the research project. Deliverables should at minimum include:

1. Project management
    a. Monthly progress reporting
    b. Development of project work plan
    c. Quarterly virtual meetings with the Technical Advisory Committee (TAC)
2. Research analysis
    a. Data/dataset used in the analysis
    b. Research methodology and procedure, usable in-house
3. Resulting Proposed PTV VISSIM Settings
    a. Network elements
        i. Network settings
    b. Calibration
        i. Calibration metrics including:
            1. Lane change parameters
            2. Speed distributions
            3. Driving behavior
            4. Conflict areas and priority rules
        ii. Calibration guidelines for:
            1. Freeways and ramp terminals
            2. List of recommended parameters by urban freeways in highly populated Tennessee cities
        iii. Validation of:
            1. Throughput traffic volumes
            2. Speeds
            3. Vehicle travel times
            4. Queues
            5. Required number of simulation runs
4. Examples
    a. Freeway and ramp terminals coding (i.e., simulation settings, calibration parameters, and other model development characteristics that are required for practical simulation models)
    b. Case studies providing examples of how the recommended results are implemented into in-house simulation models for practical use in the project development process.
5. Recommendations/Checklists

    a. List of ITS urban freeway data limitations and recommendations and enhancements, if any, to the ITS data collection sensors and cameras
    b. Model developer checklist of calibration parameters for practical use in model development
    c. Model reviewer checklist of calibration parameters for practical use in model development
6. Final report and research results presentation
    a. Contribution to the training and/or use manual if needed.

Benefits and Implementation:

Determining data-driven calibration parameters for PTV VISSIM would improve TDOT's accuracy and reliability of microsimulation models and traffic analysis results. TDOT is currently using microsimulation software using default calibration parameters, which increases variability in the model and could result in inaccurate traffic analysis results. Data-driven calibration parameters would allow TDOT to improve agency efficiency for traffic analysis by adopting the recommended calibration factors for use in microsimulation model development. TDOT STID is currently in the process of working with a consultant to develop an in-house training and user manual for PTV VISSIM. The calibration parameters determined from this research would be an essential component in the training and user manual and further implemented for more robust microsimulation model development, reducing both the time and cost associated with calibration of PTV VISSIM and other software and resulting in improved quality of projects. Data-driven calibration factors would provide consistency statewide for model development. Furthermore, other state DOTs could benefit from this research by either applying the calibration factors if similar to their state or viewing the research to help them determine more accurate calibration factors for their respective roadway systems.

Research Team Requirements:

The research team must have practical experience using PTV VISSIM software, and to some extent SYNCHRO+SIMTRAFFIC, and the necessary familiarity with calibration parameters to develop robust microsimulation models that will result in quality traffic analysis results for use along urban freeways in Tennessee.

TDOT Assistance:

TDOT will provide timely support throughout the duration of the research project and will supply the necessary ITS urban freeway data that is needed to perform the analysis for calibration parameter determination.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $225,000.00

Research Request for Proposal

Title: The Effect of Extreme Climate Shifts to Pavement Infrastructure in Tennessee

RRFP Number: 11

Problem Statement:

Recently Tennessee has experienced several adverse weather challenges ranging from cold winters, hot summers, and intensive heavy rainfall. In 2010, the flooding that occurred in Nashville crippled the entire transportation network system, with enormous recorded economic loss. Not too long ago, a similar situation occurred in other part of Tennessee resulting in loss of lives in 2021, floods claimed lives, resulted in loss of property, and destroyed infrastructures. It was reported that 6 people died in Nashville because of floods in August 2021 and 21 people died in Humphreys County. The damages on pavement infrastructure are yet to be determined since it takes time to evaluate such damages. The rate of deterioration on the pavement structure increases with such occurrences, resulting in frequent failures and change in maintenance strategies. The pavement life is reduced due to excessive pavement cracking after the flood events, potholes, and other pavement distresses. This project seeks to assess the trends in Tennessee with respect to historic climate data and pavement performance and establish new design considerations for pavement materials and pavement design to improve resilience to extreme events.

The disruption to TDOT 's maintenance strategy due to excessive weather challenges calls for urgent remedy to the viability to the current system. This urgent need requires proper pavement design considerations and effective resource management as these are key to sustainable pavement management systems. This research will establish new climate data for pavement design considerations and material specification. This will benefit TDOT by being proactive on new designs and rehabilitation of existing roads.

Not doing this research will results to lower design standards (with lower reliability levels) and low performing pavements in case of adverse weather conditions. For that reason, maintenance and reconstruction costs of pavements will increase and overall customer satisfaction will decline.

Research Objectives:

The objectives of this research are to:

- To evaluate current and historical climatic conditions and develop new trend analysis. It would be especially beneficial to determine exponential change potential.
- To develop new pavement design criteria in terms of material and climatic inputs following new trends.
- To recommend pavement maintenance strategies that may be helpful in resisting new adverse weather conditions.
- Advise on implementation strategies for various designs.

Research Deliverables:

Deliverables should at minimum include:

- At the end of the project, new design recommendation in terms of materials specification and temperature must be provided. This project is expected to improve pavement design criteria to consider recent adverse climatic changes. In return it will enable TDOT to design pavements that will survive adverse weather conditions.
- A final report and research results presentation will be submitted, highlighting findings, new climatic trends, and proposed design input parameters to design robust pavement structures.

Benefits and Implementation:

Pavement design depends on traffic, climate (e.g., temperature, wind and rainfall) and material inputs. Understanding climate transformation and the shift needed on climate inputs will help to improve material specifications from the subgrade soil to asphalt surfaces and to implement needed change on design considerations according to the new climate data and subgrade soil strength. Specific benefits should include:

- Enabling TDOT to design robust pavement structures that will withstand the adverse climatic challenges and last longer.
- Using proper design parameters where TDOT will save money with less maintenance.
- New material specifications: climate data inputs corresponding to traffic load will be availed.
- Implementation which will be immediately after the research project is over.
- New material specifications on areas with adverse weather conditions will be utilized.
- Subgrade soil stabilization considerations in place for areas prone to flooding.
- Providing design considerations for water table levels, pavement drainage, and performance grade binder specifications as well as improved asphalt mixes as needed.

Research Team Requirements:

The research team will require access to weather information needed for the project, both historical and current trends from which the projections can be developed. Additional environmental expertise, particularly in the area of transportation and/or pavement engineering is preferred.

TDOT Assistance:

TDOT will need to provide a number of pavement sections that will be evaluated from troubled areas. Design data, such as layer thickness and materials used. Pavement condition data and pavement maintenance data for the last 20 or 30 years on the same sections selected for the study, especially on trouble areas, and traffic data on the same road sections.

Estimated Cost and Project Duration:

Project Duration: 30 months

Estimated Cost: $220,000.00

Research Request for Proposal

Title: Considerations for Landslide and Debris Flow Monitoring

RRFP Number: 12

Problem Statement:

TDOT is in need of determining the most useful and most cost-effective methods to monitor movements and displacements on landslides, debris flows, and other unstable ground (collectively hereafter referred to as "landslide") projects. An understanding of the various technologies and techniques which are currently available is necessary for selection and deployment of an appropriate system to provide real-time movement observations and even early warning of potential serious landslide events.

The incorporation of the resulting monitoring program will assist to position TDOT in a technologically upward manner among its nationwide DOT peers, many of which are currently applying advanced monitoring techniques on landslide sites. However, the primary goal is to further the understanding of problematic landslides and related geohazard processes in an applied manner, and to use the resulting knowledge to increase the safety of motorists and the public while simultaneously providing necessary and increased protection to TDOT and State of Tennessee transportation assets.

Research Objectives:

In general terms, the objectives of the stated research are to:

- Identify the various failure mechanism(s) present at the individual landslide sites (e.g., by site reconnaissance, field mapping, drone flight with 3D data visualization),
- Evaluate the applicable monitoring and other instrumentation necessary to adequately monitor and collect the desired data, based on the determined failure mechanisms, boundary conditions, or other site-specific circumstances,
- Implement the designated monitoring system and initiate all monitoring requirements; and
- Provide for the proper collection, storage, and utilization of the gathered data in the defined manner (e.g., automated call-out based on triggered threshold, real-time data transmission via web-based or other means, etc.).

The research will endeavour to conduct all necessary analyses and implementation of all monitoring components in a timely manner, with the resulting monitoring system to be put into operation within the designated budget.

Research Deliverables:

It is expected that the research project will result in the development and presentation of several deliverables, which will include at a minimum the following:

- A Final Report of Findings to include each landslide site being investigated, addressing the

various failure mechanisms identified at each site and the monitoring system determined to be appropriate for the particular site.
    - A "User's Manual" section to provide guidance to the User for the necessary operation of the monitoring system (how to initiate the system, how to view or utilize the collected data, how to deal with anticipated fault or error situations, etc.);
    - The collection of any instrumentation device serial numbers, calibration certificates, or other information determined to be important for future reference.

Benefits and Implementation:

There are many benefits to TDOT resulting from this research, not the least of which is an improved understanding of landslides and related geohazard processes along our transportation corridors. In accompaniment, there is the potential for significant cost savings to be realized by the sensible, practical, and perceptive prioritizing of various landslide sites to be investigated, which has the added benefit of moving TDOT's newly implemented Unstable Slope Program further along (both practically and technically). However, the most significant benefit and outcome of this research stands to be the improvement to and the increase of safety for the traveling public, our transportation assets, and the state of Tennessee taxpayers in general.

The ultimate outcome of this research – a landslide monitoring system(s) and its associated appurtenances and components – is of prime importance to the Department and will be a key part of our Unstable Slope Program. In addition to the Geotechnical Office, we anticipate at a minimum our TDOT Maintenance personnel to contribute information toward the project outcome in the form of data (unstable sites), and our Construction and Planning personnel should be able to draw upon the results of the program for future project planning (sites to avoid, etc.).

Ultimately, TDOT expects to refine our understanding of landslides and related geohazards, and then apply this knowledge to our on-going commitment to managing landslides and the roadways which travel over and along them.

- Depending on the particular data and warning/alert processes generated by the research program, the resulting monitoring system may offer as-yet unknown benefit and use to local or sister state agencies (local Sheriff departments, TDEC, State Highway Patrol) or federal partners (FHWA).
- TDOT will be able to refine its Unstable Slope Program based on the results of the research program, with the identification, classification, rating, and cataloging of additional problem areas.

Research Team Requirements:

The research team shall have experience in the geology of Tennessee and knowledge of geotechnical engineering with regards to landslides. The research team is also expected to have expertise/capabilities in the following:

- Field mapping
- Drone flight with 3D data visualization
- Remote sensing related to geotechnical hazards
- Geographic Information Systems and Databases
- MicroStation

- Land Surveying

TDOT Assistance:

TDOT may provide the research team access to relevant information/data, such as: a copy of the Microsoft Access database which contains all logged TDOT geotechnical projects, maintenance records, existing geotechnical reports/memorandums, historical information on file, existing survey data, TDOT Design Guidelines, TDOT policies and guidelines, and other TDOT documents. TDOT Geotechnical Engineering Section will have limited availability to attend scoping meetings if performed, along with initial/preliminary site visits when schedule allows.

Estimated Cost and Project Duration:

Project Duration: 30 months

Estimated Cost: $325,000.00

Research Request for Proposal

Title: **Chemical Stabilization of Pavement Subgrade**

RRFP Number: **13**

Problem Statement:

Low strength subgrade soils are often encountered during roadway construction, with current practice being to design the pavement section for the lower strength material, or to remove and replace weak soils with stronger material for improved pavement design parameters but at a high cost. Chemical stabilization of the subgrade soils can be a cost-effective alternative to increase the strength of subgrade soils, and is utilized throughout the United States, although experience with, and use of, has decreased within TDOT. Research is requested to determine the most cost-effective means of subgrade stabilization for pavement design, by utilizing individual chemicals, materials, or additives (or combinations thereof), for use with the various soil types that will be encountered in Tennessee.

Research Objectives:

This Research should include a synthesis of existing research studies and other DOTs specifications and guidelines. This research should also collect and analyse additional data in order to recommend a precise, calculated chemical stabilization dosage for a specific soil class/group, through inclusion of the following:

- Determining what subsurface exploration, laboratory testing, and soil properties and classification of in-situ soils are required in order to recommend a specific chemical treatment.
- Developing laboratory testing procedure(s), laboratory mix design(s), and testing program(s) of laboratory-prepared, chemically-treated soil samples for evaluation of suitability.
- Determining relevant test methods and measurements required for pavement design strength improvements (plasticity reduction, unconfined compressive strength, CBR/modulus increase, etc.) and correlation to pavement design parameters.
- Establishing necessary field-testing procedures employed in the construction phase to ensure proper implementation and acceptance metrics for the chemically stabilized subgrade.
- Discerning relevant pavement design properties, and the required improvements provided by chemical stabilization.
- Classifying any limitations to subgrade chemical stabilization (highly organic soils, excessive depth of weak soils, etc.)
- Delineating costs to use subgrade chemical stabilization per cubic yard.

Research Deliverables:

Deliverables should at minimum include:

- Recommendations for subsurface exploration, sampling, and testing of the in-situ soils.
- Comprehensive Guidance documents, tables, and charts, dictating the applicability of each chemical treatment material to be used for each soil class, including precise dosages, mix designs, and the subsequent increase to engineering properties related to pavement design.
- Field Testing Manual and Guidelines, including training and instruction for geotechnical and construction personnel, with specified field-testing equipment, procedures, test frequency, and acceptance parameters.
- Update to TDOT Standard Specifications for Road and Bridge Construction, including but not limited to, the construction requirements, testing requirements, and basis of payment.
- A cost comparison of the different options.
- A final report and research results presentation documenting all work completed.

Benefits and Implementation:

The research is expected to provide an additional option for subgrade strength improvement beyond undercutting and replacement, that would yield cost savings to current practice.

The results and deliverables will be implemented through an update to TDOT Standard Specifications, their insertion into departmental workflows, their contribution to recommendations used during plans development, and construction process updates/improvements.

Research Team Requirements:

The research team's expertise should include engineering theory and principles of chemical stabilization, geotechnical engineering, pavement design, soils and materials laboratory and field-testing expertise, and familiarity with construction specifications

TDOT Assistance:

A dataset containing some past construction projects' CBR values, with corresponding AASHTO soil classifications, is available.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $175,000.00

Research Request for Proposal

Title: Improved Management Strategies of Processing Acid Producing Materials on Transportation Projects

RRFP Number: 14

Problem Statement:

Roadway excavation cuts in Tennessee frequently encounter rock, shale, or soil materials that could be considered acid producing material (APM). The geotechnical material properties of APM are adequate for roadway fill, but the APM produces acidic leachate that creates a condition of environmental pollution. Present APM processing strategies consist of blending with lime, relocating to landfills, or placement in engineered encapsulation cells on-site or off-site. Determination of APM requires off-site laboratory analyses which by its nature inhibits construction productivity. TDOT seeks improved strategies to enhance our management of APM encountered in roadway excavation cuts.

Research Objectives:

Objectives of this project seek to assess current APM construction procedures and internal Departmental requirements. To offer strategic methodologies that could promote process improvements, the project should:

- Evaluate current site characterization methods being employed.
- Consider present APM processing methods critically, using engineering judgement.
- Gauge practicalities of present APM encapsulation and relocation requirements.
- Compare non-destructive testing methods that have evolved.
- Evaluate APM monitoring methods that have evolved.
- Contrast mining requirements and roadbuilding requirements.
- Consider quality assurance \ quality control methods.
- Establish GIS location mapping of potential relocation sites\facilities capable of accepting APM.
- Prepare a cost-benefit analyses of current practices against altered practices.

Research Deliverables:

Deliverables should at minimum include a final report containing:

- Desktop study
- Laboratory Results
- Potential Modifications to typical drawing details
- Recommended Testing procedures

- Innovative best management practices
- Benefit/Cost Analysis of changing procedures
- GIS layer depicting landfill locations

Benefits and Implementation:

TDOT is currently one of the most respected leaders in DOT APM processing and, as such, takes this very seriously. Previous costs incurred by the single Item Number 203-01.07 RD & DRNG EXCV (ACID PRODUCING- OFF SITE DISPOSAL) have been considered by some to be substantial, but substantial returns are expected from substantial investments.

Findings of this research would be used to further guide inter-Divisional APM policy discussion. This research has potential to (1) adjust some of the contractual processes presently being employed, (2) be used as guidance by other DOTs in the Appalachian region, and (3) improve the environmental value provided to Tennessee further.

Research Team Requirements:

Researchers applying would have preferred expertise in geology, geochemistry, geo-environmental, environmental, geotechnical engineering, GIS\Geospatial, and civil\construction.

TDOT Assistance:

TDOT is available to provide assistance providing archived documents. The Materials & Tests Division would likely be able to provide use of some specific testing equipment, depending upon specific availability requirements that can be discussed during the Scope of Work discussions. Information for previous projects can be retrieved for assistance in benefit-cost analysis.

Estimated Cost and Project Duration:

Project Duration: 30 months

Estimated Cost: $200,000.00

Research Request for Proposal

Title: Investigating the Long-Term Frictional Properties and Establishing Aggregate Polishing Guidelines for Asphalt Surface Mixtures in Tennessee

RRFP Number: 15

Problem Statement:

The frictional properties of asphalt mixtures are provided by micro and macro textures. Macro texture is related to gradation, density, shape, angularity, and arrangement of aggregates within the mixture layer. Coarser gradation and more angular particles result in more macro texture. Micro texture is related to polishing properties of aggregates at the mixture surface. Micro texture is a major factor affecting the friction of dry pavements, while macro texture provides a way to drain water from wet pavement surface.

Currently, TDOT controls the micro texture of surface asphalt mixtures by requiring a minimum of 75% of siliceous aggregates in the mixture. However, this specification requirement is based on experience only. There is no current research to support an appropriate amount of siliceous materials to provide adequate friction for asphalt surface mixtures used in Tennessee. In addition, the routine use of reclaimed asphalt pavement (RAP) poses new challenges due to the unknown amount of siliceous materials in the RAP materials. Therefore, it is imperative to address and optimize friction of surface mixtures in Tennessee.

Additionally, some regions of Tennessee experience increased costs for importing polish-resistant aggregates for asphalt surface mixtures. It is challenging to optimally choose a combination of surface micro-texture and macro-texture properties to provide an economical mixture while sustaining a safe wearing surface. The lack of locally available polish-resistant aggregate sources can require contractors to haul polish-resistant aggregates at a great expense. Also, surface approved aggregates are a non-renewable resource that should be used with sustainability in mind.

Research Objectives:

Objectives include the following:

1) Correlate the long-term frictional properties of asphalt mixtures commonly used in Tennessee with a practical engineering performance tester, such as the dynamic frictional tester (DFT)
2) Examine validity of the 75% minimum siliceous materials requirement for the surface asphalt mixtures in Tennessee
3) Develop a practical method to quickly determine the siliceous aggregate content in RAP
4) Recommend specification limits for blending aggregates as well as performance-based testing limits that provide adequate frictional properties
5) Compare the frictional properties using the DFT with the current methods of friction testing used in TN with the BPN (British Pendulum Number) and Locked Wheel Trailer

Research Deliverables:

It is expected that the outcomes and recommendations developed through this research would be immediately implemented and used. Deliverables should at minimum include:

1) A State DOT survey focused on the Cumberland Plateau states (southern West Virginia to northern Alabama) and literature review on the friction performance of asphalt mixture.
2) Development and evaluation of quick test of silica content for RAP aggregates.
3) Evaluation of current TDOT specifications regarding friction of the pavement and resistance to polishing of aggregates and to propose new specification.
4) Evaluate the common TDOT surface mixtures by different measuring systems like DFT and compare to current BPN and Locked Wheel Trailer testing currently used.

Benefits and Implementation:

Benefits include:

1) Increasing the use of local materials with low silica content to achieve more economical asphalt wearing surface.
2) Providing an easy way to determine the influence of RAP material on friction of asphalt mixtures.
3) Optimizing the macro-texture and micro-texture to establish the desired frictional properties.
4) Based on the findings from the study, recommendations will be made to TDOT and adopted in the TDOT specifications.

Research Team Requirements:

The research team is expected to have staff knowledgeable with pavement design, testing and evaluation, pavement maintenance, mix design of asphalt pavements, and pavement materials.

TDOT Assistance:

TDOT can assist the research team by providing lock-wheel friction testing, historical friction data conducted by lock-wheel testing, coring, and traffic control.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $200,000.00

Research Request for Proposal

Title: Inspection of Drilled Shaft Rock Sockets in Karst Areas Prior to Concrete Placement

RRFP Number: 16

Problem Statement:

East Tennessee has proven to be a difficult location for the installation and construction of drilled shafts due to many areas having karst features. Despite their difficulty, drilled shafts continue to be the preferred foundation for bridges in deep water or adjacent to existing structures. Currently, only the bottom of the drilled shaft excavation is inspected. On multiple projects, voids in the sides of a rock socket have led to problems during concrete placement. There have also been instances where the casing has not been advanced deep enough into steeply dipping rock. This can cause significant delays during construction as problems arise with extra concrete placement, water infiltration into the shaft, and possible rejection of a shaft. TDOT needs a better way to inspect rock sockets within karst areas to avoid construction delays and additional construction costs. Inspection would need to be real time to allow for quick decisions on the acceptance of a rock socket and should include inspection of all sides of the socket as well as the casing/rock interface if casing is used. Turbid water or slurry, as well as high pressures due to depth of water should be anticipated.

Research Objectives:

This research should create a device that can utilize inspection methods within a drilling medium (slurry or water) that can also be utilized at high pressures for deep shafts ranging from four to twelve feet in diameter. The goal would be to clearly define the edge of the casing-rock interface as well as define any voids in the side walls of the rock socket. If a void is detected, the device should have the capability for further analysis of the void to determine the horizontal extents of the void within two diameters of the shaft width. The device should be able to be lowered into the shaft securely by either utilizing its own launching system or by attaching to a Kelly bar maintaining vertical orientation. Additionally, the device should have the capability to measure water flow in the bottom of the shaft. It should be able to give real-time visual results to allow for immediate decisions relating to the acceptance of the shaft and be a non-destructive testing method.

Research Deliverables:

Deliverables should at minimum include:

- Proof of testing of the manufactured device complete with tests of manufactured shafts with known voids and proof of identification of the voids. If successful, deliverables would also include a working, non-destructive prototype, user's manual, and any applicable software. Please see the Additional Note at the bottom regarding patentable products.
- A final report, presentation of results and training on the operation of the system is required.

Benefits and Implementation:

If successful, the new device could be helpful throughout the drilled shaft industry. For TDOT, inspection of this kind would reduce risk during construction, lessen construction delays, and help provide better foundations for the bridges in Tennessee. The results of this project carry potential for great statewide indirect economic benefits as well as cost-savings for TDOT. Additional potential for broader use across states may also be available and would be invaluable.

Research Team Requirements:

A research team for this topic would need to include geotechnical engineers that understand karst and drilled shaft construction as well as someone with experience in industry that understands the instrumentation and manufacturing needed to develop the device.

TDOT Assistance:

TDOT would be willing to allow the inspection of an upcoming drilled shaft when the device is ready for deployment if a shaft is available within the research timeframe. The results of this inspection will be helpful to the research even if the shaft is not in a karst area. TDOT will also provide details on problems encountered on previous projects involving drilled shafts within karst areas to help develop the test shafts for the research.

Estimated Cost and Project Duration:

Project Duration: 36 months

Estimated Cost: $300,000.00

Additional Note:

TDOT is providing additional information about its use of any patentable items from research projects. The Research Office contracts read: "The State and the Grantee are subject to the provisions of 37 CFR Part 401 governing patents and inventions, and the standard patent rights clause at 37 CFR Part 401.14 is hereby incorporated… The State and the Federal Highway Administration (FHWA) shall have a royalty-free, non-exclusive, and irrevocable right to unlimited use of any and all aforesaid material developed or created as a result of the work or services specified…"

For this proposal, please refer to the legislation cited for product ownership considerations resulting from this project.

Research Request for Proposal

Title: Optimized Aggregate Gradations for Concrete Mixture Designs

RRFP Number: 17

Problem Statement:

Tennessee does not currently have procedures and/or specification requirements that fully support the use of optimized gradations in concrete mixtures. Current practices detailed in Section 604.03 of TDOT's Standard Specifications utilize a prescriptive practice of setting minimum and maximum contents of various mixture components. These prescriptive concrete mixtures are often over-designed for the intended purpose of meeting strength requirements - since acceptance for payment is based on strength. Advancements in mixture practices could allow for mixtures designed for a specific purpose to be designed with a less prescriptive approach.

The impacts of this research include the potential to create new procedures that will result in all producers creating more durable and equal and/or higher strength concrete mixtures. With improvements to the aggregate structure of the concrete mixtures, future designs could have much lower paste contents. This impact would lead to both a reduction in overall price of the mixtures and a reduction in the overall carbon footprint of each mixture. This research also supports other on-going research in Performance Engineered Mixtures or PEM. Changing the aggregate structure would lead to more durable mixes that result in better performance of our concrete mixtures.

Ultimately, the goal of this research is to allow concrete mix designers to utilize innovative methods to tailor their designs to the departments specific performance needs all while reducing cost and environmental impacts.

Research Objectives:

- Collect data regarding the available aggregates available to Tennessee concrete producers
- Determine/Analyze the effects of adjusting the target mixture gradations in relation to the paste content and the overall strength of each mixture
    - Control mixtures in comparison to optimized mixtures of the same constituent materials
- Observe the performance of TDOT concrete mixtures with and without an optimized gradation
    - Determine the performance benefits of optimized gradations
- Determine necessary changes needed to the 2021 TDOT Standard specifications, supplemental specifications, and/or Standard Operating Procedure (SOP) 4-4
    - Determine if any of the minimum and/or maximum limits have merit
- Will a minimum of three bins be necessary to implement optimized gradation procedures?

Research Deliverables:

This project should intend to deliver:

- Recommendations for optimized gradation blends with currently available stockpiles
- Recommendations for testing various aggregate sizes as well as recommended frequencies.
- Necessary changes needed to the 2021 TDOT Standard specifications, supplemental specifications, and/or Standard Operating Procedure (SOP) 4-4
- A final report and research results presentation

Benefits and Implementation:

Multiple new theoretical and experimental methods have been recently developed for aggregate optimization for concrete structures and pavement design. The Tarantula curve, which was developed based on a large amount of highway pavement data, has been quickly adopted in the highway pavement industry and state highway agencies. This research will help keep TDOT on the forefront of implementation. This effort also supports other on-going research initiatives relative to Performance Engineered Mixtures (PEM). Optimized gradations will be used to reduce paste volume. Reducing the past volume provides several benefits including an overall reduction in the cost of concrete structures, an environmental benefit of less cement use (reduction in CO2 Emissions), and reduce the potential for shrinkage cracking, which ultimately reduces long term maintenance and replacement costs.

Research Team Requirements:

The research team tasked with this assignment should have an intimate understanding of TDOT's current mix design practices/procedures detailed in Section 604.03 of TDOT Standard Specifications and SOP 4-4. The research team must also understand the applicable usage of each individual constituent material – including the various aggregates, various cement types (I, IL, III), cement replacements, admixtures, etc.

TDOT Assistance:

TDOT can provide contact information to aggregate, cement, and/or ready-mix producers as well as guidance on the use of SOP 4-4 and details of Section 604.03 upon request. Note: Collecting and shipping of materials related to this project should be considered in cost estimation.

Estimated Cost and Project Duration:

Project Duration: 24 months

Estimated Cost: $225,000.00

Research Request for Proposal

Title: Development of an Intelligent Traffic Monitoring System Based on Artificial Intelligence

RRFP Number: 18

Problem Statement:

A traffic monitoring system is an essential tool to collect traffic data such as vehicles volume, classification, and speed, that are used to analyze the performance and operation of roadway systems to improve traffic efficiency and safety. Existing traffic monitoring systems are largely categorized into intrusive, nonintrusive, and off-roadway systems. Intrusive systems install different types of sensors such as magnetic sensors, vibration sensors, and inductive loops, under the pavement of a roadway. Nonintrusive solutions utilize sensors such as magnetic sensors, acoustic sensors, and LIDAR sensors, deployed either on roadsides or over the road. Off-roadway traffic monitoring systems use airborne sensor systems such as unmanned aerial vehicles and satellite systems. The intrusive solutions incur very high costs to install the sensors under the pavement, typically requiring temporary lane closure. Nonintrusive traffic monitoring systems, on the other hand, have been widely adopted to achieve better performance at a reduced cost. However, the performance of the nonintrusive traffic monitoring systems greatly depends on the environment where they are deployed and how the systems are configured.

Research Objectives:

The objective of this research is to develop a self-adaptive, low-cost traffic monitoring system that can be easily deployed anywhere at any time to accurately collect traffic data without requiring expert knowledge of TDOT personnel. The research objectives include:

- Development of a reinforcement learning algorithm to allow the traffic monitoring system to autonomously configure the sensors to achieve the optimal performance regardless of the traffic environments.
- Development of a sensor-fusion algorithm to effectively utilize heterogeneous sensor data to enhance the accuracy of vehicle classification and speed estimation under various weather and lighting conditions. Thus, such data can be used to analyze traffic performance.
- Analysis of data in real time and an assessment to the traffic performance of the area being monitored.
- Identification of metrics and parameters to serve such assessment in collaboration with the Transportation Operations stakeholders. In addition, the developed system should evaluate the identified parameters to classify the parameters based on the critical status based on the traffic performance.
- A proof-of-concept traffic monitoring system will be developed and deployed at a test site to autonomously train the vehicle classification and speed estimation models, to configure the system, and to validate the performance.

Research Deliverables:

If successful, deliverables should at minimum include:

- A easy and quick installation process of the developed traffic monitoring system.
- A low cost nonintrusive, self-adaptive traffic monitoring system.
- The sensor-fusion and machine-learning algorithms of the traffic monitoring system.
- An interface to:
    - Integrate into the real time database from the SmartWay Central Software
    - Allow for the user to select the limits of the area being monitored
    - Present the identified critical parameters to the user
- Any applicable workshop(s)/training(s) for TDOT (or other transportation) personnel to understand the system developed and deploy it appropriately.
- A user manual will be created to explain the details on the potential installation and operation process of the traffic monitoring system.
- A final report and presentation on the research will be required with the necessary information needed by the Research Office.

Benefits and Implementation:

The results of this research will potentially be implemented in policy:

- The monitoring system may be deployed at the areas of TDOT's interests.
- The traffic data collected using the traffic monitoring system will be used to enhance the performance of the traffic monitoring system by improving the machine learning algorithm and correcting potential hardware or software issues. The traffic data will also be used for further research to improve traffic efficiency and safety.

If successful, the following benefits are expected for TDOT:

- The easy and quick installation process of the traffic monitoring system will allow TDOT to deploy the system anywhere at any time to promptly provide up-to-date traffic information to their customers.
- The low cost of the traffic monitoring system will allow TDOT to deploy a large number of traffic monitoring systems to provide fine-grained traffic information covering multiple road segments.
- The self-adaptive feature of the traffic monitoring system will minimize the training time for TDOT personnel to operate the traffic monitoring system.
- The sensor-fusion and machine-learning algorithms of the traffic monitoring system will allow TDOT to collect highly accurate traffic data including vehicle types, vehicle speed, and lane usage, etc., in real time.
- The potential for deployment of a highly sophisticated system would save TDOT and road users and taxpayers a significant amount of time and money over the long-term.

Research Team Requirements:

The research team should have knowledge on traffic safety and analysis knowledge to conduct the research. In addition to that, the team should have members who have expertise on computer programming and hardware.

TDOT Assistance:

TDOT may be able to provide access to datasets, samples for testing, access to equipment/facilities, etc.

Estimated Cost and Project Duration:

Approximately, projects will take 2 years to complete and cost between $200,000.

Additional Note:

TDOT is providing additional information about its use of any patentable items from research projects. The Research Office contracts read: "The State and the Grantee are subject to the provisions of 37 CFR Part 401 governing patents and inventions, and the standard patent rights clause at 37 CFR Part 401.14 is hereby incorporated into this Grant Contract by reference. The State and the Federal Highway Administration (FHWA) shall have a royalty-free, non-exclusive, and irrevocable right to unlimited use of any and all aforesaid material developed or created as a result of the work or services specified in this Grant Contract."

Please keep this in mind with any and all potential inventions (this does not include copyrightable items) that may arise from federal and state-funded projects. TDOT withholds the right to maintain the copyright of any copyrightable items that result from the research projects it funds.

Research Request for Proposal

Title: Evaluating the Impacts of I-24 Smart Corridor Strategies

RFP Number: 19

Problem Statement:

The I-24 Smart Corridor Study evaluated multiple capacity and operational improvements to manage congestion and improve safety on I-24 Corridor. Due to physical, environmental, and financial constraints, further widening is not feasible, nor will it permanently reduce congestion on the I-24 Corridor. Now, TDOT is forming partnerships with local authorities to implement the resulting I-24 Smart Corridor initiative. This initiative proposed various deployment objectives that included, among others, increasing travel time reliability and reducing crashes on the I-24 Smart Corridor. Proposed improvements to be deployed on I-24 Smart Corridor as part of Phase 1 include emergency pull offs, ramp extensions, and connected vehicle infrastructure; Phase 2 comprises dynamic lane use control, variable speed limits, and queue warning; and Phase 3 includes ramp metering. Now as these strategies are being deployed, TDOT needs to better understand the impacts of these improvements to inform future transportation projects.

Research Objectives:

This research will identify performance measures and the necessary data to determine the impacts of the strategies deployed as part of the I-24 Smart Corridor. The research will also review before-conditions of all phases and after-conditions for Phases 1 and 2 of each strategy deployed, and it will provide a benefit-cost analysis of the Phase 1 and 2 strategies. The final report should provide information that will be useful in scoping future Smart Corridors.

In summary, TDOT needs the project to:

(1) Establish performance metrics and the necessary data for all phases,
(2) Measure before conditions for all phases,
(3) Measure after-conditions for Phases 1 and 2, and
(4) Include a benefit/cost comparison for each strategy in Phases 1 and 2.

Research Deliverables:

Most deliverables for this project can be provided as part of the final report and should at minimum include:

(1) Identification of appropriate performance measures for all phases.
(2) Identification of the data needed and where to get it to measure the performance.
(3) An analysis of the before conditions for the corridor for the identified performance measures for Phases 1 and 2.
(4) An analysis of the after impacts of each strategy deployed during Phase 1 and 2.
(5) A benefit-cost analysis of each strategy from Phases 1 and 2.

(6) The report shall include a transferable methodology for each analysis.

Methodologies should be easily replicable for TDOT staff to use in further evaluations. If necessary, a separate workshop can be provided to assist DOT staff in the technology transfer required.

Lastly, before data needed for an analysis of ramp metering should also be collected and provided as a separate deliverable.

If project time allows recommendations for other corridors to deploy SMART technology should also be considered.

Benefits and Implementation:

Widening interstates is getting more difficult though traffic congestion is continuing to grow. The findings in this report will help TDOT in determining the best performance measures for a Smart Corridor. The report will provide the details on what data is needed and where to get that data. The analysis of the specific strategies will help TDOT to know which strategies are the most impactful to the congestion conditions and which strategies may be beneficial on other corridors in Tennessee. The success of the I-24 Smart Corridor will determine how Smart Corridors are deployed in the future.

Research Team Requirements:

The research team needs to have a good understanding of Integrated Corridor Management, Active Freeway and Arterial Management, ramp metering, and other operations improvement strategies. The team needs an understanding of performance measurement and data analysis as well as the data sources available from TDOT or outside TDOT. Experience with benefit-cost analyses in transportation is also preferred. The team should demonstrate an understanding of the strategies TDOT is deploying as part of the I-24 Smart Corridor.

TDOT Assistance:

TDOT can provide access to any TDOT raw data from RDS, Ritis, ETRIMS, Traffic volume data, Incident data from the Smartway Central Software. TDOT can also provide Planning documents and Project Plans for the I-24 Smart Corridor Project as well as access to the ROW for research team to collect field data.

Estimated Cost and Project Duration:

Project Duration: 36 months

Estimated Cost: $200,000.00

The “before” data analysis should start within the first 6 months of the project. The “after” data will need to be collected 6 months to a year after phase 2 installation is complete.

Research Request for Proposal

Title: Evaluation and Improvement of Traffic Signal Clearance Safety in Tennessee

RRFP Number: 20

Problem Statement:

Signalized intersection safety relies primarily on the precise calculation and implementation of traffic signal clearances (yellow change interval and red clearance interval). Determining the clearances are dependent on many factors, such as the geometry of an intersection, the vehicle length and speed, etc. A reasonable clearance interval will reduce the potential for intersection crashes by providing sufficient time to clear the intersection without decreasing intersection capacity. Therefore, precise calculation and implementation of traffic signal clearances is crucial for traffic signal design.

Vehicular speed and average deceleration rate are two essential parameters used in the current (and any future or revised) traffic signal clearance calculation methodology. Common practice in Tennessee and around the country points to the use of approach speed (typically based on adjusting the posted speed limit by movements) to determine the change period. However, in recent years, there is an argument that the deceleration required before turning movements is not completely considered in the equation that is used to determine clearance intervals. To address this issue, the Institute of Transportation Engineers (ITE) issued a new guidance which incorporates extended kinematic equation into the determination of signal clearance. Therefore, it is necessary to investigate the feasibility of using extended kinematic equations in TDOT Traffic Design Manual. In addition, this research study would use current technology (radar, or even potentially video) to examine vehicular approach speed trends for different movements at different intersection geometries and in different regions of the State.

Research Objectives:

To address the issues above, the objectives of this research include:

1) Conduct a nationwide survey to gather information regarding how other agencies implement traffic signal clearances.
2) Investigate Chapter 7 of TDOT traffic design manual and identify the potential issues with traffic signal clearance.
3) Utilize appropriate technologies to conduct case studies to validate signal clearance and extended kinematic equations.
4) Provide recommendations, if there is any, on how to improve the design practices of traffic signal clearance and develop related guidance that may be adopted by TDOT.

Research Deliverables:

Deliverables should at minimum include:

- A final report and final presentation that document all the findings of this research.

- Data and equations for changes based on extended kinematic equations that can easily be replicated as TDOT may update its Traffic Design Manual in the future.
- A proposed revision of Traffic Signal Design Sect. 7.5.5 -Yellow Change Interval and Red Clearance Interval.

Benefits and Implementation:

As TDOT's been continuously working on providing a safety transportation system to the traveling public, the results and findings from this study would be beneficial to TDOT in the following areas:

1) Reducing the potential for crashes at intersections by considering the influence of different turning movements.
2) Optimizing signal timing by incorporating the most recent research findings into TDOT design manual.
3) Providing guidance to State and local agencies on the appropriate selection of traffic signal clearances.

Research Team Requirements:

The research team is expected to have knowledge and working experience with traffic engineering, especially in the field of traffic operation.

TDOT Assistance:

TDOT can assist the research team by providing access to TDOT database, such as ETRIMs.

Estimated Cost and Project Duration:

Project Duration: 18 months

Estimated Cost: $175,000.00

Research Request for Proposal

Title: TDOT RDS Data Quality Assurance and High-Resolution Content Enhancement

RRFP Number: 21

Problem Statement:

TDOT has invested significantly in and benefited tremendously from its RDS data system, which is the backbone for gathering real-time and long-term traffic flow information along major arteries in and around major urban areas in Tennessee. The large amount of data produced by current RDS devices, about 2GB per day, exhibits typical data quality issues occasionally, has mixed accuracy in lane-level average traffic speeds, and does not classify vehicle types (except the 'bin 3' long counts, which are not very accurate and only available for less than 10% of the stations). Additionally, stored data can be cumbersome to view, query, or to generally work with.

To this end, research is needed to improve RDS data quality, usability, viewability, assurance, and high-resolution content. The outcome of this research aims to enhance RDS data quality without the need for infrastructure investments. Aside from traditional data analysis and modelling techniques, more robust approaches could help achieve this goal (such as machine-learning algorithms).

Additionally, this research aims to develop a user-friendly graphical user interface (GUI) to allow for easy access and viewing of databases while being able to query its content based on certain criteria (e.g., date range, time range, State, County, route, roadway direction, type of vehicle, type of facility, number of lanes, speed range, volume range, etc.). Incorporating such criteria will be beneficial in identifying and working with historical data versus live data (currently every 30 seconds). The GUI should provide graphing capabilities of select variables within the data.

Research Objectives:

Develop an algorithm that is based on advanced data analysis methods such as machine-learning algorithms to enhance the quality and content of TDOT's RDS system. Develop a graphical user interface to access stored data while being able to query data based on specific criteria. The algorithm and GUI should provide:

1. data health assessment and lost/erroneous imputation,
2. direct lane-by-lane truck counts derivation (more accurate than the current limited 'bin 3' option),
3. more accurate lane-based car speed and truck speed derivations, and
4. GUI to query, view, and graph RDS data

The successful implementation objective of advanced data analysis should also give RDS data files new columns of 30-second lane-by-lane number of trucks (long count), number of cars (short count), average truck speed, average car speed, and imputed traffic flow throughout each day at each RDS

station.

Note: The implementation is straightforward and non-intrusive to TDOT's other existing functions. No new policies are needed.

Research Deliverables:

In project scoping, a schedule of interim deliverables will be determined to demonstrate progress throughout the research project.

Deliverables should at minimum include:

- Final research report and results
- A user-friendly GUI to query and view RDS data
    - The tool should allow for data health assessments and derivations mentioned in the objectives section
    - This program should also give RDS data files new columns of 30-second lane-by-lane number of trucks (long count), number of cars (short count), average truck speed, average car speed, and imputed traffic flow throughout each day at each RDS station.
    - Transferrable knowledge for equation derivations and updateable information
- A workshop on using the new tool for applicable TDOT employees

Benefits and Implementation:

RDS data are collected continuously already. The sooner this algorithm is developed, verified, and implemented the sooner the RDS system could be providing more accurate and more insightful info beyond the traditional realm of traffic operations.

The benefits of this research include:

1. better awareness of and improvement of RDS data health,
2. more accurate lane-by-lane traffic speed data (not attainable from WAZE or NPMRDS),
3. large area-coverage of truck counts at near 1,000 locations for over 5,000 lane/spots,
4. insightful lane-based truck load distribution info for pavement material and roadway design purposes,
5. info for TDOT Freight and Logistics activities with new weight and classification sites, and
6. data accessibility and viewability through a graph-capable, user-friendly GUI.

For implementation, the daily 2GB RDS data will be scrubbed for imputation purposes and processed with machine-learning algorithms to generate additional data columns (such as truck counts, car counts, truck speed, car speed, overall speed, and data quality index). As the new database will be several times larger, it will be archived and separated to preserve the integrity of the raw data. TDOT will require that the newly enhanced RDS database be uploaded to TDOT designated servers and that the GUI would be a web-based application with easy access to TDOT staff.

Research Team Requirements:

Research team needs to be well versed in traffic counts and in handling traffic count data. They also need to be knowledgeable on how RDS's work and their benefits and shortcomings. Proficiency with machine learning software, programming, and application development are necessary.

TDOT Assistance:

TDOT personnel will be able to provide access to TDOT databases and equipment. Field access and TMC access can also be provided.

Estimated Cost and Project Duration:

Project Duration: 30 months

Estimated Cost: $250,000.00

Enough time should be allotted for applicable testing of the created tool.

Research Request for Proposal

Title: Investigation into Towing Regulation in Tennessee

RRFP Number: 22

Problem Statement:

Towing and recovery services are a critical, and often underappreciated, element of TIM. A standard practice to clear crash scenes in Tennessee (TN) is to charge by the hour for complex scenes that involve commercial vehicles. This may disincentivize quick clearance. Many innovative strategies for towing commercial vehicles, such as pay-by-the-pound, zone-based coverage, and time-based incentive-disincentive payments, are used by some cities within Tennessee and other States. These innovative strategies are reported by agency staff from GDOT and FDOT to have significantly beneficial impacts on time to clear. The proposed research project seeks to quantify the effects on clearance times in TN if innovative regulations were to be enacted. The proposed research should also provide guidance concerning regulations and statutes that would need to be addressed to employ more efficient strategies. It is understood that updating towing regulations can be controversial; therefore, TN-specific data are needed to quantify any positive effects on clearance time.

Research Objectives:

The overarching research objective is to determine if more advanced commercial vehicle towing regulations would improve clearance times on Tennessee's interstates and State Routes. Improving clearance times has a proven ability to improve safety by reducing the risk of secondary crashes, as well as improve traffic operations. It is also expected that the research team would interview each of the four Regional Traffic Management Center (TMC) managers. If more advanced towing regulations are shown through the research to improve clearance times, then the project should recommend revisions to Tennessee's existing regulations.

For additional information concerning the research objectives, please see the "Research Deliverables" section.

Research Deliverables:

Deliverables should at minimum include:

- *Final deliverable is a separate white paper summarizing findings and the benefits of improvements to incident clearance times*, including the reduction in secondary crashes and travel time reliability. If the research demonstrates that enhanced regulations would be beneficial the paper will be used to promote changes in State regulations and policies.
- *"State of the Practice" summarizing other State Agencies regulations and policies*. Focus should be on border states to TN plus Florida. Georgia is an emphasis state as it is understood they have more advanced regulations.
- *"State of the Practice" of Tennessee's four largest Cities (Memphis, Nashville, Knoxville, Chattanooga) summarizing these municipalities towing regulations to Tennessee's less restrictive*

state regulations (where applicable). For example, it is understood Nashville uses a zone-based and Chattanooga has a pay-by-the-pound (instead of pay-by-time) approach.
- *Charts and figures of Roadway Clearance Time (RCT) and Incident Clearance Time (ICT) throughout the state with current regulations and policies in place.* It is assumed these would vary by geographic location. Mapping with heat maps may provide insight concerning where improvements need to be targeted for most benefit.
- *Comparison of Roadway Clearance Time (RCT) and Incident Clearance Time (ICT) in areas* of the state that have different towing regulations and guidance than those found in the Tennessee Highway Patrol Towing Service Standards Manual as well as between Tennessee and border states that have advanced towing regulations.
- *Recommended changes (if any) to the State of Tennessee's regulations and towing manuals* that would improve clearance times, and therefore lower the risk of secondary crashes improving safety and operations (may need to consider geographic contingencies).
- *General project management including monthly progress meeting and progress report.*
- *Research Results Final Presentation and Final report required by the Research Office.*

In project scoping, a schedule of interim deliverables will be determined to demonstrate progress throughout the research project.

Benefits and Implementation:

Benefits of the project will be to assess if changes in regulations would improve clearance times in Tennessee, if so which changes have the most benefit, and what changes would be needed in state laws and policies.

Quick and efficient Traffic Incident Management (TIM) strategies bring significant benefits in that it:

- Reduces congestion.
  - Decreases fuel consumption, minimizes emissions, diminishes travel time delays, improves travel time reliability, and lowers vehicle operating costs.
- Boosts efficiency and productivity for local agencies (law enforcement, responders, highway agencies, etc.).
  - Improves customer satisfaction for these agencies.
- Increases the safety of people involved in incidents and other road users.
  - Reduces mortality/morbidity rates, decreases the opportunity for secondary incidents, and reduces exposure for first responders.
- Cuts the number of required law enforcement officers at the scene.
- Widens responders' understanding of how their actions affect the greater community.
- Heightens drivers' confidence in travel time reliability.

Research Team Requirements:

The team should be experienced with TIM principles including Roadway Clearance Time and Incident Clearance Time. The team should be experienced working with TDOT and RITIS data sets, including RITIS' Probe Analytics incident data. The team should have expertise assessing Tennessee's regulations and legal framework, especially in relation to towing regulations. The team should be familiar with the State of Tennessee Department of Safety and Homeland Security (DOSHS) Tennessee Highway Patrol Towing Service Standards Manual, as well as the skillset to

research, summarize, and compare towing-related regulations in Tennessee's municipalities to the State regulations. Overall, expertise in accident clearance strategies and incentive-based policies to improve clearance is preferred. Experience for students to participate in this work should be extensive as TDOT is expecting quick turnover from this project.

TDOT Assistance:

TDOT will provide access to any TDOT raw data from RDS, RITIS, ETRIMS, Traffic volume data, and Incident data from the Smartway Central Software. TDOT will also provide access to TDOT staff for interviews.

Estimated Cost and Project Duration:

Project Duration: 15 months

Estimated Cost: $100,000.00

Research Request for Proposal

Title: Updated Median Cable Barrier System Safety Effectiveness Evaluation

RRFP Number: 23

Problem Statement:

In 2016 TDOT completed an evaluation of safety effectiveness with respect to the reduction in the number of crashes, injury severities, and fatalities using 3 years of crash data before and after the cables were installed. The previous study utilized three (3) years of crash data before and after 2010 to evaluate 577 median cable barrier segments along 32 different highways in 48 counties with a total of 302 miles in length. It is expected that using 10 years of crash data after the cables were installed will significantly change the previous findings numbers. This proposed research seeks to update the safety effectiveness performances of the Median Cable Barriers in Tennessee with respect to the reduction in the number of crashes, injury severities, and fatalities. The study will also consider the benefit cost ratio for installation and maintenance cost compared to the safety and operational benefits that may result in any changes in crash frequency, severity, and delay related to major crash incidents.

Research Objectives:

The study will:

1. Rank the Cable Barrier Segments based on crash frequency and crash rate (using 10 years of data after the cables were installed up to 2013 crashes)
2. Evaluate Safety Effectiveness Performances of the Median Cable barriers in Tennessee (using 3 years of data before and 10 years after the cables were installed up to 2013 crashes)
3. Evaluate how some of the road geometries and traffic characteristics affect cable barrier performances (using 10 years of data after the cables were installed, up to 2013 crashes)
4. Develop a Benefit Cost Ratio for median barriers in Tennessee. The cost should include initial investment and annual maintenance and the benefits should include any changes in crash frequency measured by the crash cost, motorist delay, and any other related cost that would be realized.
5. Develop Crash Modification Factors (CMFs) for median cable barriers in Tennessee (using 10 years of data after the cables were installed up to 2013 crashes)
6. Each of these items should be compared to the results from the previous study and should provide analysis on the validation of the previous study's methods.

This proposed study attempts to update the previous findings using 10 years of crash data before and after the cables were installed, that will capture the diversity of cable safety performances compared to previous findings. The study will also evaluate any task or component that was not included in the previous tasks.

Research Deliverables:

Deliverables should at minimum include:

(1) The study should provide a final report and presentation to applicable TDOT staff.
(2) The study should also provide a robust benefit-cost analysis and should provide thorough methodological narrative to help TDOT determine the efficacy of its median cable barriers.
(3) Additional easy-to-read documentation regarding the updated findings may be requested.
(4) Assist in the incorporation of CMFs into any necessary TDOT policies/procedures/manuals.

Benefits and Implementation:

Findings from the safety effectiveness study will assist in determining whether cable barriers are a cost-effective solution and define the Benefit Cost Ratio when installed. These finding will be used to help evaluate the current state of practice for Tennessee and may help support future decision for consideration of potential expansion of the program as well as respond to the public perception on the program. The study will inform TDOT safety effectiveness with respect to the reduction in the number of crashes, injury severities and fatalities. The study will inform TDOT of the impact of different geometric features as well as traffic characteristics to the safety performance of the cable barriers. The study will develop crash modification factors (CMF) for segments with median cable barriers relative to no cable barrier segments.

Research Team Requirements:

The Research Team is preferred to have expertise and/or experience in transportation safety infrastructure and analysis (specific expertise in cable barriers is preferred) and effective benefit cost analyses of transportation infrastructure.

TDOT Assistance:

TDOT can provide assistance with ETRIMS crash data, traffic volumes, route feature data and access to cable rail installation records as requested by the research team throughout the duration of the project.

Estimated Cost and Project Duration:

Project Duration: 15 months

Estimated Cost: $125,000.00

Research Request for Proposal

Title: Strategies for Improved Driver Behavior within Work Zones

RRFP Number: 24

Problem Statement:

Work zone crashes and fatalities continue to be of increased concern on Tennessee Roadways. It is generally accepted that these events are at least partially due to unsafe driver behavior, travelling at excessive speeds, and/or distracted driving as they approach and travel through work zones. TDOT is looking for effective strategies to decrease driver speeds, increase attentiveness and ultimately lead to safer TN work zones. Work zone safety is a top priority for TDOT, and the Department will greatly benefit from learning more about effective control measures.

Research Objectives:

The general objectives of this research include the following:

- Research the effectiveness of targeted law enforcement strategies on driver behavior, both short-term and long-term effects to achieve lasting changes in driver behavior.
- Research the use of automated and other alternative law enforcement strategies and technologies for use within work zones where conditions may not permit the needed space for safely pulling drivers over.
- Explore the use and effectiveness new or existing technologies of providing information to drivers. This could be via mobile communication or real time changeable message boards
- Explore the effectiveness of better quality and different types of Pavement Marking, Sign Types and Placement. Such details can include differing sizes, reflectivity, etc.

Research Deliverables:

Proposed research should provide TDOT with data driven results that reflect improved driver behavior or increased work zone safety. Deliverables should at minimum include:

- A case study or studies that show work zone safety improvements measures in comparable areas either within Tennessee or in surrounding states.
- A review of different types of work zone areas that drivers may encounter along with the varied approaches that contribute to greater safety for worker and driver alike.
- Recommendations for pilot testing of options explored from the study.
- Recommendations for better enforcement or more effective control measures.
- A final report and presentation documenting these deliverables and other requirements from the Research Office.

Benefits and Implementation:

Benefits from this research could lead to both safer roadways for vehicles and for workers. This information could lead to improved Work Zone Traffic management strategies within the state of

TN and nationally. Other notable benefits include the following:

- Decreased Work Zone Crashes, injuries, and deaths
- Safer Work Zones for TDOT staff and workers
- Improved Driver Behavior – Increased attentiveness and decreased speed

Research Team Requirements:

Team should have expertise in the fields of transportation engineering, transportation technology, work zone and traffic devices, etc. Team should also have expertise in statistical and data analysis, traffic modelling and other related fields, especially as it relates to driver behavior.

TDOT Assistance:

TDOT will provide support needed to complete this research. Such support may include TITAN crash data, RITIS traffic data, access to active work zones as well as ongoing consultation and discussion.

Estimated Cost and Project Duration:

Project Duration: 36 months

Estimated Cost: $250,000.00