**Guide to Life-cycle Data and Information Sharing Workflow for Transportation Assets**

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1. **Abstract**

The purpose of this proposed research is to enhance the understanding of data and information workflow during the life-cycle of transportation assets by capturing the industry knowledge and experience and developing a business process map and a data sharing map. The adoption of various advanced digital technologies has enabled a large portion of the project life cycle data to become available in digital format. However, due to the fragmented nature of the highway industry sector, digital data sets are being archived, and managed separately. Due to this reason, the transportation assets as a whole have not yet fully benefited from the growing amount of digital data since digital data from distinct actors are yet to be linked and fully reused. By seamless exchange of data and information throughout the project life cycle, a significant amount of efforts can be saved, and high efficiency can be achieved. This research aligns with the MTC’s theme “Data driven performance measures for enhanced project delivery”. This proposed project aims to enable the transportation sector to accomplish that goal by: (1) identifying business processes that require data sharing during the project life cycle, (2) identifying data exchange requirements specifying what data to be shared by whom and to whom. These objectives would be achieved by conducting intensive, literature review, benchmarking the vertical industry, focus group discussions with industry professionals from various disciplines and phases. This proposed project is expected to enhance the process of data and information sharing; and consequently, help to reduce operational costs of highway assets.

1. **Problem Statement**

The adoption of various advanced computerized technologies such as 3D modeling, LiDAR and Geographic Information System (GIS) is making a transformative change in how project information is produced, exchanged, and managed throughout the life cycle of a transportation project from an analog to a digital data based system. With ample evidence and success stories from the vertical construction industry and some promising case study results from the highway industry, the significant improvement of data and information sharing between project participants and across various project development stages is possible with a model based project delivery process, and electronic and digital data transfer systems, which will in turn translate into increased productivity, efficiency in project delivery, accountability, and asset management.

However, in current practices, digital data and information are being used and managed independently in proprietary formats by separate project participants, and the data exchange processes are still relying on paper or electronic paper based formats rather than digital datasets. Several efforts have been made by the Federal Highway Administration (FHWA) through various Webinar series to provide guidance and assistance for digital modeling implementation for highway projects, but there is not yet specific guidance on the flow of data and information across highway project phases. Research is needed to understand the current state of practices in digital data sharing throughout the life cycle of transportation projects and to develop a guidance on data flows, data sharing requirements, and supporting software applications and techniques to allow full reuse of digital data and information for particular use scenarios.

The proposed research aims to develop a guide to help professionals of State Departments of Transportation (DOTs) understand the digital data and information flow during the project life-cycle for various type of transportation assets including pavements, bridges, culverts, signs, guardrails, etc. The guidebook will include but not limit to the following topics: (1) business use cases in which data sharing between project actors is needed, (2) business processes that define clear sequences of the activities to be performed for data and information sharing and exchange, and expected outcome; and (3) data requirements, data sources, levels of detail, software applications and tools involved in specific data exchange use cases.

1. **Relevance to MTC Theme and Thematic Thrust Areas**

The proposed project directly meets the MTC theme of “data driven performance measures for enhanced project delivery” by enhancing our understanding of data and information flow throughout the project life cycle and developing a data and information exchange map to support data driven asset management. It also meets the US DOT’s strategic goal of *Economic Competitiveness and Livable Communities* by contributing to reducing significant wastes of data and information re-creation during the asset management stage due to incomplete data and information handover. A PhD student who will be hired throughout the duration of this study will be given an opportunity to develop leadership and a professional career in the transportation field.

1. **Research Approach and Methods**

The objective of this study is to capture industry experts’ knowledge and needs regarding digital data and information sharing during the life cycle of transportation assets. In order to achieve that goal, Literature review, benchmarking the vertical industry practices, and focus group discussions will be extensively used. A working group will be formed including domain industry professionals with various expertise from State DOTs, consultants, contractors, and software vendors. This focus group discussion will help identify and document the data exchange scenarios, data flows, data requirements, data format, and supporting software applications. Based on discussion results, a process map and a data map will be developed. The process map will show the data exchange processes throughout the project lifecycle, and the data map presents what data required to be shared by whom and to whom and when. The next section specifically describes required work tasks.

1. **Description of Tasks to be completed in Research Project**

To accomplish the research objectives, five tasks below will be performed.

***Task 1: Literature review and benchmark the vertical industry practices***

The transportation sector is behind the building construction sector in this area. The research team will document the best practices of the vertical industry through extensive literature review and identify and document lessons learned and possible areas of adaptations for the highway infrastructure industry. As part of Task 1, the Information Delivery Manual (IDM) will also be extensively studied and analyzed. IDM aims to define (1) processes through the life cycle of a building project in which information exchange is required, (2) which actors sending and receiving information for each process, and (3) definitions and descriptions for information to be shared (See et al., 2012). There are some IDMs available, for instance, IDM for building programming phase, IDM for Geographical Referencing (buildingSMART, 2016). This guidance has been widely accepted as an industry standard in the building and facility construction and management sectors.

***Task 2: Identify business use case narratives and develop process maps***

Focus group discussions will be used to identify business use cases in which data sharing between project stakeholders (actors) would occur. For example, the “cost estimating” use case would need data sharing between the engineer and cost estimator. Each identified scenario narrative will be described in plain language and consisted of the following information: (1) project phase (e.g., design), actors involved (e.g., designers, estimators), activities (e.g., cost estimating), software platforms used (e.g., CAD), purposes of the activities and anticipated outcome (e.g., total cost).

The research team will translate the narratives obtained above into a formal process map. The map needs to be readable to both human and machine so that it can be used for educating and training professionals and supporting the development of software tools to assist data sharing. Social Network and/or Business Process Modeling Notation (BPMN) which can both visualize the relationships between activities, actors, and information flow (input and output). The research team will test and benchmark these two tools and select the best tool to develop the process maps.

***Task 3: Identify data exchange requirements and develop data maps***

The workgroup will continue to discuss and identify data exchange requirements (ERs) based on the developed process maps. ERs specify what specific data to be shared, who is requesting the information and, to whom the data will be sent, and the rationale for the data requests. Based on the discussion results, the research team will document ERs in plain language with the level of detail that clearly defines what data entities (e.g., pavement layer), attributes (e.g., geometry information such as width, thickness), and specifications describing each data item so that the inconsistency of data names used among the experts can be eliminated. Also, software applications that create and receive those data would also be identified by the workgroup.

The data exchange requirements resulted from the discussions will be used by the research team to develop data maps that visualize the network of linked data items through data ownership links (relationships between data and project actors or DOT divisions). Table 1 below shows an example of the anticipated map in the tabular format.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Phases: design | | | | |
| **Data** | **Data description** | **Data creator** | **Data receiver** | **Data attribute** |
| Pavement layer |  |  |  |  |
|  |  |  |  |  |

**Task 4: Develop a guide for data and information sharing**

With the successful completion of the tasks above, the research team will develop a guidance for DOTs on data sharing during the life cycle of transportation assets. The guidebook will include the process maps and data maps along with plain language description which clearly describes the following items: a) business use cases where data sharing is needed, b) data and information requirements, c) detailed specifications for each data and information type, d) actors responsible for creating, receiving, validating, securing and maintaining the data and information, and e) software applications involved during each data transaction.

**Task 5: Preparation of Final Report**

A workshop/seminar will be held to quickly disseminate the findings to Transportation Agencies. A final report documenting research results from previous tasks will be developed and delivered to MTC.

1. **Expected Results and Products**

This project is expected to provide a better understanding on data and information flow throughout the lifecycle for various transportation assets. It will significantly enhance the process of data collecting and sharing between project participants. The major deliverables of this project include process maps, data maps and a guidebook for DOTs that can facilitate the implementation of data and information transfer for highway asset management.

1. **Technology Transfer Implementation Plan**

The research team will offer a webinar through the Tom Maze Transportation Seminar series to the member states of MTC and disseminate the research findings through the Mid-Continent Transportation Research Symposium and the Transportation Research Board (TRB) meetings.

1. **Timeline (GANTT CHART)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Work Tasks | 2016 | | | 2017 | | | | | |
| JulAug | SepOct | Nov Dec | Jan Feb | Mar Apr | May Jun | Jul Aug | Sep Oct | NovDec |
| Task 1 |  |  |  |  |  |  |  |  |  |
| Task 2 |  |  |  |  |  |  |  |  |  |
| Task 3 |  |  |  |  |  |  |  |  |  |
| Task 4 |  |  |  |  |  |  |  |  |  |
| Task 5 |  |  |  |  |  |  |  |  |  |

1. **Discussion of Pertinent Completed Research and Related Research in Progress**

The vertical sector is ahead of the horizontal sector in this area. Various studies have been undertaken to enhance the awareness of data and information sharing throughout the life cycle of a building project. BuildingSMART, which is a pioneer organization in this direction, has developed several Information Delivery Manuals (IDMs) that specify use cases where data exchange is required, what data to be exchanged, data sharing processes and what actors get involved in the processes (See et al., 2012). National Institute of Building Science (NIBS) has adopted the IDM methodology suggested by buildingSMART and has included this as a chapter in the national BIM standard (NIBS, 2007). There are several IDMs available for various types of business use cases, for instance, IDM for exchanging within the building programming phase, the use case of geographical referencing (BuildingSMART, 2016), construction to operation (Cobie) (East, 2007; East et al. 2012), designer and supplier collaboration (Berard et al. 2012), and data transferring for environmental and energy performance assessment (Pinheiro et al. 2015).

However, there are few studies on this issue conducted for the civil infrastructure sector. Some previous research focused on standardizing the data structure format such as Landxml (landxml.org, 2016) and Transxml (Scarponcini, 2006). These data standards provide rich sets of data generated through the transportation project life cycle. However, the data sharing problem which requires specifications for what and when data to be shared by whom and to whom has not yet been fully addressed.

Our research team has been successful with the recent efforts to enhance efficiency in data sharing through the life cycle of the civil projects. For example, we developed a social network based framework to analyze the relationships between data actors and data items to (e.g., roadway inventory, pavement cracks) for various use cases (e.g., treatment selection, selection of rehabilitation and maintenance) (Woldescenbet et al. 2015). In addition, we have developed a framework for interlinking isolated life cycle data spaces of a pavement asset to support decision making in asset management (Le and Jeong 2016). Also, we have proposed a methodology for addressing the issue of inconsistency of data attributes names which arises when integrating data from multiple sources. The successes in our prior research would enable us to successfully develop a practical guidance and tools to assist DOT staff in manipulating, searching and sharing data.

1. **STAFFING PLAN**

Dr. David Jeong will serve as the PI on this project. Drs. Chuck Jahren, Jennifer Shane, and Kristen Cetin will serve as CoPIs. One PhD student in Civil Engineering at Iowa State University will work during the entire period of this project. Dr. Jeong is the Director of the Data Analytics Laboratory for Project and Infrastructure Management (DALPIM) at Iowa State University. His research interests center around data, information and decision making processes throughout the project lifecycle including asset management. The increasing size of digital project and asset data has created new challenges and opportunities for the industry to better deliver the project and manage the assets. Big Data technologies, data analytics and data mining are the main methodologies that his research team has used to tackle the problems that arise from data to improve decision making processes. He has published more than 60 peer reviewed technical papers in this area for the past 10 years. His excellence of research has been recognized nationally. He has received 2008 best application paper award in operation engineering from the Institute of Industrial Engineering (IIE) and 2010 outstanding researcher of the year award from the Construction Industry Institute (CII). His research sponsoring agencies include National Cooperative Highway Research Program (NCHRP), Federal Transit Administration, Iowa Department of Transportation, Construction Industry Institute, Oklahoma Department of Transportation, Mid-American Transportation Center, Minnesota Department of Transportation, Midwest Transportation Consortium, etc.

Dr. Charles T. Jahren is the W. A. Klinger Teaching Professor and the Assistant Chair for Construction Engineering in the Department of Civil, Construction and Environmental Engineering at Iowa State University. He earned his Bachelor of Science in Civil Engineering and his Master of Business Administration from the University of Minnesota and his PhD in Civil Engineering from Purdue University. He has over six years of industrial experience as a bridge construction project engineer for a construction contractor and as a research engineer for the Naval Civil Engineering Laboratory in Port Hueneme California. His teaching interests include construction equipment, cost estimating and construction process design. His research interests include highway and heavy construction methods, road maintenance methods and innovations for the administration of transportation agencies, including digital data exchange, data warehousing and information management systems.

Dr. Jennifer S. Shane is an Associate Professor of Construction Engineering in the Department of Civil, Construction, and Environmental Engineering at Iowa State University and the Director of the Construction Management and Technology program at the Institute for Transportation. Prior to entering academia, Dr. Shane worked as an Engineering Associate I and II for the Kansas Department of Transportation (KDOT). Her position focused primarily on the construction of highways and bridges in northwest Kansas. She oversaw the construction of a bridge using precast beam and deck panel sections while with KDOT.

Dr. Shane has been involved with many national and local projects. Through this work she has developed technical reference manuals, reports, guidebooks, training materials, and other printed materials. Jennifer served as the PI for SHRP 2 R10: Project Management Strategies for Complex Projects. The objective of this SHRP 2 research project was to determine the specific requirements for successfully managing complex rapid renewal projects. Training sessions were held across the nation for nearly 200 participants. Participants are from state transportation agencies, the FHWA, universities, and industry consulting and contracting firms. The ultimate goal of the research was to develop a comprehensive training and development program to enable project partners to work more cooperatively on such projects.

Jennifer currently serves as the communication coordinator on one TRB committee, AFH10 Construction Management and is a member of the American Societies of Civil Engineering (ASCE) committee on Management Practices in Construction. In 2012 Jennifer was awarded the Iowa State University College of Engineering Early Career Engineering Faculty Research Award. She has also been recognized with a Black and Veatch “Building a World of Difference” Faculty Fellowship, Design-Build Institute Distinguished Leadership Award for Faculty, the Iowa State University Civil, Construction, and Environmental Engineering Charles W. Schafer Award for Excellence in Teaching, Research, and Service, and as a co-author of the ASCE Journal of Management in Engineering Best Peer Reviewed Paper in 2008 and 2014.

Dr Kristen S. Cetin is an Assistant Professor at Iowa State University in the Department of Civil, Construction and Environmental Engineering. She is also a licensed Professional Engineer and LEED AP certified.  She received her Ph.D. from the University of Texas at Austin in Civil Engineering.  Her research efforts broadly focus on assessing and improving the sustainability and energy efficiency of the built environment. She has partnered and worked with multiple universities, non-profits, research laboratories, businesses, and local government agencies in her research efforts thus far. Dr Cetin also has significant industry experience, including working as a consulting engineer at Simpson Gumpertz & Heger in the Building Technology division, energy modeler at Johnson Consulting Engineers, and an energy engineer in Facilities Services at the University of Texas at Austin, in the Energy and Water Conservation Program. She has had significant experience working with gathering, managing, and developing large sets of data on multiple energy related laboratory and field projects. She also taught a Building Information Modeling course in Fall 2015.

This project will be monitored by Shawn Blaesing-Thompson, Maintenance GIS coordinator, Office of Maintenance, Iowa Department of Transportation.

# Budget

The total request budget from IHRB as a match for the MTC project is $50,000. This budget includes salaries and fringe benefits for the principal investigators, and a graduate research assistant. The itemized budget is provided on the last page.

1. **Literature Cited**

BuildingSMART. (2016). Information Delivery Manuals. (Accessed: April 18, 2016, at: http://iug.buildingsmart.org/idms/information-delivery-manuals.)

Berard, O. B., & Karlshoej, J. (2012). Information delivery manuals to integrate building product information into design. Paper presented at the CIB W78-W102 2011: International Conference.

East, E. W. (2007). Construction operations building information exchange (COBie): DTIC Document.

East, E. W., Nisbet, N., & Liebich, T. (2012). Facility management handover model view. Journal of Computing in Civil Engineering, 27(1), 61-67.

Le, T., & Jeong, H. D. (2016). Interlinking life-cycle data spaces to support decision making in highway asset management. Automation in construction, 64, 54-64.

landxml.org. (2016). About landxml.org. (Accessed April 18, 2016, At: http://www.landxml.org//)

National Institute of Building Sciences. (2007). United States National Builing Information Modeling Standard- Version 1 - Part 1: Overview, Principles, and Methodologies.

Pinheiro, S. V., Corry, E., Kenny, P., & O'Donnell, J. T. (2015). Development of a Model View Definition for Environmental and Energy Performance Assessment. Paper presented at the CITA BIM Gathering 2015, Dublin, Ireland, 12-13 November, 2015.

P. Scarponcini. (2006). Transxml: Establishing standards for transportation data exchange, in: Joint International Conference on Computing and Decision Making in Civil and Building Engineering, Montreal, Canada.

See, R., Karlshoej, J., & Davis, D. (2012). An Integrated Process for Delivering IFC Based Data Exchange.

Woldesenbet, A., Jeong, H. D., & Park, H. (2015). Framework for Integrating and Assessing Highway Infrastructure Data. Journal of Management in Engineering, 32(1), 04015028.