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Case Study on 3D Modeling and AMG Practices

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ABSTRACT

The adoption of 3D modeling and automatic machine guidance (AMG) are becoming more popular in the transportation industry. With a 3D model uploaded to an on-board computer within a piece of heavy construction equipment, operators can easily monitor machine operations with respect to grad and location or engage the machine to produce the proper grade automatically. Thus, it provides great convenience and improved productivity for field workers.

AMG and 3D modeling have been identified as enabling technologies for a Civil Integrated Management (CIM) system. When CIM is implemented, an entire transportation agency and stakeholder partners share in the use and development of a common data pool that is accessible to authorized users involved with all phases of a transportation facility life cycle (such as planning, design, construction, maintenance and rehabilitation) and all departments in the agency (Administration, finance, operation and others). The concept of CIM was developed and promoted by the United States Federal Highway Administration in 2013 and was established to make better use of accurate data and information that results from the utilization of advanced technologies and/or tools thus to facilitate more effective decision making for transportation projects.

Using the CIM concept and framework, technologies such as 3D modeling and AMG could be more efficiently adopted within the full life cycle of a transportation facility. More importantly, data could be collected and managed systematically in the early phases of a project life cycle so they could be useful for later phases of the facility lifecycle. The purpose of this study is to investigate how CIM system could support autonomous construction and vice versa. During a domestic scan effort, seven state agencies and their contractors collaborated to present their extensive experiences on certain CIM related practices and tools. In particular, the experiences

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of the agencies that were under investigation regarding 3D modeling and AMG will be addressed in this paper. In addition, the benefits and challenges of using 3D modeling and AMG will also be discussed.

Keywords: civil integrated management (CIM)—3D modeling—automatic machine guidance (AMG)

PROBLEM STATEMENT

Productivity, quality, and safety are important aspects of any transportation project and are used as measures of project success. Various technologies and tools have been used to achieve better productivity, quality, and safety. Adoption of 3D engineered models in the transportation industry is relatively behind the adoption of Building Information Modeling (BIM) in the building industry. However, this is now changing; the transportation industry is adopting 3D engineered models at an increasing rate. In 2010, the adoption rate of 3D engineered models for transportation projects was 27%, which was increased to 46% in 2012 (McGraw-Hill 2012). The successful implementation of BIM in the building industry is a good example. It is critical for transportation industry to investigate the lessons learned from the building industry and start implementing 3D engineered models and other supporting technologies such as Automatic Machine Guidance (AMG) in their projects. The implementation of 3D engineered models is expected to bring benefits such as less rework and change orders (Parve 2013), more effective communications (Olde and Hartmann 2012), reduced time and costs, and improved quality and productivity (Myllymaa and Sireeni 2013; Cylwik and Dwyer 2012). Similarly, the major benefits of using AMG include increased quality and productivity, and reduced time and costs on job sites (Peyret 2000).

For an agency planning to implement a new technology, it is important to investigate the best practices and lessons learned from other agencies that already have extensive experiences with that particular technology. Since Iowa DOT was identified as one of the leading state DOTs for 3D modeling implementation (EDC 2013), this paper presents a case study on Iowa DOT's best practices and lessons learned from the use of 3D modeling and AMG.

RESEARCH OBJECTIVES

The objectives of this study are presented as follows:

- Learn Iowa DOT's progress on the use of 3D engineered models and AMG;
- Study how the agency transitioned from the traditional processes to the new processes of implementing 3D engineered models and AMG;
- Identify the benefits and challenges of using 3D engineered models and AMG within the agency;
- Conclude lessons learned from the adoption of 3D engineered models and AMG for the agency.

RESEARCH METHODOLOGY

The results presented in this paper are obtained from the National Cooperative Highway Research Program (NCHRP) Domestic Scan project 13-02 - Advances in CIM. The scan project investigated the current practices related to Civil Integrated Management (CIM) adopted by various state DOTs. During the project, 3D engineered models and AMG were identified as two of the enabling technologies for CIM implementation. The scan panel members were composed of various state DOTs and the Federal Highway Administration (FHWA) personnel, and a

subject matter expert (SME). The third author of this paper served as the SME, and the other two authors assisted the SME during this project. The scan team conducted an initial survey, called desk scan, to obtain knowledge on CIM and CIM-related technologies and tools. The amplifying questions were prepared by the scan team and sent to target agencies. The scan team then spent two weeks in total visiting seven leading state DOTs who had extensive experiences in CIM-related practices. All day workshops and presentations were provided by the host agencies and their contractors. It is also important to note here that there were also intensive interactions during these meetings between the host agencies and the scan team members. Detailed notes were taken during the meetings for further analysis. The data related to the implementation of 3D engineered models and AMG by Iowa DOT were extracted and analyzed in this paper. The results obtained from the coding strategies (Maxwell 2013) are presented in the following section.

KEY FINDINGS

Progress on 3D Engineered Models and 3D Renderings

Transitioning from 2D to 3D design is one of the main goals of Iowa DOT. Iowa DOT uses 3D renderings extensively to communicate with public, which allows the public to have a better understanding about the project and its impact on the surrounding environment. Great amount of details can be added to 3D renderings, although it might be challenging to add paint lines on roads. Furthermore, these renderings can be used as a starting point for 3D design. Currently, they are modeling all their highway projects in 3D using Bentley Corridor Modeler software package. Newly hired personnel are given proper training on 3D modeling knowledge and skills. When Iowa DOT first started 3D modeling, 2D cross sections would be developed and used to build a 3D model. This has been improved over the years. Today, 3D models are developed first and cross sections are extracted from the 3D models. Model development process has been standardized within the agency to ensure designers use the same approach to build the model, so that the same type of information can be obtained from a 3D model. Iowa DOT also adjusted the proportion of in-house modeling development effort over time. They used to develop all 3D models in-house, which consumed great amount of their time since they wanted to ensure the resulting products fit contractors' needs. Currently, 70% of the 3D models are developed in-house, and the rest 30% are developed by their consultants. The standardized tools and templates, which were developed by Iowa DOT, are shared with their consultants. With this adjustment, time and effort for in-house modeling development is reduced while maintaining the same model quality. The completed models are typically provided to the contractors before the bidding process, since design-bid-build is the dominant project delivery method for their projects. Overall, it can be concluded that 3D models and 3D renderings help improve communications between Iowa DOT and their contractors and with the public respectively.

Some of the challenges experienced by Iowa DOT in implementing 3D modeling are as follows. First, copyright issues can be quite challenging. It is hard to determine who can change or modify which information. Iowa DOT has a copyright policy and the state of Iowa has a copyright law in place. However, this is not yet included in the consultant contracts. Second, the entire model development process has to be changed. Attribute data should properly be assigned to each 3D object in 3D models. In the future, Iowa DOT plans to develop 4D (3D+ time (schedule)) animations for their projects. Having 4D models is expected to give public a better idea about how the project will look like once it is completed.

Progress on AMG

In the past, contractors who wanted to implement AMG would take 2D project plans to their consultants and have them build 3D models based on the 2D plans, so that they could use the

3D models on their equipment for AMG. This was changed after Iowa DOT started to develop 3D models and provide them for AMG use. Before Iowa DOT start implementing 3D modeling for machine control, they met with Trimble, Leica, CAT, and other manufacturers to learn about the current status and discuss the future direction for construction equipment. Based on the discussions during those meetings, they decided to do a pilot project where they made it mandatory to use 3D models and AMG. Based on the benefits observed, they continued using these technologies for other projects. This pushed their grading contractors transition from traditional equipment to AMG in order to stay in business. Construction equipment is continuously improved, and it is becoming easier for contractors to use. Operators can easily adjust the location and movement of certain parts of equipment (such as blade or bucket) based on the guidance provided by GPS. Construction equipment with a GPS device installed can be either purchased or rent from dealers. Most contractors in Iowa prefer purchasing equipment to renting, as most jobs require the use of AMG to some extent.

Based on Iowa DOT's experiences, stringless paving technology helped increase the quality of paving greatly. Stakes only need to be placed every 1000 feet when using stringless paving, which greatly improves the safety in the field. Competition among contractors became more intense with little changes in bid prices. Although setting up the machine control in the field increased the upfront project costs, the overall project cost did not change much compared to traditional process of not using AMG.

From contractor's perspective, the following benefits were observed when AMG was used:

- Productivity and accuracy are greatly improved with the adoption of AMG
- Owners tend to be more satisfied with the product delivered with AMG.
- Design changes could be integrated easier and faster.
- Problems could be detected early in the process via 3D models that are intended to be used for AMG.
- Field safety is greatly improved since less people are needed on the job site for AMG-implemented projects.

Lessons Learned from the Model Centric Design

Iowa DOT learned the following lessons from implementing 3D modeling and AMG for highway projects.

- Before implementing a new technology or a new approach, it is important to set the goals first, and then determine how to achieve them.
- It is beneficial to consult with industry practitioners to better understand their needs. Iowa DOT started to use standard data exchange format (LandXML), naming convention, color paper, and others based on the feedback they received from their contractors and consultants.
- It is beneficial to set up some rules to standardize the process and keep those rules consistent. For example, color plans were adopted about five or six years ago within the agency. The same color coding system was used for all projects to maintain the consistency, so that there were no confusions about the color codes.
- It is critical to organize the data or documents (naming convention, file format, etc.) well. Better organized documents help people perform better when searching and sorting information.
- It would be beneficial to maintain continuous communication with industry associations. For example, discussions with the associated general contractors of America (AGC) helped Iowa DOT determine a future direction that matches the direction of AGC. Also,

annual meetings with AGC keep Iowa DOT up to date with the development and utilization of the most recent technologies and tools in the industry.

- How the agency approaches training is a key to success. In-time and periodical training is proven to be the most efficient.

CONCLUSIONS

This paper focused on the implementation of 3D engineered models and AMG by Iowa DOT, which was identified as one of the leading state DOTs in this area. A brief introduction was provided on how the agency transitioned from traditional design and construction processes to new processes where 3D models and AMG are used. Benefits, challenges, and lessons learned from using these technologies were also discussed. The findings of this study would be beneficial to the agencies that are planning to implement these technologies within their organization. Before implementing a new technology, it is important for agencies to consult other agencies and/or companies with extensive experiences using a particular technology and discuss it with software or hardware vendors to set up a clear goal and select the best way to start. Lessons learned from pilot projects can be great guidance for future projects. Benefits and challenges should also be clearly identified. This may help motivate employees to use the technologies and tools. Finally, as agencies become more experienced with new technologies and tools, proper standards should be put in place to improve the overall work efficiency.

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