KDOT's Evaluation of Sharing Electronic Data with Contractors and GPS Construction Processes

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ABSTRACT

The electronic processes of the Kansas Department of Transportation (KDOT) were evaluated in response to advancing technology in the construction industry. As the use of Global Positioning Systems (GPS) machine controlled grading and construction staking became more popular, contractors in Kansas began requesting additional electronic design files to aid in the construction of their three-dimensional (3D) grading models. This paper analyzes the electronic processes directly related to GPS machine controlled grading and evaluates the affects any proposed changes would have on current KDOT design and construction inspection practices. Information obtained from other state practices, a pilot project within Kansas and partnering within KDOT and throughout the construction industry was used to develop new electronic processes.

The electronic processes developed updated construction specifications and the electronic deliverables policy. The updated construction specifications addressed contractors' responsibilities for using electronic design files and adjusted KDOT's staking requirements and construction inspection practices to account for projects using GPS machine controlled grading. The main decisions made regarding the electronic deliverables policy included determining what electronic design files to provide to contractors, the timing of the files release and the legal considerations. It was decided to release the two-dimensional Computer Aided Design (CAD) files most frequently created during the design process to contractors prior to bidding. A new disclaimer was used to cover legal concerns of releasing the files. Under the policy, KDOT does not provide contractors with a 3D model; contractors are required to create their own model to use GPS machine controlled grading.

KEYWORDS: GPS Machine Controlled Grading, Construction Staking Specification, Electronic Deliverables

INTRODUCTION

At the time of this study, State Transportation Agencies (STAs) were beginning to share electronic design data (EDD) between consultants, contractors and other project partners. One of the more popular uses of this data by contractors was for Global Positioning Systems (GPS) machine controlled grading and construction staking. Requests for additional electronic design files became more frequent as contractors sought files to assist in the creation of three-dimensional (3D) models for GPS grading. The evaluation of the Kansas Department of Transportation (KDOT) existing electronic processes began in 2008 in response to these industry trends. The initiative focused on KDOT let and administered construction projects; KDOT projects that are administered by local partners were not evaluated.

Some STAs had previously developed internal processes to support GPS construction technologies. The practices developed vary between states and each approached the numerous challenges to implementation differently. This paper presents the process followed by KDOT to evaluate and update their electronic deliverables policy and GPS construction staking specifications. The information presented in this paper is specific to Kansas; however, it builds on and supports the research of other states summarized in the literature review. The data collection compiles input from contractors, surveyors and designers who worked with KDOT and a pilot project which was used to identify potential issues with modifying KDOT's existing processes. The results of the data collection were used to make decisions regarding KDOT's revised construction staking specification and new electronic deliverables policy.

LITERATURE REVIEW

A literature review was completed to define the existing state of practice for electronic deliverables, summarize the recent research completed by STAs and determine the benefits of releasing EDD.

GPS machine control and guidance systems first appeared in the 1990's *(1)*. A survey of 48 states completed for a 2007 National Cooperative Highway Research Program (NCHRP) synthesis *(2)* found that one quarter of respondents had no experience with GPS technology, one quarter had fewer than a dozen projects where GPS was used and the remaining had varying levels of experience *(2)*. "Adoption of this technology [was] rapid on the part of contractors, but state departments of transportation (DOTs) [were] lagging in sharing the benefits of GPS machine guidance" *(3)*. There were a variety of reasons why so few states had adopted the use of GPS machine controlled grading or electronic data exchange with contractors. The most significant barrier was found to be the lack of agency specifications for GPS machine controlled grading *(2)*. A 2006 survey of nine states with GPS experience showed that only four had developed such a construction specification. These states were Iowa, Maryland, Minnesota and New York *(3)*. The most popular survey response for not using GPS technologies was lack of equipment or knowledge *(2)*. For STAs to successfully begin implementing GPS technology, they needed to overcome these and possibly other barriers.

Recent STA Initiatives

Studies completed in three states, Mississippi, Minnesota and Wisconsin were reviewed, because they had recently published summaries of their initiatives. These studies provided insight on how other STAs approached GPS technology and the considerations made in the development of agency processes and construction specifications.

Mississippi Department of Transportation, MDOT

The Mississippi Department of Transportation (MDOT) created an implementation plan in 2010 *(4)*. MDOT used the construction specifications of California, Colorado, Iowa, New York and Wisconsin as examples. Previously, MDOT had released EDD to contractors, upon request, for the use in creation of 3D models and GPS machine controlled grading. To develop a new process for releasing EDD, three options of when to release files were evaluated; releasing files pre-bid, after the contract was awarded or at the pre-construction meeting. The first option allowed for the highest potential cost savings, but also posed liability concerns since it was "unknown if transferring EDD with traditional bidding documents would alter their status as 'official contract documents' imposing liability" *(4)*. The implementation plan contained recommendations for MDOT, but the timing for release of EDD to be used by MDOT was not determined by this study.

Wisconsin Department of Transportation, WisDOT

The Wisconsin Department of Transportation (WisDOT) began a study to develop, pilot, refine and implement a subgrade construction specification for GPS controlled grading in 2006 *(3)*. The WisDOT specification was developed by an advisory group with representatives from WisDOT contractors, engineers, consultants and surveyors. The group discussed the source of 3D models while developing the construction specification. Creating 3D models was "tedious and time-consuming which could create bottlenecks that offset productivity gains" *(3)*. To increase efficiency, WisDOT found that some STAs provided 3D model data to contractors or were moving towards using 3D models as contract documents. However, WisDOT decided to require the contractor to create the 3D model. To aid in the construction of the model, WisDOT provided the following electronic design files:

- Reference line data,
- Design profile data,
- Proposed cross section data,
- Existing ground surface data,
- Existing topographic features,
- Superelevation data,
- Graphical information,
- Design surface points, and
- Breaklines. *(3)*

A 2008 study was completed to evaluate the wider use of 3D information in design and construction. As a result of the study, a 3D technology group was created at WisDOT to help define future 3D initiatives within the agency *(5)*.

Minnesota Department of Transportation, Mn/DOT

The Minnesota Department of Transportation (Mn/DOT) completed an evaluation of 3D machine control in 2007. The core issues identified in the study were acceptance, accuracy, cost, evolving responsibilities, liability, and training. Mn/DOT developed a construction specification for machine control and design procedures for the construction of 3D models *(1)*.

In the report, the Mn/DOT and Iowa DOT specifications were compared. Iowa DOT allowed the use of GPS machine control grading on embankments only, but Mn/DOT allowed GPS grading anywhere it met technical specifications. Both DOTs placed the liability for the use of electronic files on the contractor. As for staking, Iowa DOT required conventional grade stakes at critical points while Mn/DOT required the same staking for projects constructed with machine control as conventional methods *(1)*.

The Mn/DOT let construction projects had four variations of 3D machine control support. Through these variations, Mn/DOT had experience with agency and contractor developed grading models. Mn/DOT found advantages and disadvantages to each option. STA models improved the efficiency of the process and had fewer opportunities for conversion errors. Contractor models, being created by the end user, presented the information in the most efficient way to meet the contractor's immediate needs *(1)*.

Mn/DOT discussed benefits of GPS controlled grading in its report, however, was unable to complete a benefit/cost analysis. "The factors involved with a benefit/cost ratio [were] difficult to assign to one particular stakeholder group. In some instances, Mn/DOT [incurred] a large share of the additional labor costs, while the contractor [realized] a bigger share of the benefits" *(1)*.

Benefits of Machine Controlled Grading

As the construction industry quickly adopted GPS machine controlled grading, STAs were evaluating the benefits of the technology to determine appropriate applications. Various benefits were found through multiple sources:

- Reduced staking,
- More efficient processes,
- Greater accuracy,
- Less experienced machine operators can be used,
- Lower bids from contractors,
- Lower fuel consumption,
- Lower emissions,
- Safer work environment and
- Higher quality product. *(1,2)*

Quantifying the benefits of GPS machine controlled grading was harder to pinpoint. The majority of the benefits were a result of the reduced time required to complete earthwork and reduction in survey support. "Claims of increased efficiency by as much as 50 percent and increase in equipment utilization by as much as 30 percent [had] recently been made" *(1)*. Another study *(6)* found a 43 percent fuel savings with the use of GPS. This study compared the speed of construction for GPS machine controlled grading and conventional grading methods by constructing two identical test roadways. The roadway was completed in one-and-a-half days with GPS machine controlled grading and three-and-a-half days with conventional grading methods *(6)*. It was unclear what portions of the benefits of GPS machine controlled grading were passed on to the STA, even though the benefits of the technology theoretically included lower bids and higher quality products.

In summary, the literature review identified a number of challenges that affect design policies, construction project contract provisions and construction inspection practices. Overall there was a lack of

knowledge and experience and a fear of releasing additional EDD due to possible misuse and liability. A consideration for design practices was the creation of 3D models; however, according to the literature review, the best source of 3D models was debatable. Also, it was difficult to evaluate for the STA if the additional time necessary during the design process was offset by the benefits of GPS machine controlled grading.

DATA COLLECTION

Partnering was a major component of the data collection, as insight was obtained from contractors, industry experts, consultant designers, KDOT designers, KDOT construction personnel and KDOT surveyors. Practical experience was obtained through a pilot project and projects constructed under an interim policy. Figure 1 depicts the timeline of KDOT's electronic processes evaluation.

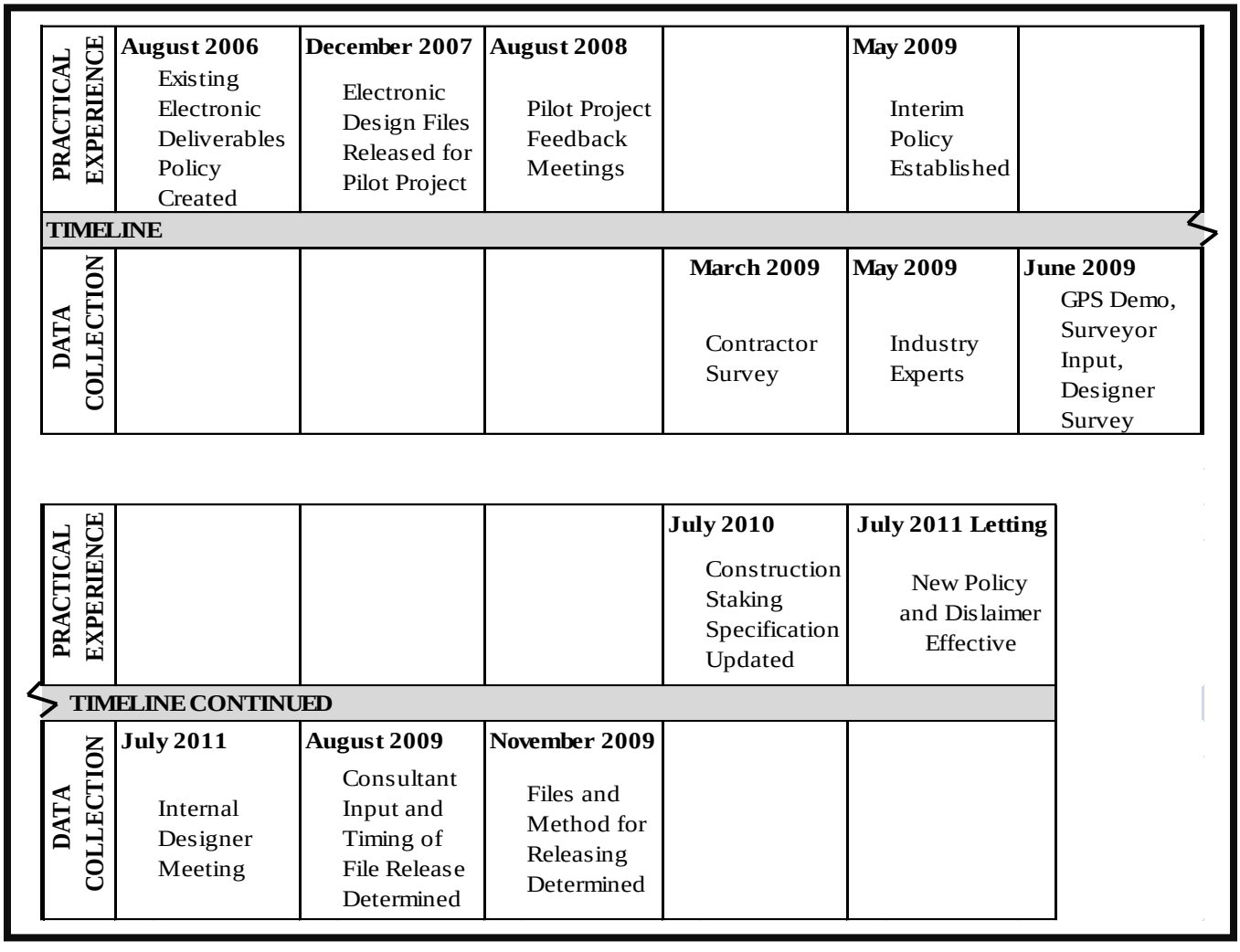

FIGURE 1 Electronic processes initiative timeline.

Existing Policies

KDOT began releasing electronic files to contractors in 2006. KDOT's policy at that time involved releasing alignment report files, cross section report files and earthwork computation files to contractors, when feasible. The alignment files described the existing and proposed horizontal alignments and proposed vertical alignments. The cross section report files gave the station, offset and elevation of each break point for the existing ground and proposed templates for all cross sections. The report files were generated from the electronic design files, typically using GeoPak Software. The earthwork files were provided in Microsoft Excel format, text file format (txt) or Adobe Portable Document Format (PDF) and provided the cut and fill quantities at cross sections along with the end area calculations. Of these, the two file types useful in creating 3D models were the alignment and cross section report files. These electronic deliverables were provided to contractors pre-bid, via KDOT's Exploratory and Project Reports website *(7)*. This website provided project related information to the contractors for use in bid preparation and construction.

There are a number of additional electronic files created during the design process. The typical CAD files created for KDOT projects were in Microstation format and included a base file (plan view), profile, plan and profile sheets and cross sections. At the time, KDOT did not design in 3D and 3D models were not required to be created during the design process.

On the construction side, prior to the electronic processes initiative, contractors were allowed to use GPS machine controlled grading as a tool on KDOT projects. GPS graded projects were still required to meet the same staking requirements as conventional grading methods given in the specifications *(8)*.

Pilot Project

Prior to 2007, KDOT released additional electronic design files on some construction projects; however, there was not a consistent policy. In 2007, the prime contractor requested additional electronic design files for the US-59 grading project. The project was approximately 19 miles in length and the construction scope included grading and bridges for a four-lane freeway on an offset alignment. Initially KDOT turned down the request, but ultimately decided to release the files.

- Additional electronic design files provided to the contractor:
    - Base file (plan view of the entire project length) (Microstation format),
    - Cross section stack files (vertical layout of cross sections) (Microstation format), and
    - Existing ground survey (GeoPak .tin format).

An electronic license agreement between KDOT and the US-59 prime contractor was established for the release of the files. This agreement stated that the paper plans controlled and required the contractor to provide KDOT with any 3D model created and a summary of the benefits directly resulting from KDOT releasing additional electronic information. The release of the files did not eliminate the contractor's responsibility to stake the project per existing KDOT specifications *(8)*. The project was monitored to help identify issues associated with the release of electronic design files. Feedback regarding GPS machine controlled grading and electronic design files was obtained during the fall of 2008 from the project partners including the prime contractor, KDOT construction inspectors and consultant designer.

Surveys and Meetings

A survey was sent to Kansas contractors in March, 2009. The survey was distributed with the assistance of the Kansas Contractors Association (KCA) with the goal of determining what electronic files were preferred, how the files would be used and what benefits would be obtained by providing electronic design files. Eight contractors responded to the survey. From 2009 to July of 2011, the contractors responding to the survey constructed two percent of KDOT's projects, and they were awarded approximately four percent of the total amount awarded for KDOT projects. Although the results from the contractor survey represented a small portion of contractors working with KDOT, it confirmed information obtained through the literature review and identified areas where more information was needed. Additional contractor input was obtained through meetings with the KCA.

An industry expert meeting with representatives from Foley Equipment Company and Trimble Navigation Limited was held in May, 2009. Foley and Trimble, along with Martin Tractor Facility, also provided a GPS machine controlled grading demonstration for KDOT design, construction and survey personnel in June 2009. The demonstration consisted of a discussion of KDOT's staking specifications, a demonstration of a GPS base station, rover and machine controlled grading and an explanation of 3D model construction using KDOT's electronic design files. After input was received from the construction industry, KDOT surveyors provided feedback about GPS machine controlled grading specific to construction inspection.

Road designers working on KDOT projects were surveyed in June, 2009. This survey included consultant designers with the assistance of the Kansas Chapter of American Council of Engineering Companies (ACEC). Responding to the survey were seven consulting firms and eight of ten KDOT Road Design squads. The process for releasing electronic design files and possible liability of releasing files was a concern of ACEC. Discussions with ACEC were held to allow for input on the electronic deliverables policy, timing of file release and KDOT's consultant contract.

There were a number of KDOT work groups outside of Road Design that produced design plans. These work groups provided input on the electronic processes evaluation during an internal designers meeting held in July 2009. Designers involved represented bridge design, traffic engineering and intelligent transportation systems (ITS). Their input was important to determine if electronic design files created outside of road design would be useful for contractors.

Overall, the data collection was an important step in making policy decisions for KDOT's electronic processes. The information obtained from the pilot project, industry expert meetings and KDOT surveyors meeting was used for the development of a construction staking specification for GPS machine controlled grading *(9)*. The input from the construction industry and KDOT surveyors was also used along with information provided by KDOT designers and ACEC for the development of a new electronic deliverables policy. Detailed use of the data collected is explained in the machine controlled grading and electronic deliverables policy sections.

MACHINE CONTROLLED GRADING

The pilot project helped determine the benefits of GPS machine controlled grading and identify how the process affected KDOT construction inspection practices. Construction inspection practices were also discussed during the industry expert meeting and with KDOT surveyors.

Pilot Project

The construction inspectors felt the benefit of GPS machine controlled grading was the ability to construct to a higher level of accuracy in less time, but were concerned due to a lack of experience with the technology. Another issue was the grade stakes were often destroyed and replaced as an afterthought, hindering the construction inspectors' ability to check the grade on a regular basis. The construction inspectors provided suggestions to alleviate the inspection issues which occurred on the pilot project. They recommended construction specifications specific to GPS controlled grading be written to identify KDOT expectations for GPS machine controlled grading and that additional inspector training be provided to help them better understand the electronic deliverables provided, 3D modeling and GPS grading.

The prime contractor did provide KDOT with a copy of their 3D model. The consultant designer reviewed a portion of the model and all critical elements matched the paper plans. KDOT did not have the staff or resources to regularly evaluate 3D models.

The prime contractor reported that, GPS enhanced grading allowed the contractor to achieve a higher quality product with relatively inexperienced survey staff and machine operators. It provided more consistent grading between cross sections which reduced rework. It was an effective survey tool that allowed for dynamic establishment of proposed grade locations and elevations in the field. This allowed the contractor to grade at an accelerated pace when compared to traditional techniques.

As a result of the pilot project, KDOT began evaluating its construction staking specification and construction inspector training.

Construction Inspection Practices

During the industry expert meeting with Foley and Trimble, participants discussed current practices for construction inspection on GPS graded projects. Of the methods presented for verifying earthwork, KDOT found the following two methods more desirable; requiring less stakes on GPS controlled grading projects and requiring the contractor to provide construction inspectors with a rover and training. By allowing less staking, KDOT might receive cost savings associated with machine controlled grading; inspector access to a rover allows for grade checks when fewer stakes are provided.

The KDOT surveyors also provided feedback regarding construction inspection practices. The surveyors felt increasing the slope stake spacing to 300 to 400 feet would be appropriate for GPS machine controlled grading. Providing the construction inspector with a rover did not seem to be a viable solution by itself, as the rover would work off the contractor's base unit and model, not providing an independent check. Based on the surveyors input and the industry experts meeting it was decided to use the combination of increased stake spacing and allowing construction inspectors access to a rover.

Construction Staking Specification Development

The construction staking specification was revised to clarify expectations of the contractor when using GPS equipment. Information from Colorado and North Carolina DOT's specifications was used to develop the draft KDOT specification.

Throughout the development, review and feedback was provided by KDOT construction personnel and surveyors and KDOT business partners, including KCA. The specification was also discussed at several KDOT/KCA meetings. Throughout these discussions, a variety of issues were addressed:

- There was a misconception among KDOT personnel that there would be no more traditional staking on the projects.
- The contractors felt KDOT was requiring too much traditional staking, when the GPS controlled grading equipment was used.
- The contractors also wanted to use GPS controlled grading equipment for finish grading and paving.

The revised specification *(9)* was approved by the Federal Highway Administration (FHWA) and implemented July 2010. The items in the staking specification included use of electronic files, GPS training for KDOT construction personnel and contractor staking.

The specification stated that the printed plans controlled over the electronic design files and contractors were required to notify KDOT of any errors, omissions, ambiguities or perceived inadequacies found in the electronic design files. The contractor was also required to provide KDOT a copy of the 3D model created. The question of how to treat the GPS model or other drawings generated from the electronic design files was discussed during this initiative. There were two options, treat the 3D model or drawings in the same manner as shop drawings with the right to review and approve and/or review and approve the resulting construction performed using such models or drawings. Evaluation of these options depends upon whether the agency treats the electronic design files as contract documents, the agency's policies on construction inspection, and whether the agency was employing more collaborative Building Information Modeling (BIM). KDOT had no current plans for BIM. Presently, KDOT did not review and approve the contractor's 3D model used for GPS grading, but does review and improve the final product.

The agency was also concerned with the degree of knowledge required of construction inspectors responsible for inspecting the contractor's work. KDOT's inspection was undertaken for KDOT's benefit and to fulfill the agency's statutory obligations, not for the contractor's benefit. Nevertheless, the agency wanted inspectors to have GPS modeling training and required the contractors employing these techniques to provide the training. Under the specification, the contractor was to provide a GPS rover to the construction inspector and training to inspection personnel on the use of the contractor's GPS system. The training furnishes an understanding of the equipment, software and electronic data.

When using GPS controlled machine grading, the contractor is required to place centerline stakes, slope stakes and grade stakes at 500 foot intervals on tangents and 250 foot intervals on curves, transitions, intersections and breakpoints. The hard survey controls required in the construction staking specification were another way KDOT verifies that the final construction using the GPS model met the plans and specifications. As the use of GPS modeling increases, KDOT anticipates including such training in the agency's Certified Inspector Training program. At that time, KDOT will revisit the merits of reviewing and approving the contractor's GPS models.

The specification required the contractor to stake the project with finishing staking or blue top staking. KDOT did not feel GPS controlled grading equipment had the vertical accuracy to be used for finish grading and paving at this time. KDOT had accepted stringless paving using Total Stations, on a trial basis. Stringless paving using GPS was not allowed because the vertical control accuracy did not meet KDOT's tolerances.

ELECTRONIC DELIVERABLES POLICY

In developing an updated electronic deliverables policy, KDOT had two main decisions to make, what types of files to release and when to release the files. When considering releasing electronic design files, legal considerations were also evaluated.

Electronic Deliverables Files

KDOT reviewed the use of the files during the pilot project and information obtained through the contractor survey and industry experts meeting to determine what types of electronic design files to release. Feedback on a proposed policy was obtained from KDOT surveyors, designers and ACEC.

Pilot Project

The prime contractor described the benefits it received from KDOT releasing electronic design files and how the information was used.

- Providing CAD files allows the contractor to:
    - Immediately incorporate plan changes through e-mail as opposed to the current paper plan process, and
    - Create value engineering proposals using established plan data.
- The existing ground survey can be used to:
    - Verify plan information during pre-construction,
    - Find suitable borrow locations,
    - Develop a more efficient work plan, and
    - Create an erosion control plan.

The KDOT project manager and construction inspectors found the electronic plans to be beneficial, as they were able to resolve small errors and discrepancies in the field by using the CAD files. The project manager noted that there was an increase in the number of Requests for Information (RFIs) on this project due to the questions from the prime contractor about details in the electronic files released.

The consultant was comfortable providing centerline, pavement edge and profile information and felt this did not require any additional work. However, the electronic cross section files were expected to be at a higher level of accuracy then what was necessary when the files were only used for printed paper plans. Not only could electronic cross sections be read to a higher level of accuracy than paper plans, but they were also being used as the main source of information for constructing 3D models. This was opposite of conventional construction methods with paper plans, where the plans and profile sheets were used as the primary source of information and cross sections were supplemental information. To achieve the higher level of accuracy, additional drafting and quality control time would be needed during the design process. Since it was not known that electronic plans would be provided to the contractor until late in the project, the consultant did not allow for the extra time or expense to review the accuracy of the electronic cross section files. The consultant noted that releasing electronic plans in this manner may cause budget issues, especially if the consultant is expected to correct discrepancies found by the contractor.

Contractor Survey

Contractors requested CAD files because they contain more comprehensive information than the design plans. The specific CAD format requested varied; however, most noted that they can convert from Microstation to their preferred format. The contractor survey results are summarized in Table 1; the number of contractors requesting each file type is denoted in parentheses. Those contractors who preferred to make their own 3D model noted that design models were not built to the level of detail necessary for machine controlled grading. Even though four contractors responded that they preferred KDOT create the 3D model to save time, there also were limitations. It was noted that formatting issues that could arise with 3D models created by KDOT and the contractors expected KDOT to assume liability for the models. The appropriate source for 3D model creation was discussed further during the industry expert meeting.

The main uses of electronic design files were to create a 3D model, verify earthwork quantities and share plan information electronically with subcontractors and vendors. The contractors believed the release of CAD files would result in time and cost savings and improved accuracy in both bid preparation and construction.

TABLE 1 Contractor Survey Results

Survey Question	Contractor Responses
Use of existing electronic deliverables	• Check quantities • Build 3D model • Layout project (survey) • Exchange information • Acquire more accurate information
Additional electronic files preferred by contractors	• Plan view (6) • Cross-sections (5) • Existing survey (4) • Profile view (3) • None (1)
Preferred format for additional files	• Autocad (3) • Autocad or Microstation (3) • Pro or Autocad (1)
Benefits of providing additional files	• Cost savings • Time savings • Improved product quality • More accurate bids • Quicker identification of errors • More accurate 3D models
3D model preference	• Contractor created (4) • KDOT created (4)

Industry Expert Meeting

Foley and Trimble were able to provide insight as to why some contractors surveyed preferred to create their own 3D models. As project grading was the contractors' responsibility, some contractors preferred

to maintain control of grading by creating their own 3D model. There were also slight differences between models created for design purposes and those created for construction.

As for electronic deliverables, Foley and Trimble recommended that KDOT release all of the electronic files created in the design process and state in the revised policy the type of files that will be provided and when the files will be provided. They concurred with the contractor survey that the files could easily be converted to other formats.

The GPS demonstration held with Foley and Trimble was an important step in the electronic deliverables initiative. It eased the apprehension of providing additional electronic design files by providing information about the process and experience with the technology.

As a result of the industry experts meeting and pilot project, KDOT decided it would not pursue the creation of 3D models during the design process.

Designer Survey

The designers surveyed stated that submitting electronic design files to the contractor would require additional time. Additional drafting time and tighter quality control would be necessary to achieve the accuracy expected by the contractors. It was felt that additional time would also be spent addressing questions from the contractors related to electronic files. The designers agreed that providing electronic design files was an industry trend and were in support of it; however, appropriate checks and balances needed to be established. They preferred to have the paper plans control over the electronic design files.

Interim Policy

An internal meeting was held in May, 2009 to discuss continued requests for electronic design files and to establish an interim electronic deliverables policy which would be in place until a final policy was enacted. The electronic design files to be released to the contractor were determined based on feedback from the contractor survey, the industry expert meeting and the designer survey.

- Electronic design files to be released:
    - Base file,
    - Cross section stack files,
    - Existing ground survey,
    - Plan and profile sheets (sheets as shown in the plans) (Microstation format), and
    - Cross section sheet files (final cross section sheets) (Microstation format).

After a project was awarded, the contractor could request the electronic design files. An electronic files license agreement, similar to that used on the pilot project, would need to be in place before the files would be released. The process for distributing files was relatively slow and on average there were three months between the request for electronic files and their release. This interim policy took effect immediately and included projects that had already been let, but were still under construction. The projects for which electronic design files were requested are shown in Table 2.

TABLE 2 Interim Policy Projects

	Project Description	Length (mi)	Contractor	Letting Date	Electronic Files Released	Approx. Project Cost
Prior to Updated Staking Specification	4-Lane Construction	8.6	Koss Construction & Subs	Feb-09	NA	41,122,000.00
	4-Lane Construction	7.4	Koss Construction & Subs	Apr-09	Aug-11	31,966,000.00
	4-Lane Construction	7.1	Koss Construction & Subs	Apr-09	Aug-09	32,241,000.00
	Interchange	-	Wildcat Construction Co Inc. & Subsidiaries	Apr-09	Jun-09	19,686,000.00
	6-lane Reconstruction	3.0	Clarkson Construction Company	May-09	Jun-09	29,154,000.00
	6-Lane Reconstruction	3.8	Clarkson Construction Company	May-09	Jun-09	53,124,000.00
	4-Lane Construction	3.4	Sherwood Construction Co Inc & Subs	Feb-09	Jun-09	42,495,000.00
	Interchange	-	Dondlinger & Sons Construction Co Inc	Jul-09	Aug-09	16,148,000.00
	Bridge Replacement - Offset Alignment	3.7	Archer Western Contractors LTD	Mar-09	Nov-09	59,394,000.00
	Interchange	-	Miles Excavating Inc	Dec-09	NA	21,388,000.00
	4-Lane Construction	1.9	SEMA Construction Inc & Subsidiaries	Mar-10	*	57,714,000.00
After Updated Staking Specification	4-Lane Construction	4.0	Koss Construction Company	Apr-11	*	41,414,000.00
	4-Lane Construction	1.4	Koss Construction Company	Apr-11	*	13,921,000.00
	Pedestrian Bridge	-	TL Enterprises, Inc.	Mar-10	May-10	887,000.00
	Bridge Replacement - Offset Alignment	-	King Construction Company, Inc. and Subsidiaries	Mar-11	Jun-11	3,576,000.00
	Collector / Distributer Roads	1.6	Clarkson Construction Company	May-11	Jul-11	101,454,000.00
	4-Lane Construction	3.1	Dondlinger & Sons Construction Co Inc	Jun-11	Jul-11	31,918,000.00

*Electronic Files Released Prior to Letting

As of July 2011, electronic design files had been provided for 17 KDOT projects, totaling approximately $598 million dollars or 41 percent of awarded construction projects. The type of project varied; there were eleven major roadway construction or reconstruction projects, three interchange projects and three bridge projects. Overall, the projects were larger than KDOT's average project size

with an average project cost of $35 million for the interim policy projects compared to the average cost of $1.7 million for other KDOT's projects let between 2009 and July of 2011.

Even though there were concerns about the accurate use of the electronic design files and liability, after two and a half years these issues had not arisen. There also had not been complaints about the quality of the files. There was a request for different file formats on one project. The contractor's surveyors preferred Extensible Markup Language (XML) files to the txt alignment files provided because they felt they were easier to convert.

Surveyor Input

A meeting was held to discuss the insufficient amount of coordinate data available on projects as construction surveyors reliance of GPS staking continued to increase. Coordinate data were provided along the project centerline, but there were limited coordinate data provided along the perimeter of the project or at any significant offset from the centerline. These data were valuable to construction staking because it allowed the surveyor to provide critical calibration points for the GPS. To address this, KDOT agreed to provide two additional pieces of information to contractors under the final electronic deliverables policy; the right-of-way staking package that provided GPS coordinates for all the right-of-way points and the section corner coordinate detail sheet that provided coordinates for all section corners located during the project survey.

Final Policy

The files previously provided to contractors continued to be released, along with the files identified for the interim policy and the files the surveyors requested for coordinate information.

- File previously provided:
    - Alignment report files,
    - Cross section report files, and
    - Earthwork computation files.
- Additional files provided under interim policy:
    - Base file,
    - Cross section stack files,
    - Existing ground survey,
    - Plan and profile sheets, and
    - Cross section sheet files.
- Additional files provided to aid in GPS construction staking:
    - Final right-of-way staking package, and
    - Section corner coordinate detail sheet.

The final electronic deliverables policy was effective for the July 2011 letting.

Electronic Deliverables Timing

The contractor for the pilot project had experience working in the private sector where files have been provided with the bid package. This allowed the contractors to more accurately and efficiently bid the project. Other benefits to releasing files early in the process were identified in the contractor survey and

literature review. However, there were liability concerns with allowing the contractors to use the files for bid preparation.

After discussions with ACEC and reviewing other states' practices, KDOT decided to release the electronic files before letting. The files continue to be available through the Exploratory and Project Reports website *(7)*. This was a notable difference between the interim policy and the final policy.

Legal Considerations

The disclaimer language for the Exploratory and Project Reports website *(7)*, the bidding contract specification and the staking specification *(8)* were edited to include specific language for the electronic design files. The modified disclaimer and specifications replace the need for an electronic license agreement with the contractors.

The most significant legal issue KDOT considered was whether the release of the electronic design files increased the agency's liability. An owner might have either an expressed or implied warranty of the adequacy and accuracy of the plans and specifications. This warranty was implicated if the electronic design files were considered part of the plans and specifications. To limit the agency's liability, KDOT treated the electronic design files as non-contract documents, designated that the KDOT-printed plans control over the electronic drawings and required the contractor to assume the risks of using these files. At the time of this paper, this limitation of liability and risk transfer is necessary for several reasons:

- The agency did not review all of the electronic design files the design consultant had prepared;
- The agency and design consultant could revise information on the paper plans without revising the electronic design files; and
- The agency did not possess the education and resources necessary to review the models the contractor generated using the electronic design files.

KDOT also treated the electronic design files as non-contract documents, because of the number of contractors which did not have the software or other technical expertise to use the electronic design files. Considering the state of the technology, KDOT did not want to require its contractors to obtain such software and technical expertise. Yet, if the contractor reviewed these files even though they were not considered contract documents, the agency would charge the contractor with knowledge of the information contained therein.

KDOT also considered a concern of design consultants that the release of the electronic design files would increase their potential liability to the contractor and other third parties. As a matter of policy, KDOT did not believe the release of the electronic files, which was undertaken for the contractor's benefit, should change the legal relationship between the consultant and contractor or expose the consultant to additional theories of liability. To limit the consultant's liability, KDOT had disclaimer language on KDOT's website, construction contract specifications, and professional services contract provisions that:

- Denied contractors third party beneficiary status for the use of electronic design files;
- Clarified that releasing the electronic design files created no duty from the design consultant to the contractor for the information contained in the electronic design files;

- Stipulated that the contractor assumed the risk of differences between the printed plans and electronic design files due to design and other modifications; and
- Made the contractor responsible for the adequacy and accuracy of all models, drawings, or other documents the contractor and its agents generate using the electronic design files. (This responsibility included requiring the contractor to indemnify the agency and consultant from damages related to such models, drawings, or other documents and the contractor's modification or negligent use of the electronic design files.)

The transmittal and use of electronic design files was a dynamic area. As technology and resources advance, new legal issues will arise and existing legal issues and policies will need to be revisited.

SUMMARY

At the beginning of this initiative, a literature review identified a number of challenges. As KDOT proceeded through the initiative, these challenges were addressed as summarized in Table 3. Overall, the various meetings were successful in making the decisions for KDOT's electronic processes including, determine the type of files to provide, file format, timing, legal considerations and impacts to the construction inspection and design processes.

TABLE 3 Summary of Electronic Deliverables Challenges

Challenge	Input	Decision
Lack of knowledge and experience	• Surveys • Industry Expert Meeting • Pilot Project	• Provide construction inspectors with GPS rover • Provide inspector training
Fear of releasing electronic data/legal concerns	• Literature Review • Surveys • Industry Expert Meeting	• Paper plans control • Liability covered by specifications and disclaimer
Source of 3D model	• Literature Review • Surveys • Industry Expert Meeting	• Provided 2D design files • 3D files created by contractor
Quantifying Benefits	• Literature Review • Surveys • Industry Expert Meeting • Pilot Project • Interim Policy	• Not practical to obtain quantitative benefits • Qualitative benefits were identified.

Throughout the evaluation of KDOT's electronic processes a few documents were created to allow for the necessary design processes to release files and to accommodate construction inspection practices when GPS machine controlled grading is used.

- Documents created during Electronic Deliverables Initiative:
    - Updated construction staking specification addressing GPS machine controlled grading and liability of releasing electronic design files,
    - New road design policy for the release of electronic design files, and
    - Updated Exploratory and Project Documents website disclaimer and bidding contract specification to cover the release of electronic design files.

FUTURE RECOMMENDATIONS

There were benefits of sharing electronic data that reached beyond 3D models and GPS controlled grading. As a result of the electronic deliverables initiative at KDOT, a KDOT/ACEC partnering subcommittee was established to evaluate KDOT's overall electronic processes. The committee consists of KDOT, consultant and contractor representatives. The committee assisted with the electronic deliverables initiative and has also updated KDOT's file naming conventions and implemented electronic shop drawing reviews. In the future, the committee plans to evaluate providing additional coordinate information in the printed plans for contractor staking and electronic plan review.

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