STATUS AND PLANS FOR IMPLEMENTING 3D TECHNOLOGIES FOR DESIGN AND CONSTRUCTION IN WISDOT

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16. Abstract

Use of Global Positioning System (GPS) technology to guide and control earth moving equipment such as dozers, motor graders, and excavators is quickly becoming common place in highway construction because it speeds project delivery and cuts costs. It has been estimated that productivity of this type equipment is double that of conventional equipment. A requirement for use of GPS technology in machine guidance is a 3D terrain model known as a digital terrain model (DTM). Current design practice is to design highways and other infrastructure facilities in two-dimensions using traditional computerized design programs. GPS machine guidance technology requires that these designs then be converted to three-dimensional (3D) representations before they can be used. This conversion is currently being done by the construction contractor which adds time, cost, and introduces a source of error into the system. To leverage the advantages of the technology throughout project delivery, the design phase must produce the DTM.

The Wisconsin Department of Transportation (WisDOT) is in the process of implementing new 3D design software which will accomplish this task. However, there are numerous cultural, legal, and work process questions which must be answered before WisDOT begins to distribute DTM's as contractual documents, eliminates traditional cross sections, uses them as a basis for determining final quantities, and allows contractors to construct directly from them. These are not trivial issues. For example, only one State highway agency currently claims to be using agency produced DTM's for these purposes. The issues and agency/industry ramifications must be carefully identified and studied before making the policy changes needed for implementation of DTM's in this capacity.

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Submitted to the Wisconsin Department of Transportation

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1. Background

Use of Global Positioning System (GPS) technology to guide and control earth-moving equipment such as dozers, motor graders, and excavators is quickly becoming common place in highway construction because it speeds project delivery and cuts costs. It has been demonstrated that productivity with this technology, referred to as “automated machine guidance (AMG)”, can be double that of conventional construction equipment and methods (Caterpillar, 2006). AMG requires a three-dimensional (3D) model, in the project coordinate system, that includes at least the alignment and a representation of the design surface referred to as a “digital terrain model” (DTM). Current design products for highways and other infrastructure facilities are two-dimensional plans, profiles, and cross sections. Use of AMG technology requires these design products to be converted to 3D models prior to construction. This conversion is currently being done, primarily, by construction contractors, which adds time and costs and introduces a potential source of error. Ironically, two-dimensional plans are often output from three-dimensional design data files. To leverage the advantages of technology throughout project delivery, the design phase must produce the 3D model. Figure 1 illustrates current and desired data and process flows from design to construction.

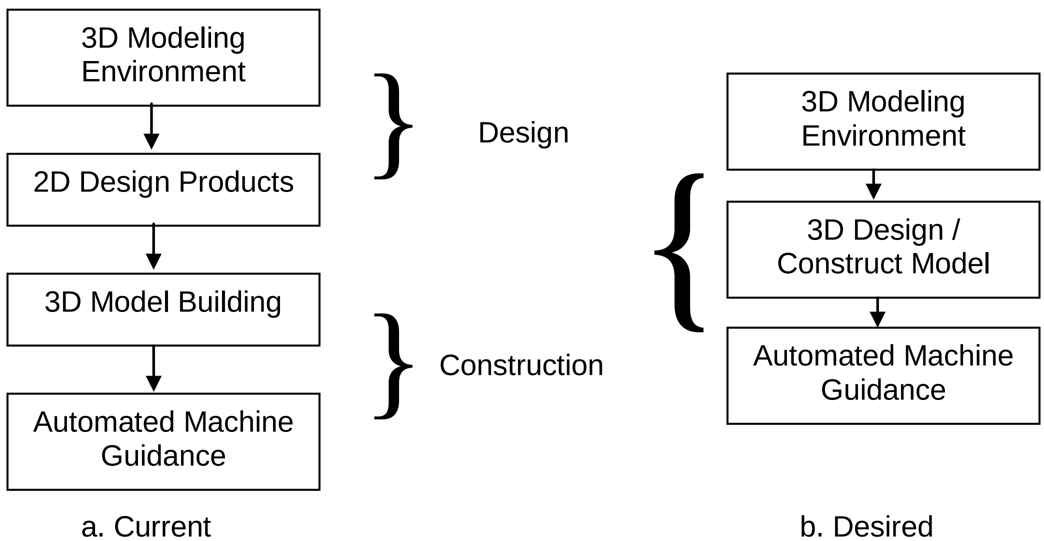


Figure 1.
Data and Process Flows

Additional irony arises from:

1. The initial photogrammetric survey of the original ground surface typically produces an original ground DTM that is then manipulated during design to produce 2D plans and cross sections, further adding time and costs.

2. When earthwork volumes for payment after construction are to be determined, an as-built survey of break lines and spot elevations is typically conducted. An as-built DTM is then derived from the survey data, merged with the original ground DTM, and as-built cross sections are cut through them. The average-end-area method is then used with these cross sections to compute as-built volumes. Of course, the merged original ground and as-built DTMs could be used to compute volumes directly without cutting cross sections.

Many sources assert that volumes computed directly from first-generation DTMs are more accurate than those computed by average-end-area, for both estimates and final quantities. If this is the case, then using DTMs throughout design and construction, as opposed to plan views and cross sections, should yield not only increased efficiencies in data flows and work processes but also greater accuracies in both estimating and measuring earthwork volumes.

The Wisconsin Department of Transportation (WisDOT) is implementing new 3D design software that provides technological support for these tasks. However, there are numerous cultural, legal, and work process issues that must be addressed before WisDOT adopts 3D models as contract documents, eliminates traditional cross sections, uses DTMs to determine final quantities, and allows contractors to construct facilities directly from 3D models. These are not trivial issues. They, and their ramifications for the department and industry, must be carefully identified, characterized, and studied before making policy changes needed for implementation of 3D models in this capacity.

2. Project Objectives

The original objective of this project was to assist WisDOT in preliminary stages of identifying institutional issues, relevant design and construction work processes that would be impacted, consequences, and legal issues that could arise by directly providing design 3D models to contractors for contractual purposes. After meeting this objective and conducting a stakeholder workshop to validate findings and develop recommendations, the project scope was expanded beyond 3D models and DTMs to include 3D technologies in general. Accordingly, the final objective of the project was development of a high-level implementation plan for 3D technologies and methods for design and construction

3. Approach

The study was comprised of the following activities:

1. A survey of state DOTs that are members of the American Association of State Highway and Transportation Officials' (AASHTO's) Technology Implementation Group (TIG) was conducted to determine their use of 3D models and DTMs for construction plans and final earthwork quantities, as well as issues or problems they encountered or identified in moving from two-dimensional to three-dimensional design.

2. Input was sought from WisDOT staff on references to cross sections in policy documents, uses of cross sections throughout the department, and status of secure digital signatures on document and data files.

3. An example comparing the DTM-to-DTM method to that of average-end-area for computing volumes was developed by WisDOT staff.

4. An interim report was prepared and distributed to WisDOT bureaus and regions, consulting engineers, and contractors in advance of a first stakeholder workshop for obtaining feedback from the community. The workshop was used to identify and address foreseen and unforeseen issues and concerns pertaining to

implementation of 3D design and broader use of 3D models and DTMs throughout design and construction processes.

5. Following recommendations arising from the first stakeholder workshop, the project advisory group was expanded and a high-level draft implementation plan was developed in four meetings of the group.

6. The draft implementation served as the basis for a second stakeholder workshop to obtain feedback from the community.

7. The project advisory group met once again to consider the results of the second workshop and finalize the implementation plan.

8. The implementation plan, which addresses six initiatives, underway or proposed within WisDOT, was distributed to departmental management personnel.

9. This report summarizes all of the project's activities and findings.

4. Survey of Other State DOTs

This activity consisted of development and distribution of a questionnaire to state DOT representatives on AASHTO's TIG, followed by interviews with key personnel at a number of state DOTs. A web-based search of presentations made at the 2007 Annual Meeting of the International Highway Engineering Exchange Program (IHEEP) was also conducted.

The questionnaire appears in Appendix A. AASHTO TIG membership includes state DOT representatives from Florida, Georgia, Michigan, Minnesota, Missouri, New York, North Carolina, and Wisconsin. WisDOT's representative (Brad Hollister) distributed the questionnaire to the other members. Florida and North Carolina provided completed questionnaires. Michigan, Minnesota, and New York provided e-mail responses. Personnel from all represented states except Florida were then interviewed. In addition, personnel from Oregon and Utah DOTs were interviewed as a result of leads provided by AASHTO TIG members. See Section 6 for a table comparing the statuses of 3D design in all these state DOTs and WisDOT.

<u>Florida</u>

At present, Florida DOT (FlDOT) uses the average-end-area method for earthwork volume computations for both design estimates and final quantities. They are aware of the benefits of using DTM-to-DTM methods and will consider using them as they move towards 3D design. FlDOT might soon adopt Civil 3D as their standard design software. Their current contract documents include 2D plans and cross sections. FlDOT's cross sections show drainage structures and pipe crossings, soil borings, elevation of the water table, underground utilities, right-of-way and construction limits, and structures that might impact the clear zone.

At present, the original ground surface is the only one typically represented with a DTM. FlDOT is re-writing its design criteria so they have an opportunity to produce design DTMs in their current software (i.e., MicroStation / GEOPAK). They see this as a stop-gap measure until their full 3D design software is implemented.

FlDOT currently uses average-end-area methods with shrinkage / expansion factors for all volume computations. Typically, a single factor is used on a given job unless there is variety in the materials warranting a change. Earthwork estimates are tabulated on cross section sheets as end areas and cumulative volumes.

FlDOT implemented electronic signatures for plans and specifications and let their first job in 1990. Since 2003, all lettings have been electronically signed and sealed. The FlDOT Engineering / CADD Systems Office is in communication with the Florida Board of Professional Engineers' rule-making committee about the need to extend current rules to include 3D models. The models they are proposing to have electronic seals and signatures are LandXML representations of proposed designs (i.e., existing ground DTMs, sub grade design DTMs, and finished surface design DTMs). They are working with Autodesk to develop a tool for appending electronically sealed and signed models.

Georgia

Georgia DOT (GaDOT) is in the process of transitioning to 3D design software and is waiting for staff to become familiar and comfortable with it before undertaking broader initiatives on 3D design products. Plans and cross sections are the contract documents. There is a desire to move towards DTM-to-DTM methods for computing volumes for both estimating and final payment, but the traditional use of average-end-area throughout the department is seen as a hurdle.

GaDOT has a specification for AMG with fine graders for base course placement. Currently, the department provides cross section reports to contractors who then build the models needed for machine guidance. No changes have yet been made to project staking requirements, but work is underway to modify the staking specification.

Moving towards 3D design will require a significant educational component to inform design-side staff of the broader significance of their data and how it will be used. The institutional hurdle is organizational structure and allocation of resources. Departmental structure and budgets separate design and construction. Aspects of 3D modeling are seen as costs to design and benefits to construction. The department needs to have a more cross-organizational, mission-oriented point of view. To help address this, an initiative on project prioritization is underway that will change the way the department does business. Currently, some projects in GaDOT's long-term program are expending design-side resources without actually being funded. The prioritization initiative will set department-wide directions for projects that need to be worked on at any given time, and resources will be allocated accordingly. As a result, it is expected that many staff will have a better understanding of how their work fits into the "big picture".

Michigan

Michigan DOT (MiDOT) has an AMG pilot program and a related but separate "design deliverable enhancement" project underway. They are keeping paper plans in place as contract documents and have not made the leap to adopting 3D modeling as their official design process. Rather, they are looking to smooth the flow of data from design to construction. Preliminary results from their design deliverable enhancement project became available in June, 2008.

Minnesota

Minnesota DOT (MnDOT) is among the leading state DOTs in implementation of AMG for highway construction. Their AMG specification was implemented statewide in 2006 (Barrett, 2007a). It requires the department to develop and manage the necessary 3D models. However, the models are built from 2D plans and cross-sections, as these are the contract documents. MnDOT has not taken any steps towards making 3D models part of the contract or towards using them for payment. Exceptions are gravel pits and ponds, that are small percentages of the work on very few projects.

Actual and perceived barriers to 3D design include legal issues, changing technology with its continual upgrades and learning curves, agency culture, and time and costs to implement (Barrett, 2007b). One of the lessons learned during MnDOT's 2003 GPS machine guidance pilot program was that designers perceive proposed roadways in 2D plan and cross section views (Barrett, 2007a). Another impediment to moving towards 3D design is limitations of MnDOT's current technology which does not have functionality for easily preparing 3D deliverables. It has been stated that the department is not ready culturally, legally, or philosophically for 3D design.

Missouri

The Missouri DOT (MoDOT) currently develops design DTMs at the district level and provides them at let for all projects that have earthwork. However, the department does not provide any assurance that the DTMs conform to project plans which are the contract documents. Districts develop design DTMs from 2D plans and cross sections because MoDOT's current design software does not support developing them directly. Currently, MoDOT has no plans to pursue the notion of 3D models as contract documents. They are not convinced that the technology, the knowledge, and the abilities exist within the department. It is believed by some that design engineers think in 3D while construction staff do not. MoDOT asserts that a large educational component would be necessary even if the technology were in place.

New York

New York DOT (NYSDOT) is among the leading state DOTs in implementation of both AMG and 3D design. NYSDOT is implementing incorporation of 3D models for AMG as part of the contract documents. The department is custodian of the 3D model as revisions are made during construction. The final updated 3D model can be used for pay item quantities.

The department has been monitoring AMG on its projects and also investigated the associated exchange of electronic engineering data. Conclusions reached by site visits to eight projects during 2007 included:

1. There is a natural resistance to change when people have been doing things in the same ways for a long time. Younger staff adapt more quickly to new technologies. Veterans become more comfortable over time as they use technology and test its reliability and accuracy.

2. Automated construction inspection technology employs GPS, a data collector, a PC, and specialized software that uses DTM-to-DTM methods for

computation of final quantities in the field. In the same time period, a single person using this technology can do the work of two or three persons using conventional methods.

3. DTM-to-DTM volume calculations are faster and more accurate than using average-end-area.

4. With 3D models, paper cross sections are being phased out because cross-sectional views can be produced from the models at will.

5. If 3D models flowed directly from design to construction, there would be reduction in misinterpretation of intent and the facility would be more precisely constructed.

NYSDOT and Associated General Contractors (AGC) have a subcommittee on emerging technologies that has been studying exchange and use of electronic engineering data for two years. In January 2008, the subcommittee produced a proposal for use of electronic engineering data in construction (AGC/NYSDOT, 2008). Among other things, the recommendations are based upon the fact that a number of highly-efficient new construction technologies require 3D models of a facility's design. These include AMG and automated stakeout and inspection. Furthermore, additional technologies are under development that will also require 3D design models, including automation of asphalt and concrete paving, slip-form curbing, and milling of pavement (AGC/NYSDOT, 2008). The stated long-term goal of the subcommittee's recommendations is transitioning from 2D paper plan contracts to electronic engineering data deliverables. This is in line with an earlier recommendation made by a practitioners' meeting in late 2007, which stated that 3D models should eventually become the bidding deliverable and take precedence over paper plans and cross sections (AGC/NYSDOT, 2008).

In its work, the subcommittee identified NYSDOT policy documents that need modification, developed initial guidelines for data development and quality control for design and as-built surfaces, and recommended full electronic deliverables for all projects in the preliminary design stage during the 2008 state fiscal year. This yields a 2-5 year transition period for regions and consultants.

North Carolina

North Carolina DOT (NCDOT) currently provides 3D models on-line prior to bid for 20-25 larger projects (i.e., greater then 100,000 yards of earthwork) per year. Each model is associated with a disclaimer stating that the contractor uses the data at their risk. The plans are the contract documents. Contractors typically need to enhance department-supplied models as they do not include complete detail. NCDOT does not have a formal method for checking 3D models at this time.

NCDOT often computes earthwork volumes using DTM-to-DTM methods, but they have not yet resolved how to apply shrinkage / expansion factors with this method. Results are shown on cross section sheets and in summary tables. They are in the midst of a study comparing volumes computed by DTM-to-DTM and average-end-area methods. Their initial hypothesis was that average-end-area results would approach those of DTM-to-DTM as the interval between cross sections was reduced. However, they have found that the relationship is not linear and actually fluctuates. This is because random variations in the surfaces sometimes skew average-end-area results at smaller intervals. NCDOT is taking measures to ensure their project sites and data produce statistically-defensible results. They have selected projects in both mountainous and rolling terrain because the character of the terrain affects the number of necessary data points.

Some at NCDOT perceive the construction side of the department and the contracting community as more ready to adopt 3D methods than designers. They believe that designers do not view the world in three dimensions and need more effective visualization tools in addition to an educational component. Designers do not see the benefits of 3D modeling as more significant than the extra work it costs them. There is a need for realization of return-on-investment on the design side. In addition, contractors assert that 3D modeling and support for AMG will lead to lower bids, but how is this to be quantified and tested? Although some NCDOT staff have clearly considered some institutional and cultural aspects of moving towards 3D design, no formal studies have been initiated.

There is a concern within the department about confusion in the community's terminology. For example, adjectives such as "original", "existing", "proposed", "design", "designed", "preliminary", "final", and "as-built" are used to describe "surfaces", "TINs", "DEMs", "DTMs", and "3D models". NCDOT believes there is a need for a glossary of terms. The author agrees (see Appendix B for definitions of terms as used in this report).

Oregon

Two-dimensional plans and profiles are the contract documents at Oregon DOT (OrDOT). Cross sections are made available on request prior to bid. Contractors in Oregon are beginning to adopt AMG, and the department makes 3D models available after contractor selection. The department uses 3D models for visualization and analysis and some think designers should provide the data. OrDOT uses both DTM-to-DTM and average-end-area methods for computing volumes. No as-built surveys are conducted.

OrDOT is considering taking a step in the direction of adopting 3D models as contract documents by investigating signing and sealing of models as verification that contractors are using the data that were designed. For engineering documents, Oregon state law requires a specific seal and the signature of a registered professional. The law does not address digital signatures and the general understanding is that a physical document and "wet" signature are required (Singh, 2007). OrDOT makes a clear distinction between "electronic signatures" and "digital signatures". Electronic signatures can include scanned images of hand-written signatures, typed notations, or signature blocks in e-mail messages without any authentication or encryption. Digital signatures require specific technical processes that provide added security, authentication, and / or encryption, thus ensuring both identity of the author and integrity of the document. OrDOT has a committee studying whether or not digital signatures can be adopted for engineering documents and data files by making changes to administrative rules (Singh, 2007).

Utah

Plans and cross sections are the contract documents at Utah DOT (UtDOT), but some within the department would like to see 3D models replace them. However, traditions and necessary comfort levels of engineers are seen as impediments. There is also a perception that development of 3D models requires more time and attention to detail (e.g., at intersections) than development of plans and cross sections. UtDOT has a research committee on AMG, but the committee has not yet produced a report.

5. The Current Situation at WisDOT

At Wisconsin DOT (WisDOT), plans and cross sections are the contract documents. Under its current pilot specification for automated machine guidance, the department provides a “contractor staking packet” upon request by the contractor at any time after the contract award. No assurances are associated with these data and contractors must verify that their final 3D models conform to the plans.

WisDOT began implementing new 3D design software (Civil 3D) during 2008. That initiative, expected higher accuracies of DTM-to-DTM methods for volume computations, needs for 3D models for AMG, and foreseen efficiencies of smoothing data flows from design to construction to final payment helped drive this study.

Department-Wide Use of Cross Sections

Through WisDOT’s Earthwork Committee and Methods Development Unit (MDU), regional staff were asked to identify specific uses of cross sections in departmental business. The results were:

1. Graphically display and determine information for culvert pipes including; pipe lengths and clearances as well as inlet and discharge elevations.
2. Graphically display and determine storm sewer lengths and depths as well as storm sewer structure (e.g., manholes and inlets) inlet and discharge elevations.
3. Graphically display and determine information for all earthwork quantities and their distributions.
4. Graphically display and determine driveway profiles.
5. Graphically display and determine clearances for underground utilities and structures.
6. Graphically display and determine ditch grades and profiles.
7. Graphically display and determine slope stakes, landscape profiles, needs for streamline slopes, and needs for right-of-way needs. Sometimes there might be two or more intercepts of the original and final cross sections to improve landscaping. This is best identified graphically on the cross sections.
8. Graphically display and determine plan quantities for salvaged topsoil, seed, sod, fertilizer, mulch, riprap and other erosion control items.
9. Graphically display and determine locations and elevations of sign supports.
10. Graphically display and identify relationships between reference lines and design lines.
11. Graphically display berms, slopes, and ditches.
12. Graphically display and identify encroachments.
13. Graphically display and identify clearing and grubbing limits.
14. Graphically display and identify match lines and grade connections to existing side roads as well as beginnings and ends of projects.
15. Graphically display and identify quantities and plan details for multi-stage construction.
16. Graphically display and determine offsets and elevations of miscellaneous items.

17. Graphically display and determine numerous other details where a cross sectional view is needed or desired to identify or clarify a plan detail.

It is expected that this is a partial list and further investigation might be warranted.

References to Cross Sections or Average-End-Area in WisDOT Manuals and Specifications

Central Office staff were asked to identify sections of the Standard Specifications and the Construction and Materials Manual that contain references to cross sections or average-end-area methods. The results appear in Tables 1 and 2. Codes for interpreting table entries are:

A = No change required.
B = Add “or DTM”.
C = Replace “cross section” with “DTM”.
D = Add “or DTM update”.
E = Remove “cross section” or replace with “lines and grades as shown on the plan”.
F = Add “or DTM-to-DTM volume computations”.
G = Other minor word changes required.
H = Subsection 205.4.2 and the term “overhaul” should be eliminated in new spec.
I = This subsection should be completely re-written, especially the 2nd to the last paragraph that states “although the software available …”

Table 1.
Entries in the 2008 Standard Specifications that Refer to Either “Cross Sections” or “Average End Areas”

Sect	Page	# of References		Code		Comments
		Cross Section	Average End Area	Cross Section	Average End Area	
105	40	1	----	E	----	Contractor staking
205	101	3	----	E	----	Roadway/drainage exc
205	104	1	2	E	F	Measurement/excav
205	105	3	3	EGH	F	Measurement/excav
208	119	3	3	B	F	Measurement/borrow
209	122	----	1	----	F	Granular backfill/meas
211	124	4	----	E	----	Preparation of foundation
211	125	6	----	E	----	Preparation of foundation

The Facilities Development Manual is expected to contain many more references to cross sections and average-end-area than either the Standard Specifications or the Construction and Materials Manual.

Table 2.
Entries in the Construction and Materials Manual that Refer to Either "Cross Sections" or "Average End Areas"

Sect	Page	# of References: Cross Section	# of References: Average End Area	Code: Cross Section	Code: Average End Area	Comments
2-2-180	1	1	----	F	----	Contract records
2-25-100	2	1	----	G	----	As built plans
2-25-100	3	1	----	G	----	As built plans
2-30-10	2	1	----	B	----	Finals documentation
3-5-102	2	1	----	F	----	Initial layout
3-5-102	5	1	----	G	----	Initial layout
3-5-102	6	8	----	BBBB DBDD	----	Initial layout
3-5-102	8	2	----	B	----	Initial layout
3-5-102	9	1	----	B	----	Initial layout
3-5-102	10	1	----	B	----	Initial layout
3-5-122	1	12	----	I	----	Cross sections/DTMs
3-5-132	1	6	----	A	----	Borrow Pits
5-20-80	1	1	----	E	----	Roadway/drainage exc
5-20-80	5	1	----	B	----	Roadway/drainage exc
5-20-110	1	3	----	B	----	Borrow excavation
5-40-20	2	2	----	B	----	Concrete structures

Electronic Signatures

Currently, plans from consultants are signed and sealed on paper with "wet" signatures, scanned, and included as .pdf files in PS&E packages while plans developed in-house have electronic signatures that are not secure. As early as 2001, Wisconsin law enabled use of secure digital signatures (e.g., encrypted with public and private keys, often including a certificate by a third party) on engineering and surveying documents. This law was revised in 2003 to give the Department of Administration authority over use of electronic signatures. An interdepartmental committee was formed to develop administrative code on state government use of electronic signatures. A draft of the initial administrative code was distributed to government agencies for comment. The draft document calls for guidelines that have yet to be developed. It requires governmental units to assess and categorize levels of security they require in electronic signatures. Professional registration seals are not mentioned in the draft document. Until these rules are finalized and in place, it might not be possible for state agencies to use either electronic or secure digital signatures.

Some document preparation software and some engineering design software have functionality for securely signing and sealing their output products. Advanced technology enables multiple signatures over time by invoking append-only modes. For example, Adobe Acrobat supports secure digital signatures on documents. Civil 3D's support for securely signing and sealing data files and 3D models is being investigated by WisDOT. It is known that Bentley's MicroStation product has such functionality.

6. Comparison of Statuses of 3D Design within All Surveyed State DOTs and WisDOT

Table 3 compares the statuses of key elements of 3D design within all surveyed state DOTs. In the table, “No Information” does not mean “No Activity”. In these cases, there might be activity unknown to the author. New York DOT has taken definitive steps towards adoption of 3D design not only as a technology, but as a process and an institutional and contractual initiative. Most of the surveyed DOTs are making some progress towards the technological side of 3D design, but not often are institutional, cultural, and legal aspects of 3D design being addressed head-on. Many of the DOTs expressed that they were being driven by the construction industry which is rapidly adopting AMG technology and demanding access to digital design data, most desirably in 3D representations.

7. Example Comparisons of DTM-to-DTM and Average-End-Area Methods for Volumes

WisDOT currently uses cross sections and the average-end-area method for computing earthwork volumes for both design estimates and final quantities. Civil 3D enables volume computation using DTM-to-DTM methods. A U.S. Army Corps of Engineers manual states that DTM-to-DTM methods are more accurate than average-end-area methods (Corps of Engineers, 2002). To demonstrate relationships between these two methods of volume computation, Rick Larson of WisDOT’s Methods Development Unit prepared the following examples.

In the first example, both methods were used to compute volumes over a 2200-ft stretch of roadway. Table 4 compares cut, fill, and composite volumes computed by average-end-area at 100-ft, 50-ft, 20-ft, and 10-ft intervals to cut, fill, and composite volumes computed by DTM-to-DTM methods within Civil 3D. Average-end-area computations were done using both CAiCE and Civil 3D. Figure 2 shows CAiCE cross sections and the Civil 3D DTM of the intersection. The two pieces of software produce different average-end-area results due to the manner in which they form cross sections. In the example, there is much more cut than fill, leading to small fluctuations in fill causing larger percentage differences than those in cut. Figure 3 is a graph of some of the data in Table 4. It can be seen that decreasing the cross section interval from 100 ft to 50 ft causes a dramatic change in the percentage differences. Decreasing the interval further does not cause appreciable change in percentage difference. Overall the percentage composite difference between average-end-area and DTM-to-DTM methods was maximum (1.66%) using CAiCE at a 100-ft interval. These results should be considered as indicating trends, not as statistically conclusive. The sample size is very small.

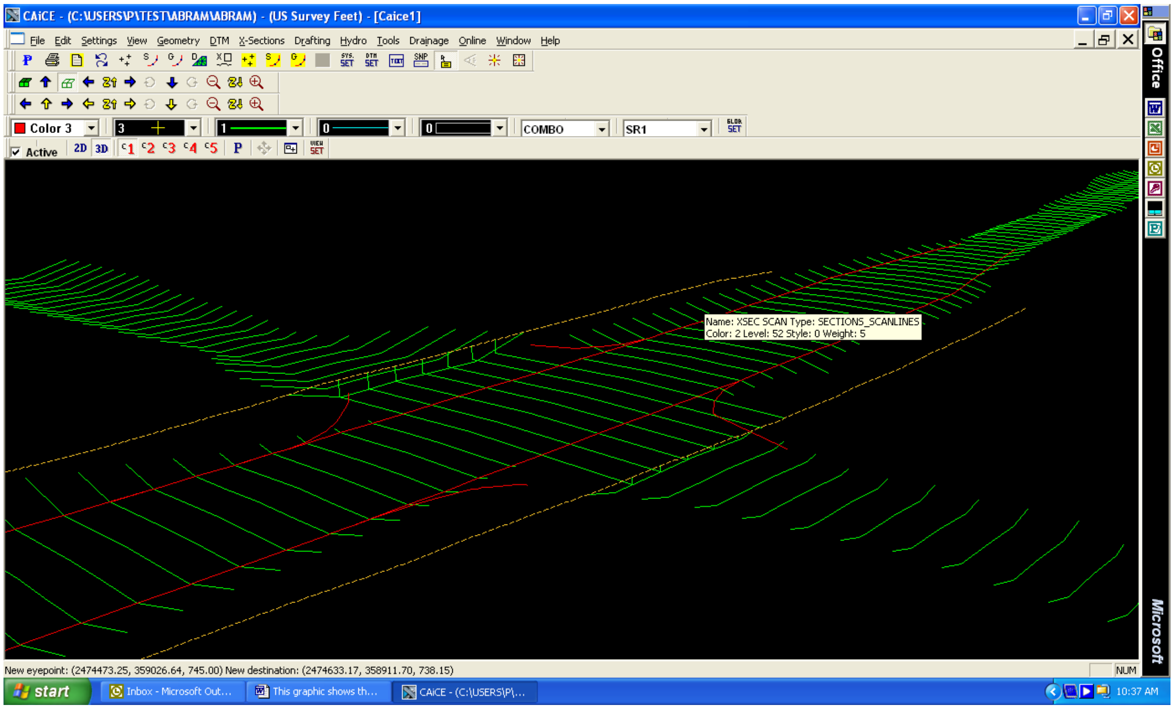
The second example compared designing an intersection using CAiCE’s match-line method with the corridor method of Civil 3D. Mr. Larson noted that the corridor method allowed him to identify a mistake in the curb profile that was not noticed when using the match-line method (see Figure 4). There was a 4.24% difference in cut and a 2.81% difference in fill between the two methods (see Table 4).

Table 3.
Status of Key Elements of 3D Design within Surveyed State DOTs
Note: “No information” Does Not Imply “No activity”

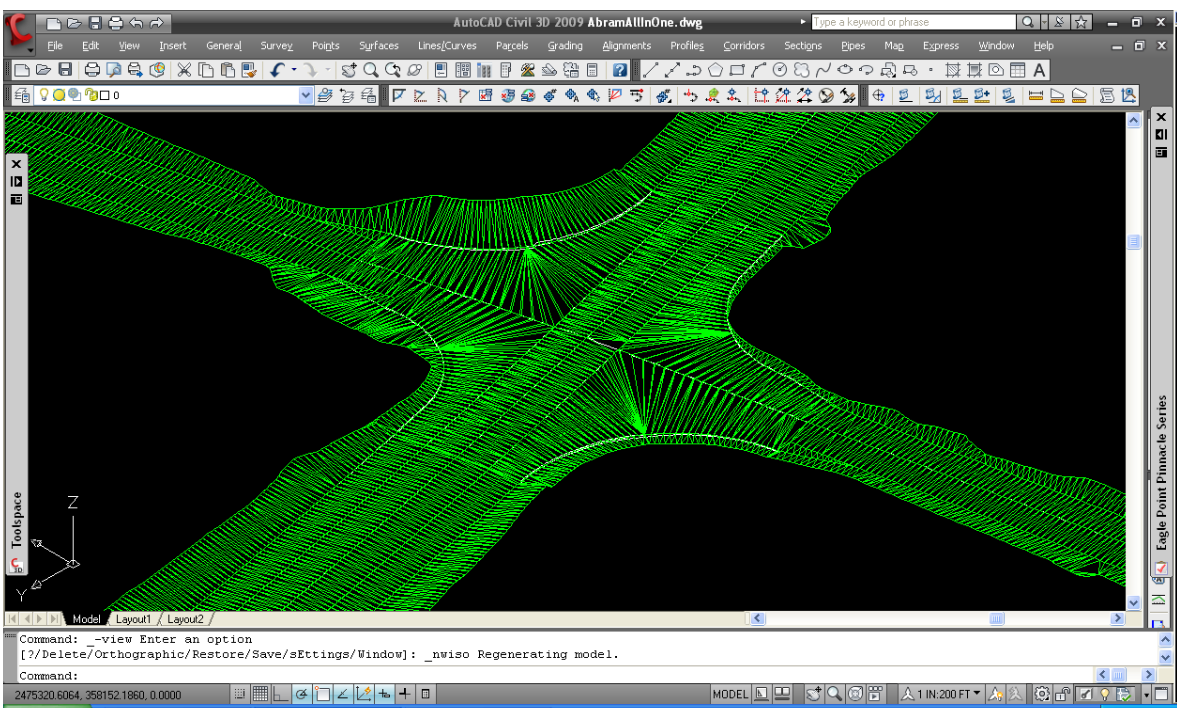
	3D Design Software	Contract Documents	3D Models For MG	Earthwork Method	Electronic Signatures	Primary Impediment	Study Group
FL	Expect to implement	Plans	No information	AEA	Yes – seeking to include 3D models	No information	No information
GA	Implementing	Plans	Cross section reports	Desire DTM	No information	Organizational structure	No information
MI	Pursuing	Plans: no intent to change	Pursuing	No information	No information	No information	Design enhancement
MN	Lacks functionality	Plans: no major steps to change	Selected projects	No information	No information	Cultural, legal, philosophical	No information
MO	Lacks functionality	Plans: no intent to change	All projects	No information	No information	Knowledge, abilities	No information
NY	Yes	Implementing 3D models	Yes	DTM	No information	Resistance to change	AGC/NYSDOT subcommittee
NC	No information	Plans	Projects over 100,000 yards	DTM and AEA	No information	Design-side culture	No information
OR	No information	Plans	On request by contractor	DTM and AEA	Initiative underway	No information	Electronic signatures
UT	No	Plans	No information	No information	No information	Traditions and comfort levels	GPS machine guidance
WI	Implementing	Plans	Components for selected projects	AEA	Joint state-wide initiative	Under study	Yes

Table 4.
Comparison of Results from DTM-to-DTM and Average-End-Area Methods (Prepared by WisDOT's Rick Larson)

Results:										
Source	Spacing	Cut	% diff Surf/Surf	Fill	% diff Surf/Surf	Composite	% diff Surf/Surf			
Civil 3D Corridor Design surface	**2**	**44683**	**0**	**904**	**0**	**43779**	**Assumed correct**			
CAiCE cross sections	10	44684	0.00%	903	0.11%	43781	0.00%			
CAiCE cross sections	20	44668	0.03%	920	1.77%	43748	0.07%			
CAiCE cross sections	50	44644	0.09%	922	1.99%	43722	0.13%			
CAiCE cross sections	100	44082	1.35%	1029	13.83%	43053	1.66%			
Civil 3D Cross Sections	10	44680	0.01%	905	0.11%	43775	0.01%			
Civil 3D Cross Sections	20	44671	0.03%	911	0.77%	43760	0.04%			
Civil 3D Cross Sections	50	44683	0.00%	849	6.08%	43834	0.13%			
Civil 3D Cross Sections	100	44136	1.22%	896	0.88%	43240	1.23%			
Notes:										
1) Civil 3D works directly on a surface and creates a surface from the corridor design. This surface was compared to the existing ground surface to compute volumes. This same surface is used to generate the final cross sections and average-end-area volumes if desired.										
2) Corridors are more robust the higher the frequency of samples (i.e., cross sections)										
3) This is a very simple surface.										
Also tested designing an intersection with the roadway using old matchline method as well as Civil 3D corridor method										
The Civil 3D method allowed me to catch a bust in my curb profile and fix it before finishing the design. I did not notice this when Designing with CAiCE										
Earthwork for mainline and intersection										
	Spacing	Mainline Cut	Mainline Fill	Spacing	Side Road Cut	Side Road Fill	Total Cut	% diff Surf/Surf	Total Fill	% diff Surf/Surf
CAiCE - using matchline method	10	44860	914	10	3204	0	48064	4.24%	914	2.81%
Civil 3D - using all in one corridor and surface to surface volumes			Frequency	Cut	Fill					
			2	50193	889					



a) CAiCE Cross Sections



b) CDivil 3D DTM of the Intersection

Figure 2.
CAiCE and Civil 3D Representations of the Intersection

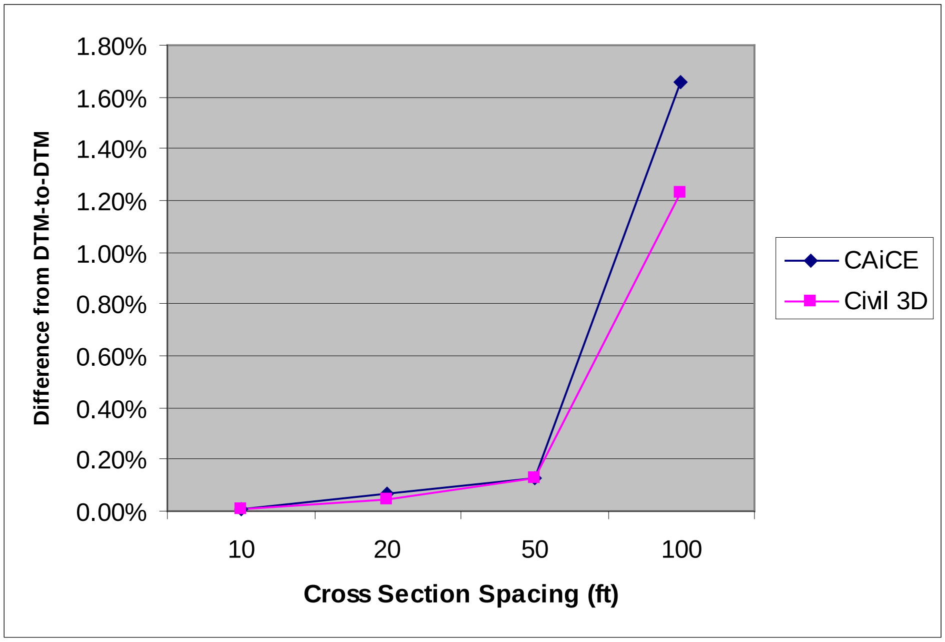


Figure 3.
Percent Differences between Composite Volumes Computed by DTM-to-DTM and Average-End-Area Methods

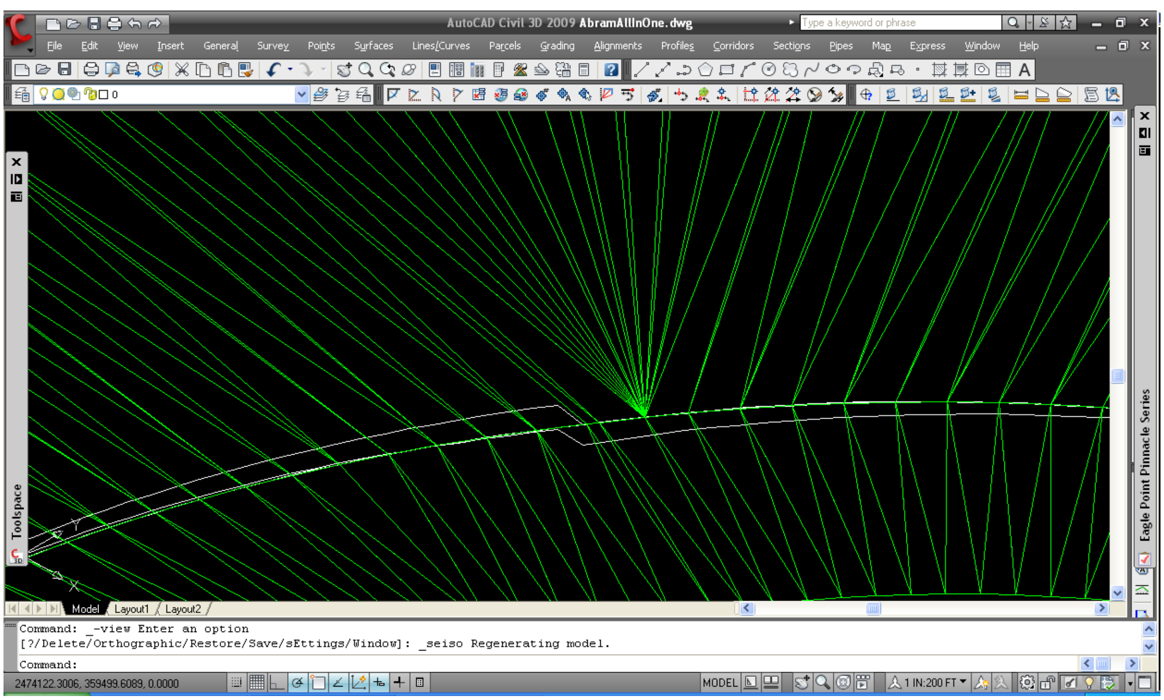


Figure 4.
Design Flaw at Match Line Detected when Working with Civil 3D

Concerning the second example, Mr. Larson noted:

> "In order to get surfaces that are machine-control ready we will have to design major intersections as I did in this Civil 3D example. Currently, this takes extra effort in Civil 3D over what we would do in CAiCE cross sections, although we are working with the vendor to make this easier. We hope to have an improved workflow prior to implementation.
>
> Even though Civil 3D intersection design requires more effort, we are able to: 1) improve the design and catch mistakes in the curb grades prior to finishing; 2) get a more accurate idea of the quantities in the intersection;… 3) the resulting surface from Civil 3D is machine control ready; 4) we actually design the curb profiles/grades and this is helpful with field layout."

8. Summary of Preliminary Findings

Many of the surveyed state DOTs expressed that they were being driven by the construction industry which is rapidly adopting automated machine guidance technology and demanding access to digital design data, most desirably in 3D models. A number of DOTs have adopted, are adopting, or are considering adopting 3D design technology, but very few have addressed institutional, cultural, and legal aspects of taking the dramatic step away from plans and cross sections and towards 3D models as contract documents. Only a few have begun to use DTM-to-DTM methods for volume computations. New York DOT is an exception. That department is implementing the recommendations of a joint emerging technologies subcommittee whose long-term goal is adoption of 3D design models as contract documents.

Institutional, cultural, and legal impediments to 3D design, identified by surveyed state DOTs, include resistance to change, tradition, viewing the world as being represented in two-dimensions, necessary comfort levels, lack of knowledge and skills, organizational structure and the manner in which resources are allocated between design and construction, lack of demonstrated design-side return-on-investment, lack of understanding of extended data needs and utility, entrenched policy and procedural documentation, lack of mission-wide points of view at operational levels, issues with data security and authentication, and entrenched philosophies on how to do business.

Seventeen business uses of cross sections within WisDOT, beyond their being core contract documents, were identified. Seventy-three references to either cross sections or average-end-area methods were identified in WisDOT's 2008 Standard Specifications and its Construction and Materials Manual. The Facilities Development Manual is expected to contain many more.

Electronic signatures are an issue in Wisconsin, with the Department of Administration having authority under the law and a draft administrative code document distributed to state agencies for comment. The draft document calls for guidelines but does not provide them.

Two simple examples were presented that illustrate quantitative differences between surface-to-surface and average-end-area methods for computing volumes.

In this period of transition, there are issues with conflicting terminology and semantics that need to be addressed to avoid confusion and develop mutual understanding of meaning and intent as the community moves forward towards 3D design. See Appendix B for definitions used in this report.

9. First Stakeholder Workshop (September, 2008)

The first stakeholder workshop was conducted on September 18, 2008 in Madison, Wisconsin. The objective of the workshop was to provide a forum for participation by the stakeholder community in achieving the study objectives. Participants included WisDOT employees, construction contractors, consulting engineers, staking contractors, municipal employees, vendors, and academics (see Appendix C).

Prior to the workshop, this study's interim report (Vonderohe and Brockman, 2008) was distributed to the pre-registered participants. The project advisory group had also developed a vision statement that was presented and discussed at the workshop:

> "Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, and payment processes."

.
The workshop consisted of an opening general session, a breakout session with four breakout groups, and a closing general session where breakout group findings were reported and discussed. See Appendix D for the workshop schedule and Appendix E for slides from the opening general session.

The breakout groups focused upon:

1. 3D model content, format, and security.
2. Digital terrain model (DTM) data collection and data quality.
3. Impacts, training, and communication.
4. Implementation planning.

Focus statements for each breakout group were prepared and distributed to participants prior to the workshop. Each focus statement included objectives for the group, a list of questions to be addressed, and a paragraph explaining what was hoped to be gained from the group's discussion (see Appendix F). Participants were assigned to breakout groups prior to the workshop, but were allowed to switch if they felt they could contribute more strongly to one of the other groups. Each participant was also assigned an identifier so written statements could be associated with individuals if follow-up or clarification was needed.

A summary of findings from each of the breakout groups and the closing general session follows.

Breakout Group 1 - 3D Model Content, Format, and Security (Facilitators: Rick Larson / Brad Hollister)

Breakout group 1 was asked to address five questions, with the group's focus being ideas and recommendations on what needs to be done to develop a 3D model content standard for initial survey, design, contracting, construction, as-built survey, and payment. Additional aspects of group 1's focus were options for data exchange and means for data security.

Questions

1.a. What is the most appropriate mechanism for development of a data content standard for 3D models for initial survey, design, contracting, construction, as-built survey, and payment?

There was consensus that a group effort is needed. Individual user groups, focus groups, and a task force with all stakeholders represented were discussed. The group effort should have a well-defined scope and a good management sponsor. It was suggested that if individual focus or user groups were for each business area, they could work in parallel with each providing periodic updates on progress to the others. A coordination effort would be needed to bundle the efforts of the individual groups into a final product. It was suggested that existing standards should be adopted or built upon if possible and that the effort should have development, pilot, and implementation phases. As a new standard is being developed, attention should be given to today's standards. Suggested communication mechanisms included face-to-face meetings, teleconferences, and written reports.

1.b. What groups should be represented and participating in development of such a 3D model content standard?

There was consensus that design engineers, construction engineers, contractors, surveyors, and vendors should be represented. It was suggested that the playing field be broadened to include bridge and structural engineers as they will be impacted by and using 3D design also.

1.c. What questions must be addressed during development of such a 3D model content standard?

Platform independence and portability between computer-aided design (CAD) packages must be considered. Data needs of all stakeholders must be taken into account as well as costs and benefits of satisfying all needs (NOTE: This implies that some prioritization might be necessary).

At a more fundamental level, what do we mean by "3D model" and what can a 3D model contain? What do consultants currently provide and what do our plans consist of now? Are any of today's standards obsolete and does the new standard satisfy today's standard? NCHRP developed a set of Extensible Markup Language schemas, called "transXML", for exchange of highway engineering data. These should be examined for utility in Wisconsin's case.

There must be verification that 3D models are properly registered in the same coordinate space for initial survey, design, construction, as-built, and payment processes. Triangulated irregular networks (TINs) allow only one elevation at any given X,Y, so any standard must account for multiple surfaces.

1.d. What file formats are appropriate for exchange of 3D model data?

The format must support alignments, profiles, mass points, break lines, and surfaces. Dxf, dgn, dwg, ASCII, and LandXML were mentioned with a note that LandXML had some difficulties on the early GPS machine guidance pilot projects and some have experienced difficulty with compatibility of dwg between software packages. NCHRP developed a set of Extensible Markup Language schemas, called “TransXML”, for exchange of highway engineering data. These should be examined for utility in Wisconsin’s case. The most basic file format that satisfies needs is desirable. The format must be fully tested on all known major platforms. There might be a need for flexibility in the format component of a standard.

It was noted that triangulation algorithms for generating TINs from mass points and break lines can differ, leading to different surfaces produced from the same input data. This problem is mitigated by using a data exchange format (e.g., LandXML) that supports surface representations (that is, the actual triangles in the TINs are exchanged). However, triangulated surfaces require much larger file sizes than do the break lines and mass points from which they are generated. It was also noted that equipment and software used in the field typically have limited capacities and these might need to be expanded for large files sizes.

1.e. What means are there for ensuring the integrity of 3D model data as it is exchanged and manipulated from design through construction? Here, we are referring not to data quality, but rather to data security.

It was generally recognized that data security is critical and that all parties must have assurance that the data they are using are the correct data. Both technology and management techniques were suggested for ensuring data security. Technology solutions include a software lock with changes tracked so that they can be viewed, encrypted files with public and private keys, and read-only files that are passively locked. It was noted that Florida DOT has a means for marking documents to ensure they have not been changed. Suggested management techniques were promotion of a single location where data are accessed (no copying or distribution of data), having the new WisDOT survey data coordinators approve and document all changes to the data, and integration of concepts from the on-going Department of Administration effort while staying informed of emerging legal requirements.

<u>Additional Discussion</u>

Additional considerations included envisioned bid items for earthwork, uniform control to ensure consistency of multiple disciplines, and unbiased assignment of roles, responsibilities, and risk of work not meeting requirements.

Breakout Group 2 – DTM Data Collection and Data Quality (Facilitators: Kim Schauder / Cindy McCallum)

Breakout group 2 was asked to address six questions, with the group’s focus being ideas and recommendations on management of data quality, particularly surface data, as WisDOT moves towards adoption of 3D models as contract documents and use of them throughout design / construct processes. Group 2 addressed appropriate data resolution (level of detail), data accuracy, data collection and model building methods, and quality standards and procedures. Additional aspects of group 2's charge were allocation of responsibility for data quality and development of consensus on standards and procedures.

<u>Questions</u>

2.a. Three types of DTMs: Initial surface, design surface(s), as-built surface(s). What are the spatial accuracy requirements for each of these types of surfaces?

Considerable work needs to be done to achieve consensus on spatial accuracy requirements. It was assumed to be a 3D accuracy statement, as there were no comments concerning potential differences between horizontal accuracy needs and vertical accuracy needs.

Statements ranged from 0.10 ft to 0.3 ft for all surface types. The more common response was 0.1 ft with variations in accuracy requirements typically due to project location (rural / urban) and cost / benefit.

Project location:

- There was a suggestion that urban (0.05 ft) and rural (0.25 ft) accuracy needs are different.

Cost / benefit:

- It was suggested that accuracy requirements be based upon economic considerations. If high accuracies must be maintained over larger projects at greater cost, is it worth it?
- Accuracy requirements should be based upon fair payment.
- There was an assertion that 0.10 ft accuracy is a must for both estimating and payment, otherwise there could be negative impacts on contractors and others.
- 1:1000 aerial imagery can yield ±0.05 ft in mapping accuracy, but results in more stereo models and more work. In addition, it is sometimes difficult to obtain flight clearance for low-altitudes. 1:3000 aerial imagery is more common.
- One noted that if the as-built DTM is as accurate as the initial DTM, then the as-built could be used as an initial for the next project. There are many potential uses for as-builts, so accuracy must be high.

In some cases, it was suggested that initial surface (0.1 ft) and as-built (0.15 ft) accuracy needs are different, yet some felt that 0.3 ft is adequate for both initial and as-built surfaces. One suggested going no lower in accuracy than what is currently in FDM 9-65-5 (Field Procedures: Cross Sections / Digital Terrain Models (DTMs)). Another suggested that if accuracies are defined for two-dimensional (2D) representations we should be able to adopt them to 3D representations.

It was generally understood that data used for creating the design surface are generated by the design process, not measured, and are therefore not subject to a positional accuracy.

There was some discussion of survey control. Project (construction) control should be ±0.01 ft, but this accuracy is not always achievable. When creating project control, time should be devoted to finding the original design control, then densifying the vertical component by differential leveling and the horizontal component by proper GPS methods. It was noted that adjoining projects on different control networks have discrepancies.

It was suggested that perhaps GPS machine guidance and 3D design have more stringent control requirements than older methods (NOTE: Experience on the GPS machine control pilot projects bears this out and suggests that a corridor with abutting projects should be treated as a unit for the purposes of project control. That is, control for the full corridor should be established and simultaneously adjusted. It is also important to provide robust control monumentation, especially for projects that extend over at least one freeze / thaw cycle).

2.b. What are the appropriate densities of break lines and mass points? In other words, what is the necessary level of detail to be included in the surfaces?

It was suggested that the amount of data to be collected depends upon overall accuracy requirements, which are dependent on terrain characteristics, project location (urban / rural), and type of project (e.g., resurface versus reconstruct). In other words, data density standards should be variable depending upon accuracy needs.

WisDOT's photogrammetry unit currently collects mass points every 20 feet with guidance that the points could be spread farther if the area is flat. But, what is meant by "flat"? One suggested that if all ditches and high points were collected on a flat surface, the mass point density could be 25 ft. Another suggestion was that because break lines are so important, they can be supplemented with mass points on a 50-ft grid for most surfaces.

It was generally agreed that all break lines should be collected (NOTE: How does one decide upon the location of a break line?). It was suggested that data density be such that no triangle edge (in the TIN) be greater than 40 ft in length.

It was noted that barriers to collecting a lot of detail include economics (i.e., cost of data collection versus difference in payment quantities), limits to user knowledge of tools, and machine memory and speed in dealing with large files. With regard to file size, it is undesirable to break models apart into smaller pieces due to the chances of losing or corrupting data.

It was noted that some software can simulate jobs to determine proper data density and that some contractors do this now. Standards need to be developed so that field staff collect sufficient data. The question of "who would do the simulations" still remains.

2.c. What are the appropriate field and office procedures for collection and / or generation of data to achieve the required accuracies and levels of detail?

Appropriate data collection procedures for DTMs should be followed. It is better to start with good field procedures and quality data than to correct mistakes later. Field checks should be made before, during, and after generation of data to monitor progress. These

include independent checks, verification of survey control, and map checks of photogrammetric data. Discrepancies should be reported to parties involved.
It was generally agreed that good, consistent survey control is the key to getting started correctly. Those who collect and process the data should have an education / background in surveying or engineering. On the design side, a survey data coordinator should examine survey control data and results from the survey crew before turning them over to the designer. On the construction side, personnel using the data should be knowledgeable in survey control, equipment, and limitations of the available technology. Errors in plans and 3D models should be detected and corrected before construction is started. Design and project (construction) control should be in the same reference frame and used from beginning to end.

The group noted algorithms for generating TINs vary among software. The amount of detail provided should be what is economically feasible to meet required accuracies. Data resolution might be limited by what the equipment can handle.

2.d. What means are there for ensuring that the required accuracies are being met?

Suggestions included using the same control from concept to final; educating office and field personnel; using experienced staff; making checks before (design), during (construction), and after (finals); and comparing measured quantities to load counts. There is a need for documentation of who did what, where it was done, how it was done, and when it was done. All parties must share results whatever they might be. It was noted that DTMs should have owners and that data security is essential. It should be made clear who is responsible for design surface changes during construction.

WisDOT's photogrammetry unit does field checks on selected projects. They could use more feedback from the regions. There is a need for office review of field data and a need to publish GPS network (static / rapid-static) and real-time kinematic (RTK) GPS guidance in WisDOT documents.

2.e. What should be the roles of WisDOT, its design consultants, and its construction contractors in ensuring data quality and use of appropriate data collection procedures? Who should be the "custodians" of the data?

It was suggested that the WisDOT Survey Data Coordinator positions need to be in place as soon as possible, that these people should be the custodians of the data, and that WisDOT should ensure consistency and reliability in the data and that required accuracies are being met. On the other hand, the question of whether or not WisDOT had a legal obligation to be custodian of the data was raised. Another suggested that all parties should share responsibility and that there should be many custodians that agree upon surface models and specified minimum intervals for data collection.

It was suggested that key personnel be "certified", potentially as a professional engineer (PE) or registered land surveyor (RLS). Others felt a license is not needed and suggested that "certification" be more of a WisDOT-specific criterion or use the National Society of Professional Surveyors (NSPS) Certified Survey Technician (CST) program. It was noted that some states are implementing different classifications for surveyors (e.g., boundary, construction). ASPRS also has a certification program for photogrammetrists and related professions.

There is a need for data archives. There are potential applications for the data beyond construction. Perhaps the data themselves should be certified to meet a specific standard.

2.f. What is the appropriate way to develop and implement data collection and data quality standards?

By polling experienced people, talking with other state DOTs, and having workshops like this one. Education and training are keys. This includes a major educational effort for field crews and coordinators and a minor effort for other parties involved in the process. Training should include real-world, hands-on practice.

There is a continuing need for communication among central office and regional staff. The Facilities Development Manual (FDM) and Construction Methods Manual (CMM) should be updated and cross-referenced. There needs to be a way to address material that is pertinent to both design and construction (e.g., RTK GPS is used for both data collection for design and stake out for construction).

Additional Discussion

There was concern that the bidding process was not addressed during the workshop. There was an assertion that cross sections and 2D information are needed for the bidding process. Contractors currently print out the plans. Will they need to generate their own cross sections in the future? (NOTE: Quantities can be computed using DTM-to-DTM methods without cross sections if appropriate software is on hand).

On a similar note, some envision a continuing need for cross sections for visualization in the field (e.g., pipes, percent slope). If cross sections are not included in the plan, could they be generated in the field from 3D models? Can personal digital assistants (PDAs) or rover data collectors be used to do this if they contain the models? Which governs if there is conflict, 3D models or cross sections (NOTE: There should not be conflicts if cross sections are generated from 3D models)?

Breakout Group 3 – Impacts, Training, and Communication (Facilitators: John Espie / Alan Vonderohe)

Breakout group 3 was asked to address six questions, with the group's focus being ideas and recommendations on appropriate training, education, and outreach as WisDOT moves towards adoption of 3D models as contract documents and use of them throughout design / construct processes. The context for the group's discussion was technological, institutional, cultural, and legal implications of the vision statement. An additional aspect of group 3's charge was mechanisms for keeping the entire community abreast of developments.

Questions

3.a. Do the positive impacts of 3D design outweigh the negative impacts (why or why not)?

Positive impacts include:

- Easier construction checking / validation of project features.
- Better understanding between WisDOT and contractors when discussing changes or quantity disputes.
- Savings in contractors', WisDOT's, and the public's time and money. Construction costs will be drastically reduced. Design costs, in the long run, may not be higher than when designing in the current fashion.
- More effective real-world visualization of projects.
- Reduced errors, claims, and change orders.

Negative impacts include:

- Impediments to elimination of 2D representations in plans because designs and design standards are inherently 2D. 3D can be added, but can 2D ever be taken away?
- Transitioning from 2D to 3D for the design process will require time, commitment, and sustained effort.
- Requirement for investment on the part of some contractors.
- WisDOT and contractors might have incompatible software, requiring different formats and inhibiting data exchange.
- Breadth and depth of the full community, including other non-DOT users (e.g., consultants, utilities, agencies).

Intuitively, if we need 3D models for construction then designing in 3D seems logical. However, success might depend on other customers' abilities to use the product. From an agency standpoint, it seems that seamless data flow and use can only be of benefit. There is need for a well-thought-out plan to transition to 3D.

3.b. Is the vision statement too ambitious (why or why not)?

Many in the group stated that the vision is not too ambitious because it sets a goal and direction. It is not an end product. Visions should be ambitious. WisDOT should not be driven to change by contractors; rather, WisDOT should lead change. The Department has the technology – WisDOT should strive to be proactive and make this happen. Designers are producing 3D data to some level already and contractors want to use 3D to construct. It only makes sense to mesh the processes.

Some struggled with the notion of the ultimate outcome being seamless. The technology is changing rapidly and contractors have the most to risk by not adopting, falling behind, and not staying competitive. Will the design side be prepared to adapt at the same pace and keep this process seamless? There might be some compatibility issues that will have to be addressed through data transfer standards.

3.c. What training is necessary to address technical aspects of 3D design and use of DTMs throughout the transportation facilities development process?

Individuals need to be educated on their roles and their relationships to others in the process. Everyone needs an understanding of the entire design / construct process to see where they fit in. There might be needs for new skills and classifications that are non-traditional. Education and training specifics include:

- Usage of 3D models and attributes required in construction and beyond including the full range of data customers.
- Preliminary DTM weaknesses and strengths.
- Accurate and efficient collection of data required for design.
- Packaging data for contracting and construction. Understanding the deliverables.
- Data management.
- Model development, including necessary level of detail.
- Construction and inspection.
- Internal data transfer issues on design elements.
- Upstream and downstream uses of data to ensure utility.

3.d. How can training be used to overcome resistance-to-change and institutional impediments?

Just what is it that people need to be convinced of and what can convince them? Training and education can be used to help all involved parties understand the survey-design-bid-build process. Education and consent are needed at high levels within WisDOT. Implementation of 3D design has to be understood, within the context of a well-defined philosophy of the future, as a benefit to the WisDOT / consultant / contractor relation. This will mitigate current perceived differences in how end results are achieved. The most effective way to overcome resistance is through success. If the positive impacts exceed the negative, then change will be swift. As public servants, we owe it to the people who have hired us to provide the best service for cost.

Once people see the savings and quality that result from 3D design and GPS machine guidance, they will want to be involved. People can be helped to understand their legal liability and address it if there is any concern about shift in risk. Education and training are also needed outside of WisDOT.

Perhaps designers should become involved in construction processes for projects they design. Another mechanism might be to develop and involve staff in comparison studies that determine time, costs, accuracies, and benefits of designing and constructing in both 3D and 2D.

Continuing education is mandatory in many fields - this could include 3D design. The driving force will always be to keep up in our field. In the end it may come down to job security. If 3D design / construct is the most efficient means to complete a project, then this is what needs to be done or there is risk of losing jobs to outsourcing. Education needs to start at the technical school level.

Does technology drive the process or does the process drive adoption of technology? Does there need to be some fundamental reorganization of the Department to move forward with 3D design? Just as we expect people to change, should not the agency also expect to change?

What kind of feedback do we have post construction to use for evaluation purposes of technology and process? How far back up the chain does the “as-built” go?

3.e. What are the most effective means of communication to keep us all informed and participating in developments in 3D design?

Among the suggestions were user groups, frequently-asked questions (FAQ) discussions, hands-on training, and expert demonstrations; cross-discipline group meetings to share challenges, techniques, and successes on a regular basis; and outreach through existing forums such as WEMA, WTBA, and ACEC. It was suggested that there be an authoritative voice for information to ensure consistency and minimize confusion.

3.f. How can we achieve more balance between design-side costs and construction-side benefits of 3D design?

Identified problems include:

- There are construction-side costs that this question overlooks (e.g. training and expensive equipment purchased to take advantage of the technology).
- We need to first understand costs / effort / efficiencies on all sides:
    - Contractor benefit – increased productivity, increased profit, more work in Wisconsin's short season;
    - Public – shortened timeframes, less impact to traveling public;
    - Design – cost (labor) to produce the product, investment needed to get up to speed and shift the way we deliver the product.
- What are the means for measuring design costs and benefits such as efficiency, quicker re-design response, and greater design flexibility?
- Construction benefits are not yet reflected in lower bids because not all contractors are using GPS machine guidance.

Suggested solutions include:

- Efficiency, not profit, is thought to be the driver for the design side.
- Project costs need to be viewed in totality, not merely design versus construction. If the "build-out cost" is less with 3D it will be much easier to accept any transfer of cost within the project. As savings are realized in one sector, additional resources may be allocated to other sectors.
- Good standards will ensure a balance between design efforts and construction benefits.
- Yes, there will be start-up costs but these will be more than offset by long-term benefits.

Breakout Group 4 – Implementation Planning (Facilitators: Ken Brockman / Jerry Zogg)

Breakout group 4 was asked to address five questions, with the group's focus being ideas and recommendations on planning the planning process as WisDOT moves towards adoption of 3D models as contract documents and use of them throughout design / construct processes. The group was asked to address implementation planning activities, management structure, and communication mechanisms. Group 4 chose to group its five questions into three parts (A, B, C).

Questions

Part A.

> Focus 1. Is the vision "Adoption of 3D methods and seamless data flows throughout the initial survey, design, contracting, construction, as-built survey, and payment process" feasible?
>
> Focus 2. If "yes", what do we need to do to achieve this vision? More specifically, what short-term and long-term tasks are needed to ensure meeting this vision?

The consensus was that the vision is feasible and represents a goal that WisDOT should pursue. This must be done in a way that does not prohibit small contractors or engineering firms from participating in design and construction. They may not have the resources or technology to use 3D models and they should not be excluded. There is a concern that not all projects are easily adapted to 3D models and, for many other projects, not all aspects of them would benefit from using 3D models. All stakeholders must be involved in future studies - these include utilities, maintenance, real estate, DNR, FHWA, SHPO, COE and all others that must be coordinated with in development of plans and construction activities. It is possible that not all stakeholders or those with whom design and construction are coordinated can use this technology to obtain the information they need or share the information WisDOT needs using this technology. Stakeholders might need to be accommodated by provision of plan information in the current 2D format. WisDOT needs to develop strategies for extracting 2D information from 3D models. Mechanisms must be developed for phasing 3D models into bidding documents.

Identified short-term activities:

- Develop standards, procedures, quality control and training for creation of DTMs.
- Transition to 3D design for all new "in-house" projects, which, by their type of work, require models.
- Review the standard specifications, FDM, and CMM to determine necessary changes. Revise as appropriate. Need to get more industries involved. It seems that only the earth work contractors are involved at this time. Base and paving contractors need to be involved also.
- Consult with DBE office to ensure that DBEs and other small contractors are able to bid and compete.
- Implement 3D design software as soon as possible (one year). Provide tools and training to designers to perform their work. Provide good guidance material for design and construction on how the process should be followed since there is such a high turnover rate in employees. Have support people available to guide staff through the process and solve problems.
- Allow some time to become familiar and proficient with the software to ensure accurate designs and DTMs (3 years). Provide training for stakeholders.
- Solve the electronic signature problem (1 –2 years).
- Assign Survey Data Coordinators in all regions.
- Develop standard procedures for adding survey information to original surface DTMs during the design process.

Identified short-term / long-term activities:

- Stay in close contact with vendors and user groups of GPS software, machine control software, and design software.
- Educate stakeholders, identify changes, communicate necessity for changes.
- Determine requirements for documenting and saving “finals” information.

Identified long-term activities:

- 3D models to be the bidding deliverable and take precedence over paper plans and cross sections.
- Do a 1-year review (during plan development and after plans are let) to assure that customers are getting products needed.
- Evaluate the feasibility of providing complete 3D models versus partial 3D models.

Expressed concerns, questions, and comments:

- Are there certain types of projects not conducive to 3D design? If so, do designers need additional tools? For example, will existing tools not work tomorrow (technology or support)?
- Data exchange with utilities. It would be desirable to have utilities add their infrastructure in WisDOT design plans so it can be turned on / off as a layer. This could reduce utility survey requests.
- At this point, Civil 3D is not strongly suited for processing survey data. Are we going to have separate tools for survey and design?
- Open records request – How do non-engineering personnel review plans for viewing, printing, or sharing with those requesting the information? Non-engineers (such as real estate agents) might need some training as well.
- Not knowing how 3D plans will appear, will paper and electronic plans still be required to list incidental items such as sewer, electrical, and bridges? How will quantity estimates be shown? How will shrinkage factors be applied? Earthwork must identify distribution of quantities for bidding purposes.
- Review the activities identified in all of the other three workgroups to determine if they should be long-term or short-term.
- We need to address modeling of different stages on multi-staged projects.
- How will the as-built plan appear in 3D models?

Part B.

Focus 3. How should the implementation effort be structured from a management perspective?

Focus 4. Is it appropriate to assume that there will be at least two implementation groups: policy-level and operational-level?

The group felt there should be policy-level and operational-level groups. However, many of the stakeholders and their activities will require them to be involved with both policy level and operational level groups. It is very important to have involvement of all stakeholders in both policy- and operational-level committees. This involves most groups within WisDOT as well as vendors, coordinating agencies, contractors, consultants, and others. There was a feeling that WisDOT will have to mandate implementation at some point. There is need for an overall steering group / advisory group. Use should be made of standing technical committees such as CCAW, HMA Technical Team, Concrete Pavement Technical Committee, GLS Committee, Bridge Technical Committee, Aggregate Technical Committee, and others. Three critical things in this effort are to involve all the stakeholders, do a good job of communication, and provide needed tools and training to those involved in the process.

Identified activities:

- Develop standards, procedures, QA/QC and training for creation of DTMs. (BTS-Surveying and Mapping Section and BPD-Design Standards / Methods Unit) (policy and operational level).
- Take the primary lead in development of 3D plans and methods. (BPD – Design Standards / Methods Development unit.) (Policy level and operational level).
- Training of all staff who develop WisDOT plans or use them in construction. (Regions, consultants, designers, and construction staff who use WisDOT plans).
- Discuss timeline for implementation and discuss how plans would progress to a 3D design. (Grading contractors, staking contractors, and other affected contractors).

Expressed concerns, questions, and comments:

- One of the issues during the CEAL days was that the software was not mandated for use. Personnel were allowed to use old inefficient methods of the past. They either retired or slowly adopted. Goals or expectations should be set to avoid repeating past transition problems
- Pursue initial buy-in from WisDOT upper management to commit resources to this effort. Need FHWA buy-in for method of documentation.
- Make sure managers and supervisors understand and willingly support the effort. Assign key liaisons who can properly communicate the process from project conception to final stages.
- WisDOT should be setting up meetings with all stakeholders to develop standards. Knowledge of different vendors of electronic equipment and software should be used. Consultants and contractors should also be involved.
- The Methods Development Unit should work with contractors to determine the minimum level of detail needed for design models to be “biddable”.
- What will constitute an “as-built model”? What and how many DTMs will be taken for “as-built”?
- A person or group must be responsible for carrying the initiative through the entire process. This is necessary to ensure consistency, cooperation, and timely completion.
- The New York DOT model should be investigated further.
- Investigate the work being done by the AASHTO Joint Technical Committee (sponsored by Subcommittees on Design and Construction) on sharing electronic data among survey, design, and construction.

Part C.

Focus 5. What are the most effective means for ensuring good communications?

Expressed suggestions:

- Provide minutes of meetings to all other groups. Reporting mechanism: email. Frequency: all meetings.
- One management liaison for each group. Reporting mechanism: face-to-face meetings. Frequency: all meetings.
- Have bi-monthly implementation team meetings. Reporting mechanism: face-to-face. Have monthly teleconferences. Reporting mechanism: phone. The implementation team partial makeup should include as a minimum: 1 regional PDS, 1 regional TSS, and 1-2 bureau representatives. Perhaps each region has its own subgroup that obtains updates and brainstorms issues and suggestions to bring back to the implementation team.
- Assign clear responsibility for communications to individuals or groups.
- Provide knowledge and information to different associations through all means. Provide information at individual industry meetings for ideas and then bring them all together for conglomerate meeting.
- Schedule meetings of designers using the new software so that everyone can learn from each other.
- Make presentations or have breakout sessions at conferences such as ACEC Improvement Conference, Contractors / Engineers Conference, and others.
- Use traditional communication opportunities provided through WisDOT monthly statewide chiefs meetings with PDS, TSS, Operations, and others.
- Consider creating a 3D design website as a central repository for status information.

Closing General Session

This session was devoted to reports from each of the breakout groups. Discussion points raised during the session, that extend beyond those described above, include:

<u>Breakout Group 1 – 3D Model Content, Format, and Security</u>

- Concerning standard development, having individual user groups coordinate suggestions into a final product is a key element.
- Include not only the stakeholders identified by the group but also utility companies, cooperating agencies (e.g., DNR), traffic engineers, maintenance, and real estate.
- A joint task force between design and construction engineering is needed.
- Among the questions that should be addressed during development of a data content standard are 1) Who is using the data? 2) What are the uses of the data? 3) What information needs to be transmitted for all to use, what are its benefits, and what are the costs to develop it?

Breakout Group 2 – DTM Data Collection and Data Quality

- Concerning appropriate field and office procedures to achieve required accuracies, from a contractor's point of view, it is important that the contractor and engineer agree on the method to quantify payment.
- Consistent project control that is used by all parties is critical. This is even more important for "corridor" projects that include abutting segments under different contracts.
- Concerning the necessary level of detail in 3D models, what are the costs of not collecting enough data? How much data can be managed by technology in the field?

Breakout Group 3 – Impacts, Training, Communication

- Transition will not happen overnight.
- Training needed by many users (e.g., surveyors, designers, field personnel).
- There is a need for understanding legal liability and shift of risk.
- Feedback tools are needed to evaluate benefits and outcomes.
- There are significant costs on both the design and construction sides. Contractors invest up to $1 million to install and train on GPS machine guidance technology.

Breakout Group 4 – Implementation Planning

- Implementation planning must address how to fold 3D models into bidding and contract documents.
- Policy and operational decisions must be blended.
- What happens next after this preliminary study? Hopefully, we can communicate outward and upward, move forward, and take action on ideas constructed at this workshop.

10. Recommendations Derived from First Stakeholder Workshop Results

Based upon the outcomes of the first stakeholder workshop, the following recommendations were developed:

- Expand the vision statement to "Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, payment, and downstream applications such as maintenance, utilities, and real estate."
- Develop a high-level implementation plan that provides a management structure; identifies participants, roles, and responsibilities (including lead); provides charges to working groups; and includes timelines and milestones.
- Create policy and operational level groups with appropriate liaisons, communications, and reporting mechanisms.
- Include all stakeholders in both policy and operational level groups.
- Address outreach in the implementation plan.
- Operational level groups include data content standards, data collection and quality standards, training and educational needs…sub-groups to be developed if needed.

- Build upon the findings of this preliminary study.
- Advocate filling the regional survey data coordinator positions as soon as possible.
- Proactively support the initiative for corridor-wide adjustments and more robust (3D) monumentation for project control from design through construction and beyond.

11. Implementation Planning

Acting upon the recommendations of the first stakeholder workshop, the project advisory group was expanded to include representatives from WisDOT's real estate and photogrammetric units and from the design engineering consulting community. The expanded advisory group was charged with developing a high-level implementation plan for 3D technologies and methods for design and construction for WisDOT. The group first revised the vision statement upon which the plan was to be based:

> "Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, payment, and other applications included within the infrastructure lifecycle."

The advisory group met four times during November, 2008 – February, 2009 to develop a draft of the implementation plan to be considered by participants at a second stakeholder workshop. The draft plan (without appendices) appears in Appendix G. The draft plan describes six initiatives, some of which are underway and others of which are proposed:

1. Height Modernization Program (HMP) and Continuously-Operating Reference Stations (CORS).
2. Digital Terrain Model (DTM) Data Collection and Analysis.
3. 3D Design Process.
4. Automated Machine Guidance (AMG).
5. Field Technology and Inspection.
6. Infrastructure Lifecycle Uses of 3D Data.

The first five initiatives have identified backgrounds, issues, stakeholders, recommendations, short-term goals, long-term goals, timelines, relative levels of effort, priorities, benefits, relationships with other initiatives, and lead WisDOT sections. Initiative 6 is more open-ended, with detail to be developed during the second stakeholder workshop.

The draft plan also calls for appointment of an umbrella management team that coordinates and provides a reporting mechanism for the activities of the six initiatives.

12. Second Stakeholder Workshop (February, 2009)

The second stakeholder workshop was held in Madison, Wisconsin on February 17, 2009. Invited participants included those of the first workshop and additional representatives from WisDOT planning, operations, and maintenance; utilities; local government; and private sectors surveyors and design engineers (see Appendix H for a list of pre-registered workshop participants).

The workshop consisted of an opening general session, a breakout session with four breakout groups, and a closing general session at which the breakout groups reported there findings and there was additional discussion. The workshop schedule appears in Appendix I. Slides from the opening general session appear in Appendix J. Participants were provided, in advance, with the workshop schedule, their breakout session assignments, and the draft implementation.

The breakout groups and their assignments were:

1. Initiative 3 (3D Design Process) and Initiative 4 (Automated Machine Guidance). Facilitators: Rick Larson and Bruce Enke.
2. Initiative 2 (DTM Data Collection and Analysis). Facilitators: Kim Schauder and Cindy McCallum.
3. Initiative 1 (HMP and CORS) and Initiative 5 (Field Technology and Inspection). Facilitators: Dennis Keyzer and John Espie.
4. Develop Concepts for Initiative 6 (Infrastructure Lifecycle Uses of 3D Data). Facilitators: Amy Coughlin and Jerry Zogg.

Groups 1-3 were asked, for each assigned initiative, to assess and refine the draft plan's stated issues, goals (short-term and long-term), recommendations, priorities, and timelines and develop sequencing for high-priority recommendations. Group 4 was asked to develop concepts for potential downstream uses of 3D data (e.g., 3D as-builts) and to develop relationships with initiatives 1-5. The reports of the breakout groups and the final general session appear in Appendix K. The report of Breakout Group 4 includes information obtained after the workshop from interviews with WisDOT staff from both planning and maintenance.

13. Final Implementation Plan

Based upon the outcomes of the second stakeholder workshop and follow-up interviews, the advisory group met once again to finalize the implementation plan. It was clear that priorities (importance) of goals and sequencing (dependencies) among goals needed to be distinguished. Therefore, the final implementation plan includes a high-level diagram of dependencies among initiatives and a more detailed diagram of dependencies among goals, within and across initiatives. Appendix L contains the executive summary of the final implementation plan. Appendix M contains a summary diagram of timelines for all short-term goals. Appendix N contains the final implementation plan itself.

Acknowledgements

Ken Brockman and Jerry Zogg served as WisDOT project managers and provided invaluable guidance, assistance, and insight throughout the course of this project. The dedication and contributions of all project advisory group members are deeply appreciated. In addition to Ken Brockman and Jerry Zogg, they are: Rick Larson, Kim Schauder, Cindy McCallum, Brad Hollister, Don Greuel, John Espie, Dennis Keyzer, Bruce Enke, Drew Kottke, Allen Gilbertson, Amy Coughlin, Jessica Lewis (Crispell-Snyder), and Chris Goss (Hoffman Construction). Others making contributions to this study include Mike Hall, Kris Sommers, Gail Vukodinovich, and other region and central office personnel. WisDOT's Director of the Bureau of Project Development, Don Miller, provided guidance, advice, and support throughout this project.

Staff at nine other state DOTs contributed their time to interviews. Many of the interviewees are members of the AASHTO Technology Implementation Group, whose assistance is gratefully acknowledged. Dan Streett at New York DOT provided particularly in-depth information and considerable time.

Finally, the author acknowledges the contributions of all participants in the two stakeholder workshops. These professionals gave freely of their time and expertise to this study.

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Appendix A.

Questionnaire Distributed to State DOT Representatives on AASHTO's Technology Implementation Group (TIG)

Wisconsin Department of Transportation Questionnaire on 3D Design for Highway Construction

Background: The Wisconsin Department of Transportation, with assistance from the Construction and Materials Support Center at the University of Wisconsin – Madison, has formed a study group on three-dimensional design for highway construction. WisDOT is adopting 3D design technology and is interested in determining the institutional and cultural implications of, and impediments to, moving towards 3D design practice. As part of the study, we are gathering information from others on their experiences. We are particularly interested in your agency's experience with using surfaces, as opposed to cross-sections, for volume computations (both at the design and final payment stages) and in any thought given, or initiatives taken, by your agency towards adopting 3D models as contract documents.

Initially, we are distributing this questionnaire to you, as members of the AASHTO Technology Implementation Group, because we feel that you are the most likely of the transportation community to have considered or addressed the issues in which we are most interested. We would very much appreciate your devoting a few minutes to this questionnaire and returning it to Alan Vonderohe (vonderohe@centurytel.net) by April 25, 2008, if at all possible. Please be sure to include the requested contact information at the end of the questionnaire. Please contact Alan Vonderohe if you have any questions about this questionnaire. Thank you very much for your valuable assistance.

A. If your agency uses original and final surface models (DTMs) to determine earthwork quantities for final payment, please briefly answer the questions below. Otherwise, skip to Part B:

1. What is the frequency or size of the segments that are analyzed?

2. What are the factors in considering the frequency or size in 1, above?

3. How are the DTMs for final payment reviewed to assure reasonable accuracies?

4. What is your agency's experience with comparing earthwork quantities computed by the average-end-area method from cross sections vs earthwork quantities determined by use of original and final surface models?

5. How are minor quantities of marsh excavation, rock excavation, pavement removal, and granular backfill computed and accounted for in final payment?

6. Does your agency have any identified standards or procedures for creating original and/or final DTMs (highlight, bold, or underline Y or N). If "yes", please consider attaching associated documents to the returned questionnaire.

7. Is there any other information you would like to share?

B. If your agency has given consideration to moving towards 3D models as contract documents, please answer the questions below by highlighting, bolding, or underlining "Y" or "N". Otherwise, skip to Part C:

1. Y N Has your agency investigated implications of, and/or impediments to, adopting 3D models as contract documents? If "yes", please consider attaching any resulting reports to the returned questionnaire.

2. Y N Has your agency developed any strategies or implementation plans for adopting 3D models as contract documents? If "yes", please consider attaching any resulting reports to the returned questionnaire.

3. Y N Has your agency identified any legal issues associated with adopting 3D models as contract documents? If "yes", please indicate which of the following were identified by highlighting, bolding, or underlining the lead letter:

   a. Electronic signatures.

   b. Transfer of liability, as related to electronic data exchange.

   c. Auditability of plans.

   d. Other (please identify):

4. Y N Are you aware of any other agency that has adopted, or is considering or studying adoption of, 3D models as contract documents? If "yes", please indicate which agency(ies) :

   If "yes", please provide contact information for the other agency(ies) if you can:

C. If your agency uses, or has plans to use, original and design surface models (DTMs) for earthwork on plans, please answer the questions below. Otherwise, skip to Part D:

1. Indicate how earthwork information is shown on plans by highlighting, bolding, or underlining the lead letter:

a. Cross sections.

b. Slope intercepts.

c. Earthwork quantities.

d. Other (please identify):

2. Cross sections on plans are used for many things other than determining earthwork quantities. Some examples of these are culvert pipe lengths, invert and discharge elevations of pipes, erosion control devices, right-of-way widths, and areas of salvaged topsoil.

Does your agency use cross sections at select locations to design these features in plans (highlight, bold, or underline Y or N)? If "no", what changes in processes or procedures has your agency made to design these elements of the plan without use of cross sections?

3. Does your agency have any method of analyzing the DTMs to determine if there are errors in the data or if it is resulting in the intended plan alignment and grades (highlight, bold, or underline Y or N)? If "yes", please briefly describe:

4. What is the frequency or size of the segments that are analyzed for earthwork?

5. What are the determining factors or considerations for selecting the frequency or size in 4, above?

6. How are minor quantities of marsh excavation, rock excavation, pavement removal, and granular backfill computed and accounted for in the plans?

7. How are earthwork quantities computed?

8. How are shrinkage and expansion factors for various earthwork items factored in?

9. How is the distribution of earthwork quantities computed and shown on the plans?

10. How is the mass ordinate or mass diagram obtained using surface-to-surface generated earthwork quantities?

11. How does your agency provide information on the plan surface model to bidders?

12. Are there other aspects of the plan or bidding process that have changed as a result of using original and final surface models (highlight, bold, or underline Y or N)? If "yes", please identify:

13. Is there any other information you would like to share?

D. Please provide your name and contact information for any follow up questions:

   Name:

   e-mail address:

   Telephone number:

Please return the completed questionnaire to Alan Vonderohe at vonderohe@centurytel.net by April 25, 2008.

Again, thank you for your time and help.

Appendix B

Definitions of Terms Used in This Report

3D Model – All engineering data which are geospatially positioned and graphically displayed on project-related datums and are used to describe the existing conditions or proposed design of a project. These can include multiple DTMs, alignments, other features (such as utilities), and related graphics information. (Adapted from AGC/NYSDOT, 2008)

Average-End-Area - A method for computing the volume between two surfaces, represented by cross sections, wherein the areas of successive pairs of cross sections are averaged and multiplied by the distances between them. The resulting volumes are then summed to obtain the overall volume.

Break Line – A set of consecutive line segments connecting points (vertices) in three-dimensional space. Break lines are chosen to represent significant changes in slope on a surface.

Digital Terrain Model (DTM) – A digital representation of a three-dimensional topographic surface. A DTM typically consists of a triangulated irregular network (TIN) connecting spot elevations and vertices of break lines chosen to represent the terrain. (Adapted from AGC/NYSDOT, 2008). An original ground DTM represents the undisturbed ground surface prior to construction. A design DTM represents any of a number of surfaces proposed by a design (e.g., sub grade, base course, finished pavement). An as-built DTM represents any of a number of designed surfaces as they were actually constructed.

DTM-to-DTM - A method for computing the volume between two surfaces, represented by TINS, wherein individual volumes of polyhedra bounded by the triangles in each TIN are computed and summed.

Feature – A natural or cultural object that can be represented in abstract form in a digital geospatial model. Features represented in digital geospatial models can be associated with attributes such as symbols and text.

Spot Elevation – A point in three-dimensional space chosen to be representative of terrain. Spot elevations are typically chosen at peaks (local maxima), pits (local minima), and other locations of interest. Spot elevations chosen in a regular grid pattern over relatively flat terrain are sometimes referred to as “mass points”.

Triangulated Irregular Network (TIN). A triangular tessellation of a set of data points in two-dimensional space. The tessellation can be constrained to force triangle edges to coincide with pre-specified line segments connecting pairs of data points (e.g., break lines). The data points are typically associated with known or measured values of a dependent variable (e.g., elevation) such that the triangles can be used to represent a three-dimensional surface.

Appendix C.

List of Pre-Registered Participants for the First Stakeholder Workshop

September 18 Workshop Invitees — Number of confirmed attendees = 57

Advisory Groups, Project Team, Central Office				
		ID	**Breakout**	
Michael Bradley	Ayres & Associates	5	2	bradleym@ayresassociates.com
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Amy Coughlin	WisDOT	90	4	amy.coughlin@dot.state.wi.us

Appendix D.

First Stakeholder Workshop Schedule

Schedule for Stakeholder Workshop on 3D Design
Thursday, September 18, 2008
Howard Johnson's, 3841 E. Washington Ave, Madison, WI

Vision: Adoption of 3D methods and seamless data flows throughout the initial survey, design, contracting, construction, as-built survey, and payment processes.

Workshop Objective: Identify issues associated with realizing the vision and suggest strategies to address them.

<u>Date: Thursday, September 18, 2008.</u>

Time: 1:00 – 5:00pm

Location: Howard Johnson's on East Washington Avenue in Madison, WI.

1:00 – 1:10 Welcome and Introductions (Ken Brockman).

1:10 – 1:20 Project Overview and Objectives (Alan Vonderohe).

1:20 – 1:30 Workshop Overview and Objectives (Alan Vonderohe).

1:30 – 2:00 Interim Report / Activities within Other States / Incentives and Impediments (Alan Vonderohe).

2:00 – 2:10 Break.

2:10 – 3:30 Breakout Sessions:

<u>1. 3D Model Content, Format, and Security (Facilitators: Rick Larson / Brad Hollister)</u>

a. What is the most appropriate mechanism for development of a data content standard for 3D models for initial survey, design, contracting, construction, as-built survey, and payment?
b. What groups should be represented and participating in development of such a 3D model content standard?
c. What questions must be addressed during development of such a 3D model content standard?
d. What file formats are appropriate for exchange of 3D model data?
e. What means are there for ensuring the integrity of 3D model data as it is exchanged and manipulated from design through construction? Here, we are referring not to data quality, but rather to data security.

<u>2. DTM Data Collection and Data Quality (Facilitators: Kim Schauder / Cindy McCallum)</u>

a. Three types of DTMs: Initial surface, design surface(s), as-built surface(s). What are the spatial accuracy requirements for each of these types of surfaces?
b. What are the appropriate densities of break lines and mass points? In other words, what is the necessary level of detail to be included in the surfaces?

c. What are the appropriate field and office procedures for collection and / or generation of data to achieve the required accuracies and levels of detail?
d. What means are there for ensuring that the required accuracies are being met?
e. What should be the roles of WisDOT, its design consultants, and its construction contractors in ensuring data quality and use of appropriate data collection procedures? Who should be the “custodians” of the data?
f. What is the appropriate way to develop and implement data collection and data quality standards?

3. Impacts, Training, Communication (Facilitators: John Espie / Alan Vonderohe)

a. Do the positive impacts of 3D design outweigh the negative impacts (why or why not)?
b. Is the vision statement (in bold font, above) too ambitious (why or why not)?
c. What training is necessary to address technical aspects of 3D design and use of DTMs throughout the transportation facilities development process?
d. How can training be used to overcome resistance-to-change and institutional impediments?
e. What are the most effective means of communication to keep us all informed and participating in developments in 3D design?
f. How can we achieve more balance between design-side costs and construction-side benefits of 3D design?

4. Implementation Planning (Facilitators: Ken Brockman / Jerry Zogg)

a. Long-term (5-10 year) objectives.
b. Short-term (1-2 year) objectives.
c. Policy-level stakeholders, involvement, and activities.
d. Operational-level stakeholders, involvement, and activities.
e. Coordination and communication between policy-level and operational level groups.

3:30 – 3:40 Break.

3:40 – 4:30 Reports from Breakout Groups – Questions / Answers (Facilitators).

4:30 – 5:00 Gaps, Overlaps, and Wrap-Up (Facilitators: Alan Vonderohe / Ken Brockman).

Appendix E.

Slides from the Opening General Session of the First Stakeholder Workshop

Stakeholder Workshop on 3D Design

Vision: Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, and payment processes.

September 18, 2008

CMSC Construction and Materials Support Center

Partnership between WisDOT and UW Madison for collaborative problem solving and implementation of research findings

Preliminary Study on Implementing 3D Design

- Objectives of the study:
  - Identify institutional issues, relevant design and construction work processes, consequences, and legal issues associated with realizing the vision.
  - Suggest strategies for addressing the issues.
- Objective of this workshop:
  - Provide a forum for participation by the stakeholder community in achieving study objectives.

Workshop Schedule (1:00-5:00pm)

- Objectives, preliminary findings, and workshop procedures.
- Breakout sessions:
  - 3D model content, format, and security.
  - DTM data collection and data quality.
  - Impacts, training, and communication.
  - Implementation planning.
- Reports from breakout groups / discussion.
- Gaps, overlaps, wrap-up.

Workshop Materials

- Schedule.
- Participants list (ID # and breakout session #).
- Preliminary study interim report.
- Breakout session focus statements.
  - Specific breakout session objectives, focus, and questions to be addressed.

Where We Are And Where We Want To Be

Current → Future

The Vision Goes Even Further

1

Summary of Interim Report

- Other State DOTs (questionnaires and interviews to AASHTO TIG and others):
  - Driven towards 3D design by contractor demand.
  - Many are adopting 3D design technology.
  - Some are using DTM-to-DTM methods for volumes.
  - Only NYSDOT is taking strong steps towards 3D models as contract documents.

Summary of Interim Report

- Impediments Identified by Other State DOTs:
  - Resistance to change.
  - Tradition.
  - Viewing the world as being represented in two-dimensions.
  - Necessary comfort levels.
  - Lack of knowledge and skills.
  - Organizational structure and the manner in which resources are allocated between design and construction.
  - Lack of demonstrated design-side return-on-investment (more work to do modeling then to do plans).
  - Lack of understanding of extended data needs and utility.
  - Entrenched policy and procedures (including formal documents and business processes).
  - Lack of mission-wide points of view at operational levels.
  - Issues with data security, authentication, and transfer of liability.
  - Entrenched philosophies on how to do business .

Summary of Interim Report

- Within WisDOT:
  - Seventeen business uses of cross sections (beyond core contract documents).
  - Seventy-three references to cross sections or average-end-area in Standard Specs and CMM.
    - Expect many more in FDM.
  - Electronic signatures are an issue.
    - DOA has authority by law.
    - Draft administrative code under review.

Summary of Interim Report

- Two simple examples compared DTM-to-DTM and average-end-area methods.
- Considerable confusion throughout the community with terminology and semantics.

Glossary

- 3D Model – All engineering data which are geospatially positioned and graphically displayed on project-related datums and are used to describe the existing conditions or proposed design of a project. These can include multiple DTMs, alignments, other features (such as utilities), and related graphics information. (Adapted from AGC/NYSDOT, 2008).
- Digital Terrain Model (DTM) – A digital representation of a three-dimensional topographic surface. A DTM typically consists of a triangulated irregular network (TIN) connecting spot elevations and vertices of break lines chosen to represent the terrain. (Adapted from AGC/NYSDOT, 2008). An original ground DTM represents the undisturbed ground surface prior to construction. A design DTM represents any of a number of surfaces proposed by a design (e.g., sub grade, base course, finished pavement). An as-built DTM represents any of a number of designed surfaces as they were actually constructed.

Glossary

- Triangulated Irregular Network (TIN). A triangular tessellation of a set of data points in two-dimensional space. The tessellation can be constrained to force triangle edges to coincide with pre-specified line segments connecting pairs of data points (e.g., break-lines). The data points are typically associated with known or measured values of a dependent variable (e.g., elevation) such that the triangles can be used to represent a three-dimensional surface.
- Feature – A natural or cultural object that can be represented in abstract form in a digital geospatial model. Features represented in digital geospatial models can be associated with attributes such as symbols and text.

2

Glossary

- Break Line – A set of consecutive line segments connecting points (vertices) in three-dimensional space. Break lines are chosen to represent significant changes in slope on a surface.
- Spot Elevation – A point in three-dimensional space chosen to be representative of terrain. Spot elevations are typically chosen at peaks (local maxima), pits (local minima), and other locations of interest. Spot elevations chosen in a regular grid pattern over relatively flat terrain are sometimes referred to as "mass points".

Glossary

- Average-End-Area - A method for computing the volume between two surfaces, represented by cross sections, wherein the areas of successive pairs of cross sections are averaged and multiplied by the distances between them. The resulting volumes are then summed to obtain the overall volume.
- DTM-to-DTM - A method for computing the volume between two surfaces, represented by TINS, wherein individual volumes of polyhedra bounded by the triangles in each TIN are computed and summed.

Breakout Group 1 - 3D Model Content, Format, and Security

- **Objectives:**
  - **Suggest a plan for developing a 3D model content standard.**
  - **Suggest mechanisms for data exchange and security.**
- **Questions / Issues:**
  - What is the most appropriate mechanism for development of a data content standard for 3D models for initial survey, design, contracting, construction, as-built survey, and payment?
  - What groups should be represented and participating in development of such a 3D model content standard?
  - What questions must be addressed during development of such a 3D model content standard?
  - What file formats are appropriate for exchange of 3D model data?
  - What means are there for ensuring the integrity of 3D model data as it is exchanged and manipulated from design through construction? Here, we are referring not to data quality, but rather to data security.

Breakout Group 2 - DTM Data Collection and Data Quality

- **Objectives:**
  - **Develop high-level concepts addressing questions/ issues below.**
  - **Suggest a mechanism for developing detail.**
- **Questions / Issues:**
  - Three types of DTMs: initial surface, design surface(s), as-built surface(s). What are the spatial accuracy requirements for each of these types of surfaces?
  - What are the appropriate densities of break lines and mass points? In other words, what is the necessary level of detail to be included in the surfaces?
  - What are the appropriate field and office procedures for collection and / or generation of data to achieve the required accuracies and levels of detail?
  - What means are there for ensuring that the required accuracies are being met?
  - What should be the roles of WisDOT, its design consultants, and its construction contractors in ensuring data quality and use of appropriate data collection procedures? Who should be the "custodians" of the data?
  - What is the appropriate way to develop and implement data collection and data quality standards?

Breakout Group 3 – Impacts, Training, Communication

- **Objectives:**
  - **Develop high-level concepts addressing questions / issues below.**
  - **Suggest mechanisms for developing detail.**
- **Questions / Issues:**
  - Do the positive impacts of 3D design outweigh the negative impacts (why or why not)?
  - Is the vision statement (in bold font, above) too ambitious (why or why not)?
  - What training is necessary to address technical aspects of 3D design and use of DTMs throughout the transportation facilities development process?
  - How can training be used to overcome resistance-to-change and institutional impediments?
  - What are the most effective means of communication to keep us all informed and participating in developments in 3D design?
  - How can we achieve more balance between design-side costs and construction-side benefits of 3D design?

Breakout Group 4 – Implementation Planning

- **Objectives:**
  - **Develop high-level concepts addressing questions / issues below.**
  - **Suggest mechanisms for developing detail.**
- **Questions / Issues:**
  - Long-term (5-10 year) activities.
  - Short-term (1-2 year) activities.
  - Policy-level stakeholders, involvement, and activities.
  - Operational-level stakeholders, involvement, and activities.
  - Coordination and communication between policy-level and operational level groups.

Appendix F.

Breakout Group Focus Statements from the First Stakeholder Workshop

Focus for Breakout Session 1 – 3D Model Content, Format, and Security
Facilitators: Rick Larson, Brad Hollister
Workshop on 3D Design (September 18, 2008)

Vision: Adoption of 3D methods and seamless data flows throughout the initial survey, design, contracting, construction, as-built survey, and payment processes.

Breakout Objectives:

1. **Suggest a plan for developing a 3D model content standard.**
2. **Suggest mechanisms for data exchange and security.**

<u>Focus:</u> What we are looking for from this group are ideas and recommendations on what needs to be done to develop a 3D model content standard for initial survey, design, contracting, construction, as-built survey, and payment. Do we need a stakeholders' committee? If so, who should be represented? What questions must be addressed during this process and how long will it take?

Second, what are the options for data exchange, given that design contractors might not have the same software as WisDOT and construction contractors might have a third software package (e.g., should there be a software standard across the industry in Wisconsin (is this feasible))? What are the latest developments and future directions for electronic data security (e.g., secure digital signatures) and are these technologies applicable to 3D design files (how can we be sure the data we have at any given time are the same data that were produced by the designer…how are design changes securely managed)?

<u>Questions / Issues:</u>

a. What is the most appropriate mechanism for development of a data content standard for 3D models for initial survey, design, contracting, construction, as-built survey, and payment?
b. What groups should be represented and participating in development of such a 3D model content standard?
c. What questions must be addressed during development of such a 3D model content standard?
d. What file formats are appropriate for exchange of 3D model data?
e. What means are there for ensuring the integrity of 3D model data as it is exchanged and manipulated from design through construction? Here, we are referring not to data quality, but rather to data security.

Focus for Breakout Session 2 – DTM Data Collection and Data Quality
Facilitators: Kim Schauder, Cindy McCallum
Workshop on 3D Design (September 18, 2008)

Vision: Adoption of 3D methods and seamless data flows throughout the initial survey, design, contracting, construction, as-built survey, and payment processes.

Breakout Objectives:

3. **Develop high-level concepts addressing questions a-e, below.**
4. **Suggest a mechanism for developing detail (question f, below).**

Focus: What we are looking for from this group are ideas and recommendations on management of data quality, particularly surface data, as we move towards adoption of 3D models as contract documents and use of them throughout the design / construct processes. This group should not be directly concerned with what features should be included in 3D models. Rather, what we need is clear guidance on appropriate data resolution (level of detail), data accuracy, data collection and model building methods, and quality standards and procedures. We are not looking to develop detailed standards or specifications in a short breakout session. Rather, we are looking for high-level concepts, over-arching ideas, and existing sources of information that can be built upon. The full range of business processes should be addressed, from initial survey, to design, to design revisions, to as-built surveys.

Second, how should responsibility for data quality be allocated and managed and what is the best way to develop consensus on standards and procedures?

Questions / Issues:

a. Three types of DTMs: Initial surface, design surface(s), as-built surface(s). What are the spatial accuracy requirements for each of these types of surfaces?
b. What are the appropriate densities of break lines and mass points? In other words, what is the necessary level of detail to be included in the surfaces?
c. What are the appropriate field and office procedures for collection and / or generation of data to achieve the required accuracies and levels of detail?
d. What means are there for ensuring that the required accuracies are being met?
e. What should be the roles of WisDOT, its design consultants, and its construction contractors in ensuring data quality and use of appropriate data collection procedures? Who should be the “custodians” of the data?
f. What is the appropriate way to develop and implement data collection and data quality standards?

Focus for Breakout Session 3 - Impacts, Training, Communication
Facilitators: John Espie, Alan Vonderohe
Workshop on 3D Design (September 18, 2008)

Vision: Adoption of 3D methods and seamless data flows throughout the initial survey, design, contracting, construction, as-built survey, and payment processes.

Breakout Objectives:

5. **Develop high-level concepts addressing questions a-f, below.**
6. **Suggest mechanisms for developing detail.**

Focus: What we are looking for from this group are ideas and recommendations on appropriate training, education, and outreach as we move towards adoption of 3D models as contract documents and use of them throughout the design / construct processes. Adoption of 3D design has technological, institutional, cultural, and legal implications. Who needs to be educated, who needs to be trained, what are the high-level concepts (not details) that must be addressed in education and training, and what are the most effective means for doing so?

Second, the entire community needs to be kept abreast of developments as we proceed. What are the most effective means of outreach and what resources must be allocated to them? Whose responsibility is it to direct and guide the educational, training, and outreach processes?

Questions / Issues:

a. Do the positive impacts of 3D design outweigh the negative impacts (why or why not)?
b. Is the vision statement (in bold font, above) too ambitious (why or why not)?
c. What training is necessary to address technical aspects of 3D design and use of DTMs throughout the transportation facilities development process?
d. How can training be used to overcome resistance-to-change and institutional impediments?
e. What are the most effective means of communication to keep us all informed and participating in developments in 3D design?
f. How can we achieve more balance between design-side costs and construction-side benefits of 3D design?

Focus for Breakout Session 4 – Implementation Planning
Facilitators: Ken Brockman / Jerry Zogg
Workshop on 3D Design (September 18, 2008)

Vision: Adoption of 3D methods and seamless data flows throughout the initial survey, design, contracting, construction, as-built survey, and payment processes.

Breakout Objectives:

7. **Develop high-level concepts addressing issues a-e, below.**
8. **Suggest mechanisms for developing detail.**

Focus: What we are looking for from this group are ideas and recommendations on planning the planning process. Firstly, is the vision in bold, above, feasible? If yes, what do we need to do to achieve the vision? More specifically, what initial or short-term activities or tasks are necessary to ensure realizing the vision? Correspondingly, what are the longer-term activities or tasks?

Secondly, how should the implementation effort be structured from a management perspective? Is it appropriate to assume there would be at least two implementation groups: 1) policy-level and 2) operational level? If so, who should be represented in each of these groups (not persons' names, rather, what groups, organizations, kinds of companies, agencies) and what should be the charges of both of the groups? If not, then what alternatives are there for structuring the management process? Who has overall responsibility to see that these things happen?

Thirdly, communication among implementation groups or parties is critical. What are the most effective ways of ensuring good communication (e.g., some shared membership between groups, liaisons, reporting mechanisms and frequency)?

<u>Questions / Issues:</u>

a. Long-term (5-10 year) activities.
b. Short-term (1-2 year) activities.
c. Policy-level stakeholders, involvement, and activities.
d. Operational-level stakeholders, involvement, and activities.
e. Coordination and communication between policy-level and operational level groups.

Appendix G.

Draft Implementation Plan for Second Stakeholder Workshop

PARTIAL DRAFT WisDOT IMPLEMENTATION PLAN:
3D TECHNOLOGIES AND METHODS FOR DESIGN AND CONSTRUCTION
February 6, 2009

VISION STATEMENT

Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, payment, and other applications included within the infrastructure lifecycle.

PURPOSE OF THIS DOCUMENT

This plan addresses a management strategy and six initiatives for moving towards realization of the vision statement. Components of the initiatives are either underway or proposed herein for WisDOT and relate directly to three-dimensional technologies and methods. The objectives of the plan are to establish or reiterate justifications for the initiatives, identify relationships among them, coordinate among the initiatives where appropriate, recommend actions that will help realize synergistic benefits, assign priorities, establish or reiterate milestones and timelines, and identify responsible parties.

SUMMARY OF INITIATIVES, GOALS, EFFORTS, AND PRIORITIES

Initiative	Goal	Effort	Priority
Height Modernization and CORS			
	Internal / External Support Groups Secure Funding	High	High
	Implement 5-Year Completion Plan (2009-2013)	High	High
DTM Data Collection and Analysis			
	Fill Survey Data Coordinator Positions	Moderate	High
	Determine Map-Check Frequency	Low	Medium
	Revise FDM and Business Practice for Map Checks	Moderate	Medium
	Develop Standards and Procedures	High	High
	Training on DTM Data Collection and Use	Moderate	High
	Pilot Standards and Procedures	Moderate	High
	Pilot CORS Support for Airborne GPS	High	Medium
3D Design Process			
	Existing Civil 3D Pre-Deployment Plan	Moderate	High
	Civil 3D New User Training	High	High
	Develop and Execute Extended Deployment Plan	Moderate	Medium
	Annual Users Conference Process	High	Low
	3D Model Content and Format Standards	High	High
	Add 3D Model Deliverable Option to Design Contracts	Moderate	High
	Establish Date for 3D Models for PS&E	Low	High
	Evaluate 3D Models as Construction Contract Docs	High	Medium
Automated Machine Guidance			
	Monitor and Refine Grading Specification	Low	High
	Develop, Pilot, and Implement Base Course Spec	Moderate	High
	Monitor and Refine Base Course Specification	Low	High
	Study Paving, Bridges, Utilities	Moderate	Medium
	Develop and Test Paving, Bridges, or Utilities Spec	High	Medium
Field Technology and Inspection			
	Rovers-for-Construction Group		
	Investigate Scenarios and Feasibility	Moderate	High
	Develop Implementation Plan	High	High
	Execute Implementation Plan	High	High
	Inspection Automation Group		
	Investigate Feasibility	Moderate	High
	Develop Implementation Plan	High	High
	Execute Implementation Plan	High	High
Post-Construction Uses of 3D Data	To Be Developed		

INITIATIVES

1. Height Modernization Program (HMP) and Continuously Operating Reference Stations (CORS).

Background: WisDOT's height modernization program was initiated in 1998 with funding from NOAA / NGS to densify and improve the vertical component of Wisconsin's geodetic control network. HMP is installing a hierarchical network of monumentation and measurements that includes the existing high-accuracy reference network, and new primary, secondary, and local stations. Measurements include static GPS and high-order differential leveling. The network is being installed in eight phases, working from south to north and east to west, then back east across the state (see Appendix A). Phases 1-5 are complete with published coordinates. Phases 6-7 are underway with monumentation and measurements. Phase 8 (northeastern Wisconsin, Green Bay to Ashland and including Door County) will have decreased monumentation with no secondary or local stations due to the advent of CORS.

CORS is an on-going WisDOT / NOAA project to construct a network of continuously operating reference stations in Wisconsin to support RTK GPS applications with 3D positional accuracies at the 2cm level in real time. WisDOT's geodetic survey unit partnered with other state and local government agencies, as well as educational institutions on implementation and development of the system. Through cooperative agreements, partners have and continue to contribute facilities, power, Internet access, and possible GPS hardware to the program. WisDOT has supplied most of the GPS hardware; all of the GPS software components; nearly all of the supplies and materials to construct the CORS monuments; and all information technology (IT) components to operate the system.

CORS sites include public educational buildings, county facilities, municipal facilities, and a park. The network will be operated and controlled by GPS network software running on servers in Madison. CORS data are archived and made available for post-processing applications (e.g., airborne GPS).

The network (defined by an area known as Zone 1) was set operational in July, 2008. Zone 1 consists of 24 permanent CORS sites, east of a line from Marinette to Shawano to Fond du Lac to Beaver Dam to Janesville. Construction of Zone 2 is underway. Zone 2 consists of 13 permanent CORS sites located just west of Zone 1 from Madison to Rhinelander (see Appendix B). As of December, 2008, there were 130 subscribed users, including some from out of state. Applications range from geodetic surveys to precision agriculture. CORS is becoming part of the infrastructure of Wisconsin and is being viewed by some as having the role of a utility.

At least eight more CORS will be built during 2009. The location of Zone 3 is tentatively planned just west of Zone 2 from the Illinois border to central Wisconsin. Zone 4 would possibly include as many as 18 CORS in north central Wisconsin (if grant funding is available). Funding for HMP and CORS development comes from NOAA / NGS with some matching funds from WisDOT. The effort is currently operating on a federal fiscal year 2007 grant of $1,200,000 that ends in March, 2009. Approval has been received for a $300,000 federal fiscal year 2008 grant that will start in April, 2009. An application has been submitted for a $2,450,000 federal fiscal year 2009 grant. During the current fiscal year, WisDOT provided matching funds for purchase of receivers and hiring of consultants to perform field and office activities.

Issues:

- There is uncertainty with future grant funding.
- Problems with remote access to GPS receivers need to be resolved. These involve host site IT security issues that must be addressed to avoid maintenance and upgrade visits to each CORS station.
- An overall maintenance plan for the network needs to be developed.
- Operation of system software needs to be learned by several individuals.
- Additional staff will be needed to support CORS when it is complete. There is a strong IT / communications technical component in addition to a public relations component.

These five issues indicate that the long-term viability of the system is at stake.

Stakeholders: Design, construction, planning, surveying and photogrammetry, contractors, utilities, consulting engineers, staking contractors, and numerous external groups that require high-precision positioning services (e.g., precision agriculture).

Recommendations: Given the significance of HMP and CORS to effective, efficient, and consistent use of 3D technologies throughout design and construction and the uncertainty of the long-term viability of HMP and CORS, we recommend:

- Developing a WisDOT support group that advocates internally for sustained support throughout WisDOT for the HMP and CORS efforts.
- Advocating formation of an external users group that works for sustained support for the HMP and CORS efforts.

Short-Term Goals (1-2 years):

- Raise the awareness of management and upper management within WisDOT of the significance of HMP and CORS to the overall mission of the department and to the State of Wisconsin.
- Ensure continued federal and departmental funding.

Long-Term Goals (beyond 2 years): Assuming sustained current levels of funding, both HMP and CORS are on a 5-year completion plan (2009-2013). Without implementing the two above recommendations, the assumption of sustained funding is, at best, tenuous. Even with implementation of the recommendations, the assumption of sustained funding is uncertain. Ultimately, the long-term goal is not only completion of HMP and CORS but also sustaining them as operating systems servicing a host of internal and external users.

Timeline: The first recommendation should be implemented by April, 2009 (start of new funding cycle). The second recommendation should be on-going and, in addition, should become part of the charge of the internal support group formed under the first recommendation.

Relative Levels of Effort:

- Securing sustained funding - High.
- Implementing the 5-year completion plan – High.

Priorities:
- o Securing sustained funding - High.
- o Implementing the 5-year completion plan – High.

Benefits: Although HMP and CORS are integral to full success of the overall 3D initiatives, they have been and can be justified on their own merits. HMP and CORS
- o Eliminate the need and cost for local base station GPS receivers.
- o Eliminate resource time associated with equipment setup at the base site.
- o Greatly enhance consistency of coordinate determination, facilitating corridor control development.
- o Ensure reliability and redundancy in position determination.

Relationships with Other Initiatives: Through the benefits outlined above, HMP and CORS have direct linkages to automated machine guidance (Initiative 4), DTM data collection (Initiative 2), and inspection (Initiative 5). In addition, facilitation of consistent corridor control and minimization of problems with project control is supportive of the entire set of processes addressed by this plan.

Responsible Parties: Surveying users group (Ray Kumapayi) takes up charge of the first recommendation to include project development, operations, state patrol, and perhaps others.

2. Digital Terrain Model (DTM) Data Collection and Analysis.

Background: Original ground and final DTMs are developed by 1) WisDOT's photogrammetry unit, 2) consultants using photogrammetry, 3) WisDOT survey field crews, and 4) consultants using ground survey methods.

Field crews and consultants receive guidance from region survey coordinators. The Facilities Development Manual (FDM) contains a short section on procedures for DTM collection (ground survey and photogrammetric). This section defers to field procedures for collecting cross sections as these are what are currently required for design and often used for computing final earthwork quantities. The master contract special provisions for photogrammetric services contain a brief statement on procedures. The Construction and Materials Manual (CMM) contains many references to cross sections and methods that use cross sections.

The FDM contains a section on accuracy standards for photogrammetric products. It does not contain an accuracy standard for ground survey products. The master contract special provisions for photogrammetric services contain a brief statement on required accuracies. WisDOT practice for photogrammetric contracting has been to require that products meet specified accuracies and to remain silent on details of procedures. Map checks are performed on some products to ensure conformance to accuracy requirements.

As standard practice, final earthwork quantities are currently determined from cross-sections by average-end-area. In actual practice, a variety of methods are used by consulting engineers and contractors to compute earthwork. If the data are collected appropriately, DTM-to-DTM methods should be more accurate than average-end-area because they use more complete representations of the original ground and final surfaces. Moreover, final DTMs are sometimes developed from survey data, then sliced into cross-sections to use with the prescribed average-end-area method of computation. Final DTMs are a primary input to the envisioned 3D as-builts (see Initiative 5).

<u>Issues:</u>

- The FDM needs modification to place emphasis on DTM data collection as opposed to cross section data collection.
- The CMM needs revision if utility of cross sections is to be decreased in favor of DTM methods.
- Ground survey data collection is sometimes iterative with crews needing to return to the field after the designer decides that data are too sparse (completeness and accuracy are different issues).
- Map checks of photogrammetric products are infrequent.
- The software mechanisms for creation of DTMs from survey data are not well understood by field and office personnel.
- There is lack of consensus on accuracies required for finals.
- There is need for both in-class and on-the-job training for both data collection and analysis.
- There are relevant technologies (e.g., airborne GPS, LiDAR) that have not been fully investigated by WisDOT. Applications extend beyond DTM data collection. For example, the Division of Transportation Infrastructure Management is considering use of LiDAR for inventory purposes.

<u>Stakeholders:</u> Technical services, engineering consultants, surveyors (public and private), project engineers, contractors.

<u>Recommendations:</u>

- Continue implementation of survey data coordinator positions.
- Determine the desired frequency of map checks and incorporate in FDM and business practices.
- Appoint a stakeholder advisory group to address the following:
    - Standards and procedures for collection of original ground and final DTMs to ensure consistency, accuracy, and cost-effectiveness in results whether the methods are photogrammetric or ground survey. This includes review and revision of existing standards documents and coordination with Initiative 5 for final DTMs as inputs to 3D as-builts.
    - Development and implementation of training on:
        a. Software methods for creation of DTMs from survey data (i.e., understanding the algorithms).
        b. Means for survey coordinators to better communicate procedures and expectations to survey crews to reduce the frequency of returns to the field.
        c. Use of DTM-to-DTM methods for computing earthwork quantities.
    - CORS support for airborne GPS.
    - Rapidly evolving data collection technologies (e.g., LiDAR, advanced softcopy photogrammetric methods, integrated GPS/IMU) and their appropriate uses, to include coordination with efforts beyond DTM data collection.

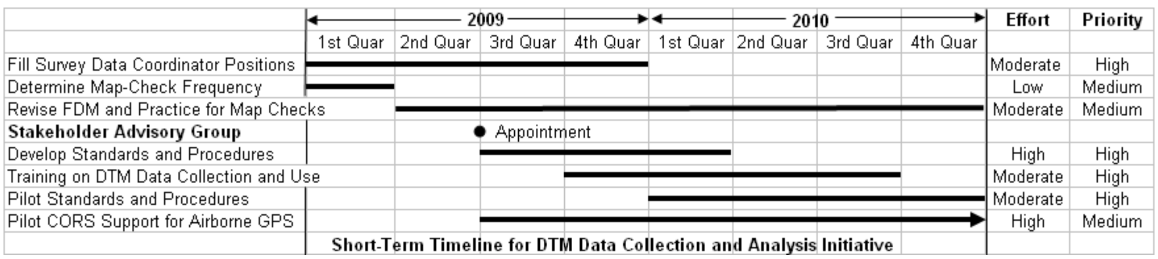
<u>Short-Term Goals (1-2 years):</u>

- Fill regional survey data coordinator positions.
- Achieve consistency in map-check frequency.

- o Refine or develop, then pilot, DTM data collection standards and procedures and use of DTM-to-DTM methods for earthwork computations. Revise standards documents accordingly.
- o Provide training on procedures for DTM data collection and use for earthwork computations.

Long-Term Goals (beyond 2 years):
- o Implement DTM data collection standards and procedures and use of DTM-to-DTM methods for earthwork computations.
- o Develop and conduct a pilot program for CORS support of airborne GPS.
- o Evaluate other technologies that might increase the efficiency of accurate DTM data collection.

Timeline, Relative Levels of Effort, and Priorities:



Benefits:
- o The survey data coordinator positions were justified and approved by the Project Development and Technical Services Chiefs prior to this initiative, but inclusive to this initiative are benefits flowing from 3D information management between design and construction and, assistance with development and implementation of standards and procedures for data collection.
- o Consistency in map-check frequency will increase confidence in use of photogrammetric DTMs.
- o Standards, procedures, and associated training will ensure consistency in original ground and final DTM completeness and accuracy and reduce revisits to the field for further data collection.
- o If the data are collected appropriately, use of DTM-to-DTM methods should not only lead to better results, it might also reduce the number of disputes over final quantities.
- o CORS support for airborne GPS has the potential to reduce not only the required number of ground control points for photogrammetric projects but also the cost of equipment by eliminating the need for a local base station. Base stations for RTK GPS cost approximately $35,000 (2009 dollars).

Relationships with Other Initiatives: The original ground DTM is a primary input to the design process (Initiative 3). Final DTMs are primary inputs to 3D as-builts (Initiative 5) ands, as such, have post-construction uses (Initiative 6). Data collection for the original ground DTM will benefit from HMP and CORS (Initiative 1) by elimination of the need for local RTK GPS base stations and by reduction in problems with project control.

Responsible Parties: Technical Services Section (Ray Kumapayi) with assistance from Bureau of Project Development on use of DTMs for earthwork computations.

3. 3D Design Process.

Background: WisDOT's Methods Development Unit has a detailed plan for the initial deployment of Civil 3D, including tasks, milestones, and timelines. The plan addresses hardware upgrades, design products, workflows, and phased-in training. The initial objective is replacement of CAiCE with Civil 3D as the primary design platform, with the transition occurring over a 3-5 year period. Initially, some designs started in CAiCE will be converted and completed in Civil 3D. Eventually, all designs will be developed completely with Civil 3D. There is no pre-determined termination date for CAiCE. Ultimately, more extensive use of Civil 3D, for example in field surveys, photogrammetry, drainage, and impact analysis for environmental documentation, is expected as future enhancements to the software provide more robust functionality beyond design. Initial training of new users on Civil 3D is expected to begin during mid to late summer of 2009.

Moreover, 3D design is a process, not a technology. A number of software packages support the 3D design process and engineering design consultants might be using any of these software packages. One of the challenges is to establish technology-independent standards and procedures for 3D design its products.

Issues:

- There are retraining implications for keeping current with software advances.
- The initial deployment plan for Civil 3D does not address its full range of functionality. In addition, future enhancements by the vendor will need to be considered. Impacts of technology changes, upon both internal and external users must be addressed.
- Future modifications to plans as the primary design deliverable should be evaluated. For example, consider the possible adoption of 3D models as contract documents and retention or elimination of two-dimensional views.
- 3D model content and generic format standards are needed to address data exchange and downstream uses such as automated machine guidance, inspection and final quantities, and post-construction uses of 3D technology.

Stakeholders: Design, construction, CAE advisory group, CADD users group, real estate, utilities, access control, contractors and consultants, local governments and state and federal agencies.

Recommendations:

- Execute the existing Civil 3D deployment plan and develop an extended deployment plan.
- Appoint a stakeholder advisory group on enhancement of design deliverables to address:
    - Conduct of annual statewide 3D design users' meetings.
    - Development of 3D model content and generic format standards.
    - Evaluation of 3D models as contract documents.

Short-Term Goals (1-2 years):

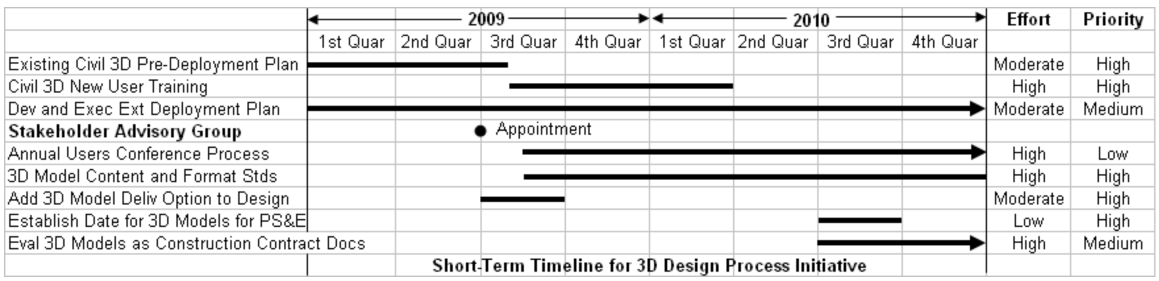
- Deployment of Civil 3D according to existing plan.
- Development and execution of an extended deployment plan for 3D design.
- Development and implementation of annual statewide 3D design users' conference process. This goal is part of the charge to the study group.

- o Development of non-proprietary 3D model content and format standards by the study group.
- o Add 3D model deliverable option to WisDOT design contracts.
- o Establishment of a date when consultants will be required to provide 3D models as a PS&E deliverable.

Long-Term Goals (beyond 2 years):

- o Continued execution of the extended deployment plan for 3D design.
- o Evaluation of 3D models as construction contract documents by the advisory group.

Timeline, Relative Levels of Effort, and Priorities:



Benefits:

- o Adoption of Civil 3D as WisDOT's primary design tool has been previously justified and stands on its own merits (CAiCE Replacement Recommendation Report, WisDOT, 2007).
- o The benefit of developing and adopting an extended deployment plan addressing the 3D design process is a statewide increase in production capabilities and efficiencies as the technology rapidly increases in power and functionality.
- o An annual users conference will provide a forum for information exchange to the benefit of all involved and a possible mechanism (e.g., through workshops) for the study group to pursue its other goals.
- o Standards for 3D model content will facilitate uniformity in data sets shared among parties, reduce duplicative data development, reduce conflicts in data interpretation, and level the playing field of data expectations.
- o A generic data exchange standard will increase efficiencies in utility of data shared among parties and reduce redundant data development.
- o Generating 3D models as design outputs and providing them directly to contractors will eliminate the need to develop them, through "reverse engineering", from 2D plans, thus reducing the greatest technological impediment to wider and more effective use of automated machine guidance for construction.

Relationships with Other Initiatives: Primary input data to the design process include the original ground DTM (Initiative 2). Design outputs are required for automated machine guidance (Initiative 4), inspection (Initiative 5), and post-construction uses of 3D technology (Initiative 6).

Responsible Parties: Methods Development Unit for stakeholder advisory group charter.

4. Automated Machine Guidance (AMG).

Background: WisDOT is nearing completion of a 2.5-year effort to develop a statewide specification for automated machine guidance (AMG) for grading operations. 2008 was the second and final year of pilot projects related to the specification development effort. The developed statewide specification gives contractors the option to use AMG in their grading operations. Use of AMG is not mandated on WisDOT projects. Starting with December 2008 lettings, WisDOT will include the new AMG specification for grading (as a special provision) on all WisDOT projects that have the construction staking subgrade item. The new AMG specification for grading will be included in the 2010 version of WisDOT's standard specifications and, then, will no longer need to be included as a special provision.

Issues: A message received from pilot project contractors is that they would like to have the 3D design model become a design deliverable. Current practice requires contractors to either acquire 3D models from designers if they are available or reverse-engineer model data from traditional plans and staking data. WisDOT is taking steps to remedy this with Civil 3D implementation (Initiative 3).

WisDOT wants to continue to refine the AMG specification for grading as needed. The department also desires to build upon the experience of the AMG grading specification to develop new AMG specifications for base course placement, paving, and perhaps utilities and bridges.

Stakeholders: Design, construction, contractors, consulting engineers, model developers, staking contractors, utilities.

Recommendations:

- Develop and implement a plan for monitoring and refinement of the AMG specification for grading.
- Appoint a stakeholder advisory group to develop an AMG specification for base course placement.
- Investigate implications of AMG for utilities, bridges, and paving to include which would be easiest to adopt. AMG for paving, bridges, and utilities might include laser augmentation for increased vertical accuracies and articulated machinery for excavation.

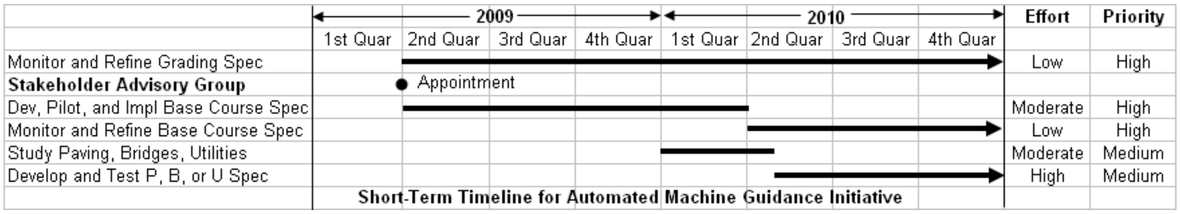
Short-Term Goals (1-2 years):

- Monitoring and refinement of the AMG specification for grading.
- Development, testing, and implementation of an AMG specification for base course placement.
- Initiation of AMG specification development for paving, bridges, and / or utilities.

Long-Term Goals (beyond 2 years):

- Monitoring and refinement of AMG specifications for grading and base course placement.
- Implementation of AMG specifications for paving, utilities, and bridges.

Timeline, Relative Levels of Effort, and Priorities:



Benefits: Contractors report 20%-40% productivity gains from automated machine guidance for grading. At least one state DOT has reported lower than expected bids as a result of contractors using AMG.

Relationships with Other Initiatives: Automated machine guidance requires a 3D model of the design (Initiative 3). There is a potentially strong direct benefit from HMP and CORS (Initiative 1), through elimination of the need for an RTK GPS base station (NOTE: CORS support for automated machine guidance has not yet been successfully demonstrated in Wisconsin. Tests are currently being conducted by the technology vendor).

Responsible Parties: GLS committee for subgrade specification monitoring (Don Greuel / Brad Hollister). Bureau of Project Development forms the advisory group for base course specification, including engineering and contractor representatives from grading, base course, HMA pavement, and concrete pavement construction. Bureau of Project Development for study of paving, bridges, and utilities.

5. Field Technology and Inspection.

Background: Construction project staff typically do not have access to GPS and electronic automated inspection technology. Consequently, they conduct surveys, perform inspections, make measurements, and determine quantities with obsolete technology and methods that are time consuming and costly.

There are estimates (NYSDOT) that using 3D models, methods, and GPS-based inspection automation technology can reduce the overall cost of construction staking, inspection, and determination of quantities by 50%. Currently there is no program in WisDOT that is actively pursuing this use. There is potential for significant savings in time and costs.

Issues:

- Development and retention of knowledge and skills base among many project engineers.
- Lack of standard approaches to data collection and analysis among regions and among consultants.
- Lack of field equipment and software.
- Failure to exploit emerging inspection automation technology.
- Current as-builts are 2D paper plans that are marked with revisions by project engineers. Such products and methods cannot realize the potential benefits flowing from the availability of 3D electronic as-builts.

Stakeholders: Contractors, project engineers, engineering consultants, surveyors (public and private).

Recommendations: Appoint two stakeholder advisory groups:

1. Rovers-for-Construction Group – Investigates alternatives for implementing GPS technology for construction measurements, determines their feasibility, and, if found feasible, develops a detailed implementation plan. Coordinates with the DTM data collection and analysis group (Initiative 2) and the inspection automation group.

   Two possible scenarios have been preliminarily identified:
   1) Having specialized one- or two-person regional field crews that perform inspection and as-built surveys for multiple projects in proximity with one another;
   2) Furnishing each project engineer with the technology and knowledge to perform inspection and as-built surveys with 3D methods and data.

   Advantages of scenario 1 over scenario 2 include reduced numbers of rovers, controllers, and software; less training; and relief of effort on the part of project engineers. Disadvantages of scenario 1 compared to scenario 2 include the need to manage multiple data sets from multiple projects on one technology platform and logistics and scheduling among staking and inspection needs on multiple projects.

   Rough costs for the technology component of both scenarios are developed by assuming a unit cost of $35,000 (2009 dollars). A technology unit consists of an RTK GPS rover with controller and accessories, a dedicated laptop computer, and the software necessary to manage, analyze, document, and archive inspection data. Scenario 1 has a technology cost of $350,000 (two technology units per region for five regions). Scenario 2 has a technology cost of $700,000 (one technology unit for each of 20 projects per year, statewide). These costs address only the technology component and are based upon the assumption that CORS is operational wherever the technology is used, thus eliminating the need for local base stations. Also, it is expected that any recommendation to implement will include phases and an early pilot. So, these technology costs are not “up front”, but, instead, are more overall.

2. Inspection Automation Group – Investigates the feasibility of adopting inspection automation technology, and, if found feasible, develops a detailed implementation plan. Coordinates with the DTM data collection and analysis group (Initiative 2) and the rovers-for-construction group.

   “Inspection automation technology” has broad scope and includes not only GPS rovers but also, for example, in-field record-keeping technologies such as electronic notebooks and personal digital assistants (potentially wireless) and associated software. Such technologies can be capable of supporting or assisting, for example, development of final DTMs, location-based materials testing and records keeping, development of 3D as-builts by manipulation of 3D design models and inclusion of final DTMs, development of attribute databases linked to 3D models, and querying and reporting from such databases for purposes such as final quantities computation and acceptance of construction products.

Short-Term Goals (1-2 years):

- Completion of feasibility studies for rovers-for-construction and inspection automation.
- If found feasible, completion of detailed implementation plans for rovers-for-construction and inspection automation.

Long-Term Goals (beyond 2 years):

- Implementation of rovers-for-construction, if feasible.
- Implementation of inspection automation, if feasible.

Timeline, Relative Levels of Effort, and Priorities:

	2009				2010				Effort	Priority
	1st Quar	2nd Quar	3rd Quar	4th Quar	1st Quar	2nd Quar	3rd Quar	4th Quar		
Rovers-for-Construction Group		● Appointment								
Investigate Scenarios and Feasibility									Moderate	High
Develop Implementation Plan									High	High
Execute Implementation Plan									High	High
Inspection Automation Group		● Appointment								
Investigate Feasibility									Moderate	High
Develop Implementation Plan									High	High
Execute Implementation Plan									High	High
	Short-Term Timeline for Field Technology and Inspection Initiative									

Benefits: Based upon available information, a low estimate for construction engineering / administration costs is 8% of the construction contract. Applying the 50% cost savings realized by NYSDOT in construction staking and inspection, an estimate for the overall reduction in costs of construction engineering is 4 % (0.5 x 8% = 4%) of the contact bid price. Additional downstream benefits can be realized, for example, by ease of retrieval of information from 3D as-builts for post-construction purposes.

Relationships with Other Initiatives: Inspection depends upon data from 3D design (Initiative 3), and original ground and final DTMs (Initiative 2). Technology costs and costs associated with project control problems are lowered by HMP and CORS (Initiative 1. Inspection data have post-construction uses (Initiative 6).

Responsible Parties: Bureau of Project Development.

6. Post-Construction Uses of 3D Data.

This includes such things use of as-builts other 3D data flowing from design and construction by utilities, surveys, permits, right-of-way, operations, maintenance, planning, and all other activities that occur on the highway right-of-way after construction. Concepts for this initiative will be developed at the February, 2009 workshop.

The breakout group will be asked to

- Think about the 2D products they use now, and for each of these products consider if 3D information would serve them better.

- Probe what kinds of 3D information would have utility (e.g., original ground DTM, design model, as-built model, etc.).

If this is accomplished, then the group will be asked to address filling in details of background, issues, stakeholders, recommendations, short-term goals (1-2 years), long-term goals (beyond 2 years), timeline, relative levels of efforts, priorities, benefits, relationships with other initiatives, and responsible parties.

MANAGEMENT STRATEGY

Implementation Management, Coordination, and Outreach.

Background: Recommendations associated with Initiatives 1-6 call for creation of five stakeholder advisory groups and two support groups, with outlines of charges and timelines for completion of their work. A number of other activities are also recommended to be undertaken by various units within WisDOT.

Issue: The work of these groups and the other activities need coordination, support and advocacy, reporting mechanisms, and means for outreach.

Recommendation: Appoint a management group, chaired by a bureau director, that keeps abreast of and coordinates the activities recommended in this plan, provides a reporting structure for the recommended groups and activities, keeps upper-level management informed of progress, advocates for the overall effort, and develops outreach mechanisms to keep the broader design and construction communities aware of and involved in the recommended activities. The management group should include at least one representative from each of the six initiatives.

Timeline: The recommended management group should be appointed no later than April, 2009. The group should remain functional until completion of the activities recommended this plan.

Appendix H.

List of Pre-Registered Participants for the Second Stakeholder Workshop

February 17 Workshop Participants			Number of confirmed attendees = 47
Advisory Groups, Project Team, Central Office			
		Breakout	**E-mail**
Richard Larson	WisDOT	1	richard.larson@dot.state.wi.us
Alan Rommel	WisDOT	3	alan.rommel@dot.state.wi.us
Jerry Zogg	WisDOT	4	jerry.zogg@dot.state.wi.us
Alan Vonderohe	Vonderohe Consulting, LLC	4	vonderohe@centurytel.net
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Cindy McCallum	WisDOT	2	cynthia.mccallum@dot.state.wi.us
Michael Hall	WisDOT	1	michael.hall@dot.state.wi.us
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Tom Brokaw	WisDOT	1	thomas.brokaw@dot.state.wi.us
John Kinar	WisDOT	4	john.kinar@dot.wi.gov
WisDOT (GLS or Earthwork Committee-Related)			
Dave Buschhkopf	WisDOT	3	david.buschkopf@dot.state.wi.us
David Layton	WisDOT	1	david.layton@dot.state.wi.us
WisDOT Regions			
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Jerry Glentz	WisDOT Southwest	2	jerome.glentz@dot.state.wi.us
Lisa Herrmann	WisDOT Northwest	2	lisa.herrmann@dot.state.wi.us
Construction Contractors			
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Ken Bork	Hoffman Construction	1	kenneth_bork@yahoo.com
Consulting Engineers and Surveyors			
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Kurt Kruger	Kapur Associates	3	kkruger@kapur-assoc.com
Diann Danielsen		2	dkdanielsen@uwalumni.com
Shane Zodrow	R.A. Smith	2	Shane.Zodrow@rasmithnational.com
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Utilities			
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Matt Kiracofe	WE-Energies	4	matt.kiracofe@we-energies.com
Ernie Kretschmann	WE-Energies	3	Ernest.Kretschmann@we-energies.com
Local Government			
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Tom Horness	City of Sheboygan	4	thorness@ci.sheboygan.wi.us
Henry Meller	City of Sheboygan	1	

Appendix I.

Second Stakeholder Workshop Schedule

Schedule for Stakeholder Workshop on
3D Technologies for Design and Construction: WisDOT Implementation Plan
Tuesday, February 17, 2009
Howard Johnson's, 3841 E. Washington Ave, Madison, WI

Vision: Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, payment, and other applications included within the infrastructure lifecycle.

Workshop Objectives: 1) Assess and refine the first five initiatives in the draft implementation plan. 2) Develop concepts and relationships to other initiatives for the sixth initiative.

Date: Tuesday, February 17, 2009.

Time: 1:00 – 5:00pm.

Location: Howard Johnson’s on East Washington Avenue in Madison, WI.

1:00 – 1:10 Welcome and Introductions (Jerry Zogg).

1:10 – 1:20 Project and Workshop Overview and Objectives (Alan Vonderohe).

1:20 – 1:30 Outcomes from September, 2008 Workshop (Alan Vonderohe).

1:30 – 1:50 Draft Implementation Plan (Alan Vonderohe).

1:50 – 2:00 Break.

2:00 – 3:30 Breakout Sessions:

1. Initiative 3 (3D Design Process) and Initiative 4 (Automated Machine Guidance); Facilitators: Rick Larson and Bruce Enke.

2. Initiative 2 (DTM Data Collection and Analysis); Facilitators: Kim Schauder and Cindy McCallum.

3. Initiative 1 (HMP and CORS) and Initiative 5 (Field Technology and Inspection) Facilitators: Dennis Keyzer and John Espie.

4. Develop Concepts for Initiative 6 (Post-Construction Uses of 3D Data) Facilitators: Amy Coughlin and Jerry Zogg.

3:30 – 3:40 Break.

3:40 – 4:50 Reports from Breakout Groups – Questions / Answers (Facilitators).

4:50 – 5:00 Wrap-Up (Alan Vonderohe).

Appendix J.

Slides from the Opening General Session of the Second Stakeholder Workshop

Stakeholder Workshop on 3D Technologies for Design and Construction: WisDOT Implementation Plan

Vision: Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, payment, and other applications included within the infrastructure lifecycle.

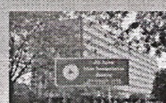
February 17, 2009

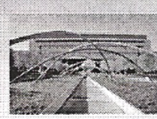
Project Advisory Group

Jessica Lewis, ACEC	**Kim Schauder, BITS**
Chris Goss, WTBA	**Cindy McCallum, BITS**
Ken Brockman, BPD	**Drew Kottke, BITS**
Jerry Zogg, BPD	**Dennis Keyser, NE**
Don Greuel, BPD	**Bruce Enke, NE**
Rick Larson, BPD	**Allen Gilbertson, SE**
Brad Hollister, BPD	**Amy Coughlin, SW**

CMSC Construction and Materials Support Center

Partnership between WisDOT and UW-Madison for collaborative problem solving and implementation of research findings





COLLEGE OF ENGINEERING
UNIVERSITY OF WISCONSIN-MADISON

cmsc

WisDOT's Implementation Plan for 3D Design and Construction Technologies

- Vision:
  - Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, payment, and other applications included within the infrastructure lifecycle.
- Objective of the study:
  - Develop an implementation plan that addresses the issues, opportunities, recommendations, and strategies identified at the September, 2008 workshop.
- Objectives of this workshop:
  - Provide a forum for participation by the stakeholder community in development of the plan.
  - Assess and refine the first 5 initiatives in the draft plan.
  - Develop concepts for the 6th initiative and relationships between it and the other initiatives.

Workshop Schedule (1:00-5:00pm)

- Objectives, workshop procedures, overview of the draft plan.
- Breakout sessions:
  1. Initiative 3 (3D Design Process) and Initiative 4 (Automated Machine Guidance). Facilitators: Rick Larson and Bruce Enke.
  2. Initiative 2 (DTM Data Collection and Analysis). Facilitators: Kim Schauder and Cindy McCallum.
  3. Initiative 1 (HMP and CORS) and Initiative 5 (Field Technology and Inspection). Facilitators: Dennis Keyzer and John Espie.
  4. Develop Concepts for Initiative 6 (Post-Construction Uses of 3D Data). Facilitators: Amy Coughlin and Jerry Zogg.
- Reports from breakout groups / discussion.
- Wrap-up.

Workshop Materials

- Schedule.
- Participants list (includes breakout session #).
- Slides from this opening session.
- Draft Implementation Plan.

Sept 2008 Workshop Focus

- 3D model content, format, and security:
  - Addressed needs for model content standards, flexibility and platform independence in format standards, and criticality of data security.
- DTM data collection and data quality:
  - Addressed needs for consensus on accuracy and level-of-detail standards, education and training on data collection procedures, consistency in project and corridor control, and importance of filling survey data coordinator positions.

Sept 2008 Workshop Focus

- Impacts, training, and communication:
  - Addressed needs for well-thought-out transition plan, education and training at all levels, and means for communication and outreach.
- Implementation planning:
  - Addressed needs for openness and inclusiveness in implementation planning, incremental phasing-in of 3D technologies, considerations for structure and content of an effective plan.

Recommendations from Sept 2008 Workshop

- Expand the vision statement to include downstream (post-construction) uses of 3D data flowing from design and construction.
- Develop a high-level implementation plan that provides a management structure; identifies participants, roles, and responsibilities; provides charges to working groups; and includes timelines, milestones, and priorities.

Recommendations from Sept 2008 Workshop

- Create policy and operational-level groups with appropriate liaisons, communications, and reporting mechanisms.
- Include all stakeholders in both policy and operational level groups.
- Address outreach in the implementation plan.
- Operational level groups include data content standards, data collection and quality standards, training and educational needs…sub-groups to be developed if needed.

Recommendations from Sept 2008 Workshop

- Advocate filling the regional survey data coordinator positions as soon as possible.
- Proactively support an initiative for corridor-wide adjustments and more robust (3D) monumentation for project control from design through construction and beyond.
- Build upon the outcomes of the workshop.

Structure and Content of the Draft Plan

- Six Initiatives:
  1. Height Modernization Program (HMP) and Continuously-Operating Reference Stations (CORS).
  2. Digital Terrain Model (DTM) Data Collection and Analysis.
  3. 3D Design Process.
  4. Automated Machine Guidance (AMG).
  5. Field Technology and Inspection.
  6. Post-Construction Uses of 3D Data.
- Management Strategy:
  - Management-level group that coordinates among initiatives, provides a reporting mechanism, informs upper-level management, advocates for the overall effort, and develops outreach mechanisms.

Structure and Content of the Draft Plan

- Initiatives 1-5 have background statements, lists of issues, identification of stakeholders, recommendations, short-term and long-term goals, timelines, relative levels of effort, priorities, benefits (justification), relationships with other initiatives, and responsible parties. To be assessed and refined by Breakout Groups 1-3.
- Initiative 6 will address such things as use of 3D as-builts and other data by utilities, surveys, permits, right-of-way, operations, maintenance, planning, and all other activities that occur within the highway ROW after construction. Concepts to be developed by Breakout Group 4.

About the Initiatives and the Plan

- Some of the initiatives are underway.
- Others are not underway and are proposed within the plan.
- Some of the activities within the initiatives might or might not occur with or without the plan.
- None of the activities will be coordinated across initiatives without the plan.

The Purpose of the Plan

- Establish or reiterate justifications for the initiatives.
- Identify relationships among the initiatives.
- Coordinate among the initiatives where appropriate.
- Recommend actions that realize synergistic benefits.
- Establish or reiterate goals and timelines.
- Assign priorities to goals and recommendations.
- Identify responsible parties.

Focus of the Initiatives

- HMP and CORS:
  - Completion, operation, and sustainability of HMP and CORS.
- DTM Data Collection and Analysis:
  - Standards, procedures, business practices, training, data collection technologies.
- 3D Design Process:
  - Model content and format standards, training, phased implementation of 3D design deliverables.

Focus of the Initiatives

- Automated Machine Guidance:
  - Monitoring of sub grade spec. Development, testing, and implementation of specs for base course, paving, and beyond.
- Field Technology and Inspection:
  - Feasibility and implementation planning for project-based field technologies, including GPS rovers, inspection automation such as location-based materials testing and recording, 3D as-builts, and others.
- Post-Construction Uses of 3D Data:
  - Downstream applications of 3D data flowing from design and construction.

Breakout Groups

1. Initiative 3 (3D Design Process) and Initiative 4 (Automated Machine Guidance). Facilitators: Rick Larson and Bruce Enke.
2. Initiative 2 (DTM Data Collection and Analysis). Facilitators: Kim Schauder and Cindy McCallum.
3. Initiative 1 (HMP and CORS) and Initiative 5 (Field Technology and Inspection). Facilitators: Dennis Keyzer and John Espie.
4. Develop Concepts for Initiative 6 (Post-Construction Uses of 3D Data). Facilitators: Amy Coughlin and Jerry Zogg.

Breakout Focus

- Groups 1-3 (Initiatives 1-5):
  - For each assigned initiative, assess and refine the draft plan's stated issues, goals (short-term and long-term), recommendations, priorities, and timelines.
  - Develop sequencing for high-priority recommendations.
- Group 4 (Initiative 6):
  - Develop concepts for potential downstream uses of 3D data (e.g., 3D as-builts).
  - Develop relationships with initiatives 1-5.

Appendix K.

Reports of the Breakout Groups and the Closing General Session from the Second Stakeholder Workshop

Breakout Group 1: Initiative 3 (3D Design Process) and Initiative 4 (Automated Machine Guidance)

3. 3D Design Process.

Issues:

- There are retraining implications for keeping current with software advances.
  - Ok,
- The initial deployment plan for Civil 3D does not address its full range of functionality. In addition, future enhancements by the vendor will need to be considered. Impacts of technology changes, upon both internal and external users must be addressed.
  - Ok
- Future modifications to plans as the primary design deliverable should be evaluated. For example, consider the possible adoption of 3D models as contract documents and retention or elimination of two-dimensional views.
  - **How much detail to we model to?**

- 3D model content and generic format standards are needed to address data exchange and downstream uses such as automated machine guidance, inspection and final quantities, and post-construction uses of 3D technology.
  - **Model accuracy?**
  - **Which projects are targeted?**
  - **Build model for contract document, produce plan from model**.

Stakeholders: Design, construction, CAE advisory group, CADD users group, real estate, utilities, access control, contractors and consultants, local governments and state and federal agencies.

  - **Vendors/Software Developers**
  - **Surveys**
  - **Whoever can take advantage of model.**

Recommendations :

- Execute the existing Civil 3D deployment plan and develop an extended deployment plan.
- Appoint a stakeholder advisory group on enhancement of design deliverables to address:
  - Conduct annual statewide 3D design users' meetings.
  - Development of 3D model content and generic format standards.
  - Evaluation of 3D models as contract documents.

Any missing recommendations that should be addressed as part of this initiative?

1) Survey Data Coordinator needs to be filled

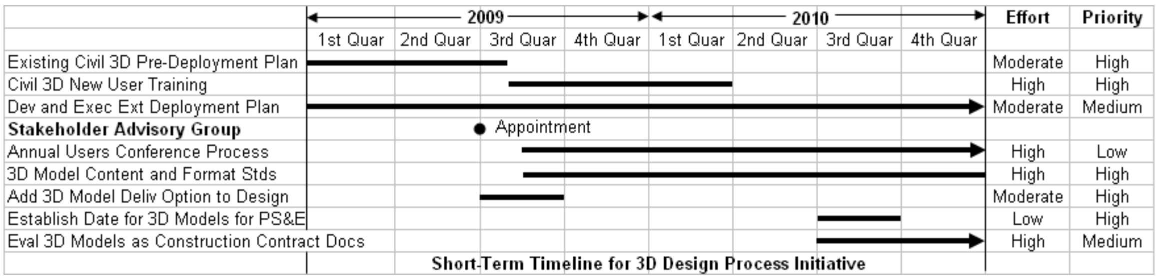
Short-Term Goals (1-2 years) (5 minutes):

- Deployment of Civil 3D according to existing plan.
  - **Consider Consultant need for C3D training**
- Development and execution of an extended deployment plan for 3D design.
- Development and implementation of annual statewide 3D design users' conference process. This goal is part of the charge to the study group.
- Development of non-proprietary 3D model content and format standards by the study group.

- o Add 3D model deliverable option to WisDOT design contracts.
- o Establishment of a date when consultants will be required to provide 3D models as a PS&E deliverable.

<u>Long-Term Goals (beyond 2 years) (5 minutes):</u>
- o Continued execution of the extended deployment plan for 3D design.
- o Evaluation of 3D models as construction contract documents by the advisory group.

<u>Timeline, Relative Levels of Effort, and Priorities:</u>



1) **Existing Civil 3D predeployment**
2) **C3D New User training**
3) **Add 3D model development option to Design**
4) **3D model content and format stds**
5) **Establish date**

4. Automated Machine Guidance (AMG).

<u>Issues (<= 5 minutes):</u> A message received from pilot project contractors is that they would like to have the 3D design model become a design deliverable. Current practice requires contractors to either acquire 3D models from designers if they are available or reverse-engineer model data from traditional plans and staking data. WisDOT is taking steps to remedy this with Civil 3D implementation (Initiative 3).

WisDOT wants to continue to refine the AMG specification for grading as needed. The department also desires to build upon the experience of the AMG grading specification to develop new AMG specifications for base course placement, paving, and perhaps utilities and bridges.
Ok?/Comments?

<u>Stakeholders (<=5 minutes):</u> Design, construction, contractors, consulting engineers, model developers, staking contractors, utilities.
<u>Recommendations (5 minutes):</u>
- o Develop and implement a plan for monitoring and refinement of the AMG specification for grading.
- o Appoint a stakeholder advisory group to develop an AMG specification for base course placement.
  - o **Develop AMG spec for Paving**
- o Investigate implications of AMG for utilities, bridges, and paving to include which would be easiest to adopt. AMG for paving, bridges, and utilities might include laser augmentation for increased vertical accuracies and articulated machinery for excavation.

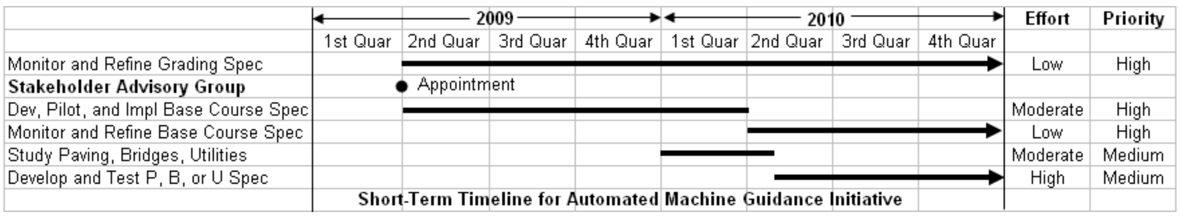
Short-Term Goals (1-2 years) (10 minutes):

- o Monitoring and refinement of the AMG specification for grading.
- o Development, testing, and implementation of an AMG specification for base course placement.
- o Initiation of AMG specification development for paving, bridges, and / or utilities.
- o **Development, testing, and implementation of an AMG specification for Paving – <u>consider this before looking at structures and utilities</u>**

Long-Term Goals (beyond 2 years):

- o Monitoring and refinement of AMG specifications for grading and base course placement.
- o Implementation of AMG specifications for paving, utilities, and bridges.

Timeline, Relative Levels of Effort, and Priorities:



Breakout Group 2: Initiative 2 (DTM Data Collection and Analysis)

PURPOSE OF THIS WORKSHOP BREAKOUT

- Ensure issues, goals, recommendations, and priorities are correct.
- Focus on what the priorities should be.
- Be critical of the high priorities… what really needs to be done first?
- Identify some sort of sequence for the priorities… What needs to be done before the next step?
- Do not go into details.
- Guide: ~ 5 minutes per goal

Stakeholders:
Technical services,
engineering consultants,
surveyors (public and private),
project engineers,
contractors.

Responsible Parties: The sponsor will be the Technical Services Section (Ray Kumapayi) with assistance from Bureau of Project Development on use of DTMs for earthwork computations.

GOAL = Charge	EFFORT	PRIORITY	Begin
Short-Term Goals			
1. Fill Regional Survey Data Coordinator Positions Lead? Team? *Technical Services Supervisors to discuss further.* Cindy summarized the position and why there is a need. The group agreed with the concept and importance. (Glentz) There was some concern that if the contractors are responsible for the model for machine control, is this position really needed. It was questioned whether the survey coordinator could take on some of the role. It may vary with the regional office and the workload over time. (Danielson) Custodian vs. production role should be identified. Custodian can delegate responsibility to contractor, but it should be passed backed to the agency for long-term retention. (Mahun) May lower priority until the position is better defined. Although there is a position description, there is quite a bit of discussion among the group on the focus of the position. The position is tied to more than just machine control. There is a need to have consistency throughout the process.	Moderate ✓	High ✓ *#1*	Now ✓
2. Determine Map Check Frequency (achieve consistency) *for photogrammetric products of existing DTM surface.* Lead? *Photogrammetry Unit Supervisor (Schauder)* Team? *Photogrammetry Unit; Region survey staff; Region designers; contractors who had a bad experience with photogrammetric DTM* *How frequent? Who is responsible?* *(Hermann) May only take one meeting of the right people. (Danielson) Could also solicit input by email or calls.* *(Mahun) Is there a sponsor within DOT to move forward? We'll need to find out who within DOT can set the policy. (Urbain) There should be a way to ensure consultant work is checked independently.* *(Hafermann/Martin) It may be possible to collect check shots while setting targets, but it will depend on workload.*	Low ✓	Medium ✓	Now *Move to Q3 2009 due to spring flying season*
3. Revise FDM and Business Practice for Map Checks Lead? *Photogrammetry/Geodetic Surveys Engineer (Perfetti)* Team? *Subset of group in 2.* *(Hermann) The priority to get documentation in FDM may be lower. There is some existing documentation that can be used as a basis. More effort will be needed to implement the checks.*	Moderate ✓	Medium ✓	Q2 2009 Move to Q4 2009 and decrease the duration

4. Appoint Stakeholder Advisory Group to address the remaining goals Lead? *(Schauder?)* Team? *Team was unsure how to address or whether the "team" would be slightly different on each goal. Does this team ensure the goals are implemented? If so, this should be done first. (Mahun) Who is going to monitor the effects of each initiative as they are implemented? There should be a representative from each area (or team leads) who meet and monitor implementation.*	Low	N/A	mid-2009
5. Refine and Develop Standards and Procedures for original and final DTM data collection (field or photogrammetric)… Lead? Team? *Consultants; vendors; Photogrammetry Unit; Region survey staff* *(Set as separate goal) …*and use of DTM-to-DTM methods for earthwork computations. Coordinate with Initiative 5 for final DTMs as inputs to 3D as-builts. Lead? Team? *Methods Development Engineer (Rick Larson)* (McCallum) Even without documented procedures, photogrammetric DTM from consultants and in-house are quite similar. Regions seem to have more problems with field DTM. *(Zodrow) There would be a benefit for training. For example, merging field survey with photogrammetric data. (Urbain) Need to document format. Digital Data Exchange is documented for design, but not for construction. (Schauder/Hermann) There is "plan packet" information in the Construction and Materials Manual, but data is not getting back to WisDOT.* *(McCallum) Need to agree on software that produces the same results. (Urbain/Hermann/Mahun) We should define a level of tolerance that is acceptable. (Hermann) If we set the standards for collection, it should address the acceptable accuracy of earthwork comps).* *(Vonderohe) Within 2009, the CMSC will compare software and methods used to build DTM and earthwork comps. Zogg is on the advisory panel, and Larson is providing data. This must be done prior to implementation. Low effort, High priority.*	High ✓ *See last comment under goal*	High ✓ *#2, rest will follow sequentially* *See last comment under goal*	Q3 2009 ✓ *Assemble group ASAP*

6. Develop and Provide Training on DTM Data Collection and Use for earthwork computations. o Means for survey coordinators to better communicate procedures and expectations to survey crews to reduce the frequency of returns to the field. (McCallum) Beginner training or refresher training should be provided on a regular basis. (Glentz) Note that project development staff is also using survey equipment to check construction. PDS meetings in spring and fall to update staff and contractors on current o Software methods for creation of DTMs from survey data (i.e., understanding the algorithms). *(Schauder) Does this relate somewhat to CMSC initiative in 5?* Lead? Team? *(Urbain) There are many different methods being used. Seiler is developing a field to finish training with respect to Trimble software, but does include some fundamentals of data collection. The training could be customized to meet DOT needs. Could require continuing education (RLS will require PDH). (Hafermann) There are collection standards in place (SDMS). (Mahun) Verified that training available to others outside DOT.* *5 must be done prior to 6.*	Moderate *Low (if training contracted)* High (if training in-house)	High ✓	Q4 2009 ✓
7. Pilot Standards and Procedures for DTM data collection and use of DTM-to-DTM methods for earthwork computations. Lead? Team? *(Danielson) This should be done as part of 5 before 6 training. (Mahun) Test standards, refine and test again before implementing. (Urbain) This may relate to 3 (put in FDM), but does relate to 5.*	Moderate ✓	High ✓	Q1 2010 *Should overlap with #5.*
Long-Term Goals			
8.Implement DTM data collection standards and procedures. Lead? Team? This should be modified to "maintain and evolve" or "implement and re-evaluate". *(Schauder) This is similar to 7.*	Low		
9. Implement the use of DTM-to-DTM methods for earthwork computations. Lead? Team? This should be modified to "maintain and evolve" or "implement and re-evaluate". *(Schauder) This is similar to 7.*	Low		(Q3 2009)

10. Develop and conduct a Pilot CORS Support of ABGPS Lead? Team? *(Schauder/McCallum) Consultants have advised DOT that ABGPS is not practical without an IMU (~$1 million). Most only invest in an IMU when also investing in a digital camera.*	High	Medium (Low?)	Q3 2009
11. Evaluate other technologies that might increase the efficiency of accurate DTM data collection (e.g., LiDAR, advanced softcopy photogrammetric methods, integrated GPS/IMU, *terrestrial scanner, ABGPS, etc.*). Lead? Team?	Low	High	

Breakout Group 3: Initiative 1 (HMP and CORS) and Initiative 5 (Field Technology and Inspection)

Initiative # 1: HMP and CORS
FOCUS: completion, operation, and sustainability of HMP & CORS

Priorities are High for both CORS & HMP

(Internal / External Support Group) Securing sustained funding - High.

- Need new advocates, from outside of WisDOT
    - WSLS
    - Agricultural
    - External requests / demands: what WisDOT should be doing
    - External users should be communicating the importance of this technology and how it will benefit their business needs
    - Who would external users advocate to
    - Who makes funding decisions
- Private Funding?
    - Caution needed
    - User Fees

Implementing the 5-year completion plan – High.

- Management Group (Don Miller, Bureau Chief is current lead / champion)
    - Make-up?
    - Contacts (DOT, SEC, or Bureau
- LEVEL of EFFORT
    - Continued Operation and Maintenance
    - Keep up with Technology

Federal Grants?
How many people are using it?
Plan based on assumptions of future funding allocated to the program.

Initiative # 5: Field Technology and Inspection
FOCUS: feasibility and implementation planning for project-based field technologies, including GPS rovers, inspection automation such as location-based materials testing and recording, 3D as-builts, and others.

It has been decided: WisDOT will not be buying Rovers for Construction.
Are we talking about People or Equipment?
Everyone (contractor & inspector) using the same data, will checks be valid?
Will inspector use contractor base or check into CORS?
Concept not ready, more work needed before consideration of implementation needs.
Protocols and Standards Needed

Initiative # 5, in general a LOW PRIORITY, too many unknowns
Move ahead with investigation, not ready for implementation at this time

1) **Rovers** for Construction Group (PRIORITY – **medium**)
   Investigate Scenarios and Feasibility
   - Specialized Crew
     - Keep up with technology
     - Unique training needs
   - We had problems with what was done on North Leg (MIP)
   - What will it be used for, need to know in order to plan
   - Need to work out with contractors on methods / procedures (how to compute final quantities)
   - Feasibility Study, of this issue, will determine implementation priorities

2) **Inspection** Automation Group (PRIORITY – **low**)
   Investigate Scenarios and Feasibility
   - Need centralized / unified guidance.
     - C. O. doing one thing
     - This team going in a different direction
   - Quantity Measurement, near term; Field record-keeping technologies a future effort?
   - RDA (records management)
   - Feasibility Study, of this issue, will determine implementation priorities
   - Feasibility depends on other initiatives

Breakout Group 4: Develop Concepts for Initiative 6 (Post-Construction Uses of 3D Data)

This includes such things use of as-builts and other 3D data flowing from design and construction by utilities, surveys, permits, right-of-way, operations, maintenance, planning, and all other activities that occur on the highway right-of-way after construction. Concepts for this initiative will be developed at the February, 2009 workshop.

Review definitions with breakout group:
- Digital Terrain Model (DTM) – A digital representation of a three-dimensional topographic surface. A DTM typically consists of a triangulated irregular network (TIN) connecting spot elevations and vertices of break lines chosen to represent

the terrain. (Adapted from AGC/NYSDOT, 2008). An original ground DTM represents the undisturbed ground surface prior to construction. A design DTM represents any of a number of surfaces proposed by a design (e.g., sub grade, base course, finished pavement). An as-built DTM represents any of a number of designed surfaces as they were actually constructed.

- 3D Model – All engineering data which are geospatially positioned and graphically displayed on project-related datums and are used to describe the existing conditions, proposed design, or as-built information of a project. These can include multiple DTMs, alignments, other features (such as utilities), and related graphics information. (Adapted from AGC/NYSDOT, 2008)

The breakout group will be asked to:

- Think about the 2D products they use now, and for each of these products consider if 3D information would serve them better.
  - Aware of 3D information already being used, either in their organization or by their counterparts?
- Probe what kinds of 3D tools would have utility (e.g., original ground DTM, design 3D model, as-built DTM, as-built 3D model, etc.).
- Identify what 3D information needs to be included in those tools to make them useful.
- Identify when the tools would be used (e.g., during the design & construction process, before, or after).

If this is accomplished, then the group will be asked to address filling in details of background, issues, stakeholders, recommendations, short-term goals (1-2 years), long-term goals (beyond 2 years), timeline, relative levels of efforts, priorities, benefits, relationships with other initiatives, and responsible parties.

Functional Area (Ops, Maint, Utilities, Planning, Local Gov't, etc)

Utilities, local gov't, traffic

May just want to list the functional areas that participated during and after the workshop

Current 2D Tool (Plan views, Profiles, X-Sections, System Maps, etc)

Use paper plans, R/W plats (paper & cadd), vertical and horizontal locations, cross-sections, construction and standard details, staging plans

Potential 3D Replacement Tool (DTM, 3D Model, Other)(Original Ground, Design, As-Built)

For DOT projects: DTM's, bottom of cuts, depths, underground structures, bridges, signs (for overhead clearances), original data and design data

3D model would need to contain everything in the design paper plan to a 90% accuracy.

For traffic, use for sign locations, sightlines, oversize permits that require lateral clearances, intersections with safety issues

Seems there are 2 potential general uses of our info by others:

- **One use is during the design and construction phases of a WisDOT project**
- **The other time is when non-WisDOT folks need to do work in our R/W that is unrelated to any WisDOT work. This work is done under permit granted by Maintenance.**

While the above two potentials exist, the external workshop participants indicated they would not be inclined to rely on our as-built data for their independent work, and they would do their own survey, utility locates, etc to develop their construction plans.

I think a key point from the workshop is that our focus for external customers should be on identifying and supplying the 3D info needed during our projects.

As noted in the table they are interested in our original ground DTMS, including whatever we have that is outside our R/W

We can probe this a little more next Friday, but it seems WisDOT internal customers (Tom N listed some) may have some use of our as-built data. I haven't gotten a hold of Barb Jenkins yet.

Info needed in 3D Tool (Relationships to other initiatives)

See above

When Used (During design & construction, before, after, etc)

A lot of use during design and construction

Minimal use between design and construction for permitted work

Use for accident reconstruction in the future?

Related Info on 3D Replacement Tool (Background, issues, goals, stakeholders, benefits, responsible parties, priorities, etc)

For permit work, there wouldn't be an "accuracy" for underground utility elevation locations, etc (see my comments above)

Private utilities have security and liability issues, open records?
Private utilities do not share x,y,z info on their utilities for liability and security reasons. They are concerned that if WisDOT provides info to them, that WisDOT will ask for same info back. Providing it for WisDOT's use may not be the concern, but they don't want the info to get outside WisDOT thru an open records request. Thought is we'd be able to say no for homeland security issues.

Now that I've written this, I don't think we want to get into this level of detail in the report, but we should just state the general concern

Other

Will the contractors machines react to utilities in the 3D Model?

This is captured in the table, and don't need to discuss in summary

Post Construction Uses of 3D Data					
Functional Area	**Current 2D Tools**	**Potential 3D Replacement Tools**	**Info Needed in 3D Tools**	**When Used**	**Issues & Comments**

Private Utility: WE Energies (gas)	o Currently using paper and electronic (CAD-Type) data to create 2D CAD designs (plan & profile) using predominately Microstation, but some limited Autocad users in-house
	o 2D CAD design files are used for WisDOT permitting and field construction
		3D model helpful for verifying vertical clearance from new WisDOT structures or utilities
		o Underground clearance from:
		  o storm pipes/structures,
		  o subgrade/EBS cuts
		  o other underground utilities.
		o Overhead clearance from bridges and signs.
		Original and design data most helpful; as-built data probably only useful if a major WisDOT change was determined <u>during</u> construction to verify proper utility depth is maintained)
			DTM surfaces helpful for private utility design:
			o Original (prior to construction) ground DTM to determine utility construction issues (utility work typically performed prior to road work)
			o Design DTM
			  o For underground utility design need:
			    o Lowest exposed surface during road construction (i.e., subgrade, bottom of new ditch line, bottom of marsh excavation)
			    o Final surface (to verify code compliance for proper depth of utility)
			  o For overhead utility design need
			    o Final surface (to verify code compliance for proper height of utility).
				During Active WisDOT Project. Utility companies will primarily use WisDOT's 3D data to plan for, design, and construct utility relocations related to road projects	**Private Utility Companies have a huge liability concern with providing 3D data on their facilities**

WisDOT - Utilities Section	Majority of sheets in plan set except erosion control	3-D model	Same as 2D tool except plans. Need to show all things in final location that are needed for 1078's, for example: street/signal light bases, storm sewer/culverts, structures, construction details, excavation limits, other utilities, all are issues when sending out 1078	**During Design, between design and construction, and during construction**	Utilities looking to use our design files to perform their design. With better data it may be possible for Utilities to locate closer to each other. Will technology progess to point where it may not allow contractors equipment operate if within 18 inches of utility facility?
Private Utility: Alliant Energy	Microstation – currently field engineers have <u>only</u> paper copies		o Location of utilities – needs to be located and identified prior to design to avoid conflicts. It is required by law that planners and designers avoid utilities where possible. o DTM's – need cuts and fills shown.	**Utility Companies would not rely on as-built drawings for utility work (permit work) between or unrelated to our road construction. They would be considered obsolete and of little value due to potential for subsequent grade changes, right-of-way changes, utility installations, etc**	Utility Clearances – 18" any line.
Private Utility: American Transmission Company (ATC)	R/W plats, x-sections, aerial background plan views, CADD files	o DTM o 3D model with above ground structures, both design and original	Complete project information – not segments – including above ground structures	For design in R/W, crossing location, and planning	**Need point of contact for WisDOT information? Will continue to be in regions, or managed centrally**? Will Utilities be required to supply as-build information to WisDOT after utilities are relocated?
Local Government: City of Sheboygan	o Plan/profile – x-section o Sanitary, storm, paving system maps o Easement tracking o Converting from land desktop to Civil 3-D	o LiDAR o DTM 3D models	o Use DOT plans extensively as control to "tie to" o **Would be very beneficial to be able to assign feature classification/values and feature intelligence to allow for linkage to municipal databases to manage the various components of their infrastructure. Quantities will be HUGE**! o Obstruction tracking o Accident reconstruction. Sheriff purchased 3D LiDAR and local police purchased total station to incorporate with municipal mapping data	All phases: o Proposed improvement o Survey o Design o Staking o Construction o As-building/to existing	Potential benefits of better exchange of 3D data between WisDOT and local gov'ts: 1. Tracking ownership, easements 2. Notification of property owners, utilities 3. Less mistakes – less change orders 4. Accurate information more readily available for planning, designing and assessment of projects 5. Updating and improvement of data made easier 6. Greater accountability How does 3D effort coordinate with WISLR?

WisDOT - Ops/Traffic	Plans views and profiles	o DTM o 3D model, design and as-built	o Sign location & dimensions o Poles - signals, lighting o Underground conduit & cable o Utility locations o Location of pavement surface o Edge of travel lane o Outside edge of shoulder o Structure clearance o Lateral clearance to obstructions/parapets/other objects	o During design: sight lines, estimating no passing zones, designing electrical components (conduit, cable, pole locations), and sign placement o After construction: sight distance (crash/operation problems, intersection control evaluation, determining no passing zones), clearance to structures and obstructions for oversize permitting, and locates for underground electrical	
WisDOT - Maintenance	Current As-Builts	3D As-Builts	All intended info to be included in 3D As-Builts	Potential Uses include: o Permitting process o Advertising Sign Placement o Roadside Management o No-Mow Zones o Scenic Easements o Roadside Design o Roadside Facilities o Shoulder Maintenance o Compass Reviews (Scott Bush)	o **BHO has no specific plans for implementing 3D technologies** o **Given large number of potential uses of 3D as-builts, should include BHO in Mgmt Oversight Group** o **Contact Structure Maintenance as potential post-construction user**
WisDOT - DTIM Data Research & Technology Unit	NA	NA	NA	NA	o **Primary focus of discussion was DTIM's consideration of potentially implementing ground based LiDAR technology in conjunction with their Photo-Log work** o **Similar to CORS & HMP, need to make other functional areas aware of LiDAR uses, and create advocacy group to support/promote DTIM's implementation**

Closing General Session

Notes from Breakout Group Reports and follow up discussion

Group 2 looked at precedence of other initiatives in a large sense, but many things were independent of the other initiatives. The advisory group will have to look at the interdependence.

Larson
Reference Initiative3_4.doc

3 3D Design Process.
Approach to design will depend on method: conventional or 3D modeling. Consultants will want to know ASAP if they will be using 3D modeling.
Initiative 2 DTM existing ground standards need to be defined before 3D design initiative.
Ranking of goals was based on looking ahead to construction, and the need to set design standards now.

4 Automated Machine Guidance (AMG)
Moved paving spec to short term goals. Zogg is concerned that the required accuracy is beyond current GPS technology. Kucza explained that the Chicago tollway projects is already using millimeter-GPS already. Vonderohe noted that although the technology is being used, there still needs to be a specification developed.

McCallum noted short vs. long-term goals may be defined by what buy-in and resources we can get from management to implement.

Vonderohe suggested that the management plan should revisit the plan on an annual basis and revise as needed.

McCallum
Reference DTM-breakout.doc

2. Digital Terrain Model (DTM) Data Collection and Analysis
Survey Data Coordinator must be the custodian of the data in order to move forward with standards.

Team questioned whether long-term goals should be included in the report. Advisory panel will discuss further.

WLIA has a consortium to fly the state. Is DOT involved? State agencies are working with the consultant to determine some level of data sharing and participation in the project. DOA is determining state needs before we move further.

Advisory group should look at inter-dependencies and consistencies with other initiatives. Within each goal, there will be a technical team.

Keyzer
Reference Breakout Notes Group 3.021709.doc

1 Height Modernization Program (HMP) and Continuously Operating Reference Stations (CORS)
How do we get external users to communicate importance of CORS/HMP?
Funding is a huge component of maintaining the system.
Other initiatives depend on the WISCORS-NET in operation 24/7/365 in order to be efficient.

5 Field Technology and Inspection
WisDOT will not buy rover for construction – is this definite? Centralized direction is needed.
Feasibility studies and other initiatives will determine priorities some goals.
Vonderohe noted that the NYDOT reported substantial cost savings, so to see inspection automation ranked at a low priority is concerning. Rommel said the definition of inspection was vague. Vonderohe responded that the Advisory Group did not go into the details.
Other efforts statewide (i.e., using PDAs in construction (Greuel)) need to be coordinated to avoid duplication or overlap of effort.

Some elements of initiative 5 (records) are not 3D related.

6. Post-Construction Uses of 3D Data

Zogg
Reference Breakout 4 Wrap up.doc

Need to contact Maintenance and Planning staff since they were not represented at the Workshop.
Due to a good representation from Utilities (private and DOT), most of the discussion was focused on their needs, but there was a good parallel to other areas, such as the Local Government in attendance.

Active project DTM would primarily be used. Older data would not be as useful. Adding intelligence (cost, date, etc.) to model would help locals. The model could be provided for them to add the info.

A 3D model may enable the utilities to compress the lines to be more efficient within the right-of-way.

McCallum noted as-built DTM needs to have digital data standards for what is expected from construction. Zogg said there are questions about the viable use of the data. Danielson said there could be critical areas identified to be DTM'ed so that locals can use to update their data.

Appendix L.

Executive Summary of Final Implementation Plan

EXECUTIVE SUMMARY
WisDOT Implementation Plan:
3D Technologies and Methods for Design and Construction

The vision that serves as the basis for this implementation plan is:

> "Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, payment, and other applications included within the infrastructure lifecycle."

The plan addresses a management strategy and six initiatives for moving towards realization of the vision statement. Components of the initiatives are either underway within WisDOT or proposed within the plan and relate directly to three-dimensional technologies and methods. The objectives of the plan are to establish or reiterate justifications for the initiatives, identify relationships among them, coordinate among the initiatives where appropriate, recommend actions that will help realize synergistic benefits, assign priorities, establish or reiterate milestones and timelines, and identify a lead section within the department for each initiative.

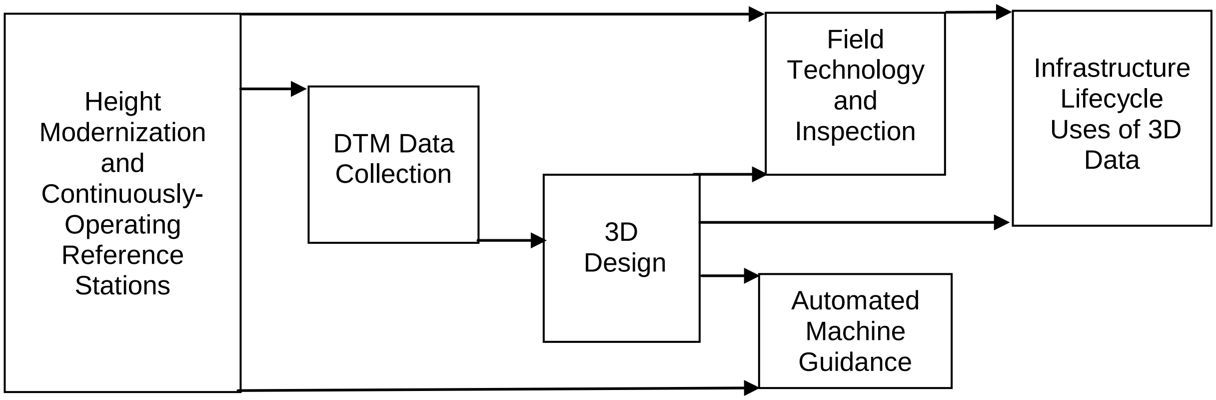
SUMMARY OF INITIATIVES, GOALS, EFFORTS, PRIORITIES, AND LEAD SECTIONS

Initiative	Goal	Effort	Priority
Height Modernization and CORS - Lead: BTS (Surveying and Mapping)			
	Internal / External Support Groups Secure Funding	High	High
	Implement 5-Year Completion Plan (2009-2013)	High	High
DTM Data Collection and Analysis - Lead: BTS (Surveying and Mapping)			
	Fill Survey Data Coordinator Positions	Moderate	High
	Determine Map-Check Frequency	Low	Medium
	Revise FDM and Business Practice for Map Checks	Moderate	Medium
	Develop Standards and Procedures	High	High
	Pilot Standards and Procedures	Moderate	High
	Impl Stds, Procs, Training on DTM Data Collection	Moderate	High
	Implement DTM-to-DTM for Earthwork	Moderate	High
	Evaluate Technologies (e.g., LiDAR, Aiborne GPS)	Low	High
3D Design Process - Lead: BPD (Roadway Standards and Methods)			
	Existing Civil 3D Pre-Deployment Plan	Moderate	High
	Civil 3D New User Training	High	High
	Develop and Execute Extended Deployment Plan	Moderate	Medium
	Annual Users Conference Process	High	Low
	3D Model Content and Format Standards	High	High
	Establish Date for 3D Models for PS&E	Low	High
	Evaluate 3D Models as Construction Contract Docs	High	Medium
Automated Machine Guidance - Lead: BPD (Project Services)			
	Monitor and Refine Grading Specification	Low	High
	Develop, Pilot, and Implement Base Course Spec	Moderate	High
	Investigate and Evaluate Need for Paving Spec	Moderate	High
	Study Bridges & Utilities and Make Recommendation	Low	Medium
Field Technology and Inspection - Lead: BPD (Project Services)			
	Rovers-for-Construction Group		
	Investigate Scenarios and Feasibility	Moderate	High
	Pilot, Evaluate, and Develop Implementation Plan	High	TBD*
	Execute Implementation Plan	High	TBD*
	Inspection Automation Group		
	Investigate Feasibility	Moderate	High
	Develop Implementation Plan	High	TBD*
	Execute Implementation Plan	High	TBD*
Infra. Lifecycle Uses of 3D Data - Lead: 3D Technologies Management Group			
	To Be Developed		

TBD*: To be determined by preceding feasibility study.

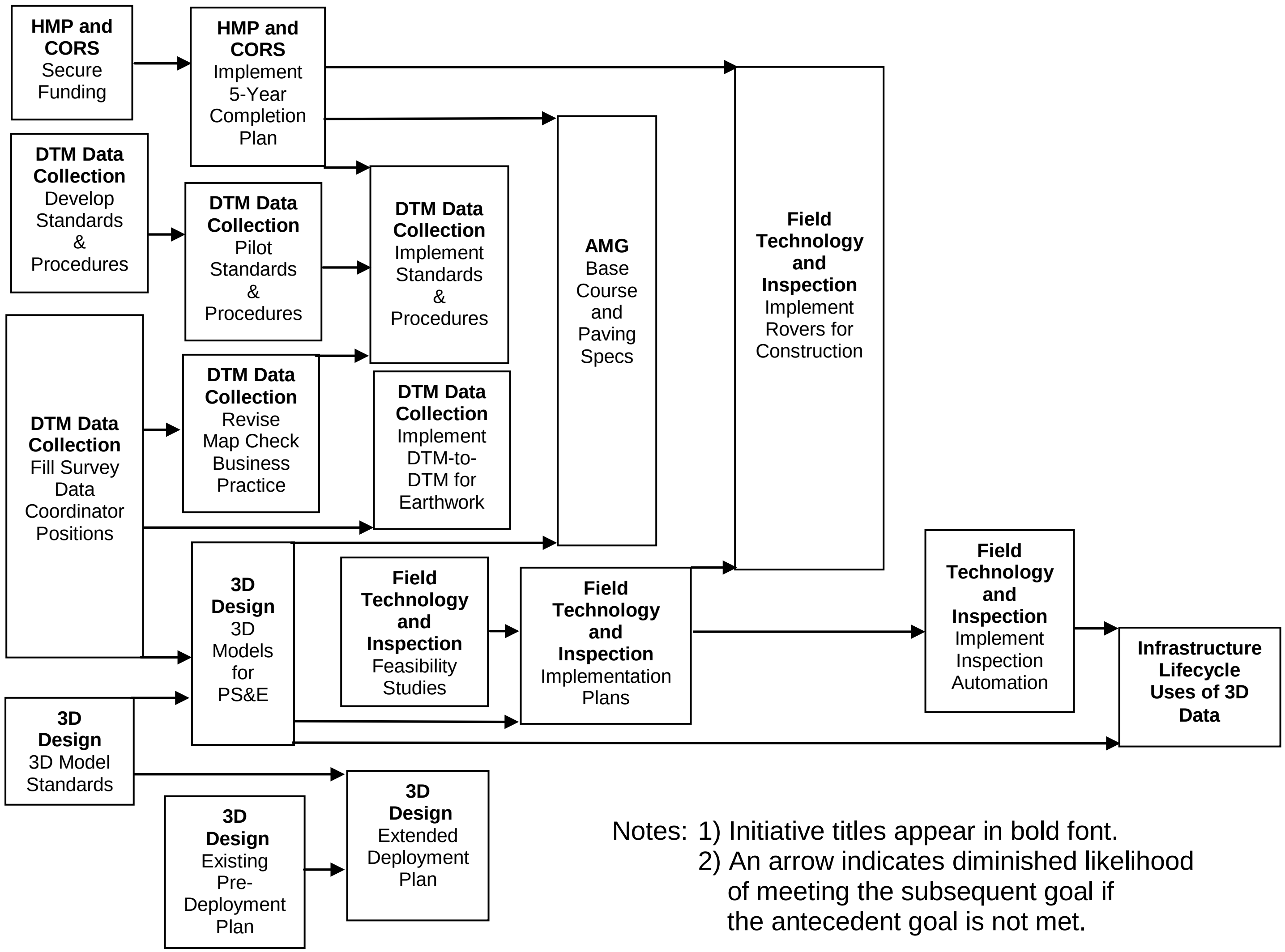
DEPENDENCIES AMONG INITIATIVES AND GOALS

Relationships among goals and initiatives include dependencies wherein benefits of some initiatives and goals cannot be fully realized without achieving other goals, in some cases, within other initiatives. Figure 1 is a high-level depiction of dependencies among initiatives. Figure 2 is a more detailed depiction of primary dependencies among goals within the initiatives. The table on the previous page includes the goals in Figure 2, as well as independent, or more moderately dependent, goals not shown in Figure 2.



NOTE: An arrow indicates that if goals of the antecedent initiative are not met, then benefits of the subsequent initiative will be diminished.

Figure 1.
Initiative Dependency Diagram

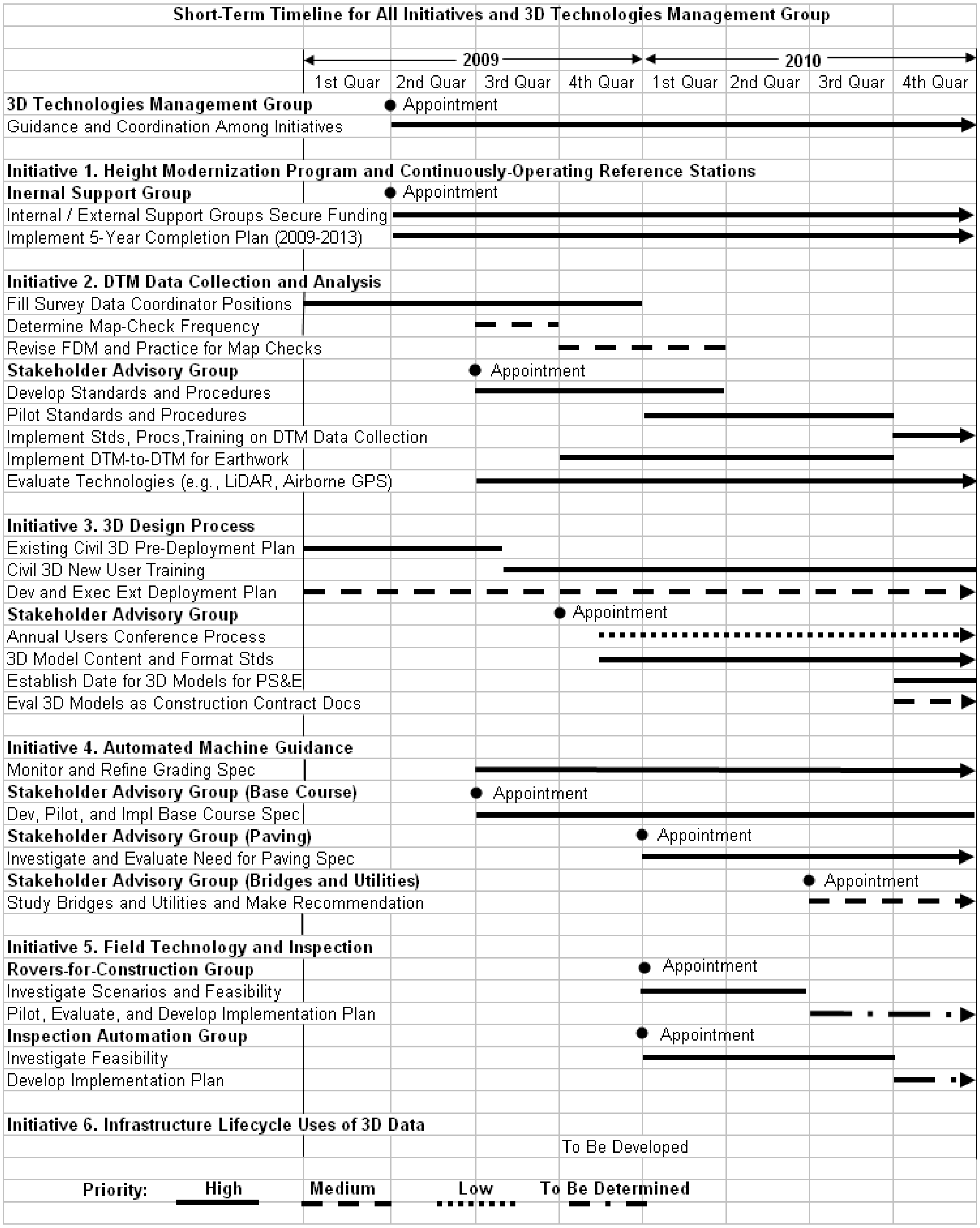


Notes: 1) Initiative titles appear in bold font.
2) An arrow indicates diminished likelihood of meeting the subsequent goal if the antecedent goal is not met.

Figure 2.
Initiative and Goal Dependency Diagram

Appendix M.

Table of Timelines and Priorities for All Short-Term Goals


Short-Term Timeline for All Initiatives and 3D Technologies Management Group
2009
2010
1st Quar
2nd Quar
3rd Quar
4th Quar
1st Quar
2nd Quar
3rd Quar
4th Quar
3D Technologies Management Group
Appointment
Guidance and Coordination Among Initiatives
Initiative 1. Height Modernization Program and Continuously-Operating Reference Stations
Inernal Support Group
Appointment
Internal / External Support Groups Secure Funding
Implement 5-Year Completion Plan (2009-2013)
Initiative 2. DTM Data Collection and Analysis
Fill Survey Data Coordinator Positions
Determine Map-Check Frequency
Revise FDM and Practice for Map Checks
Stakeholder Advisory Group
Appointment
Develop Standards and Procedures
Pilot Standards and Procedures
Implement Stds, Procs,Training on DTM Data Collection
Implement DTM-to-DTM for Earthwork
Evaluate Technologies (e.g., LiDAR, Airborne GPS)
Initiative 3. 3D Design Process
Existing Civil 3D Pre-Deployment Plan
Civil 3D New User Training
Dev and Exec Ext Deployment Plan
Stakeholder Advisory Group
Appointment
Annual Users Conference Process
3D Model Content and Format Stds
Establish Date for 3D Models for PS&E
Eval 3D Models as Construction Contract Docs
Initiative 4. Automated Machine Guidance
Monitor and Refine Grading Spec
Stakeholder Advisory Group (Base Course)
Appointment
Dev, Pilot, and Impl Base Course Spec
Stakeholder Advisory Group (Paving)
Appointment
Investigate and Evaluate Need for Paving Spec
Stakeholder Advisory Group (Bridges and Utilities)
Appointment
Study Bridges and Utilities and Make Recommendation
Initiative 5. Field Technology and Inspection
Rovers-for-Construction Group
Appointment
Investigate Scenarios and Feasibility
Pilot, Evaluate, and Develop Implementation Plan
Inspection Automation Group
Appointment
Investigate Feasibility
Develop Implementation Plan
Initiative 6. Infrastructure Lifecycle Uses of 3D Data
To Be Developed
Priority:
High
Medium
Low
To Be Determined

Appendix N.

Final Implementation Plan

WisDOT IMPLEMENTATION PLAN:
3D TECHNOLOGIES AND METHODS FOR DESIGN AND CONSTRUCTION
May, 2009

VISION STATEMENT

Adoption of 3D methods and seamless data flows throughout initial survey, design, contracting, construction, as-built survey, payment, and other applications included within the infrastructure lifecycle.

PURPOSE OF THIS DOCUMENT

This plan addresses a management strategy and six initiatives for moving towards realization of the vision statement. Components of the initiatives are either underway within WisDOT or proposed herein and relate directly to three-dimensional technologies and methods. The objectives of the plan are to establish or reiterate justifications for the initiatives, identify relationships among them, coordinate among the initiatives where appropriate, recommend actions that will help realize synergistic benefits, assign priorities, establish or reiterate milestones and timelines, and identify responsible parties.

SUMMARY OF INITIATIVES, GOALS, EFFORTS, PRIORITIES, AND LEAD SECTIONS

Initiative	Goal	Effort	Priority
Height Modernization and CORS - Lead: BTS (Surveying and Mapping)			
	Internal / External Support Groups Secure Funding	High	High
	Implement 5-Year Completion Plan (2009-2013)	High	High
DTM Data Collection and Analysis - Lead: BTS (Surveying and Mapping)			
	Fill Survey Data Coordinator Positions	Moderate	High
	Determine Map-Check Frequency	Low	Medium
	Revise FDM and Business Practice for Map Checks	Moderate	Medium
	Develop Standards and Procedures	High	High
	Pilot Standards and Procedures	Moderate	High
	Impl Stds, Procs, Training on DTM Data Collection	Moderate	High
	Implement DTM-to-DTM for Earthwork	Moderate	High
	Evaluate Technologies (e.g., LiDAR, Aiborne GPS)	Low	High
3D Design Process - Lead: BPD (Roadway Standards and Methods)			
	Existing Civil 3D Pre-Deployment Plan	Moderate	High
	Civil 3D New User Training	High	High
	Develop and Execute Extended Deployment Plan	Moderate	Medium
	Annual Users Conference Process	High	Low
	3D Model Content and Format Standards	High	High
	Establish Date for 3D Models for PS&E	Low	High
	Evaluate 3D Models as Construction Contract Docs	High	Medium
Automated Machine Guidance - Lead: BPD (Project Services)			
	Monitor and Refine Grading Specification	Low	High
	Develop, Pilot, and Implement Base Course Spec	Moderate	High
	Investigate and Evaluate Need for Paving Spec	Moderate	High
	Study Bridges & Utilities and Make Recommendation	Low	Medium
Field Technology and Inspection - Lead: BPD (Project Services)			
	Rovers-for-Construction Group		
	Investigate Scenarios and Feasibility	Moderate	High
	Pilot, Evaluate, and Develop Implementation Plan	High	TBD*
	Execute Implementation Plan	High	TBD*
	Inspection Automation Group		
	Investigate Feasibility	Moderate	High
	Develop Implementation Plan	High	TBD*
	Execute Implementation Plan	High	TBD*
Infra. Lifecycle Uses of 3D Data - Lead: 3D Technologies Management Group			
	To Be Developed		

TBD*: To be determined by preceding feasibility study.

INITIATIVES

1. Height Modernization Program (HMP) and Continuously Operating Reference Stations (CORS).

Background: WisDOT's height modernization program was initiated in 1998 with funding from the National Oceanic and Atmospheric Administration / National Geodetic Survey (NOAA / NGS) to densify and improve the vertical component of Wisconsin's geodetic control network. HMP is installing a hierarchical network of monumentation and measurements that includes the existing high-accuracy reference network, and new primary, secondary, and local stations. Measurements include static Global Positioning System (GPS) and high-order differential leveling. The network is being installed in eight phases, working from south to north and east to west, then back east across the state (see Appendix A). Phases 1-5 are complete with published coordinates. Phases 6-7 are underway with monumentation and measurements. Phase 8 (northeastern Wisconsin, Green Bay to Ashland and including Door County) will have decreased monumentation with no secondary or local stations due to the advent of CORS.

CORS is an on-going WisDOT / NOAA project to construct a network of continuously operating reference stations in Wisconsin to support real-time kinematic (RTK) GPS applications with 3D positional accuracies at the 2cm level in real time. WisDOT's Geodetic Survey Unit partnered with other state and local government agencies, as well as educational institutions on development and implementation of the system. Through cooperative agreements, partners have and continue to contribute facilities, power, Internet access, and possible GPS hardware to the program. WisDOT has supplied most of the GPS hardware; all of the GPS software components; nearly all of the supplies and materials to construct the CORS monuments; and all information technology (IT) components to operate the system.

CORS sites include public educational buildings, county facilities, municipal facilities, and a park. The network will be operated and controlled by GPS network software running on servers in Madison. CORS data are archived and made available for post-processing applications (e.g., airborne GPS).

The network (defined by an area known as Zone 1 (see Appendix B)) was set operational in July, 2008. Zone 1 consists of 24 permanent CORS sites, east of a line from Marinette to Shawano to Fond du Lac to Beaver Dam to Janesville. Construction of Zone 2 is underway. Zone 2 consists of 13 permanent CORS sites located just west of Zone 1 from Madison to Rhinelander. As of December, 2008, there were 130 subscribed users, including some from out of state. Applications range from geodetic and land surveys to precision agriculture. CORS is becoming part of the infrastructure of Wisconsin and is being viewed by some as having the role of a utility.

At least eight more CORS will be built during 2009. The location of Zone 3 is tentatively planned just west of Zone 2 from the Illinois border to central Wisconsin. Zone 4 would possibly include as many as 18 CORS in north central Wisconsin (if grant funding is available). Funding for HMP and CORS development comes from NOAA / NGS with some matching funds from WisDOT. The effort is currently operating on a federal fiscal year 2007 grant of $1,200,000 that ends in March, 2009. Approval has been received for a $300,000 federal fiscal year 2008 grant that will start in April, 2009. An application has been submitted for a $2,450,000 federal fiscal year 2009 grant. During the current fiscal year, WisDOT provided matching funds for purchase of receivers and hiring of consultants to perform field and office activities.

Issues: Many of the other initiatives and efforts described within this document require successful completion of HMP and CORS to fully realize their potential benefits. Some assume an operational CORS network in order to be technologically or economically viable.

- There is uncertainty with future grant funding.
- Problems with remote access to GPS receivers need to be resolved. These involve host site IT security issues that must be addressed to avoid maintenance and upgrade visits to each CORS station.
- An overall maintenance plan for the network needs to be developed that addresses, among other things, means for staying abreast of and exploiting technological advances over time.
- Operation of system software needs to be learned by several individuals.
- Additional staff will be needed to support CORS when it is complete. There is a strong IT / communications technical component in addition to a public relations component.

Stakeholders: Design and construction project engineers, planners, surveyors, photogrammetrists, contractors, utilities, staking contractors, and numerous external groups that require high-precision positioning services (e.g., precision agriculture).

Recommendations: Given the significance of HMP and CORS to effective, efficient, and consistent use of 3D technologies throughout design and construction and the uncertainty of funding for the long-term viability of HMP and CORS, we recommend:

- Developing a WisDOT support group that advocates internally for sustained resources throughout WisDOT for the HMP and CORS efforts.
- Advocating formation of an external users group that works for sustained support at the local, state, and national levels for the HMP and CORS efforts by communicating the importance of the technology and how it will benefit their business needs.

Short-Term Goals (1-2 years):

- Raise the awareness of management and upper management within WisDOT of the significance of HMP and CORS to the overall mission of the department and to the State of Wisconsin.
- Ensure continued federal and departmental funding.

Long-Term Goals (beyond 2 years): Assuming sustained current levels of funding, both HMP and CORS are on a 5-year completion plan (2009-2013). Without implementing the two above recommendations, the assumption of sustained funding is, at best, tenuous. Even with implementation of the recommendations, the assumption of sustained funding is uncertain. Ultimately, the long-term goal is not only completion of HMP and CORS but also sustaining them as operating systems servicing a host of internal and external users.

Timeline: The first recommendation should be implemented by April, 2009 (start of new funding cycle). The second recommendation should be on-going and, in addition, should become part of the charge of the internal support group formed under the first recommendation.

Relative Levels of Effort:

- o Securing sustained funding - High.
- o Implementing the 5-year completion plan – High.

Priorities:

- o Securing sustained funding - High.
- o Implementing the 5-year completion plan – High.

Benefits: Although HMP and CORS are integral to full success of the overall 3D initiatives, they have been and can be justified on their own merits.

- o CORS eliminates the need and cost for local base station GPS receivers.
- o CORS eliminates resource time associated with equipment setup at the base site.
- o CORS ensures reliability and redundancy in position determination.
- o CORS and HMP greatly enhance consistency of coordinate determination, facilitating corridor control development.

Relationships with Other Initiatives: Through the benefits outlined above, HMP and CORS have direct linkages to automated machine guidance (Initiative 4), DTM data collection (Initiative 2), and inspection (Initiative 5). In addition, facilitation of consistent corridor control and minimization of problems with project control is supportive of the entire set of processes addressed by this plan.

Lead Section: Bureau of Technical Services – Surveying and Mapping Section.

2. Digital Terrain Model (DTM) Data Collection and Analysis.

Background: Original ground and final DTMs are developed by 1) WisDOT's Photogrammetry Unit, 2) consultants using photogrammetry, 3) WisDOT survey field crews, and 4) consultants using ground survey methods.

Field crews and consultants receive guidance from region survey coordinators. The Facilities Development Manual (FDM) contains a short section on procedures for DTM collection (ground survey and photogrammetric). This section defers to field procedures for collecting cross sections as these are what are currently required for design and often used for computing final earthwork quantities. The master contract special provisions for photogrammetric services contain a brief statement on procedures. The Construction and Materials Manual (CMM) contains many references to cross sections and methods that use cross sections.

The FDM contains a section on accuracy standards for photogrammetric products. It does not contain an accuracy standard for ground survey products. The master contract special provisions for photogrammetric services contain a brief statement on required accuracies. WisDOT practice for photogrammetric contracting has been to require that products meet specified accuracies and to remain silent on details of procedures. Map checks are performed on some products to ensure conformance to accuracy requirements.

As standard practice, final earthwork quantities are currently determined from cross-sections by average-end-area. In actual practice, a variety of methods are used by consulting engineers and contractors to compute earthwork. If the data are collected appropriately, DTM-to-DTM methods should be more accurate than average-end-area because they use more complete representations of the original ground and final surfaces. Moreover, final DTMs are sometimes developed from survey data, then sliced into cross-sections to use with the prescribed average-end-area method of computation. Final DTMs are a primary input to the envisioned 3D as-builts (see Initiative 5).

Issues:
- The need for survey data coordinator positions was justified and approved by the Project Development and Technical Services Chiefs prior to this initiative and stands on its own merits. However, the positions need to be elevated on the critical fill list.
- The FDM needs modification to place emphasis on DTM data collection as opposed to cross section data collection.
- The CMM needs revision if utility of cross sections is to be decreased in favor of DTM methods.
- Ground survey data collection is sometimes iterative with crews needing to return to the field after the designer decides that data are too sparse (completeness and accuracy are different issues).
- Map checks of photogrammetric products are infrequent.
- The software mechanisms for creation of DTMs from survey data are not well understood by field and office personnel.
- There is lack of consensus on accuracies required for original ground and final DTMs.
- There is need for both in-class and on-the-job training for both data collection and analysis.
- There are relevant technologies (e.g., airborne GPS, LiDAR) that have not been fully investigated by WisDOT. Applications extend beyond DTM data collection.

Stakeholders: Design and construction project engineers, surveyors, photogrammetrists, and contractors.

Recommendations:
- Continue implementation of survey data coordinator positions.
- Determine the desired frequency of map checks and incorporate in FDM and business practices.
- Appoint a stakeholder advisory group to address the following:
  - Standards and procedures for collection of original ground and final DTMs to ensure consistency, accuracy, and cost-effectiveness in results whether the methods are photogrammetric or ground survey. This includes review and revision of existing standards documents and coordination with Initiative 5 for final DTMs as inputs to 3D as-builts.
  - Development and implementation of training on:
    a. Software methods for creation of DTMs from survey data (i.e., understanding the algorithms).
    b. Means for survey coordinators to better communicate procedures and expectations to survey crews to reduce the frequency of returns to the field.
    c. Use of DTM-to-DTM methods for computing earthwork quantities.
  - Rapidly-evolving data collection technologies (e.g., LiDAR, advanced softcopy photogrammetric methods, integrated GPS/IMU (with CORS)) and

their appropriate uses, to include coordination with efforts beyond DTM data collection.

Short-Term Goals (1-2 years):

- Fill regional survey data coordinator positions.
- Achieve consistency in map-check frequency.
- Refine or develop, then pilot, DTM data collection standards and procedures. Revise standards documents accordingly.
- Develop, provide training, and implement use of DTM-to-DTM methods for earthwork computations. Revise standards documents accordingly.

Long-Term Goals (beyond 2 years):

- Implement DTM data collection standards and procedures.
- Provide training on procedures for DTM data collection.
- Evaluate technologies (e.g. LiDAR and airborne GPS) that might increase the efficiency of accurate DTM data collection.

Timeline, Relative Levels of Effort, and Priorities:

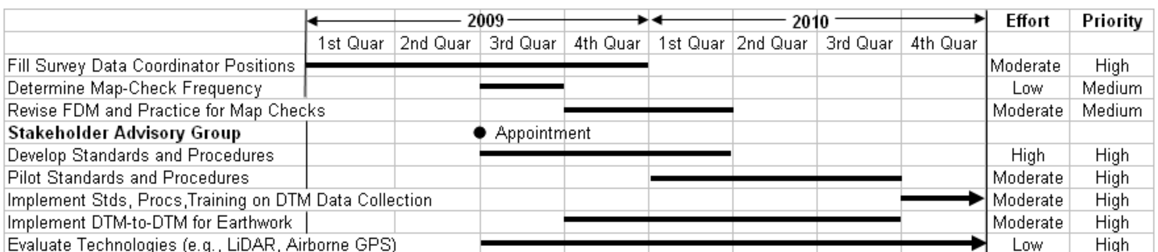


Figure 1. Short-Term Timeline for DTM Data Collection and Analysis Initiative

Benefits:

- The survey data coordinator positions will facilitate the flow of 3D information between design and construction and provide assistance with development and implementation of standards and procedures for data collection.
- Consistency in map-check frequency will increase confidence in use of photogrammetric DTMs.
- Standards, procedures, and associated training will ensure consistency in original ground and final DTM completeness and accuracy and reduce revisits to the field for further data collection.
- If the data are collected appropriately, use of DTM-to-DTM methods should not only lead to better results, it might also reduce the number of disputes over final quantities.

Relationships with Other Initiatives: The original ground DTM is a primary input to the design process (Initiative 3). Final DTMs are primary inputs to 3D as-builts (Initiative 5) and, as such, have infrastructure lifecycle uses (Initiative 6). Data collection for the original ground DTM will benefit from HMP and CORS (Initiative 1) by elimination of the need for local RTK GPS base stations and by reduction in problems with project control.

Lead Section: Bureau of Technical Services – Surveying and Mapping Section.

3. 3D Design Process.

Background: WisDOT's Methods Development Unit has a detailed plan for the initial deployment of Civil 3D, including tasks, milestones, and timelines. The plan addresses hardware upgrades, design products, workflows, and phased-in training. The initial objective is replacement of CAiCE with Civil 3D as the primary design platform, with the transition occurring over a 3-5 year period. Initially, some designs started in CAiCE will be converted and completed in Civil 3D. Eventually, all designs will be developed completely with Civil 3D. There is no pre-determined termination date for CAiCE. Ultimately, more extensive use of Civil 3D, for example in field surveys, photogrammetry, drainage, and impact analysis for environmental documentation, is expected as future enhancements to the software provide more robust functionality beyond design. Initial training of new users on Civil 3D is expected to begin during mid to late summer of 2009.

Moreover, 3D design is a process, not a technology. A number of software packages support the 3D design process and engineering design consultants might be using any of these software packages. One of the challenges is to establish technology-independent standards and procedures for 3D design and its products.

Issues:
- There are retraining implications for keeping current with software advances.
- The initial deployment plan for Civil 3D does not address its full range of functionality. In addition, future enhancements by the vendor will need to be considered. Impacts of technology changes, upon both internal and external users must be addressed.
- Future modifications to plans as the primary design deliverable should be evaluated. For example, consider the possible adoption of 3D models as contract documents and retention or elimination of two-dimensional views. There are questions concerning the required level of detail and accuracy of 3D models and which projects should be initially targeted.
- 3D model content and generic format standards are needed to address data exchange and downstream uses such as automated machine guidance, inspection and final quantities, and infrastructure lifecycle uses of 3D technology.

Stakeholders: Design and construction project engineers, CAE Advisory Group, CADD Users Group, real estate managers, utility companies, access control managers, contractors and consultants, vendors and software developers, surveyors, local governments and state and federal agencies.

Recommendations:
- Continue implementation of survey data coordinator positions.
- Execute the existing Civil 3D deployment plan and develop an extended deployment plan.
- Appoint a stakeholder advisory group on enhancement of design deliverables to address:
  - Conduct of annual statewide 3D design users' meetings.
  - Development of 3D model content and generic format standards.
  - Evaluation of 3D models as contract documents.

Short-Term Goals (1-2 years):

- Deployment of Civil 3D according to existing plan, with consideration of need for consultant training.
- Development and execution of an extended deployment plan for 3D design.
- Development and implementation of annual statewide 3D design users' conference process. This goal is part of the charge to the study group.
- Development of non-proprietary 3D model content and format standards by the study group.
- Establishment of a date when consultants will be required to provide 3D models as a PS&E deliverable.

Long-Term Goals (beyond 2 years):

- Continued execution of the extended deployment plan for 3D design.
- Evaluation of 3D models as construction contract documents by the advisory group.

Timeline, Relative Levels of Effort, and Priorities:

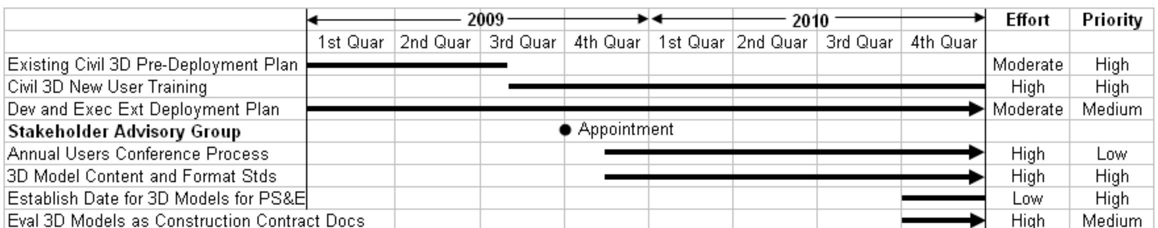


Figure 2. Short-Term Timeline for 3D Design Process Initiative

Benefits:

- Adoption of Civil 3D as WisDOT's primary design tool has been previously justified and stands on its own merits (CAiCE Replacement Recommendation Report, WisDOT, 2007).
- The benefit of developing and adopting an extended deployment plan addressing the 3D design process is a statewide increase in production capabilities and efficiencies as the technology rapidly increases in power and functionality.
- An annual users conference will provide a forum for information exchange to the benefit of all involved and a possible mechanism (e.g., through workshops) for the study group to pursue its other goals.
- Standards for 3D model content will facilitate uniformity in data sets shared among parties, reduce duplicative data development, reduce conflicts in data interpretation, and level the playing field of data expectations.
- A generic data exchange standard will increase efficiencies in utility of data shared among parties and reduce redundant data development.
- Generating 3D models as design outputs and providing them directly to contractors will eliminate the need to develop them, through "reverse engineering", from 2D plans, thus reducing the greatest technological impediment to wider and more effective use of automated machine guidance for construction.

Relationships with Other Initiatives: Primary input data to the design process include the original ground DTM (Initiative 2). Design outputs are required for automated machine guidance (Initiative 4), inspection (Initiative 5), and infrastructure lifecycle uses of 3D technology (Initiative 6).

Lead Section: Bureau of Project Development - Roadway Standards and Methods Section.

4. Automated Machine Guidance (AMG).

Background: WisDOT is nearing completion of a 2.5-year effort to develop a statewide specification for automated machine guidance (AMG) for grading operations. 2008 was the second and final year of pilot projects related to the specification development effort. The developed statewide specification gives contractors the option to use AMG in their grading operations. Use of AMG is not mandated on WisDOT projects. Starting with December 2008 lettings, WisDOT will include the new AMG specification for grading (as a special provision) on all WisDOT projects that have the construction staking subgrade item. The new AMG specification for grading will be included in the 2010 version of WisDOT's standard specifications and, then, will no longer need to be included as a special provision.

Issues: A message received from pilot project contractors is that they would like to have the 3D design model become a design deliverable. Current practice requires contractors to either acquire 3D models from designers if they are available or reverse-engineer model data from traditional plans and staking data. WisDOT is taking steps to remedy this with Civil 3D implementation (Initiative 3).

WisDOT wants to continue to refine the AMG specification for grading as needed. The department also desires to build upon the experience of the AMG grading specification to develop new AMG specifications for base course placement, paving, and perhaps utilities and bridges.

Stakeholders: Design, construction, contractors, consulting engineers, model developers, staking contractors, utility companies.

Recommendations:

- Grading, Landscaping, Sewer Tech Committee develops and implements a plan for monitoring and refinement of the AMG specification for grading.
- Appoint stakeholder advisory groups to develop AMG specifications for base course placement and paving. AMG for paving might include laser augmentation for increased vertical accuracies.
- Appoint a stakeholder advisory group to investigate implications of AMG for utilities and bridges to include which would be easiest to adopt. AMG for utilities might include articulated machinery for excavation.

Short-Term Goals (1-2 years):

- Monitoring and refinement of the AMG specification for grading.
- Development, testing, and implementation of an AMG specification for base course placement.
- Investigation and evaluation of need for an AMG specification for paving.
- Initiation of AMG specification development for bridges and / or utilities.

Long-Term Goals (beyond 2 years):

- Development and implementation of AMG specification for paving.
- Monitoring and refinement of AMG specifications for grading, base course placement, and paving.
- Implementation of AMG specifications for utilities and bridges.

Timeline, Relative Levels of Effort, and Priorities:

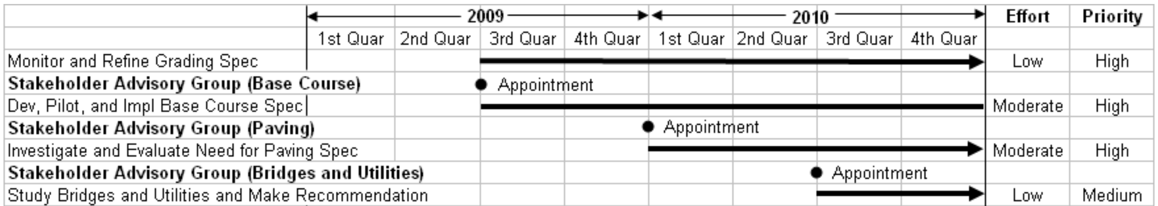


Figure 3. Short-Term Timeline for Automated Machine Guidance Initiative

Benefits:

- Contractors report 20%-40% productivity gains from automated machine guidance for grading.
- Increased uniformity of construction.
- At least one state DOT has reported lower than expected bids as a result of contractors using AMG.

Relationships with Other Initiatives: Automated machine guidance requires a 3D model of the design (Initiative 3). There is a potentially strong direct benefit from HMP and CORS (Initiative 1), through elimination of the need for an RTK GPS base station (NOTE: CORS support for automated machine guidance has not yet been successfully demonstrated in Wisconsin. Tests are currently being conducted by the technology vendor).

Lead Section: Bureau of Project Development - Project Services Section.

5. Field Technology and Inspection.

Background: Construction project staff typically do not have access to GPS and electronic automated inspection technology. Consequently, they conduct surveys, perform inspections, make measurements, determine quantities, keep records, and prepare as-builts with obsolete technology and methods that are time consuming and costly.

NYSDOT has used 3D models, methods, and GPS-based inspection automation technology to reduce the overall cost of construction staking, inspection, and determination of quantities. Currently there is no department-wide program in WisDOT that is actively pursuing this use. There is potential for significant savings in time and costs.

Issues:

- Development and retention of knowledge and skills base among many project engineers.
- Lack of standard approaches to data collection and analysis among regions and among consultants.

- Lack of field equipment and software.
- Failure to exploit emerging inspection automation technology in a comprehensive manner.
- Current as-builts are 2D paper plans that are marked with revisions by project engineers. Such products and methods cannot realize the potential benefits flowing from the availability of 3D electronic as-builts.

Stakeholders: Contractors, project engineers, engineering consultants, surveyors, ACM Users Group, Methods Development Unit, and downstream users of data flowing from the construction process.

Recommendations: Appoint two stakeholder advisory groups:

3. Rovers-for-Construction Group – Investigates alternatives for implementing GPS technology for construction measurements, determines their feasibility, and, if found feasible, develops a detailed implementation plan. Coordinates with the DTM data collection and analysis group (Initiative 2) and the inspection automation group.

   Two possible scenarios have been preliminarily identified:
   1) Having specialized one- or two-person field crews that perform inspection and as-built surveys for multiple projects in proximity with one another;
   2) Furnishing each project team with the technology and knowledge to perform inspection and as-built surveys with 3D methods and data.

   Advantages of scenario 1 over scenario 2 include reduced numbers of rovers, controllers, and software; less training; and relief of effort on the part of project engineers. Disadvantages of scenario 1 compared to scenario 2 include the need to manage multiple data sets from multiple projects on one technology platform and logistics and scheduling among staking and inspection needs on multiple projects.

   There are three possible providers of the technology: 1) WisDOT, 2) contractors, and 3) consultants.

4. Inspection Automation Group – Investigates the feasibility of adopting inspection automation technology, and, if found feasible, develops a detailed implementation plan.

   "Inspection automation technology" has broad scope and includes in-field record-keeping technologies such as electronic notebooks and personal digital assistants (potentially wireless) and associated software. Such technologies can be capable of supporting or assisting, for example, development of final DTMs, location-based materials testing and records keeping, development of 3D as-builts by manipulation of 3D design models and inclusion of final DTMs, development of attribute databases linked to 3D models, and querying and reporting from such databases for purposes such as final quantities computation and acceptance of construction products.

Short-Term Goals (1-2 years):

- o Completion of feasibility studies for rovers-for-construction and inspection automation.
- o If found feasible, completion of detailed implementation plans to include evaluation and piloting for rovers-for-construction and inspection automation.

Long-Term Goals (beyond 2 years):

- o Implementation of rovers-for-construction, if feasible.
- o Implementation of inspection automation, if feasible.

Timeline, Relative Levels of Effort, and Priorities:

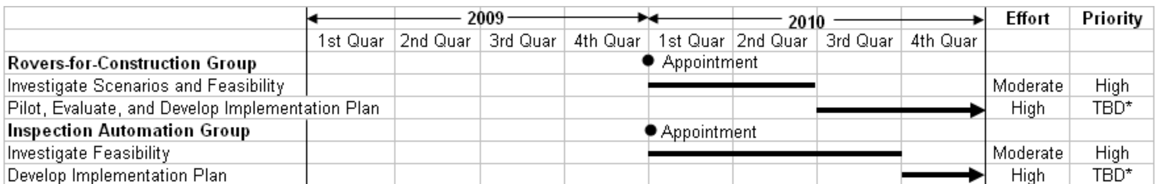


Figure 4. Short-Term Timeline for Field Technology and Inspection Initiative

TBD*: To be determined by preceding feasibility study.

Benefits:

- o More rapid completion of finals.
- o More efficient flow of information.
- o Improved staff efficiencies.
- o Shift of focus from record-keeping to project oversight.

Relationships with Other Initiatives: Inspection depends upon data from 3D design (Initiative 3), and original ground and final DTMs (Initiative 2). Technology costs and costs associated with project control problems are lowered by HMP and CORS (Initiative 1). Inspection data have infrastructure lifecycle uses (Initiative 6).

Lead Section: Bureau of Project Development – Project Services Section.

6. Infrastructure Lifecycle Uses of 3D Data.

Background: This initiative includes use of as-builts and other 3D data by utilities, surveys, permits, right-of-way, operations, maintenance, planning, and all other activities that occur on the highway right-of-way throughout the infrastructure lifecycle. A primary source of these data would be design and construction processes. An emerging source may be through the use of LiDAR technology.

WisDOT's Division of Transportation Investment Management (DTIM) – Data Research and Technology Unit is examining the potential of implementing vehicle-based LiDAR technology in conjunction with their photo-log work. Photo-log data are currently collected on a 2-3 year cycle. Design, construction, and other lifecycle uses of these data need to be explored

Issues:

- o Private utility companies have significant liability concerns with providing 3D data on their facilities.

- Utility companies would not rely on as-built 3D models for utility work (permit work) between or unrelated to WisDOT road construction. They would be considered obsolete and of little value, unless continuously maintained, due to potential for subsequent grade changes, right-of-way changes, and other utility installations.
- External users need a point-of-contact for WisDOT information. Will this continue to be at the regional level or will it be managed centrally?
- It would be very beneficial to be able to assign feature classes and feature intelligence to 3D models. This would facilitate linkages to municipal databases used to manage various components of local government infrastructure. Data volumes will be very significant.
- There is need for continued communication with users of 3D data to identify and attempt to meet their data needs.
- How does the 3D effort coordinate with Wisconsin Local Roads (WISLR)?
- WisDOT Bureau of Highway Operations (BHO) has no specific plans for implementing 3D technologies. Given their large number of potential uses of 3D as-builts, BHO should be represented in the 3D Technologies Management Group (see below).
- The WisDOT Structure Maintenance Section should be contacted as a potential post-construction user.
- Similar to HMP and CORS, there is a need to make other functional areas aware of vehicle-based LiDAR uses.

<u>Stakeholders:</u> Utility companies; federal, state, and local government; planners; traffic and maintenance engineers, surveyors; and all other users of data throughout the infrastructure lifecycle beyond design and construction.

<u>Recommendations:</u>

- Include a representative from BHO in the 3D Technologies Management Group (see below).
- Before July 1, 2009, appoint an advocacy group to support and promote DTIM's investigation and potential implementation of LiDAR in conjunction with photo-log.
- The 3D Technologies Management Group should keep this initiative on its agenda and take appropriate action, as necessary, to foster infrastructure lifecycle uses of 3D data.

<u>Benefits:</u>

- More efficient right-of-way management from, for example, placement of utilities in clusters more proximal to one another.
- Fewer mistakes and change orders.
- Accurate information more readily available for planning, design, and assessment of projects.
- Increased ease of updating and improvement of on-hand data.
- Greater accountability.
- Various users would benefit from 3D models and DTMs for original ground, design, construction, and post-construction as-builts. Some potential uses include:
  - Utilities: Planning, design, and construction of utility relocations related to roadway projects.

- Local Government: Tracking ownership and easements; notification of property owners and utilities; and planning, design, and assessment of projects.
- WisDOT Traffic Operations: Traffic engineering and safety with data needs including sign location and dimensions; poles – signals and lighting; underground conduit and cable; utility locations; location of pavement surface; edge of travel lane; outside edge of shoulder; structure clearances; and lateral clearances to obstructions, parapets, and other objects.
- WisDOT Maintenance: Permitting, advertising sign placement, roadside management, no-mow zones, scenic easements, roadside design, roadside facilities, shoulder maintenance, and Compass reviews.
- WisDOT Planning: Maintenance and updates to the primary departmental GIS spatial database (State Trunk Network (STN)) and, potentially, the Local Roads GIS spatial database (WISLR).

Relationships with Other Initiatives: Infrastructure lifecycle business functions will make use of original ground DTMs (Initiative 2), 3D design models (Initiative 3), and 3D as-builts and inspection data (Initiative 5). Planning and utilities data are inputs to the design process (Initiative 3).

Lead Group: 3D Technologies Management Group (see below).

DEPENDENCIES AMONG INITIATIVES AND GOALS

Relationships among initiatives were identified in previous sections of this plan. Some of these relationships are deep enough to be considered dependencies. That is, successes of some of the initiatives, in part or in whole, depend upon attainment of goals within other initiatives. In other cases, there are dependencies among goals within the individual initiatives themselves. These dependencies are considered distinct from the priorities assigned to the goals. For example, a pair of goals might have the same priority even though one of them cannot be met without previous or parallel attainment of the other. Also, the activities recommended to achieve dependent goals can sometimes be carried out in parallel or with overlap in their timelines.

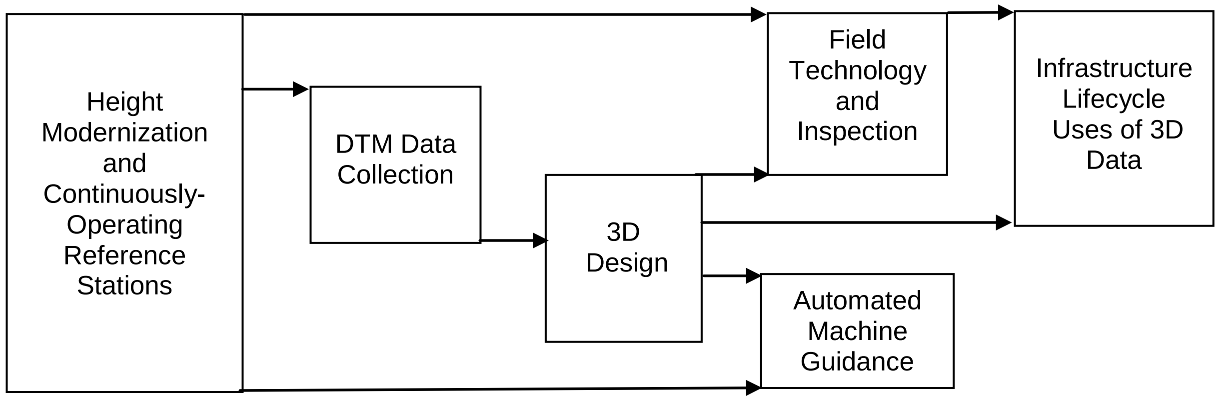
Figure 5 is a high-level depiction of dependencies among initiatives. Figure 6 is a more detailed depiction of primary dependencies among goals within the initiatives. This overall plan has described the goals in Figure 6, as well as other independent, or more moderately dependent, goals not shown in Figure 6.

MANAGEMENT STRATEGY

Implementation Management, Coordination, and Outreach.

Background: Recommendations associated with Initiatives 1-6 call for creation of seven stakeholder advisory groups and three support groups with outlines of charges and timelines for completion of their work. A number of other activities are also recommended to be undertaken by various units within WisDOT.

Issue: The work of these groups and the other activities need coordination, support and advocacy, reporting mechanisms, and means for outreach.



NOTE: An arrow indicates that if goals of the antecedent initiative are not met, then benefits of the subsequent initiative will be diminished.

Figure 5.
Initiative Dependency Diagram

Recommendations:

- Appoint a 3D Technologies Management Group, chaired by a bureau director, that keeps abreast of and coordinates the activities recommended in this plan, provides a reporting structure for the recommended groups and activities, keeps upper-level management informed of progress, advocates for the overall effort, and develops outreach mechanisms to keep the broader design and construction communities aware of and involved in the recommended activities.
- The Management Group should include at least one representative from each of the six initiatives.
- This implementation plan should be revisited and updated at least annually by the Management Group.

Timeline: The recommended 3D Technologies Management Group should be appointed no later than July 1, 2009. The Group should remain functional until completion of the activities recommended within this plan.

Responsible Party: The Director of the Bureau of Project Development for appointment of 3D Technologies Management Group.

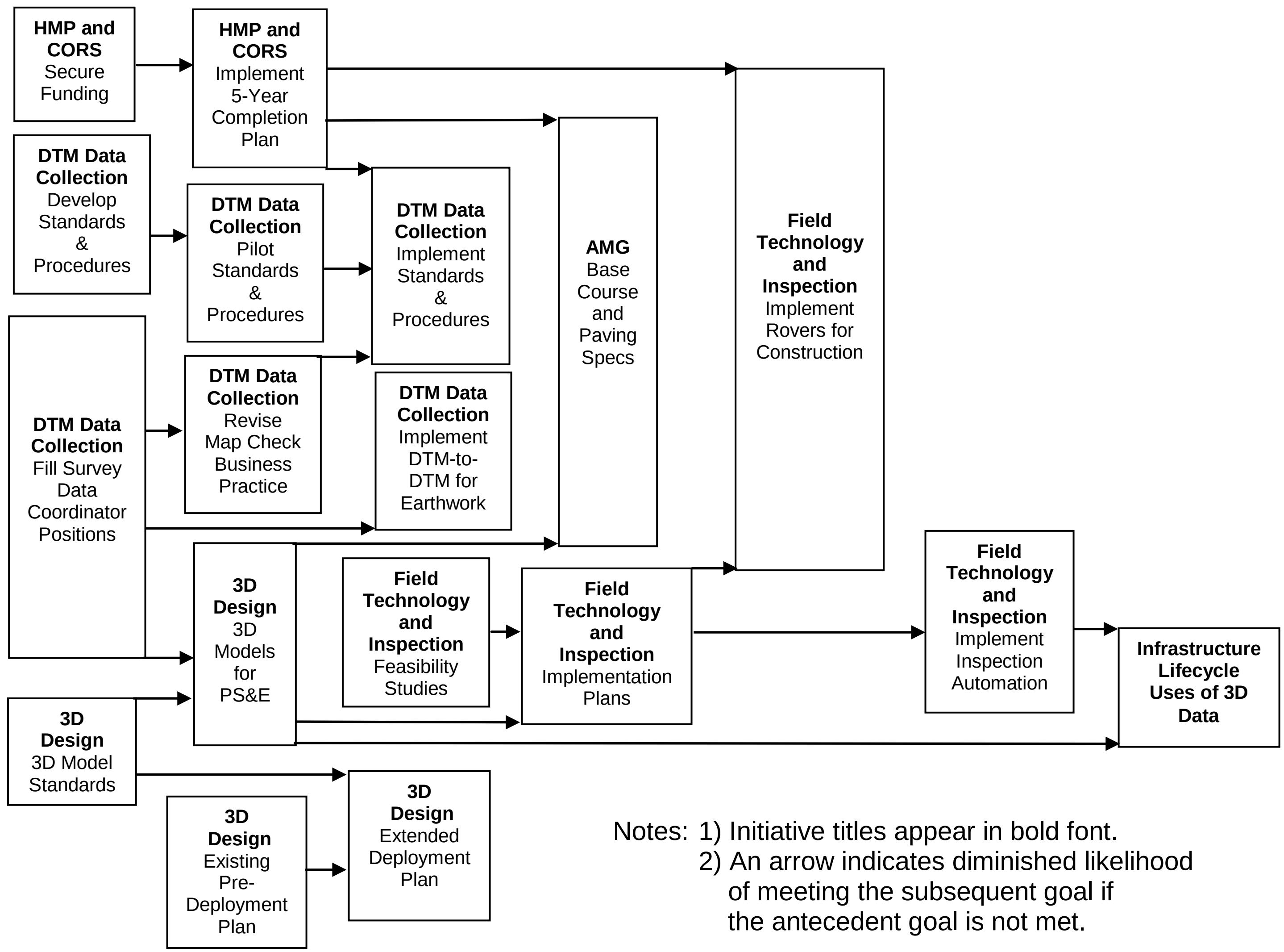
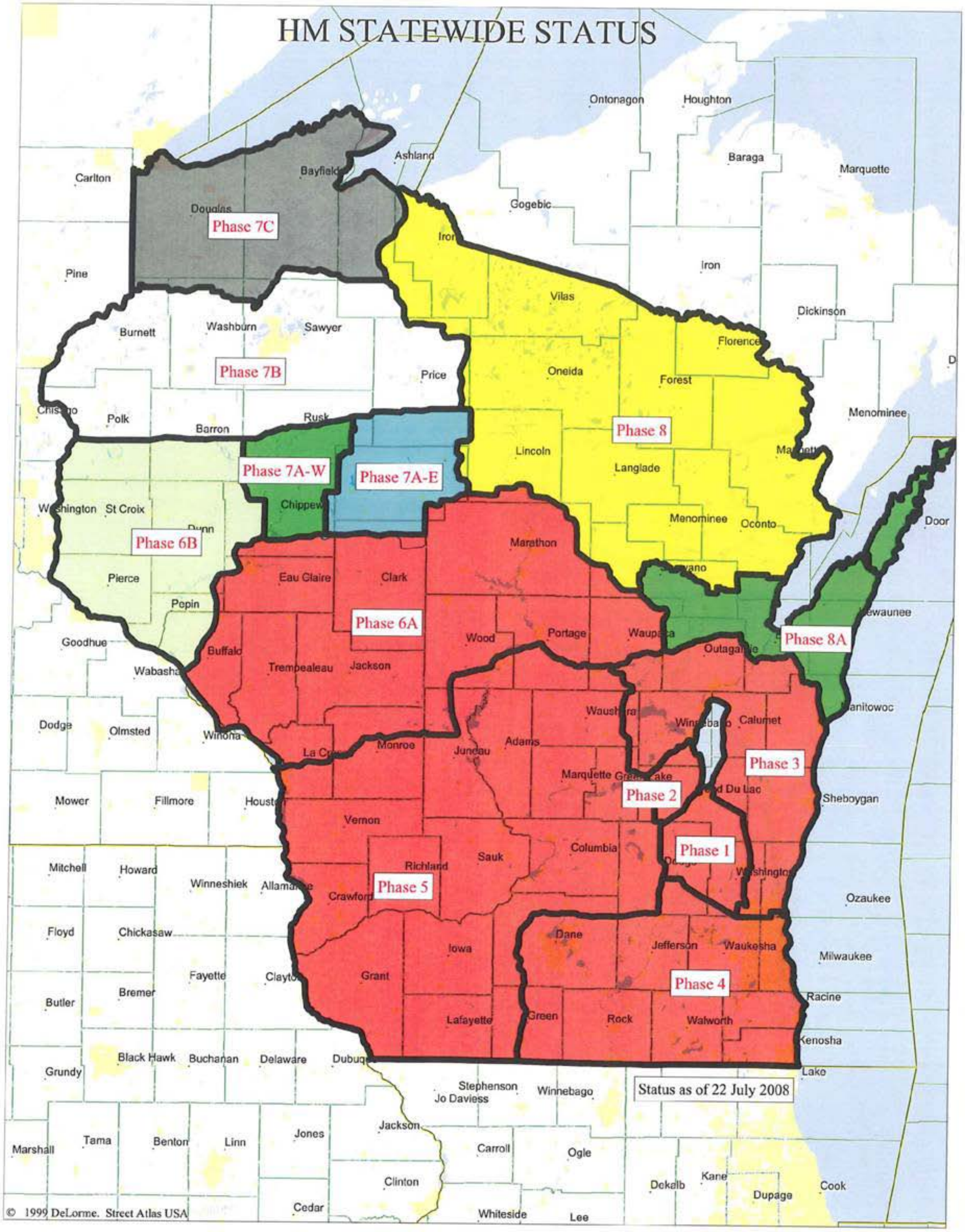


Figure 6.
Initiative and Goal Dependency Diagram

Appendix A.

Map of Height Modernization Program (HMP) Phases



HM STATEWIDE STATUS
Phase 7C
Phase 7B
Phase 8
Phase 7A-W
Phase 7A-E
Phase 6B
Phase 6A
Phase 8A
Phase 3
Phase 2
Phase 1
Phase 5
Phase 4
Status as of 22 July 2008
Ontonagon
Houghton
Baraga
Marquette
Carlton
Bayfield
Ashland
Douglas
Gogebic
Pine
Iron
Vilas
Dickinson
Burnett
Washburn
Sawyer
Florence
Price
Oneida
Forest
Polk
Barron
Menominee
Lincoln
Langlade
St Croix
Menominee
Oconto
Door
Marathon
Pierce
Eau Claire
Clark
Pepin
Goodhue
Wood
Portage
Buffalo
Trempealeau
Jackson
Outagamie
Wabasha
Dodge
Olmsted
Winona
Calumet
Adams
Juneau
Monroe
Marquette
Mower
Fillmore
Sheboygan
Vernon
Columbia
Sauk
Richland
Mitchell
Howard
Winneshiek
Ozaukee
Floyd
Chickasaw
Dane
Jefferson
Waukesha
Iowa
Milwaukee
Fayette
Grant
Butler
Bremer
Racine
Lafayette
Rock
Walworth
Kenosha
Black Hawk
Buchanan
Delaware
Grundy
Stephenson
Jo Daviess
Winnebago
Lake
Tama
Benton
Linn
Jones
Marshall
Carroll
Ogle
Clinton
Kane
Dekalb
Cook
Dupage
Cedar
Whiteside
Lee
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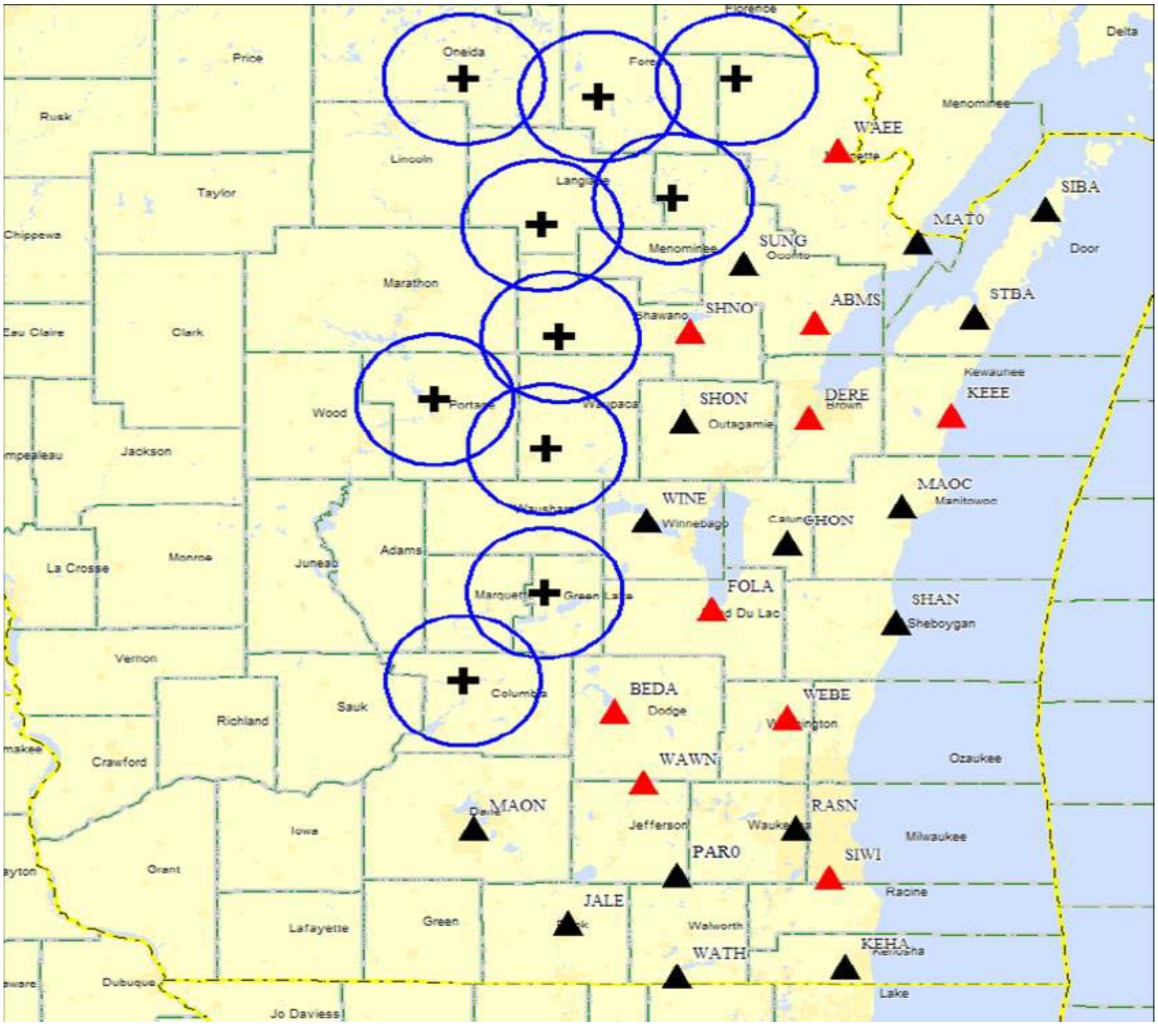
Appendix B.

Continuously-Operating Reference Stations (CORS) Zones 1 and 2



Triangles: Zone 1 Crosses: Zone 2

The Construction and Materials Support Center (CMSC) is housed in the Department of Civil and Environmental Engineering on the University of Wisconsin-Madison campus. The CMSC was formed in partnership with the Wisconsin Department of Transportation (WisDOT) to focus on implementing research findings within the department and other local, state, and federal transportation agencies. In addition, the CMSC functions as a service and applied research group to deliver timely solutions to construction management and materials engineering problems for a variety of organizations. The mission of the Center is to develop research implementation strategies and tools to help WisDOT, public agencies, and industry rapidly implement new and relevant technologies throughout the project development process. The Center draws upon university expertise to collaborate with department personnel and the private sector to find solutions to problems, minimize delays to construction, and improve the quality and efficiency in which materials are used throughout the construction process. Emphases areas for the Center are:

- Accelerated construction techniques
- Construction project management
- Innovative project delivery processes
- Materials performance and production

The Center is staffed to conduct research, develop tools and techniques to enhance project cost-control and minimize scheduling delays in project construction, identify methods and processes to accelerate project delivery and construction activities, create strategies for departments of transportation and others to implement new techniques and technologies, assess new construction materials and create project specifications.

Services include training staff on new techniques and processes, developing application guidance tools for inclusion in manuals, and holding workshops and seminars. Academic staff incorporate the field applications and lessons learned into undergraduate and graduate level engineering courses taught at the UW-Madison.

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