AASHTO

SUBCOMMITTEE OF CONSTRUCTION

QUICK REFERENCE GUIDE

FOR THE IMPLEMENTATION OF AUTOMATED MACHINE GUIDANCE SYSTEMS (AMG)

Contents

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QUICK REFERENCE GUIDE

TO THE IMPLEMENTATION OF AUTOMATED MACHINE GUIDANCE SYSTEMS (AMG)

SYNOPSIS OF THIS REPORT

This document addresses the stages of implementing AMG. This report highlights the crux of all the information gathered and is as brief as possible. Each State will need to conduct a series of buy-in meetings, in order to address individual concerns and gather input from each entity involved. This report will go thru the process that a project experiences from conception through completion.

PLANNING

If a project is going to include AMG then the decision will need to be made in the planning stage. Several states have evaluated the criteria for AMG to be included in a project. Below is a list of California DOT's criteria: (Reference 2)

1. Project needs to have a large amount of earthwork or paving,
2. a new alignment ,
3. a good Global Navigation Satellite System (GNSS) available,
4. and/or a design based on Digital Terrain Modeling (DTM)

SURVEY

Survey data that is collected will establish the level of accuracy for a set of project plans. The Cross-sections will need to be collected at closer intervals for this reason. Some state have found that 10 foot interval instead of 50 feet have provided the necessary accuracy for 3D surfacing. Also, for consistency and efficiency a greater emphasis will need to be placed on the naming schema used during data collection.

DESIGN

The Design phase is probably the phase of project development that requires the greatest amount of training. Design Squads that have created two dimensional (2D) plans will now have to translate the plans into 3D files. This modeling can also provide for visualization in public meetings as a side benefit.

If design consultant are being utilized there needs to be language in the contract that stipulates, the deliverable and updates of the deliverable.

Files needed are

1. Coordinate files,(Horizontal alignments, profiles, cross-sections) and
2. background Files,
3. (two dimensional (2D) and three Dimensional (3D) Microstation Files,
4. and Digital Design Model (DDM).

New York uses a naming schema for their files to ensure consistency. (Very effective)

BIDDING PROPOSAL / CONTRACT

BIDDING PROPOSAL

The bidding proposal will contain any Special Provisions concerning the AMG. Also, some states elect to distribute the AMG files at this time. Included in the proposal should be a disclaimer for the files provided by the State Agency on how to resolve discrepancies between data and contract plans, and who is responsible for changes in the electronic data.

CONTRACT

When the contract is signed with all pertinent provisions, a final set of files should be provided to the contractor. Some states may elect not to provide data at the time of bidding and provide that data to the winning bidder only.

FILE DELIVERY SYSTEM

A delivery system need to be implemented to accommodate the transfer of files. List below are some of the means available for file distribution :

- ProjectWize,
- ftp,
- DVDs
- Bidxpress.

Distribution by DVD is the least practical and most time consuming. The other methods allow mass distribution and update with little effort.

CONSTRUCTION

In construction, contractors are the primary users of the AMG system. However, the State Construction Workers will need to know what the limitations are of the new technology. There will be “less wood” in the ground. Staking layout will not require as many points. However, spot checking will be required to determine the level of accuracy.

ADDITIONAL REFERENCES

1. Machine Control Implementation Plan, Minnesota DOT, June 24, 2009

    a. The purpose of this project is to create a Machine Controle Implementation Plan (MCIP) for Mn/DOT. This project is an outgrowth of the Mn/DOT's pioneering experience with machine control on several pilot projects.

2. Guidelines for Implementing, Automated Machine Guidance, California DOT, June 30 2009

    a. http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/AutomatedMachineGuidanceGuidelines7_5_09.pdf

    b. .. guidelines, roles, and responsibilities, provide guidance for Department employees to facilitate contractor use of Automated Machine Guidance (AMG) technology on state highway projects. AMG technology has the potential to reduce time and cost of construction and Department support costs.

3. Implementation of GPS Highway Construction Equipment, University of Wisconsin – Madison, April 2007

    a. http://cmsc.engr.wisc.edu/Vonderohe2007Apr01.pdf

    b. Develop specifications for adoption by WisDOT to allow use of GPS machine guidance in grading operations for selected pilot projects during the 2007 construction season.

4. Best Practices – Machine Control Evaluation, Minnestota DOT, May 15, 2007

    a. http://tig.transportation.org/Documents/BestPractices-MachineControlEvaluation_FinalReport(MnDOT).pdf

    b. This report represents the results of research conducted by the authors and does not necessarily represent the views or policies of the Minnesota Department of Transportation. This report does not contain a standard or specified technique.

5. Machine Control Online

    a. http://www.machinecontrolonline.com/

    b. This website has articles and current information on Machine Control Systems.

6. Project Development Manual, New York, August 2006

    a. https://www.dot.ny.gov/divisions/engineering/design/dqab/dqab-repository/pdmapp14.pdf

    b. The purpose of this appendix is to provide guidance on managing electronic project documents throughout the life of a project until a project's acceptance. During the project development and delivery process many documents, drawings and exhibits are created in electronic format. At NYSDOT multiple program areas work concurrently on projects. Frequently a Design Group will work on part of the project, while another Functional Unit will work at the same time on another part of the project. Sometimes two Regions may need to work together on a project. Electronic project documents need to be stored in a way that all project contributors have access to the most current information at all times, no matter where they are located geographically or organizationally. This is accomplished using ProjectWise.

7. Minnesota DOT Website for GPS Machine Control

    a. http://www.dot.state.mn.us/caes/machine.html

APPENDIX A - DISCLAIMERS

MINNESOTA DOT MACHINE CONTROL DISCLAIMER

Please note that Mn/DOT believes this electronic data to be accurate, but does not guarantee it. The documents originally provided with the contract remain the basis of the contract, and the electronic data being provided is for informational use only in order to assist the contractor with the use of machine control / surveying. Therefore, if use of this data causes an error, any costs to the contractor in time or money to make corrections as a result of this error will not be considered "extra work" as that term is defined in Mn/DOT's "Standard Specifications for Construction, 2000 Edition."

All surveying reference information is contained with this electronic data. If you have any questions on the information being provided, please contact the State's licensed land surveyor on the project, xxx.

ALABAMA DOT MACHINE CONTROL DISCLAIMER

ALABAMA DEPARTMENT OF TRANSPORTATION
Design Bureau
1409 Coliseum Boulevard, Montgomery, Alabama 36110
P. O. Box 303050, Montgomery, Alabama 36130-3050
Phone: 334-242-6178 FAX: 334-269-0826

Bob Riley
Governor

Joe McInnes
Transportation Director

Memorandum

To:

From:

Re:

Attached is a CD containing point files for the use of contractors in their bid preparation. The point files are the station, offset, and the elevation of each vertex shown on the cross sections for the original ground, subgrade, and final grade. The following disclaimer is recommended to accompany each CD:

As a service to bidders ALDOT is supplying electronic files of point station, offset and elevations for the data shown in the cross sections. The files depict the original ground, subgrade, and final grade. The files provided are for assistance in bid preparation only. No representation is made that the electronic information provided is complete or accurate. All bids should be prepared from the plans. If any discrepancies are noted between the plans and this electronic information, the information in the plans supersedes this electronic file. ALDOT will not be responsible for construction claims subsequent to the use of this information.

Please advise if any additional information is needed.

Attachment

Cc: File

ALABAMA DOT ELECTRONIC FILE RELEASE DISCLAIMER

ROBERT BENTLEY
GOVERNOR

ALABAMA
DEPARTMENT OF TRANSPORTATION
CONSTRUCTION BUREAU
1409 COLISEUM BOULEVARD, G-101
MONTGOMERY, ALABAMA 36110
PHONE (334) 242-6216
FAX (334) 264-3727

JOHN R. COOPER
TRANSPORTATION DIRECTOR

ELECTRONIC DRAWING FILE RELEASE

PROJECT: <Project Number> & <County>
<Project Description>

At the request of and as a service to the Contractor, ALDOT is supplying electronic drawing files created during the design of the referenced project. Should the Contractor elect to use the electronic information it is at the Contractor's risk. No representation is made that the electronic information provided is complete or accurate. The electronic drawing files are not intended for use during construction. The project plans supersede the electronic information. The project shall be constructed according to the plans and the direction of the Engineer. ALDOT will not be responsible for any discrepancies between the plans and the electronic drawing files. ALDOT will not be responsible for construction claims subsequent to the use of the electronic information. Any errors in the work due to the use of the electronic information shall be corrected at the expense of the Contractor.

CONTRACTOR: _____

SIGNATURE: _____ DATE: _____

PRINTED NAME: _____

TITLE: _____

Cc: Contractor
<Select Division>
File

APPENDIX B – SPECIAL PROVISIONS / SPECIFICATIONS

DS-09058
(New)

Iowa Department of Transportation

DEVELOPMENTAL SPECIFICATIONS
FOR
PCC PAVING 3-D MACHINE CONTROL

Effective Date
January 19, 2011

THE STANDARD SPECIFICATIONS, SERIES 2009, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

09058.01 DESCRIPTION.

A. This specification contains requirements for slip formed PCC paving using 3-D machine control techniques. Use this specification in conjunction with Sections 2301 and 2526 of the Standard Specifications.

B. The Contractor may use equipment controlled with a PCC Paving 3-D Machine Control System in the construction of the subgrade, subbase, or PCC pavement.

C. Prior to letting, the Contracting Authority will provide available electronic surface models of the roadway design in common file formats. When such models are provided, the Contractor will be responsible for manipulating the provided file formats to make them compatible with the respective equipment and systems being used.

D. The Contractor may use any type of PCC Paving 3-D Machine Control equipment and system resulting in meeting the elevation, cross slope, thickness, and smoothness specification requirements.

09058.02 EQUIPMENT.
Provide equipment to accomplish PCC Paving 3-D Machine Control. Use equipment that generates results meeting quality requirements of the Standard Specifications.

09058.03 CONSTRUCTION.

A. Contracting Authority Responsibilities.

1. For new construction, the Engineer will set the initial horizontal and vertical control points.

2. For reconstruction or PCC overlays, the Engineer will furnish information on existing horizontal and vertical control points.

3. The Engineer will review and approve the proposed surface model within two weeks following receipt of the model.

B. Contractor Responsibilities.

1. When an electronic surface model is not furnished by the Contracting Authority, develop an electronic model providing the minimum design depth of pavement. For PCC overlays, compute an estimated quantity of overlay concrete based on pavement profiles prior to start of paving and the electronic model. This quantity will serve as the estimated concrete quantity for the project and must be approved by the Engineer prior to start of construction.

2. Provide a digital terrain model (DTM) of the subgrade surface from top of shoulder to top of shoulder for construction grading.

3. Provide an electronic file such as a D45 file, or equivalent, identifying x, y, and z coordinates for shoulder and pavement edges as well as the pavement centerline based on project alignments and elevations.

4. Make available to the Engineer a rover for use during paving operations. Provide training on the use of the rover to allow the inspector to make random checks of subgrade, subbase, and pavement station locations and surface elevations. The rover will remain property of the Contractor.

5. When total stations are used for the PCC Paving 3-D Machine Control system, set additional control points at maximum 500 foot (150 m) intervals on each side of the pavement. Furnish x,y,z coordinates and station offset information for each point.

6. Set paving hubs with cut/fill to finish pavement elevation at A, B, C, and D points along superelevated curve transitions and at station equation locations. Additional paving hubs will not be required for mainline pavement.

7. Prior to start of construction, provide the Engineer a maximum of 8 hours training on PCC Paving 3-D Machine Control equipment and system.

8. Submit required information to the Engineer for approval at least three weeks prior to start of work.

9. If necessary, check and recalibrate PCC Paving 3-D Machine Control system daily prior to start of work. Include equipment type, control software manufacturer, and software version in the submittal.

09058.04 METHOD OF MEASUREMENT.
None.

09058.05 BASIS OF PAYMENT.

A. Payment for PCC Paving 3-D Machine Control will be lump sum contract price.

B. Payment is full compensation for equipment, preparation of electronic files, survey, training, and all other items required for using PCC Paving 3-D Machine Control System.

C. Additional payment or contract period extensions will not be made for:

1. Delays due to late submittal of electronic files,

2. Placement of paving hubs and stringline due to failure of the PCC Paving 3-D Machine Control System,

3. Rework resulting from failure or errors in using a PCC Paving 3-D Machine Control System, or

4. Additional quantities placed resulting from using a PCC Paving 3-D Machine Control System.

DS-09018
(New)

Iowa Department of Transportation

DEVELOPMENTAL SPECIFICATIONS
FOR
GLOBAL POSITIONING SYSTEM MACHINE CONTROL GRADING

Effective Date
October 20, 2009

THE STANDARD SPECIFICATIONS, SERIES 2009, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

09018.01 GENERAL.

A. This specification contains requirements for grading construction using Global Positioning System (GPS) machine control grading techniques. Use this developmental specification in conjunction with Section 2526 of the Standard Specifications.

B. The Contractor has the option of using grading equipment controlled with a GPS machine control system in the construction of the roadway embankment.

C. The plans indicate the areas of the project where the Contracting Authority is providing electronic surface models of the roadway embankment construction. The Contractor may construct remaining areas with conventional construction survey techniques. The Contractor may, at no additional cost to the Contracting Authority, build the required surface models to facilitate GPS machine control grading for those areas.

D. The Contractor may use any type of GPS machine control equipment and systems that results in achieving the existing grading requirements. Convert the electronic data provided by the Contracting Authority into the format required by the machine control grading system.

09018.02 EQUIPMENT.
Provide all equipment required to accomplish GPS machine control grading. Use equipment that generates end results meeting the Standard Specifications.

09018.03 CONSTRUCTION.

A. Contracting Authority Responsibilities.

1. The Engineer will set the initial horizontal and vertical control points in the field for the project as indicated in the contract documents.

2. The Engineer will provide the project specific localized coordinate system. The control information utilized in establishing the localized coordinate system, specifically the rotation, scaling, and translation can be obtained from the Engineer upon request.

3. The Contracting Authority will make available the following electronic data files with the proposal form. This information is available for a fee at: http://www.ia.bidx.com/main/index.html. The Contractor will be required to purchase an online account to obtain the electronic data. The files that are made available were originally created with the computer software applications MicroStation (CADD software) and GEOPAK (civil engineering software). The data files will be in the native formats and other software formats as described below. Perform necessary conversion of the files for the selected grade control equipment.
   a. CAD Files:
      - GEOPAK TIN files representing the design surfaces.
      - GEOPAK GPK file containing all horizontal and vertical alignment information.
      - GEOPAK documentation file describing all of the chains and profiles.
      - MicroStation primary design file.
      - MicroStation cross section files.
      - MicroStation ROW data file.
      - MicroStation photogrammetry and text files.
   b. Machine Control Surface Model Files:
      - ASCII format.
      - LandXML format.
      - Trimble Terramodel format.

      Note: TIN files and surface model files of the proposed finish grade include the topsoil placement where required in the plans.

   c. Alignment Data Files:
      - ASCII format.
      - LandXML format.
      - Trimble Terramodel format.

   No guarantee is made that the data systems used by the Engineer will be directly compatible with the systems the Contractor uses.

   Apply Article 1105.04 of the Standard Specifications with the additional clarification that information shown on the plans governs over the provided electronic data.

   The electronic information is not to be considered a representation of actual conditions to be encountered during construction. Providing the Contractor this information does not relieve the Contractor from the responsibility of making an investigation of conditions to be encountered, including but not limited to site visits, and basing the bid on information obtained from these investigations and the their professional interpretations and judgment. The Contractor assumes the risk of error if the information is used for any purposes for which the information was not intended.

   Any assumptions the Contractor makes from this electronic information is at their risk.

   The Contracting Authority will develop and make available electronic data to the Contractor for review as part of the contract documents. Ensure the electronic data will function in the machine control grading system.

4. The Engineer may perform spot checks of the machine control grading results, surveying calculations, records, field procedures, and actual staking. If the Engineer determines the work is not being performed in a manner that will assure accurate results, the Engineer may order such work to be redone, to the requirements of the contract documents, at no additional cost to the Contracting Authority.

B. Contractor's Responsibilities.

1. Provide the Engineer with a GPS rover (with the same capabilities as units used by the Contractor) for use during the duration of the contract. At the end of the contract, the GPS rover unit will be returned. Provide the Engineer 8 hours of formal training on the Contractor's GPS machine control systems.

2. Review and apply the data the Contracting Authority has provided to perform GPS machine control grading.

3. The Contractor bears all costs, including but not limited to the cost of actual reconstruction of work, that may be incurred due to errors in application of GPS machine control grading techniques. Grade elevation errors and associated quantity adjustments resulting from the Contractor's activities are at no cost to the Contracting Authority.

4. Convert the Contracting Authority's electronic data into a format compatible with the machine control system.

5. Manipulation of the Contracting Authority's electronic data is taken at the Contractor's own risk.

6. Check and recalibrate, if necessary, the GPS machine control system at the beginning of each work day.

7. Meet the same accuracy requirements as conventional grading construction as detailed in the Standard Specifications.

8. Establish secondary control points at appropriate intervals and at locations along the length of the project and outside the project limits and/or where work is performed beyond the project limits as required at intervals not to exceed 1000 feet (300 m). Determine the horizontal position of these points using static GPS sessions or by traverse connection from the original baseline control points. Establish the elevation of these control points using differential leveling from the project benchmarks, forming closed loops. Provide a copy of all new control point information to the Engineer prior to construction activities. The Contractor is responsible for all errors resulting from their efforts. Correct all deficiencies to the satisfaction of the Engineer at no additional cost to the Contracting Authority.

9. Preserve all reference points and monuments that are established by the Engineer within the project limits. Reestablish reference points that have not been preserved at no additional cost to the Contracting Authority.

10. Set hubs at the top of the finished subgrade at all hinge points on the cross section at 1000 foot (300 m) intervals on mainline and at least two cross sections on the side roads and ramps. Establish these hubs, using conventional survey methods, for use by the Engineer to check the accuracy of the construction.

11. Provide controls points and conventional grade stakes at critical points such as, but not limited to, PC's, PT's, super elevation points, and other critical points required for the construction of drainage and roadway structures.

12. At least one week prior to the preconstruction conference, submit to the Engineer for review a written machine control grading work plan which includes the equipment type, control software manufacture and version, and the proposed location of the local GPS base station used for broadcasting differential correction data to rover units.

09018.04 METHOD OF MEASUREMENT.
None.

09018.05 BASIS OF PAYMENT.

A. Payment for GPS Machine Control Grading will be the lump sum contract unit price.

B. Payment is full compensation for all work associated with preparing the electronic data files for use in the Contractor's machine control system, the required system check and needed recalibration, training for the Engineer, and all other items described in Article DS-09018.03, B.

C. Delays due to satellite reception of signals to operate the GPS machine control system will not result in adjustment to the "Basis of Payment" for any construction items or be justification for granting contract extensions.

S-1 (2011) CONSTRUCTION SURVEYING

This write-up is to be used on all jobs when construction Project surveying is to be done by the Contractor. It is from Tech. Memo. No. 98-18-RWS-01.
REVISED 11/12/03
SP2000-42

The provisions of Mn/DOT 1508 are hereby modified and supplemented as follows:

S-1.1 CONSTRUCTION SURVEYING

(A) Construction Surveying

Construction surveying is defined as setting construction stakes from the control points in order to establish lines, slopes, elevations, and continuous profile grades as necessary for proper control of the work as determined by the Engineer. The Department will set horizontal and vertical control points for the Project as indicated in the Plans. The Contractor shall provide surveying according to Mn/DOT 1508.

Contractor Construction Surveying Supplemental Specification.

For bridge construction, construction staking will include setting:

(1) Working points as shown on the Bridge Layout sheet in the Plans.
(2) One or more bench marks in the vicinity of each substructure unit for the Contractor's reference when excavating for these units.
(3) Grade points for the substructure and superstructure forms.
(4) Beam stool heights as necessary for proper performance of the work.

(B) Contractor

The Contractor's attention is drawn to specifications in Mn/DOT 1504 regarding errors and omissions. The Contractor:

(1) Shall give the Engineer a 14 calendar day written notice before the Contractor needs horizontal and vertical control points and construction surveying. After the start of construction, the Contractor shall give notice according to Mn/DOT 1803.2.
(2) Shall establish other necessary controls, detail dimensions, and measurements as required for proper layout and performance of the work.
(3) Is responsible for all measurements made from the established stakes and marks.
(4) Is responsible for the preservation of all reference points, monuments, control points, stakes, and marks. If the Contractor fails to preserve these items, the Engineer will deduct a charge from moneys due or becoming due the Contractor according to Mn/DOT 1712 for monuments and control points and according to the Department's cost for replacing the stakes and marks.

S-1.2 CONTRACTOR CONSTRUCTION SURVEYING

This work consists of providing Project construction surveying, calculations, documentation, and the as-built Plan.

(A) Construction Requirements

The Contractor shall conduct construction surveying for the Project:

(1) From horizontal and vertical control points established by the Engineer.
(2) According to the Plan.
(3) According to the Mn/DOT Surveying and Mapping Manual.

The Engineer's approval is necessary before the Contractor may depart from these requirements. The Contractor shall also provide documentation, notes, and the as-built Plan to the Engineer.

(B) Surveying Schedule

At the preconstruction conference, the Contractor shall provide the Engineer with a written surveying schedule detailing:

(1) The proposed construction surveying.
(2) A work plan for the construction surveying.
(3) Acceptance of the work and delivery of the as-built Plan.

(C) Engineer

The Engineer:

(1) Will establish horizontal and vertical control points as indicated in the Contract.
(2) May randomly check the surveying, calculations, field notes, and layout work.
(3) May order restaking. If the Engineer determines that the work is not being performed in a manner that will assure proper controls and accuracy, as shown in Section D, Item 3 below, the Engineer will order the Contractor to redo the staking and layout work at no additional cost to the Department. If the Department sustains additional costs in the rechecking, the Engineer may deduct the Department's cost from moneys due or becoming due the Contractor in accordance with the following rates:

	Hourly Rates
Registered Engineer or Licensed Land Surveyor (in field or office)	$60.00 per hr.
4-man crew	$120.00 per hr.
3-man crew	$95.00 per hr.
2-man crew	$70.00 per hr.

(4) Will measure pay quantity items.
(5) Will set the final Right of Way monuments.

(D) Contractor

The Contractor shall:

(1) Provide material, labor, equipment, and documentation necessary for construction surveying and for producing the as-built Plan. Professional Land Surveyor or Professional Engineer, registered in the State of Minnesota, shall directly supervise these Contractor requirements.
(2) Retain a Professional Land Surveyor or Professional Engineer, licensed in the State of Minnesota, to directly supervise the construction surveying.
(3) Perform the construction surveying for the Project and for work by the listed utilities. The Contractor shall start all traverses from a control point and complete all traverses with a ratio of precision of not less than 1 part in 20,000 and a horizontal angle adjustment tolerance for each point in the traverse not exceeding 7 seconds of arc. All stakes shall be set according to the standard construction staking sheets as included in the Plan.
(4) Provide traffic control devices and procedures for surveying and staking operations according to the Section VI of the Minnesota Manual of Uniform Traffic Control Devices.

(2011) MACHINE CONTROL SPECIFICATION MINNESOTA

This Contractor may make use emerging technologies of machine control of the grading equipment for this Project as described herein;

Mn/DOT will furnish the Contractor MicroStation 2D DWG background file and 3D DWG, or TTM files for (*the designer needs to specify which areas and types of work files will be made available for)*, upon Contract approval. These files are created in MicroStation (CADD software) and GEOPAK (Civil engineering software that runs with MicroStation). It shall be the Contractor's responsibility to do any necessary conversion of the provided files for the Contractor's selected grade control equipment.

Mn/DOT shall be given three (3) working days notice prior to delivering any referenced MicroStation / GEOPAK data to the Contractor. Mn/DOT shall have three (3) working days to update any files after the Department approves any Contractor requested changes. Delays due to satellite reception of signals to operate this system will not result in any adjustment to the "Basis of Payment" for any construction items or to Contract time.

{use the following ONLY if there is GPS}
Systems that have been approved are:

Trimble GPS system (SiteVision Office)
TOPCON GPS system (3D-GPS+)

The Contractor may request approval of another system, but use will only be approved if the Survey Equipment-Machine Control System will work with the data in the form Mn/DOT currently produces.

{use the following ONLY if there is NO GPS and a robotic total station will be required}
The machine control equipment utilized on this Project shall utilize a robotic total station for control. The Contractor shall be required to provide a robotic total station for control for the State's use during their inspection and record keeping for this Project. This may be the same unit as utilized for the Contractor's machine control or an additional unit. The actual machine control may also require more than a single unit. The State's usage shall be coordinated between the Engineer and the Contractor to minimize the number of units required.

Mn/DOT believes the electronic data it will provide is accurate, but does not guarantee it. The documents originally provided with the Contract remain the basis of the Contract, and the electronic data being provided is for informational use only in order to assist the Contractor with the use of machine control. Therefore, if use of this data causes an error, any costs to the Contractor in time or money to make corrections as a result of this error will not be considered "extra work".

The system equipment will remain the property of the Contractor.

All machine control work shall be considered incidental to the grading work for which no direct payment will be made.

Use the following if Machine Control will not be supported by Mn/DOT.
(2011) MACHINE CONTROL

This Contractor may make use emerging technologies of machine control of the grading equipment for this Project. Mn/DOT does not intend to share models with the Contractor but will provide basic files.

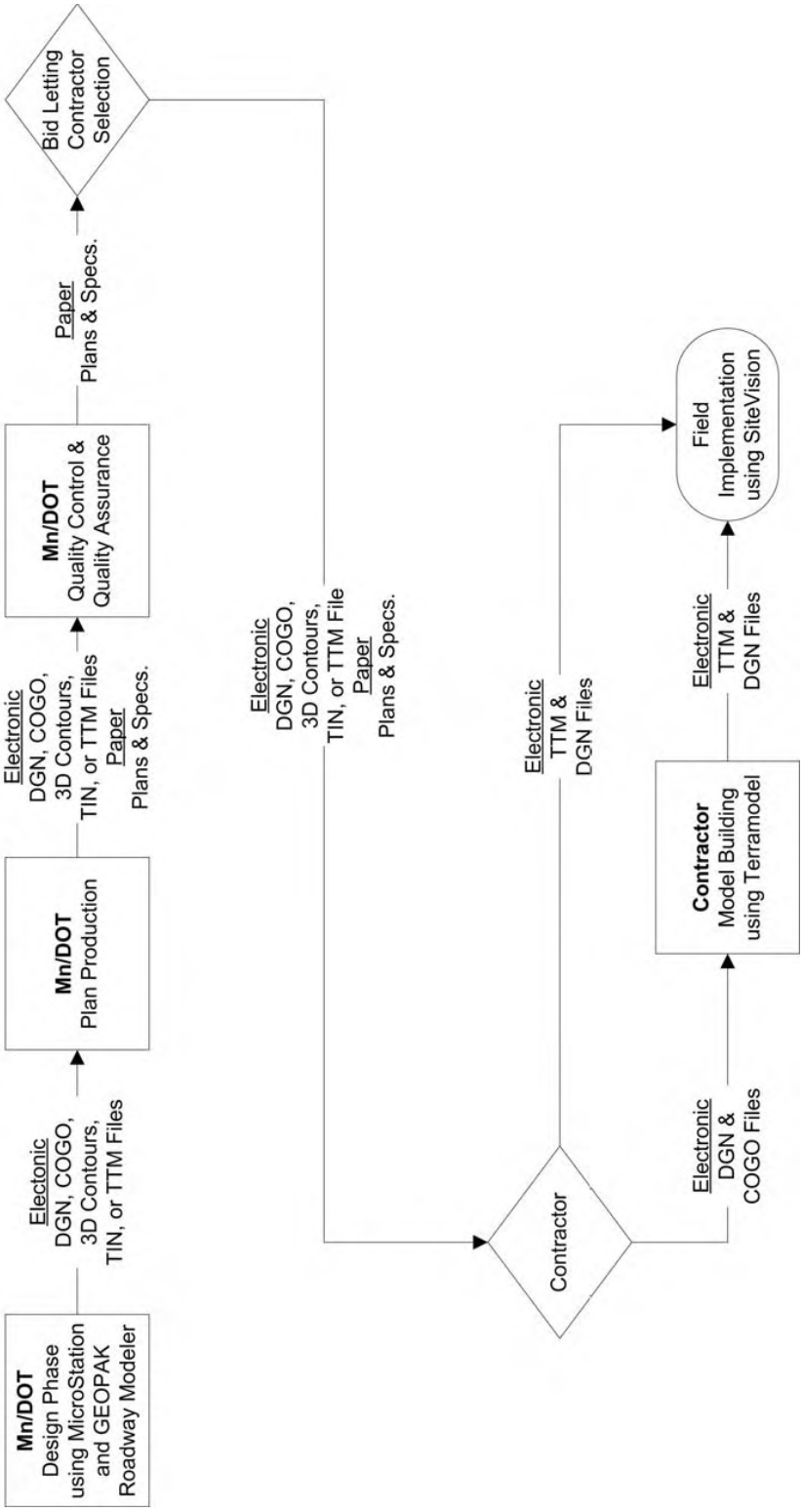
(2011) MACHINE CONTROL
The Contractor is hereby advised that this Project is located in an area of the State that does not have adequate GPS reception to support the use of GPS technologies

Changes made on Nov. 16, 2005
As a result of discussions at Machine Control Classes: changing 72 hour notice to 3 working days, indicating that basic files will be provided not models;

APPENDIX C – DELIVERY SYSTEMS

MINNESOTA DOT WORK FLOW FOR MACHINE CONTROL DELIVERY

(REFERENCE 4)



NEW YORK DOT FOR MACHINE CONTROL DELIVERY

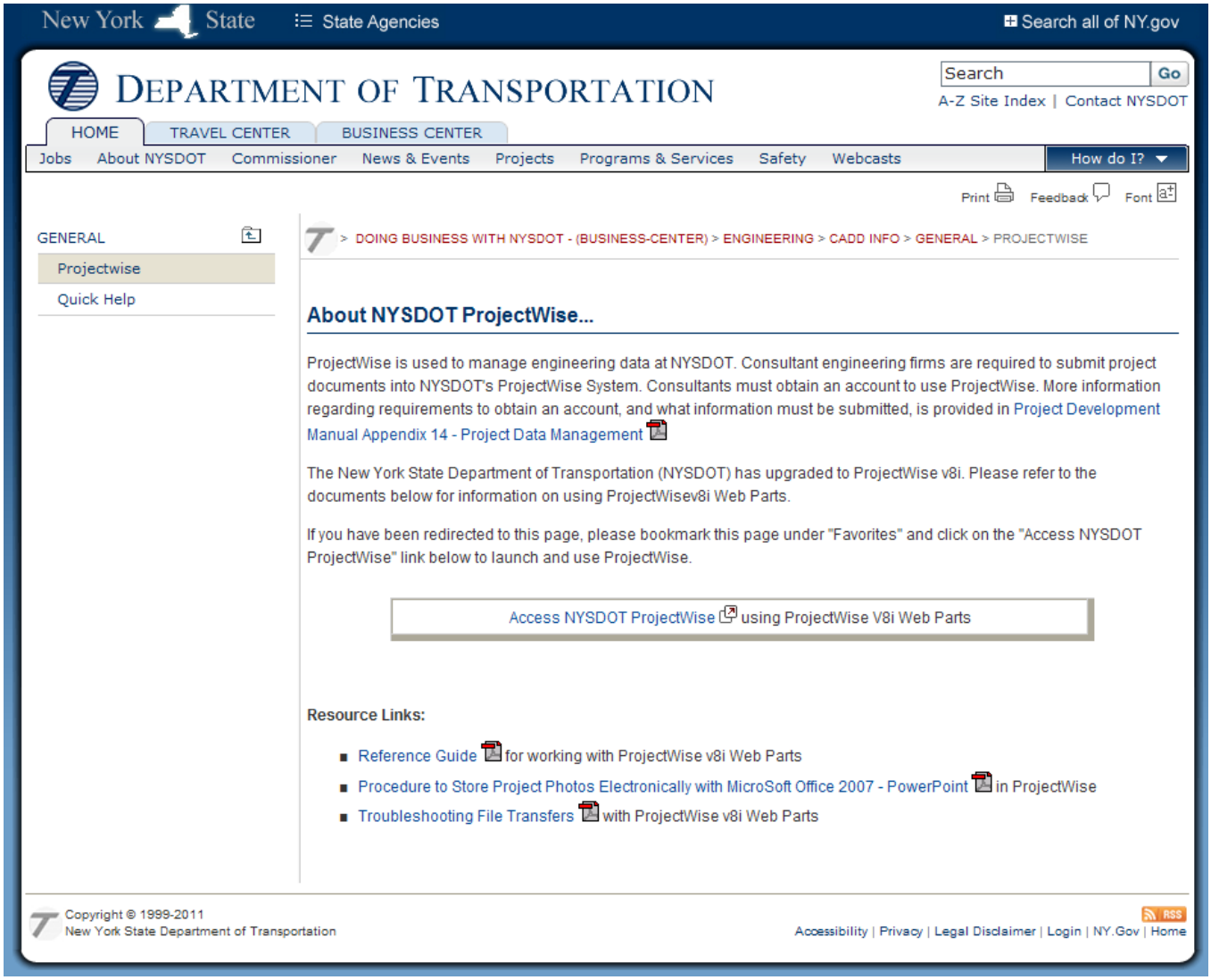
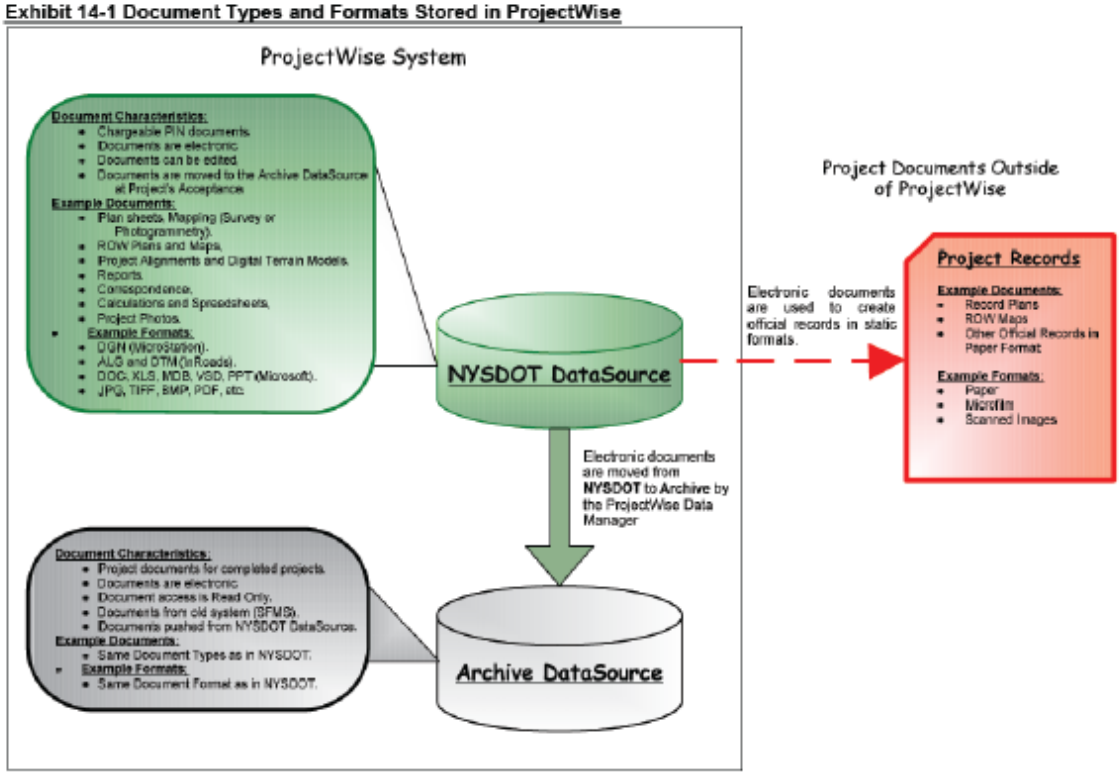
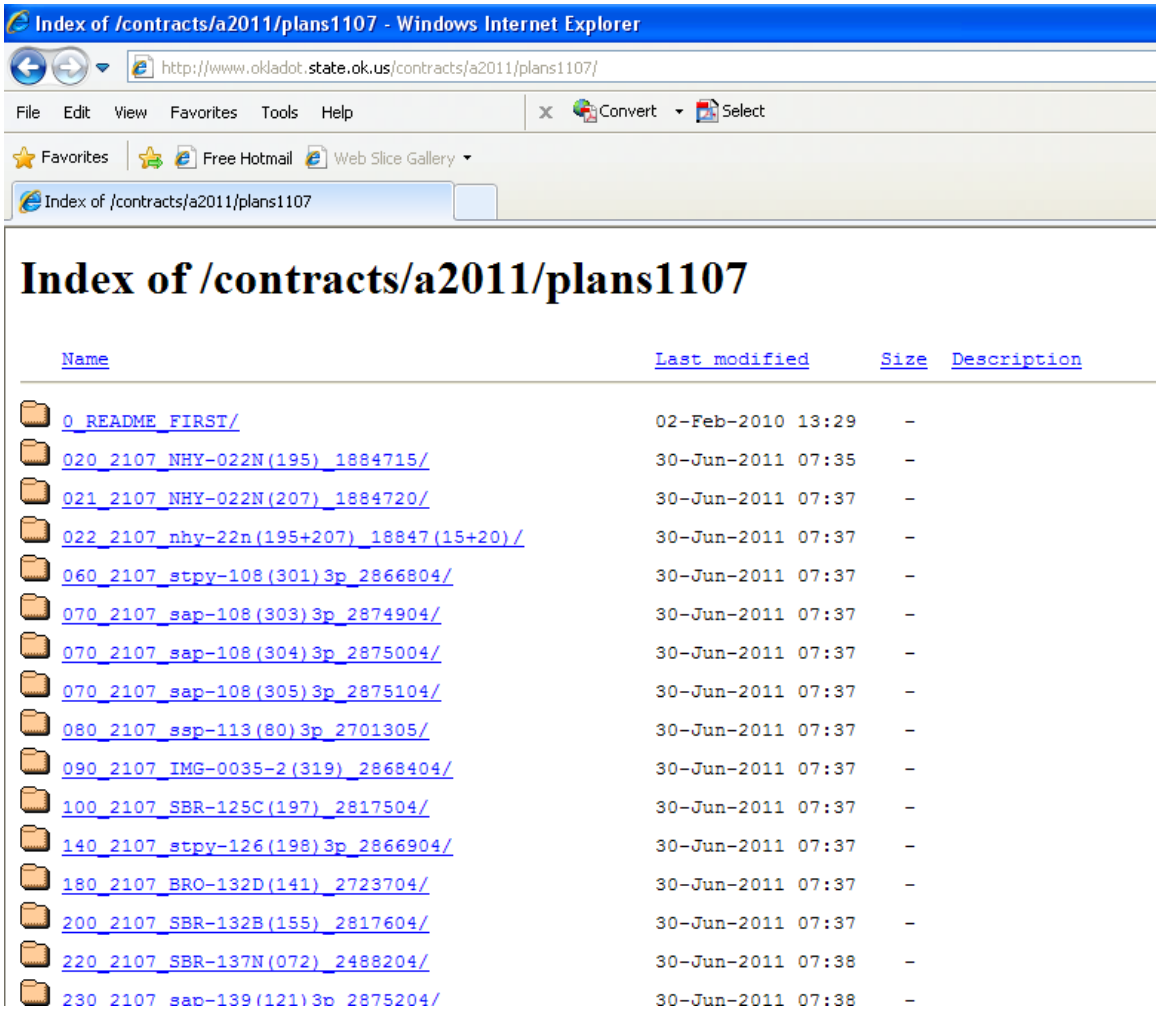


Exhibit 14-1 Document Types and Formats Stored in ProjectWise



https://www.nysdot.gov/divisions/engineering/design/dqab/dqab-repository/pdmapp14.pdf

FTP EXAMPLE DOT FOR MACHINE CONTROL DELIVERY



BID EXPRESS DOT FOR MACHINE CONTROL DELIVERY

The Bid Express service allows the agency to:

- Receive sealed, secure, digitally signed bids
- Receive bid bond verification electronically
- Instantly communicate with your bidding community
- Immediately distribute updated bid data
- Significantly reduce bid management duties and bid processing times
- Broaden your bidding audience
- Eliminate redundant data entry and careless errors
- Interface with Appia software for easy integration of capital improvement program management and Internet bidding
- **Offer plan sheets and bid related documents online**
- Publish bid tab data
- Implement the Small Business Network to improve communications between primes and DBEs

MINNESOTA FILE TYPES

TIN FILES AVAILABLE FROM PROJECT MODELS:

The following TINs are available assuming no retaining walls and no match lines.

1. Top of proposed finish grade from tie down point to tie down point.

2. Grading grade between intersection with inslope for either ditch or a tie slope.

3. Bottom of topsoil from shoulder p.i. (or berm p.i.) to tie down point. This uses either tie slope or ditch.

Note: Ideally, we would prefer items 2 and 3 merged, so we have one TIN for the machine control. I have seen results that have 2 and 3, but no merged one to date.

4. Aggregates – correspond to the limits of the main line pavement (i.e. no turn lanes) so generally 2-12' lanes or 4-12' lanes, whatever corresponds to the shaping. We provide top of pavement, however, the machine operator can dial in an offset, so they can get whatever depth they want for aggregates, or multiple layers, if desired, from one TIN.

5. If there are intersections, we follow thru the control alignment and stop at the edge of the shaping. The first project model at Willmar (down by Melvin's) had an algorithm that warped in the intersections, however, that was missing in this year's model. They claim it will be back in, but haven't seen.

BACKGROUND FILES:

We provide alignment, lane lines, edge of pavement (including turn lanes), ditch and tie slope break at clear zone. This file is used simply as point of reference for the operator and is in 2D only. Provided as a DWG or DXF using the File > Save as option in MS V8. In the case of ponds, we provide the hull (where the pond intersects ground) and a nearby alignment or distinguishable points of reference.

APPENDIX D – OUTLINE OF STATE'S IMPLIMENTATION

Page 15-16 of Machine Contrl Impletmentation Plan

Overview of the Process to Create the Implementation Plan

In order to create this Machine Control Implementation Plan, the URS team performed the following steps:

1. **Best Practices Evaluation Report Review**: Reviewed the „Best Practices – Machine Control Evaluation Report", created for Mn/DOT and dated May 15, 2007. After the review was completed, the URS team in June 2008, summarized that report, including what is pertinent to create a „Machine Control Implementation Plan". That report is available upon request.
2. **Kickoff Meeting** (See Appendix D): Held a „Machine Control Implementation Plan" Kickoff Meeting, in January 2009. Mn/DOT staff with machine control experience attended the meeting. The meeting"s purpose was to discuss and identify machine control issues, problems and solutions.
3. **Questionnaire and Responses** (See Appendix C): Based upon questions raised in the Kickoff Meeting, the URS team created a questionnaire, in January 2009, and emailed it, in February. During February and March, the responses were reviewed and, in some cases, followed up with phone interviews. The emailed questions were designed to further clarify issues raised in the kickoff meeting. They were emailed to attendees who raised the questions and to individuals with machine control experience in other states.
4. **Responses Grouped into Categories** (See Appendix D): Following receipt of the replies, in March and April the responses were summarized and grouped into major categories of „management", „project delivery process" and „other". The project delivery category was further broken into sub-categories of scoping, survey, design, and construction. Each of these sub-categories had various steps. For example „design" was broken into „3D design", build model", „criteria" and „training" steps.

For several of these categories, near-term and long-term strategies were identified in the responses. In some categories, the implementation plan identifies that more information is needed. In some cases, there appears to be a „gap", which the plan also identifies.

One example of a near term and a long-term strategy is in model creation. The machine control team appeared to be universal in the opinion that Mn/DOT „should be designing in 3D" and that Mn/DOT „should be creating machine control models". However, 3D design is a „long term" Mn/DOT strategy. Therefore in the short term, Mn/DOT can use its current 2D design capability potentially add more cross sections to its design at key transition point and possibly stations every ten feet. In addition, also in the short term contractors can continue to create models.

Model creation by contractors also appears to highlight a „gap". It appears that no QC/QA process is in place to check the contractor created model. Another example „gap" is that

apparently no QC/QA process is inplace to check if machine control models imported into the two major equipment vendors produce the same field results.

5. **Consensus Summary of Responses** (See Appendix A)**:** Before finalizing the implementation plan recommendations, the URS team analyzed the responses and 24

organized them into groups „consensus", „contention", and „new insights". The purpose of

this organization was to identify strategies, where needed, to overcome roadblocks to machine control implementation.
One example of „consensus" is the need for a machine control champion high in Mn/DOT to demonstrate support for machine control across the organization. An example of „contention" is the question of using machine control for fine grading. The report summarized its findings regarding the accuracy of machine control in order to identify a strategy to „resolve" this issue. One potential strategy is a survey rover supplemented by QC/QA to assure and to check machine control accuracies. An example of „new findings" is the observation that machine control may ultimately be most beneficial to a project in „precise material management" for the contractor.
6. **Implementation Plan Recommendations**: With the information collected and organized above, the machine control implementation plan was created. It identifies and recommends teams, steps, and timeframes to enact it. For example, it recommends the creation of internal and external machine control teams as well as a communication team. In addition, the memberships, roles, goals, leadership and frequency of meeting are identified also identified.
Next steps are recommended as well as timeframes. The steps are assigned to each team and they will be grouped into scoping, survey, design, and construction categories.

Title: **GUIDELINES for IMPLEMENTING AUTOMATED MACHINE GUIDANCE (Revised June 30th, 2009)**

Purpose

These guidelines, roles, and responsibilities, provide guidance for Department employees to facilitate contractor use of Automated Machine Guidance (AMG) technology on state highway projects. AMG technology has the potential to reduce time and cost of construction and Department support costs.

This document supersedes the 2005 **"INTERIM GUIDELINES FOR USE OF MACHINE GUIDANCE TECHNOLOGY**". These guidelines were updated based on lessons learned from the Brawley Bypass Stage 2 project, and other projects from around the state. They apply throughout the project initiation, design, and construction phases of project delivery.

Background

Automated machine guidance, also know as machine control, is a technology that uses positioning devices, singly or in combination, such as Global Navigation Satellite Systems (GNSS), total stations, or rotating laser levels to determine the real time X, Y, and Z position of construction equipment and compare the position against a digital design model (DDM) stored in an onboard computer. A computer display shows the operator several perspectives and delta values of his position compared to the design surface.

For this document, the term *electronic design data* includes horizontal alignments, profiles, cross-sections, slope stake notes, two dimensional (2D) and three dimensional (3D) Microstation dgn files, DDMs, and original ground digital terrain models (DTM).

AMG technology became feasible with the development of GNSS Real Time Kinematic (RTK) techniques, robotic total stations, rotating lasers, and advances in computer technology. AMG is used in the mining industry and increasingly for construction projects in both public and private sectors. Reported benefits of this new technology are greater production, fewer grade checkers needed, greener construction, greater safety, less rework, and less survey staking. AMG is now an everyday tool used by contractors who invest in it for safety, productivity, and to stay competitive.

A Caltrans AMG committee was formed in 2004 to explore the new technology. The committee Published Interim Guidelines for use of AMG Technology in 2005. At that time, a pilot was proposed, and the Brawley Bypass Stage 2 project in District 11 was selected. The pilot was incorporated into the Governor's Go California Industry Capacity Expansion (GO CA ICE) program. Construction was delayed due to funding and started in June 2008. On March 25, 2009, a meeting was held in San Diego between the Department and contractors to capture lessons learned from the Brawley project.

Project Selection Criteria

Not every project will be suitable for AMG and it is not mandatory. In general, projects with the following characteristics will be the best candidates for this technology:

☐ Large amounts of earthwork or paving.

☐ New alignments.

☐ A good GNSS environment for receiving satellite signals or enough line of sight for successfully using total station controlled systems.

☐ A design based on an accurate Digital Terrain Model (DTM).

Some conditions that limit or exclude the use of AMG are:

☐ Widening with narrow strip additions.

☐ Designs, such as overlays, which are not based on an existing DTM.

☐ Designs that do not exist in a 3D digital environment.

☐ Structures.

☐ Projects that are under a tree canopy, in narrow canyons, or next to tall buildings that interfere with GNSS signals. (*This limitation only applies when GNSS is used to position equipment.*)

☐ Design difficulties that would prevent the creation of an accurate and complete DDM.

Project Initiation Document (PID) Phase

At PID the project should be evaluated to determine if it is suitable for AMG construction techniques. If the project meets AMG criteria, a 3D design should be included in the workplan and scoping documents. Designing using a 3D workflow should start at the beginning of the project to create the needed files. A 3D workflow typically requires more work upfront and resource requirements need to be planned accordingly. However, overall reduction of design and construction costs should be realized later. The 3D workflow will produce files to enable the Project Development Team (PDT) to visualize potential impacts and promote intense collaboration during the planning and scoping process. Discovering design errors by inspection of the 3D DDM can potentially reduce Contract Change Orders (CCOs).

PID Phase Roles and Responsibilities

Planning/Design

☐ Evaluate the project for AMG suitability and 3D design workflow.

CADD

☐ Assist Design as requested with 3D modeling and data conversion.

Surveys

☐ Evaluate the project for GNSS satellite signal environment.

Preliminary Engineering and Design Phase

Project Engineers (PE) currently produce a variety of 2D bid documents. Cross-sections were made mandatory in 2004 and the Survey File requirements were updated in 2008. Designers are not required to develop a complete 3D DDM for the bid package. However the design should include all the 3D elements needed to build a complete DDM of the project. Contractors have stated that they prefer to build their own DDMs based on available design elements. Small details such as gore areas, side roads, curb returns, etc. should be done in 3D. Edits done to the design on slope stake notes should be eliminated.

Electronic design data that contractors will need are horizontal alignments, profiles, cross-sections, slope stake notes, 2D and 3D Microstation dgn files, original ground digital terrain models (DTM), and contour grading areas. On past projects, contractors have prepared their own earthwork grading and/or paving DDMs by hand entering data from bid plans and slope stake notes. This creates extra work for contractors and increases the risk of mistakes.

Complicated at-grade intersections may require more detailed design information to adequately create a surface. CADD has developed procedures and workflows for designing difficult intersections. A "read-me" file shall accompany the delivered electronic design data documenting the naming conventions.

In some instances, the use of the AMG may require conversion of electronic design data to another format. Design will only convert data into those available options currently within the roadway design software. The PE should work with the District, and/or HQ Surveys and CADD staff to assist in the conversion of the data.

Project control set by surveys for AMG should be established alternating on each side of the route at ½ mile intervals. Elevation values are critical because GNSS can propagate errors over long distances. GNSS real time networks (RTNs) are generally not used by contractors because of latency issues on fast moving equipment. Contractors are establishing GNSS base stations on the project.

Design Phase Roles and Responsibilities

Design

☐ Evaluate the project and if appropriate update the workplan to include 3D workflows from the start.

☐ Develop, at a minimum, horizontal alignments, profiles, and cross-sections for the project as required by Appendix QQ of the Project Development Procedures Manual (PDPM).

☐ Initiate the approval of the AMG NSSP by Design, Surveys, and Construction.

CADD

☐ Assist Design as requested with 3D Design workflow. When asked, the Office of CADD and Engineering GIS Support will provide direct aid and assistance to the Department's Design engineers with the creation of electronic design data on AMG candidate projects. This support will be made available at the engineer's site or remotely. The Office will coordinate between the Department's engineers and roadway design software vendors to report software malfunctions and seek immediate solutions.

Surveys

☐ Evaluate the project for satellite signal environment and communicate with Design.

☐ Assist Design with data format conversion as expertise permits.

☐ Review the 3D DDM with Design as expertise permits.

☐ Identify project survey control for Construction Staking Control Diagram sheet in project plans.

Preparing Bid Package

Contractors routinely ask for electronic design data from the Department during advertisement. AMG technology is now an industry norm and our contractors will be increasingly dependent on electronic design data for bidding. Providing electronic design data during advertisement allows contractors to produce estimates faster and consider different staging scenarios. Contractors say this reduces their risk and should produce better bids. Design errors can be found by the contractor before construction starts and communicated to the Department. If the electronic design data is given to contractors at start of construction there is less time to find errors.

A Non-Standard Special Provision (NSSP) has been developed to deliver electronic design data to contractors at advertising or after award. At advertising the electronic design data is included in the supplemental project information. After award the contractor submits a request for the electronic design data to the Engineer within 15 days of contract approval.

If the AMG NSSP was not used a CCO can be used to include the electronic files as a contract document. The CCO contains language stating the contractor cannot use the electronic files as a basis for claims and, in case of conflict, bid plans govern over the digital files. See example CCO language below.

Construction

Changes to the design during construction are frequently handled with staking requests and or 2D redesigns. The redesign will not always be available in a 3D format. When electronic design data is not available, Design will work with Surveys and Construction to provide hard copy data for the contractor's use. Contractors will be completely responsible for updating DDMs they create.

Section 5-1.07, "Lines and Grades," of the Standard Specifications applies to projects constructed with AMG technology. Policy and guidelines for inspection of contract work and establishment of lines and grades are covered in the Construction Manual and Surveys Manual. Survey stakes will not be eliminated, as some will always be needed for inspection and for contractor GNSS checks. At the pre-job meeting Construction, Surveys, and the contractor should discuss reducing the number of stakes set. Past experience shows that fewer slope stakes are required by the contractor. Other types of stakes can be reduced if agreed upon by the Department and the contractor.

The contractor must submit sufficiently detailed and timely staking requests to facilitate adequate inspection by the Engineer, even though the contractor may not need the stakes for construction operations. Construction and Surveys should work together to develop alternative inspection methods for future projects. Contractors are requesting the use of GNSS RTK to verify construction. The use of AMG does not supersede survey stakes. Utilities and structures are staked per the Department's normal staking methods. See Chapter 12 of the Surveys Manual at:

http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/12_Surveys.pdf

Because of the long life of a Department project, the original ground surface might have changed and should be checked prior to construction. If there are any changes to the area new data should be added to the existing DTM. Existing surfaces should be exported to the survey data collector in a compatible format for terrain checks. Checking existing terrain throughout the project then should be done to insure that mapping meets the National Map Accuracy Standards. Areas that have changed or contain errors are

identified and the surface is updated. Design can then calculate new quantities based on field conditions close to construction time.
A pre-job meeting should be held between Surveys, Construction, and the contractor to discuss control. The control points to be used in the GNSS calibration should be clearly communicated. It is critical that the contractor's calibration match Survey's calibration. Surveys and the contractor should compare calibration reports. Any problems should be communicated to Surveys as soon as they arise.
Areas with subsidence and other datum instabilities can cause problems with AMG construction. The control should be checked before construction starts to eliminate problems. Incorrect control can cause large problems if not caught early. Points not in the calibration, or have known stability problems, should not be used for setting slope stakes.

Construction Phase Roles and Responsibilities

Design

☐ Work with Construction staff to resolve problems discovered during construction.

☐ Provide updated electronic files to Construction if applicable or time permits.

Resident Engineer

☐ Require pre-construction meeting

- Contractor, Designer, Data Prep, Surveyors, Inspectors, Sub-contractors and DOT personnel.
- Agree on control and calibrations.
- Agree on shoulder and gore issues.
- Agree on cross checks between Data Prep and Surveyors.
- Agree to communicate problems ASAP.
- Inspect the project using the project model and the control.

☐ Provide the Contractor with electronic design data if available.

Surveys

☐ Review the Survey Engineer File and report problems to Design and the RE when found.

☐ Assist Design with data format conversion as expertise permits.

☐ Evaluate project control for consistency and create a site calibration.

☐ Establish supplemental project control as needed for AMG operations.

☐ Meet with Construction and the contractor to discuss control, calibration, and staking.

☐ Provide the contractor with the latest control points.

☐ Review the contractor's calibration report and compare with the Department's calibration.

☐ Set construction stakes as necessary.

☐ Assist the RE with inspection of line and grade in areas without stakes.

Investigating Site Specific GNSS Conditions

Flat open country is ideal for receiving the GNSS satellite signals while narrow canyons, tree cover, and existing structures can interfere with them. Projects with these restrictions could be unsuitable for GNSS based machine guidance. If there are GNSS concerns the district Survey staff should be consulted. Surveys personnel can visit the site and with existing surveying equipment observe the GNSS environment. Site-specific knowledge and experience with GNSS equipment will enable Surveys to make recommendations.

Additional Survey Control

Robotic total station guided equipment, such as paving machines, require more dense survey control of a higher vertical order of accuracy than GNSS controlled systems. Below is a diagram showing a typical control scheme where the total station position is set up at random and the coordinates are established using a "free station" solution. Control is staggered on either side of the highway to provide a good strength of figure. The distance between controls points on any side should be no farther than 650 Ft. (200 meters). (The 650 Ft. distance is based on a Leica Geosystems representative's recommendations) The vertical accuracy of the control must be such that the total station elevation can be established with an accuracy of +/- 0.01 Ft. (3 mm).

References and Additional Resources

Section 5-1.115, "Alternative Methods of Construction" of the Standard Specifications
Sections 3-506, "Lines and Grades" and 3-507, "Inspection" of the Department Construction Manual
Chapter 12, "Construction Surveys," of the Department Surveys Manual

Sample NSSP Language

(Insert final NSSP)

Sample CCO Language

In accordance with section 4-1.03 of the Standard Specifications, the State is providing electronic design files needed to produce a DDM to assist the Contractor in the use of machine guidance technology on the project.
The use of DDM will not supersede or conflict with Standard Specification section 5-1.07 "Lines and Grades".
The special provisions, project plans, standard specifications and standard plans shall all govern over the DDM and electronic files.
The Contractor agrees not to file a claim related to the accuracy, completeness or use of the DDM and electronic files for this project.

Links

The 2005 "INTERIM GUIDELINES FOR USE OF MACHINE GUIDANCE TECHNOLOGY" is posted on the intranet at:
http://pd.dot.ca.gov/row/offices/landsurveys/documents/machine_guidance/Interim-Guidelines-for-Machine-Guidance-Technology.pdf

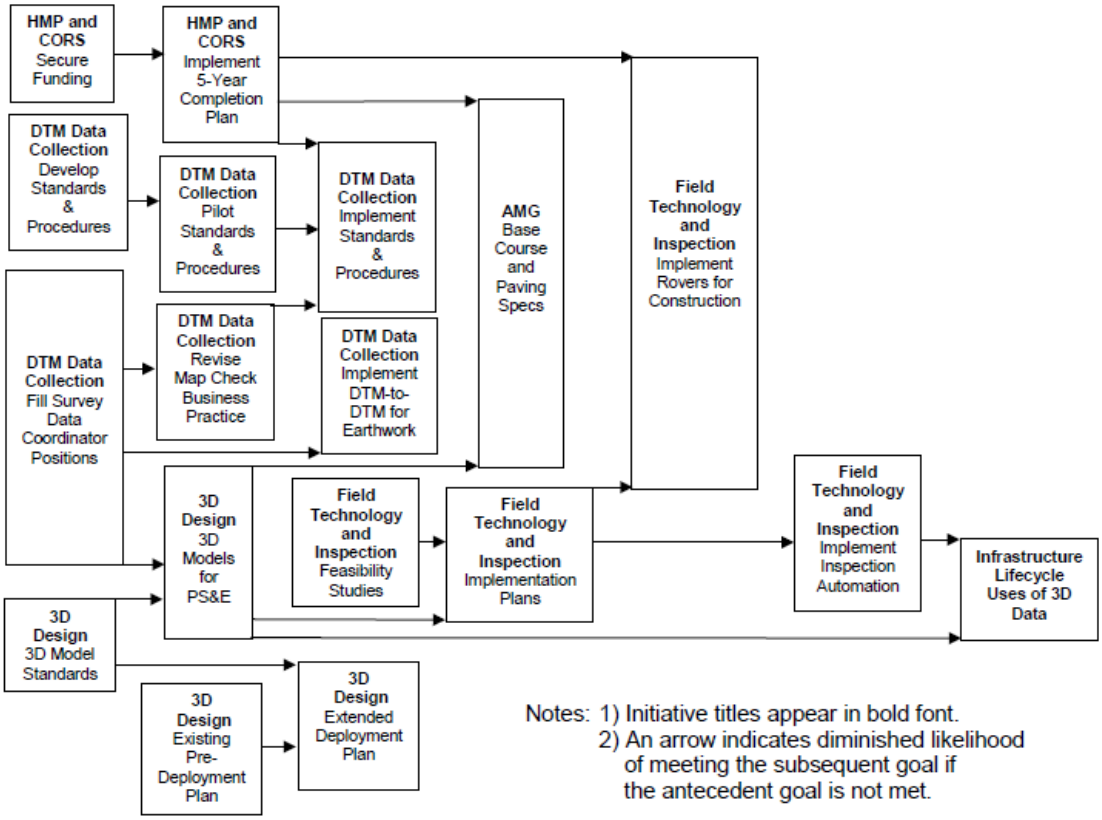


Figure 2.
Initiative and Goal Dependency Diagram