TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

Automated Machine Guidance with Use of 3D Models

EXECUTIVE SUMMARY | SUMMER 2013

ABSTRACT

Automated Machine Guidance, or AMG, uses data from sources such as 3D engineered models to guide construction equipment during earth work and paving operations. The use of AMG improves construction efficiency, quality, and safety while reducing schedule, cost, and the environmental impacts. This Executive Summary will show how deployment of AMG in the right situations can benefit all stakeholders during roadway construction projects.

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INTRODUCTION

Automated Machine Guidance (AMG) is a downstream application that can be applied to highway construction projects to provide construction efficiencies through enhanced location referencing. AMG involves using construction equipment mounted with onboard computers. Using a combination of 3D modeling data along with global positioning system (GPS) technology, AMG provides horizontal and vertical guidance in real time to construction equipment operators. AMG assists agencies and contractors in finishing projects in less time and with lower overall cost while providing higher quality and safety. AMG equipment has the potential to achieve designed grades on the first pass, reducing impacts on budgets and schedules compared with traditional staking. Using data from technologies such as 3D modeling in combination with GPS, automated machine guidance can increase productivity by up to 50 percent on some operations and cut survey costs by as much as 75 percent. Project-level optimization occurs when all elements built into and associated with the roadway are fully designed into the 3D model.

Contractors, recognizing the vast opportunities to reduce costs with AMG, are taking advantage of these technological advances. State agencies expect AMG to make more efficient use of already limited resources for construction. Industry-leading departments of transportation (DOT) recognize that potential advantages and cost savings are abundant, and have found that bid prices are minimized when the complete model is included in the bid package, available to prospective contractors, and controls the project.

TECHNOLOGY OVERVIEW

AMG, sometimes used synonymously with Machine Control Systems (although MCS might imply no need for human control), uses enhanced location referencing to provide accurate horizontal and vertical positioning for precise grading, milling, or paving. Bulldozers, graders, milling machines, and paving machines can all be programmed to use this technology when performing grading or paving tasks in the field. Moreover, scrapers, excavators, and trenching machines can be equipped with AMG for a wide variety of earthwork. A machine that uses AMG references the position of the cutting edges or pavement molds using GPS satellites, robotic total stations, lasers, or combinations of these methods. It calculates the finished-grade for that location using an electronic model of the proposed constructed facility that resides in its onboard computer. Then, it adjusts the cutting edges or pavement molds automatically for small differences in elevation or provides the cut or fill amount via the computer-user interface to the machine operator for large differences in elevation. Typically the machine operator manually grades the surface until it is close to design specifications, then switches to "automatic" for finish grading.

The data inputs from a digital terrain model and associated data preparation and formatting are important parts of a successful AMG application. The model data must be passed on to the contractor, who often transforms it into AMG compatible format. Contractors might hire a data preparation consultant to provide the final machine files for use in the field or might develop their own model if not originally provided by the DOT. Guidelines for quality assurance and quality control are required throughout the process for both design and construction. AMG construction specifications often focus upon geodetic control, location referencing and checking, machine calibration, and final construction check procedures, frequencies, and tolerances. Such specifications also usually address model development responsibilities and, potentially, data flows between owners and contractors.

BENEFITS OF AMG

Reduced Construction Costs

- Decreased costs of maintenance and fuel
- Decreased agency support costs
- Improved machine productivity
- Lowered operating costs (wages, overtime)
- Increased potential for electronic "as-builts"

• Reduced Schedules

- Increased equipment productivity
- Reduced time for survey and staking
- Improved equipment logistics arising from less rework

• Environmentally Friendly

- Greener construction with less fuel spent idling

Increased Quality

- Increased levels of accuracy with greater precision over conventional construction methods
- Increased control of elevation and cross-slope for asphalt paving
- Fewer errors requiring rework
- Decreased margin of error
- Increased calculation accuracy for quality assurance and quantity calculations
- Increased efficiency in calibration and control of paving equipment by total station compared with string line and level

Increased Safety

- Reduced need for elimination of string lines for improved worker safety
- Fewer field personnel exposed to heavy equipment and potential back-over/run-over incidents

CAPTION: Bulldozer equipped with AMG for grading

CAPTION: Grader equipped with AMG device assisting in fine grading

Selecting the "Right" Project

AMG is not ideal for every project, but can be deployed in many situations. In 2005, the California Department of Transportation formed a committee to explore this technology application and identified the following elements that characterize projects that are good candidates for incorporating AMG.[1]

- Large amounts of earthwork or paving
- New alignments
- A good Global Navigation Satellite System (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, that are not based on an existing DTM. Overlays with new profiles or cross slope construction benefit from AMG
- Designs that do not exist in a 3D digital environment (note that all jobs are capable of being modeled)
- Structures
- Projects that are under a tree canopy, in narrow canyons, or next to tall buildings that interfere with GNSS signals (note that robotic total stations or traditional methods are viable solutions)
- Design difficulties that would prevent the creation of an accurate and complete DTM[2] (if a surface model can be prepared in difficult situations, it saves on rework)
- Lack of training on AMG
- Construction specifications that do not allow the use of AMG
- Lack of equipment for DOT construction management staff to perform quality assurance

This field is constantly changing and new implementation strategies are being used by contractors. AMG is a downstream application of enhanced data from 3D models that can provide benefits such as reduced costs and faster construction, thus minimizing impacts on the driving public and providing benefits to all key stakeholders.

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[1] Note this is the findings of one group and national standards, definitions, and project selection are still evolving.

[2] Guidelines for Implementing Automated Machine Guidance, California Department of Transportation, Revised June 30th, 2009. accessed at http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/AutomatedMachineGuidanceGuidelines7_5_09.pdf

AVAILABLE RESOURCES

National Cooperative Highway Research Program (NCHRP) Synthesis 372 Emerging Technologies for Construction Delivery, Transportation Research Board, National Research Council, Washington, D.C., 2007. *http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_372.pdf*

Guidelines for Implementing Automated Machine Guidance, California Department of Transportation, Revised June 30th, 2009. accessed at *http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/AutomatedMachineGuidanceGuidelines7_5_09.pdf*

COMING SOON - NCHRP Project 10-77: Use of Automated Machine Guidance (AMG) within the Transportation Industry (expected completion 6/30/2013). *http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2504*

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