

Earthwork Haul-Truck Cycle-Time Monitoring – A Case Study

tech transfer summary

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MTC RESEARCH PROJECT TITLE

Earthwork Haul-Truck Cycle-Time
Monitoring – A Case Study

SPONSORS

Caterpillar, Inc.
Midwest Transportation Center
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of the Assistant Secretary for Research
and Technology (USDOT/OST-R)

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The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC). Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

MTC's research focus area is State of Good Repair, a key program under the 2012 federal transportation bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21). MTC research focuses on data-driven performance measures of transportation infrastructure, traffic safety, and project construction.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the project sponsors.

Understanding the factors affecting haul-truck cycle time has the potential to improve the efficiency of earthwork operations.

Objective

The objective of this project was to monitor site-level equipment operations, and specifically haul-truck cycle time, at an earthmoving project to better identify opportunities for integrating automation into the process.

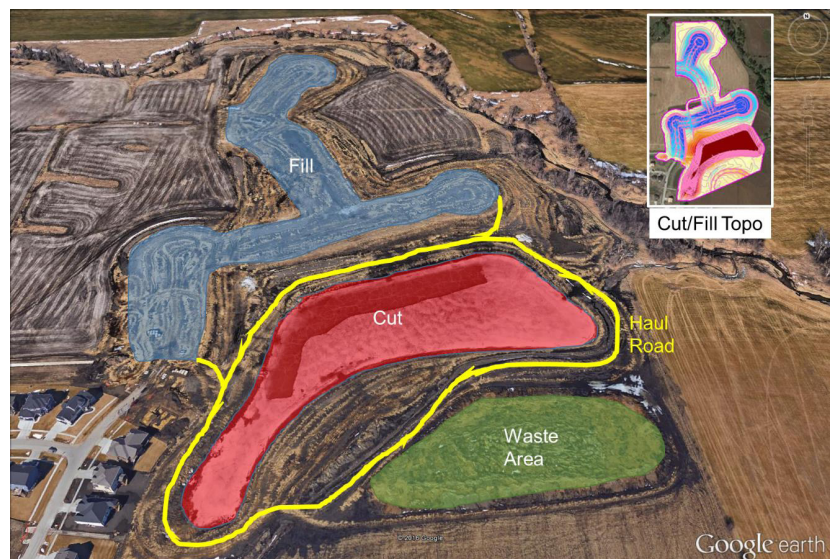
Background

Recent developments in autonomous technologies have motivated practitioners to adopt new technologies, such as automated machine guidance (AMG), in earthwork construction projects. To identify new and emerging technologies for construction automation beyond AMG, a project was initiated to identify current research and development efforts by hosting a conference of world-wide experts, the 2015 Conference on Autonomous and Robotic Construction of Infrastructure (CARCI), and identify opportunities for integrating automation into the construction process by monitoring site-level equipment operations at an earthmoving project.

The 2015 CARCI was held in June and attended by more than 100 participants from academia and industry. Papers presented at the conference are available at <http://www.ceer.iastate.edu/CARCI/proceedings/>. The conference demonstrated rapidly emerging construction applications for autonomous systems, confirmed interest in further automating construction processes, and emphasized the need for detailed site-level monitoring research.



IOWA STATE UNIVERSITY
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Simplified cut, fill, and haul plan for the project

Research Description

The site selected for monitoring was located in Johnston, Iowa and involved excavating and placing about 200,000 cubic yards of material, installing a storm sewer, and digging a pond. The project was monitored in October 2014.

Global positioning system (GPS) tracking devices were attached to three haul trucks, an excavator, and a bulldozer. Records from the devices were connected to Google Earth using .KMZ* files showing the positions superimposed on a map. Each recorded point contained the x, y, and z global coordinates, the time, and truck speed and rest time. Position monitoring was active from October 17 through October 20, 2014.

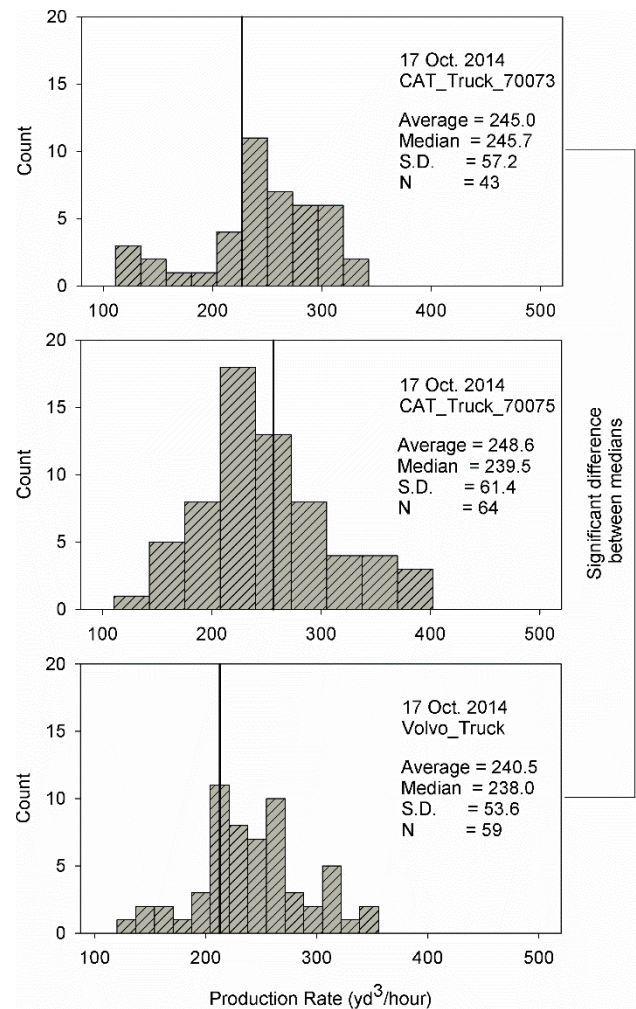
Cycle times were determined by defining the haul boundary, dump locations, and loading locations. The data were organized into individual cycle records. Within a cycle, the equipment sometimes stopped for a short period to yield to other equipment or wait for direction. Cycle times without delays were calculated by removing these stopping times from the cycles. The cycles that included an excavator location change were not included in the analysis.

Cycle-time analysis was conducted to describe the haul-truck activity. Because none of the distributions were found to be normal, a median rank scores test was performed to test for statistically significant differences between the distributions' medians. The haul-truck production rates were estimated based on the cycle-time analysis. To estimate the production rate of the excavator, the volume of excavated material was estimated by multiplying the number of loads for all trucks per day by the heaped capacity of the trucks.



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Operations of a haul truck from October 17 through October 20, showing the travel line during the evaluation period (red line), the position during moving operations (yellow points), and periods of no movement (red points)



Comparison of estimated production rates of three haul trucks on October 17

Key Findings

- The cycle time distributions are positively skewed.
- Based on the cycle time distribution analysis, the cycle times improved (i.e., were made shorter) as the monitoring period progressed. This improvement might be due to the operator's increasing familiarity with the site or other factors.
- No significant differences were found between the median cycle times for all hauling trucks on a given day. This was not unexpected because the cycle times for each truck depend heavily on the cycle times of the other trucks.
- No significant differences were found between the production rates for the different trucks. However, when the production rates were compared over time, a slight improvement was observed for one of the trucks between October 17 and 19.
- The average excavation rate was found to improve over time, especially on October 19. However, for more realistic production rates, additional details on the number of cycles for the excavator should be recorded.

Recommendations for Future Research

For future site-level monitoring programs, an emphasis needs to be placed on carefully capturing and quantifying the following key parameters influencing productivity:

- Project complexity (i.e., site layout and details)
- Dump truck size and number of dump trucks
- Loader size and number of loaders
- Excavation rates and material transfer rates
- Machine paths and traffic (i.e., speed, location, and time)
- Haul-road resistance
- Work-zone drainage
- Soil conditions

Implementation Benefits and Readiness

Understanding the factors leading to a significant change in cycle time has the potential to improve the efficiency of earthwork operations.

While this study demonstrated a relatively simple approach to cycle-time monitoring and statistical analysis, a more comprehensively designed monitoring program should be devised to capture the effects of the many factors that can influence productivity.