COMPARISON REPORT

Caterpillar Jobsite Information Study

CAT CONNECT

THE ROAD TO PROFITABILITY: A PAYOFF COMPARISON OF TRADITIONAL VS. TECHNOLOGY UTILIZATION IN ROAD CONSTRUCTION

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PURPOSE

This study was conducted to quantify and illustrate the benefits that technology provides to the environment, project, client and contractor throughout the value stream of a road construction comparison study. The study compares resources required and consumed using traditional construction methods versus methods utilizing technology. This report will discuss and illustrate the reductions in project duration, equipment hours, fuel consumption, total machine cost, operator hours, labor hours and total man hours, while also highlighting increases in safety, accuracy and profitability.

ABSTRACT

Technology is changing construction processes and the way projects are managed and built. Operating by feel, manually setting hubs and stakes, "eye-balling" grade or a truck's payload and verifying density after compaction, along with other traditional processes, are being replaced by GPS rovers, onboard real-time kinematics, and grade, payload and compaction technologies that provide near real-time information and nearly eliminate the need for additional personnel. The development of Tier 4 is behind us and technology has come to the forefront.

To demonstrate these industry game changers, Caterpillar conducted a study comparing traditional versus technology road construction methods to show how Cat® Connect Technology—specifically Cat GRADE, Cat COMPACT and Cat PAYLOAD—can increase safety and productivity, save time and make customers more profitable. To execute the study, a 400-foot section of roadway was constructed using machines with and without Cat Connect Technology. The study was conducted at Caterpillar's Peoria Proving Grounds in East Peoria, IL.

> Now, the biggest game changer in the road construction business is technology.

The study compared methods of construction during the site analysis, construction layout, earthmoving, grading and paving phases. All labor, equipment, material and fuel resources required to construct the mirrored sections of roadway, with and without technology, were documented. Throughout the duration of the study, laborers, operators, field management and data surveyors remained unchanged. Upon completion of the study, data was compiled and compared. Results and the associated benefits of technology utilization are contained within this report.

+ CAT® CONNECT MACHINE SPECIFICATIONS

In an attempt to replicate an authentic jobsite, this study also used competitive equipment:

- Today's jobsites often contain mixed fleets where no singular brand is exclusive to the customer or the jobsite.
- Because of this reality, Cat Connect Technology has been designed to be utilized on mixed fleet operations.

	CAT CONNECT TECHNOLOGY							
	LINK	GRADE				COMPACT	PAYLOAD	
CAT EQUIPMENT	PRODUCT LINK	UTS[1]	GNSS[2]	SLOPE	ASSIST	COMPACTION CONTROL	CPM[3]	3D MAPPING
140M3 (Motor Grader)	X	X	X					
349E (Excavator)	X							
745C (Articulated Truck)	X						X	
815F (Soil Compactor)	X					X		X
980M (Wheel Loader)	X						X	
AP655F (Paver)	X	X						
CB54 XW (Asphalt Compactor)	X					X		X
CS54 (Soil Compactor)	X					X		X
CT660 (On-Highway Truck)	X							
D5K (Dozer)	X							
D6T (Dozer)	X		X	X	X			
247B (Multi Terrain Loader)	X							
COMPETITIVE EQUIPMENT								
Trimble ZX5 (UAV)								X
Komatsu D61 (Dozer)	X							
Volvo A40F (Articulated Truck)	X							
Ford Pickup Truck	X							
Ford Pickup Truck	X							

1. Universal Total Station
2. Global Navigation Satellite System
3. Cat Production Measurement

MATERIAL COMPARISON

PHASE	TRADITIONAL METHOD	TECHNOLOGY METHOD
Construction Layout	(21) Wood Hubs & Lath	(3) Wood Hubs & Lath – Control Points Only
Earthmoving	Onsite Soil	Onsite Soil
Grading		
Aggregate Base Course	Imported CA-6 Agg.	Imported CA-6 Agg.
Finish Grade Control	(22) String line Pins & String lines	Universal Total Station (UTS)
Paving	RAAM 6 Millings	RAAM 6 Millings

	TRADITIONAL VS. BID	TECHNOLOGY VS. BID	TECHNOLOGY VS. TRADITIONAL	TRADITIONAL ACCURACY VS. PLAN QUANTITY	TECHNOLOGY ACCURACY VS. PLAN QUANTITY
CUT VOLUME	110%	101%	**9%**	10%	1%
FILL VOLUME	85%	98%	**-13%**	-15%	-2%
AGGREGATE BASE COURSE	113%	103%	**10%**	13%	3%
ASPHALT PAVEMENT	110%	101%	**9%**	10%	1%
TOP SOIL	105%	101%	**4%**	5%	1%

MATERIAL COMPARISON DEFINITIONS:

Traditional vs. Bid *– A measurement of the actual amount of material used compared to the theoretical bid quantity utilizing traditional construction methods.*

Technology vs. Bid *– A measurement of the actual amount of material used compared to the theoretical bid quantity utilizing technology.*

Technology vs. Traditional *– The difference in material consumption utilizing technology versus traditional construction methods compared to the theoretical bid quantity.*

Traditional Accuracy vs. Plan Quantity *– The difference between the actual amount of material used utilizing traditional construction methods compared to the theoretical bid quantity.*

Technology Accuracy vs. Plan Quantity *– The difference between the actual amount of material used utilizing technology methods compared to the theoretical bid quantity.*

TRADITIONAL ROAD CONSTRUCTION OVERVIEW

TRADITIONAL SITE ANALYSIS

Prior to having any construction equipment on the jobsite, the work area was manually surveyed, using a Universal Total Station (UTS) to record the existing topography. This labor-intensive process was done to verify the actual elevations of the site to that shown on the plans. This process was repeated and results were compared to previous surveys throughout all phases of the project to track progress.

> Utilizing traditional methods of site analysis and construction layout is time-consuming and labor-intensive.

CONSTRUCTION LAYOUT PHASE

The first of four phases was the Construction Layout phase. The existing control points were verified and additional control points, required for the layout phase, were set. Hubs and stakes were then driven at 50-foot intervals on even 50-foot stations on both the left and right Right-of-Way lines. This process required three laborers to complete. Each of the 18 hubs was surveyed for elevation and location. Applying the project’s design, grades and offsets were calculated and published. This process took approximately two hours to complete.

TRADITIONAL ROAD CONSTRUCTION: STEP BY STEP

STEP 1: The Traditional Road Construction process began with a site survey using a UTS to record the data points that were used to verify the topography of the jobsite.

STEP 2: After verification, the Construction Layout phase began. During this phase, a crew of three workers set hubs and stakes and calculated and published the offsets and grades. It took the team about two hours to complete the 400-foot stretch of roadway.

STEP 3: Upon completion of the construction layout, the edge-of-shoulder offset distances were measured from the hubs to define the edge-of-shoulder locations of the roadway.

STEP 4: The Earthmoving phase began by preparing the existing grade by scarifying, compacting and density testing. This process was repeated until desired density was achieved.

STEP 5: Onsite material was then cut from the ditches, spread and compacted in roadway areas requiring fill. The ditch material was not sufficient to reach desired subgrade elevations, which required the import of additional material to the jobsite. This material is referred to as furnished excavation.

STEP 6: During the Grading phase, Aggregate Base Course was delivered, spread and compacted. Once completed, topsoil was imported and spread in the ditches.

STEP 7: Paving hubs, stakes, string line pins and string line were set and verified for finish grading and paving purposes.

STEP 8: During the finish grading process, a crew of three laborers used the same string line to check grade, repeatedly giving instructions to the finish grade operators, until proposed elevations were achieved.

STEP 9: The same string line was then used by the paving crew to guide the screed and to check the mat for proper elevation.

+ TECHNOLOGY ROAD CONSTRUCTION OVERVIEW

TECHNOLOGY SITE ANALYSIS

Before any construction equipment was mobilized to the jobsite, six Unmanned Aerial Vehicle (UAV) ground control targets were set, and a UAV flew over the area to survey the site in a matter of minutes.

> With technological tools, a site survey can be accomplished in a fraction of the time it takes using traditional methods.

CONSTRUCTION LAYOUT PHASE

With the multitude of data points and imagery collected from this initial flight and those that followed, progress was tracked and measured throughout the construction phases and earthwork volumes were calculated and documented. No hubs or stakes were used, which required less labor, consuming fewer man hours. The plans were loaded into the machine's control and guidance systems to complete the project in nearly half the time.

+ TECHNOLOGY ROAD CONSTRUCTION: STEP BY STEP

STEP 1: The Technology Road Construction process began with a UAV flying overhead to record data points that were utilized to map and verify the topography of the jobsite.

STEP 2: Utilizing machine control and guidance technology, the motor grader operator scarified the existing ground while navigating along the edge-of-shoulder line work as seen on the operator's display.

STEP 3: The existing ground was then compacted using a soil compactor with on-board intelligent compaction technology.

STEP 4: Upon passing density verification from a geo-technical soils inspector, earth excavation began.

STEP 5: Material was cut from the ditches and moved initially to a fill area without additional passes required.

STEP 6: The ditch grade was cut to plan elevation and prepared for topsoil. Meanwhile, the cut material was spread to the proper lift thickness before being compacted.

STEP 7: Optimized payloads of furnished excavation material were hauled in, spread, compacted and finish graded to complete the fill.

STEP 8: Aggregate base course was delivered, spread and compacted.

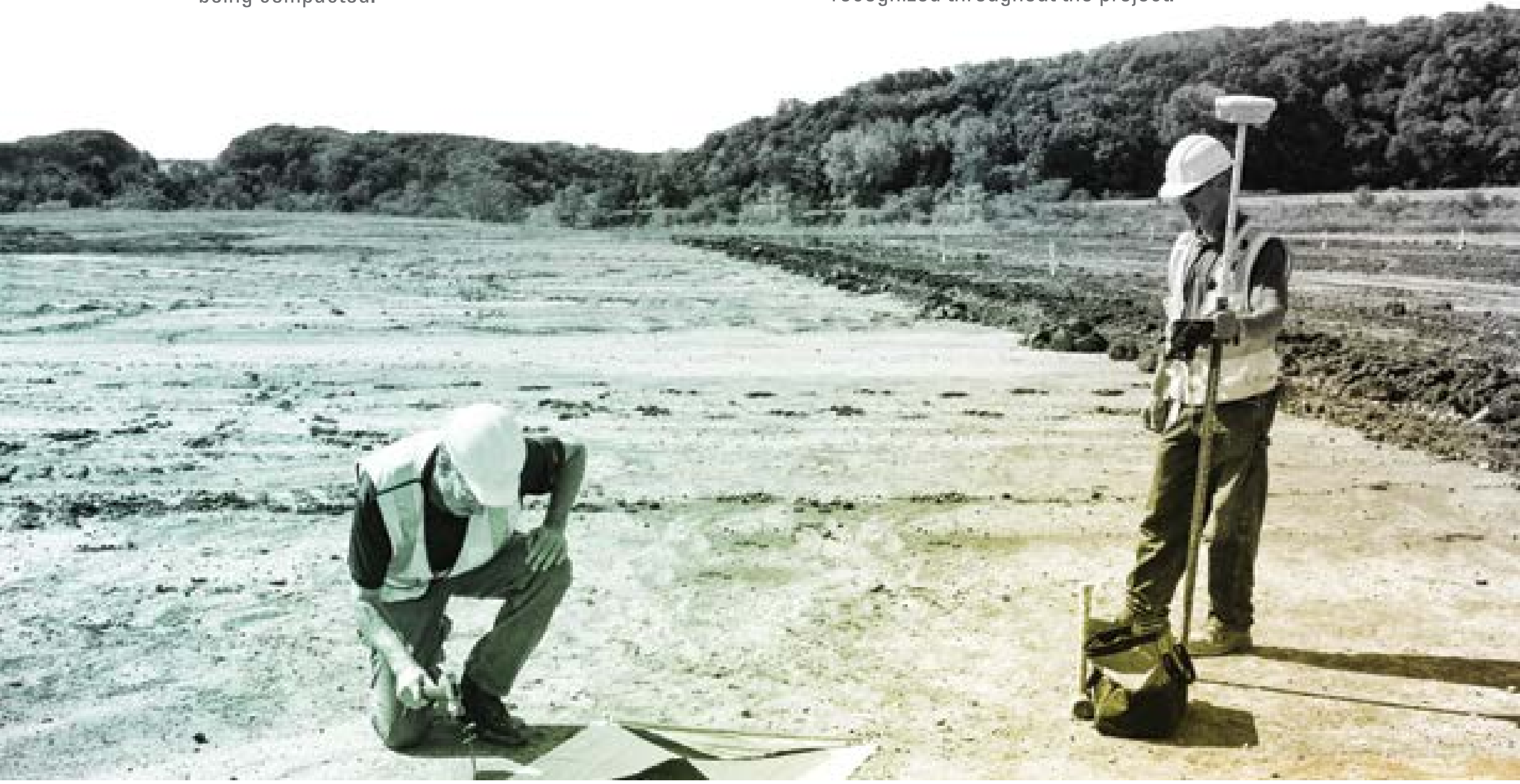
STEP 9: Intelligent compaction was used to prevent missed areas and improper compacting of the aggregate.

STEP 10: Topsoil was delivered to the project and spread in the ditches to plan thickness and cross-slope, using cross-slope technology.

STEP 11: A UTS eliminated the need for string line. Implementing UTS into the operation, the aggregate base course was finished to grade and the pavement was laid using the same UTS.

STEP 12: The use of intelligent compaction ensured maximum quality.

STEP 13: The benefits of utilizing technology were recognized throughout the project.



+ TRADITIONAL EARTHMOVING PHASE

Upon completion of the construction layout, the Earthmoving phase began. This phase consisted of preparing the existing grade, ditch excavation, importing embankment material and compaction.

STEP 1: To define the location of the roadway from edge of shoulder to edge of shoulder, and using the information provided during the Construction Layout phase, the edge-of-shoulder offset distances were measured and marked by the crew.

STEP 2: The existing grade was prepared for fill material through means of scarifying, compaction, density testing, recompaction and retesting in order to verify passing density. Recompaction and additional testing resulted from the use of traditional means and methods for achieving and verifying compaction.

STEP 3: Each hinge point distance and cut/fill value for the roadway's cross section were measured and shot from the hubs using tape measures, eye levels and stick rulers. The corresponding locations and values were marked on the ground for the operators to follow. Material from the drainage ditches was cut, spread and compacted on the fill areas of the roadway.

STEP 4: Since the project was "short" on material, furnished excavation was imported to the jobsite, spread and compacted to achieve the proposed finished subgrade elevations. The number of passes required by the machines to complete their tasks fueled the repetitive process of work verification, including measuring and marking offset distances and shooting and publishing cut/fill values.

+ TECHNOLOGY EARTHMOVING PHASE

The greatest benefits of technology were recognized during the Earthmoving and Grading phases. With technology, operators worked confidently—without guesswork and fatigue. In-cab displays provided machine control, guidance, compaction, payload and progress at a glance, keeping the operators informed and focused.

STEP 1: Equipped with GPS machine control and guidance technology, the motor grader operator followed the left and right edge-of-shoulder line work to scarify the existing ground. With the project design loaded directly into the machine and provided on the operator's display, there was no need for laying out the parameters of the roadway or shoulders.

STEP 2: The soil compactor, equipped with Machine Drive Power (MDP)—Intelligent Compaction and Mapping, compacted the scarified area to specification with proof of full compaction coverage. Machine control and guidance, as well as intelligent compaction technology, replaced manual processes. This reduced machine passes and eliminated over/under-compacting and retesting—two drivers of increased project cost and time delays when using traditional methods.

STEP 3: Excavation of cut material from the drainage ditches was spread on the fill areas at a uniform, specified thickness and was compacted to comply with density targets, all in the fewest number of passes. Since the project was "short," fill material was loaded using a wheel loader and delivered to the site using articulated trucks. Both the loading tool and the hauling units used payload systems, which reduced cycle times and ensured delivery of accurate material quantities with maximum payload efficiency to the jobsite.

STEP 4: As with the cut operation, the fill material was spread and compacted using the optimal number of passes in uniform lifts until finished subgrade elevations and density specifications were achieved.

+ EARTHMOVING PHASE

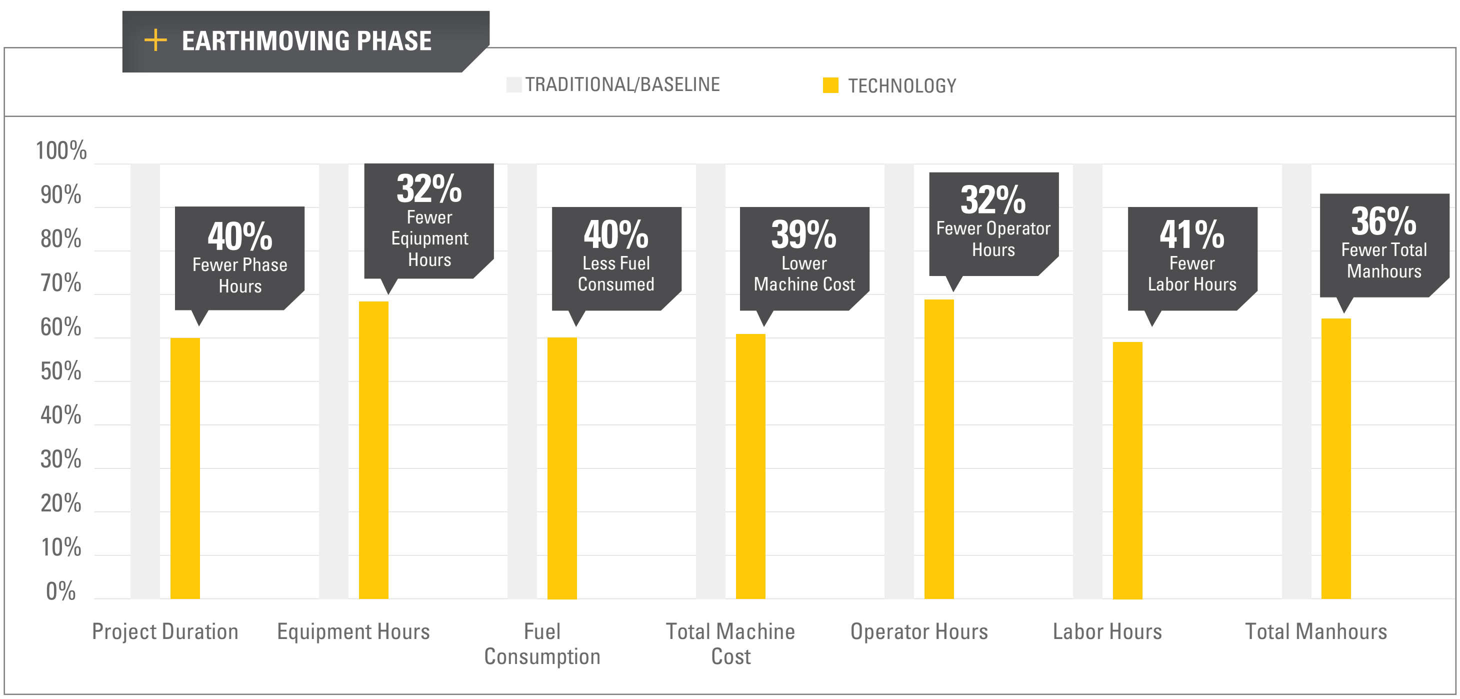
TRADITIONAL EARTHMOVING SUMMARY

The Earthmoving phase required a number of people to work in close proximity to the machines, increasing exposure to risk to perform these roles. When doing so, machines were underutilized and operators sat idle, waiting for necessary information to continue and complete their jobs. In general, this is a time-consuming, manual process that often leads to missed production targets and struggles to meet accuracy specifications in the end, creating substantial re-work. More time equals higher unit costs, increased fuel consumption and machine wear. Customers today also may face shortages in skilled labor, contributing to even longer project durations.

After each of the aforementioned operations of scarification and compaction, earth excavation and furnished excavation were completed, the surface was cross-sectioned for quantity, productivity and payment purposes. This repeated process consumed a substantial amount of resources to complete while delaying the operation from progressing to the next task.

TECHNOLOGY EARTHMOVING SUMMARY

Technology dismissed the need for repetitive hinge point determination and the multitude of cut/fill values published on the ground for the operators to follow. Periodic verification was accomplished by a single laborer and GPS rover. Machine control and guidance technology prevented undercutting, overfilling and misalignment, thus eliminating rework. Fewer people on the ground equaled a reduction in the exposure to risk and an increase in resource availability to complete other tasks. Increased productivity and corresponding reduction in machine hours reduced fuel consumption, drove sustainability and increased profits.



Percentages listed above reflect data collected during this phase only.
Please see appendix for graph definitions.

+ TRADITIONAL GRADING PHASE

After the subgrade was manually cross-sectioned for final earthwork quantities, accuracy and payment purposes, the aggregate base course operation began.

STEP 1: The proposed edge-of-pavement and aggregate fill thicknesses were established from the offsets and cut/fill grades provided on the hubs. This information was then marked on the roadway for the grading crew to follow.

STEP 2: Aggregate base course was delivered to the project, dumped, spread and compacted to create the roadway's base layer of the pavement structure. In general, this process contributed significant grade checking and rechecking, excessive compaction testing and increased exposure to risk.

STEP 3: After the aggregate base course was fine graded and compaction was verified, paving hubs were set on even 50-foot stations.

STEP 4: Referencing the hubs, a string line system was installed for the finish grading and paving operations.

STEP 5: Laborers checked the elevation of the aggregate base course every 25 feet by pulling a string line perpendicular to the roadway, making contact with the longitudinal referencing string line system and measuring the vertical distance from the string line to the aggregate. Results were communicated to the operator until multiple passes yielded finished grade elevations.

+ TECHNOLOGY GRADING PHASE

Upon completion of the aerial survey by UAV imaging the topography of the completed Earthmoving phase for quantity, accuracy and payment purposes, optimized truck payloads of aggregate base course using Cat Production Measurement (CPM) Payload technology were delivered to the roadway.

STEP 1: A dozer equipped with GPS technology, eliminating the need for manual layout, spread the aggregate over the proposed area at the proposed grade elevation using the optimal number of passes.

STEP 2: Compaction specifications were achieved using a compactor equipped with Compaction Meter Value (CMV) Compaction Control technology with mapping. Again, the optimal number of passes was made during the compaction process to deliver the best quality in the shortest time.

STEP 3: The finish grading operation leveraged UTS technology. The accuracy of UTS technology on the motor grader eliminated the need for hubs and string lines to be installed.

STEP 4: Finished aggregate elevation was achieved efficiently and accurately and ready for pavement.

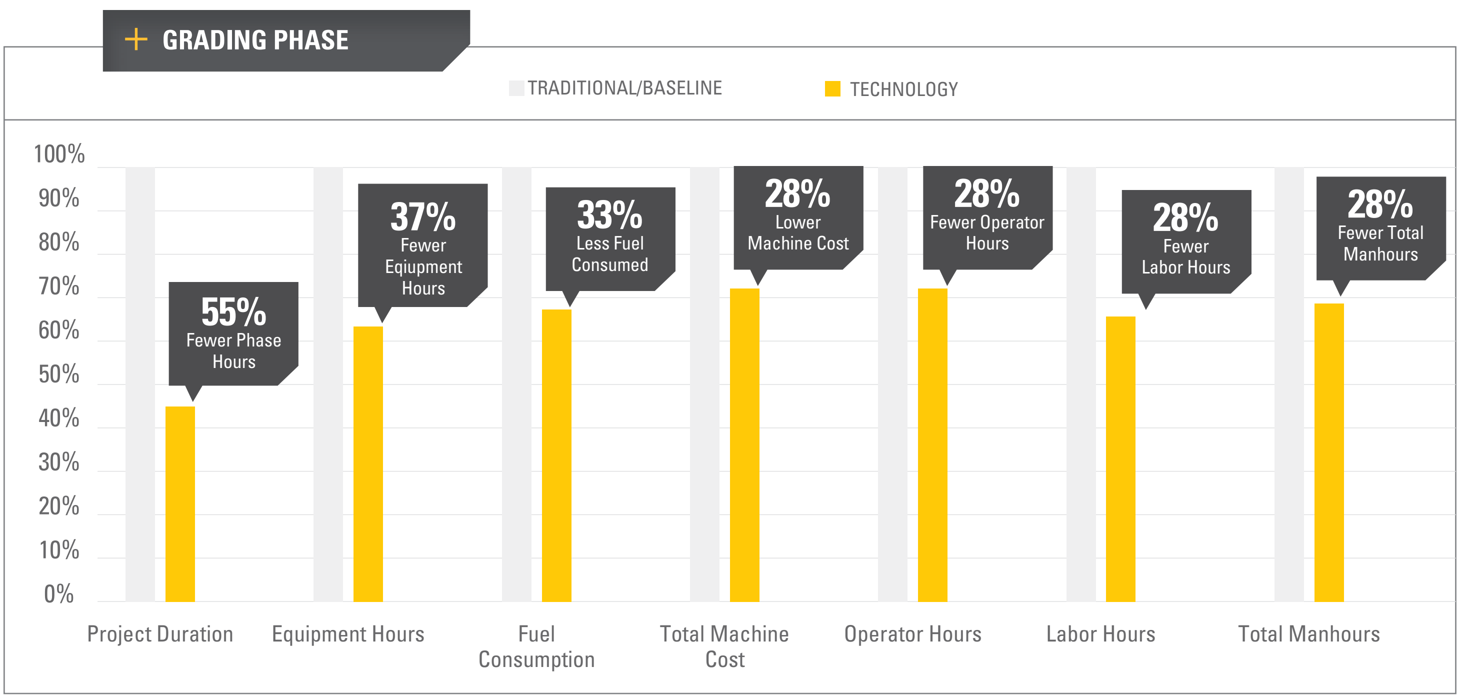
+ GRADING PHASE

TRADITIONAL GRADING SUMMARY

Detecting cuts and fills throughout, additional passes by both the motor grader and compactor were required until the proposed elevation was accomplished throughout the entire length of the road. Slow and tedious, this process can introduce error and consume valuable time while machines wait for grade information, all the while driving up costs through increased labor, higher fuel consumption, rework, material overruns, increased aggregate degradation and exposure to risk.

TECHNOLOGY GRADING SUMMARY

Using Cat Connect Technology, grading time, unit cost, machine wear, passes, material degradation, material overruns and fuel consumption were reduced while accuracy, quality, profit, safety and sustainability recognized significant gains.



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Please see appendix for graph definitions.

+ TRADITIONAL PAVING PHASE

Prior to beginning the Paving phase, the aggregate base course was manually cross-sectioned for accuracy, quantity and payment purposes. Before paving could begin, the centerline and edge-of-pavement parameters were established to guide the paver and ensure the mat was laid in the proposed location and at the correct width.

STEP 1: Bringing the paver into position at the start of the first pass, the machine's sonic sensors were set up on the string line, the hopper was charged and the paving operation began. While the operator concentrated on following the markings on the ground, the screed operators were attentive to the mat thickness, width, quality and yield analysis.

STEP 2: Grade checking was accomplished using a three-person crew to reference the string line to the mat, every 25 feet to verify elevation accuracy.

STEP 3: Compaction was achieved using an array of inconsistent pass counts, depending on the given location.

STEP 4: Nuclear density tests and grade checks were conducted repeatedly to ensure that the mat was meeting density and elevation specifications.

+ TECHNOLOGY PAVING PHASE

The aerial survey of the roadway was completed to ensure accuracy of the aggregate base course. At this point in the process and using technology, there was no longer a need to lay out the alignment of the road since the operator was already empowered with this information. Additionally, the grade control advantage that UTS leverages eliminated the need for a string line system previously required to dictate mat elevation.

STEP 1: The paver equipped with UTS positioned itself on the left side of the project, connected with the UTS gun and made final screed adjustments, at which point the hopper was charged with material and paving began.

STEP 2: A laborer using a UTS rover verified the mat's elevation behind the screed and compactor.

STEP 3: Compaction specifications were met in the fewest number of passes using Cat Compaction Control and Mapping.

STEP 4: Random density tests using a density gauge verified that compaction was being achieved.

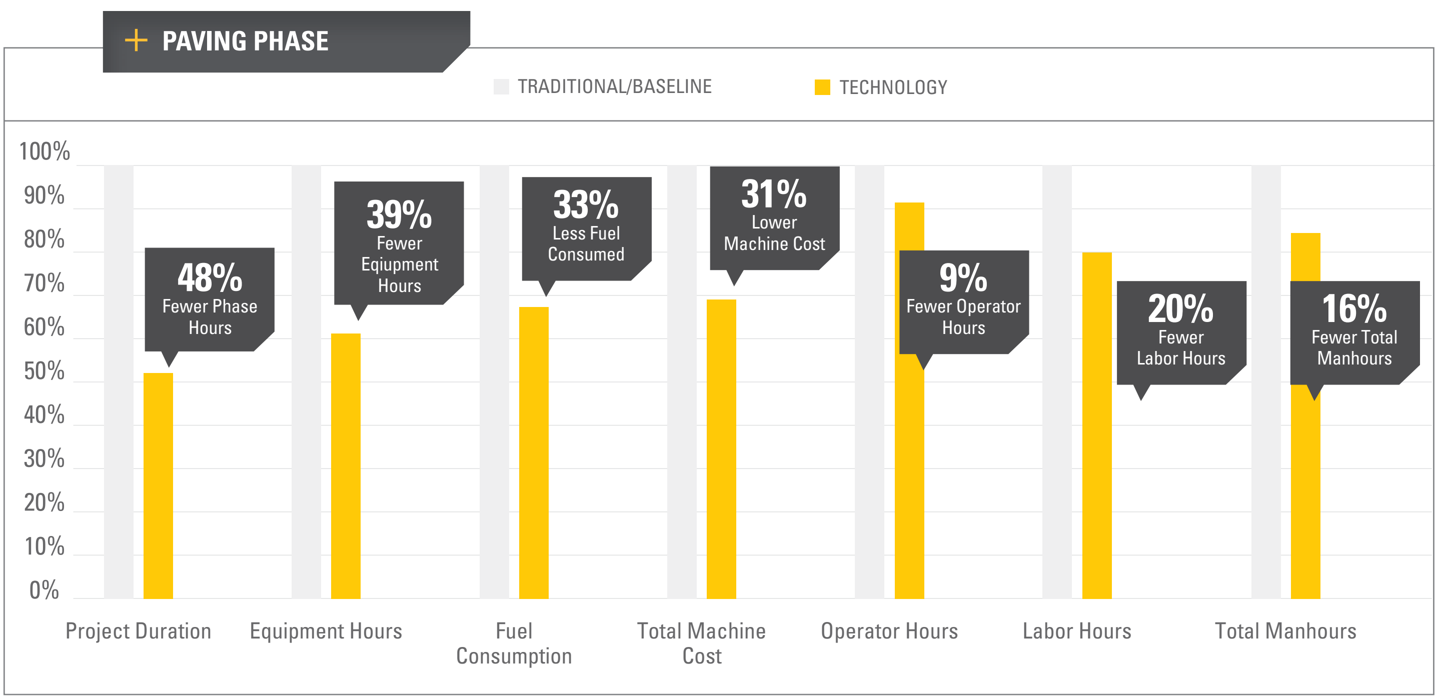
PAVING PHASE

TRADITIONAL PAVING SUMMARY

The mat thickness was inconsistent in places, showing signs of thin and thick material, evidence that the finish grade of the aggregate base course was inconsistent and inaccurate. These noticeable variations in thickness contributed to quantity overrun from the theoretical quantity of pavement required. In general, this process can lead to a slower, more costly paving process that consumes additional resources and often provides substandard quality, thus reducing pavement longevity.

TECHNOLOGY PAVING SUMMARY

Using the optimal number of passes in the rolling pattern, degradation of the aggregate particles within the pavement was significantly reduced. Machine control and guidance, in addition to Intelligent Compaction, meant efficiency—no string lines, manual grade checking or redundant compaction tests. With fewer people on site, safety was increased. Fewer passes were needed, minimizing machine wear and driving sustainability. The result was not only accuracy, efficiency and a reduction in rework and material overruns, but also a better quality road. It provided for a smoother ride and increased longevity and cost less to build.



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Please see appendix for graph definitions.

CONCLUSIONS

This study illustrates the substantial payoffs of utilizing technology over traditional road construction methods. The recognized payoff is staggering when considering the reduction in project duration, equipment hours, fuel consumption, total machine cost, operator hours, labor hours and total manhours. Also of critical importance to customer organizations and the hard-working people they employ, technology is at the forefront of increased jobsite safety and reduced exposure to risk. Regarding risk, fewer machine hours preserves machines from excessive wear, driving down fuel consumption and leading to an environmentally conscious solution and ultimate reduction in greenhouse gas emissions.

IN SUMMARY, HERE'S THE PAYOFF FOR THE CUSTOMER:

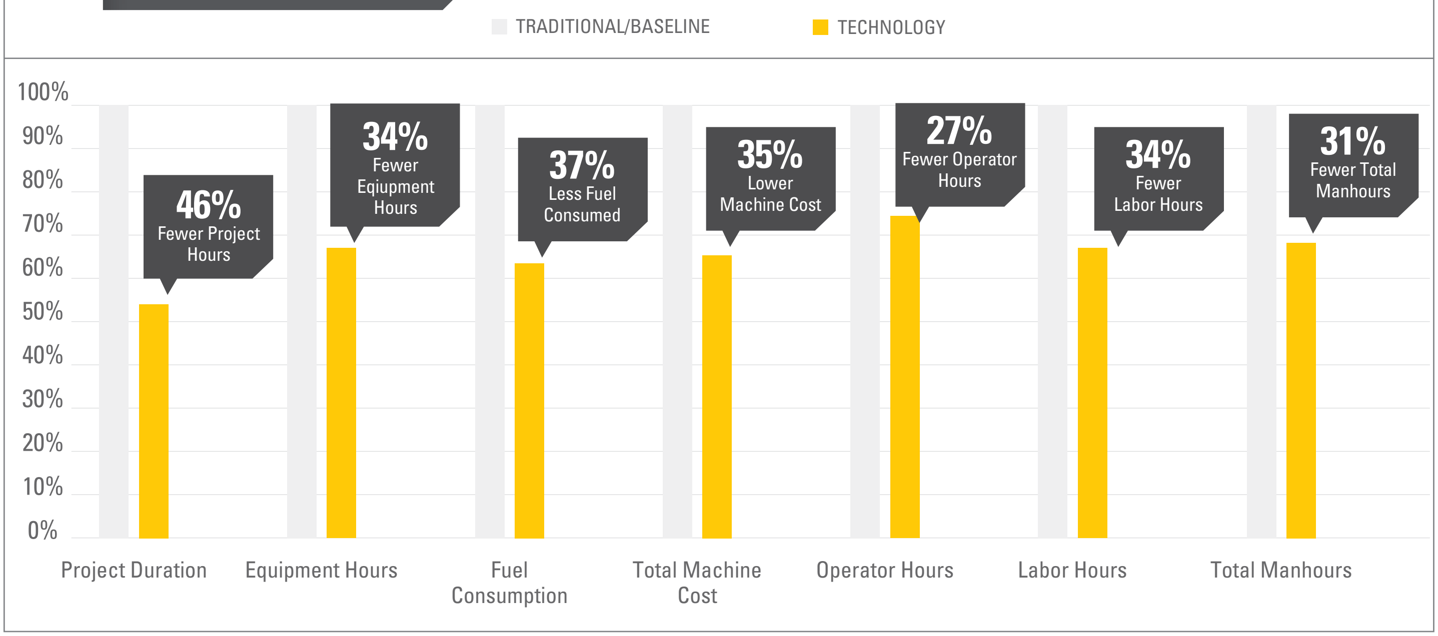
46% FEWER PROJECT HOURS: Simply more profit and more opportunity to bid additional work. It lowers unit cost and allows for company growth and expansion.

34% FEWER EQUIPMENT HOURS: Lower maintenance and repair cost, increased machine availability, effective utilization and resale value, and extended machine life cycle.

37% LESS FUEL CONSUMED: Increased profits and machine life, secured competitive bid advantage, and reduced emission levels and carbon footprint. This saved 12 acres of forest. That's a significant payoff for reducing greenhouse gas emissions.

31% FEWER TOTAL MANHOURS: Better resource allocation, less exposure to risk and a solution to skilled labor shortages.

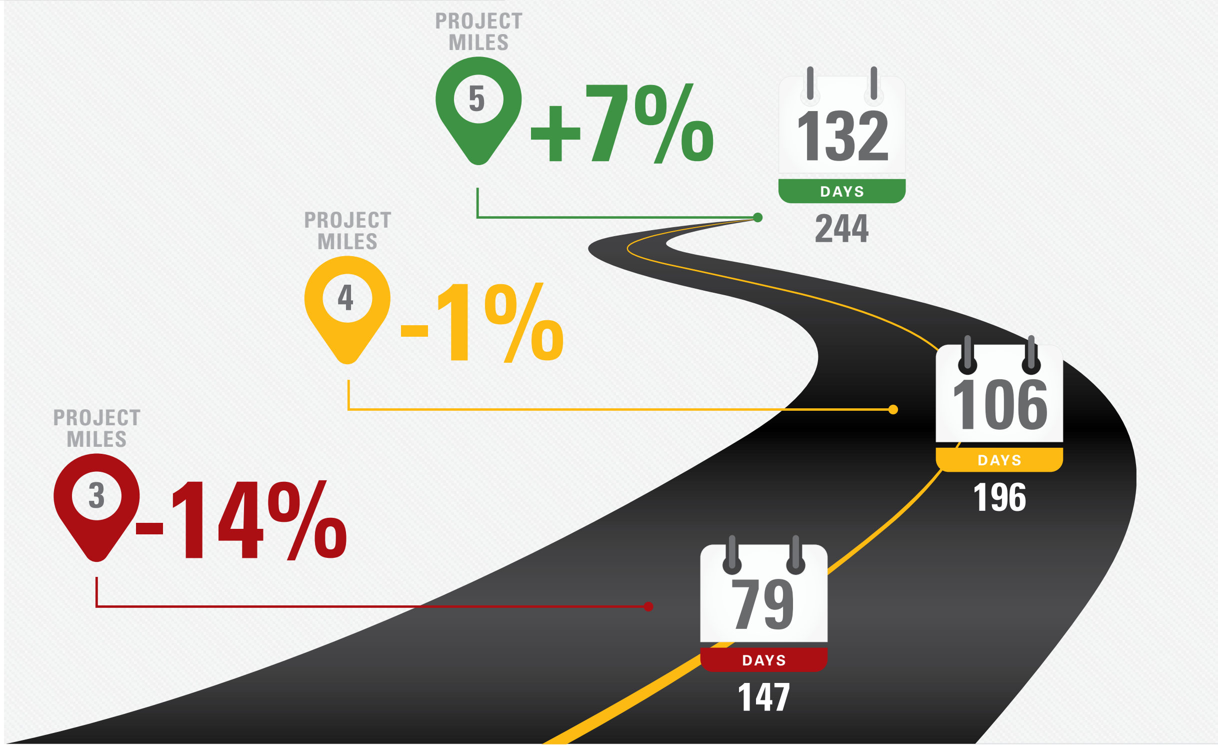
PROJECT TOTALS



Please see appendix for graph definitions.

At the start, we called this the road to profitability. But how far down the road do you have to go to recover the investment? The investment in new technology for this road was about $250,000.

+ LESS THAN ONE YEAR TO PAYBACK



On a road construction project approximately three miles in length, it would take 79 working days to complete with technology versus 147 working days with traditional methods. While 68 fewer days to complete the project is impressive, it's still short of paying back the full investment. However, at four miles the break-even point is nearly reached. That means for every mile thereafter, additional profits are recognized. This investment puts adopters of technology in the fast lane to profitability and on to the next project in record time.

The Illinois Department of Transportation's Specifications for Road and Bridge Construction were referenced and complied with throughout the duration of this comparison study.

MATERIAL COMPARISON DEFINITIONS

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GRAPH DEFINITIONS

Project Duration *– The time required to complete the project.*

Equipment Hours *– Total number of equipment service meter units (hours) accrued during the construction of the project.*

Fuel Consumption *– Total fuel consumed during the project.*

Total Machine Cost *– Includes hourly machine rate, fuel consumption and operator cost.*

Operator Hours *– Total number of operator hours consumed including standby time.*

Labor Hours *– Total number of labor hours consumed including survey and construction layout crews.*

Total Man Hours *– Total number of hours consumed by all operators and laborers required to complete the project.*