

Use of GPS and SmartGrade Technology in Heavy Civil Construction

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Heavy Civil is a sector in the construction industry involving a variety of different heavy machinery and construction practices. Technology has evolved as an important aspect in this sector striving to improve efficiency, productivity, and traditional construction methods. Global Positioning System (GPS) technology is one of the many technological advancements that benefit any size of contractor in the heavy civil industry. With the help of a 3D model, base station, and rover, contractors implement advanced building methods that provide excellent owner satisfaction. Similar to GPS, SmartGrade is a tool integrated into heavy machinery that enhances performance without the need of wiring or masts. I researched these technological systems through an interview with the Director of Construction Positioning Technology at John Deere, and President of Brough Construction, Inc. a local general engineering contractor. With these interviews I concluded that this technology indeed offers great benefits to the contractor. Examples of these benefits include: increased productivity levels, increased efficiency, minimized material overages, and a guaranteed return on equity for an investment in this technology. There is no reason why a contractor should not invest in this type of equipment since the industry is moving towards more reliable and effective construction practices.

Keywords: GPS, SmartGrade, Heavy Civil, Construction Technology, Earthwork

Introduction and Background

The construction industry has changed dramatically throughout the years with new technology playing an important role in these changes. The traditional means and methods of building are still valued today, however, technology has come to make the process much simpler and easier. Younger minds in the industry tend to adapt quickly to these new processes and have helped facilitate these technologies in the field. A sector within the construction industry that relies heavily on the use of technology is the heavy civil sector. Heavy Civil is the sector that works on grading, earthmoving, roadwork, utility installation and more. The list of specific jobs performed in this sector is ongoing. Most of the technology assists operators by guiding heavy machinery into the correct design parameters for each project or help locating specific positions at a jobsite. Global Positioning Systems (GPS) alongside SmartGrade are one of the many tools that are used in this industry.

What is GPS?

Many professionals use the terms GNSS or Global Navigation Satellite System interchangeably with GPS, however there is a bit of distinction between the two. GNSS is an umbrella term that covers different types of satellite-based positioning, navigation, and timing (PNT) systems. These systems are used globally in different ways by many different users. GPS is just one type of system that falls under GNSS. GPS refers specifically to the NAVSTAR Global Positioning System, which is a constellation of satellites developed by the United States Department of Defense (*GNSS / GPS technology differences*). These systems were created in the 1970s and were used specially for the military, it wasn't until later where these systems evolved and became more accessible to the general public

(Thornton). Some other systems that work collaboratively with GNSS include the Russian GLONASS, the European Union's Galileo, and China's Beidou. However, GPS is the most commonly used GNSS in the world due to its great positioning and timely accuracy even in poor weather conditions. GPS has three major segments: the space segment, the control segment, and the user segment. The space segment is in charge of transmitting one-way signals from satellites to individual users of the system. The United States is committed to keeping at least twenty four satellites operating in the constellation. The control segments are facilities that maintain this system operating. Control segments monitor transmissions, record data, and send commands to the satellites. A control facility that is local to our university is Vandenberg Air Force Base in Lompoc, California. Lastly, the user segment are those devices we are familiar with like smartphones, hiking wristbands, vehicle navigation, among many other devices that receive signals from these satellites to determine latitude, longitude, and height at any given time and location on earth. In this industry we especially use these systems in our survey equipment, heavy machinery, SmartGrade, and GPS system handheld equipment for construction processes (The Global Positioning System 2021).

What is SmartGrade?

SmartGrade has come to facilitate and increase the productivity for operators when using dozers, skid steers, motor graders, skip loaders, and excavators. John Deere is the pioneer of this new technological advancement, and it is becoming increasingly popular among contractors. John Deere offers four different grade management solutions including: SmartGrade, SmartGrade-Ready with 2D, 3D Grade Guidance and 2D Grade Guidance. SmartGrade uses much of the same GPS technology additionally it benefits from being integrated into the performance of the machine (Schultz, 2021). Similar to GPS, SmartGrade removes the masts and the cabling that was previously visible and instead integrated into the machine (John Deere SmartGrade™ Technology). SmartGrade uses newer measurement unit sensors instead of the older vial slope type sensors. The implementation of this technology focuses on the overall performance of the equipment. The machine performs at optimal RPMs and speeds all the time, which results in less wear and tear on the equipment and reduces fuel usage. For excavators, this technology automates the boom and bucket of an excavator to achieve the desired grade needed for the task. For dozers and graders this will work best for mass excavation, moving dirt and placing material for fine grading within four to five hundredths of accuracy (Murphy, 2022).

Equipment

The equipment needed for this type of technology is not complex. When it comes to GPS, many different brands offer many different types of products and types, but the concept is the same. The set-up begins with a GNSS receiver and its tripod, in the field this is termed the base station. This station is set up every time the project requires the use of GPS. For construction jobs that have a long duration, the station will be set up at a stationary location away from any disturbances and is powered by a stationary battery. The advantage of a stationary location is avoiding the reassembly of the station after each workday on the jobsite. The base station GNSS receiver is in charge of communicating with the satellites in the constellation and creating a correction factor. Subsequently, a rover, data collector, and tripod are required. The rover is identical to the base station device, and it is also a GNSS receiver (*See Figure 1*). The rover is used by a competent person on the site, and it is used to locate points around the site as needed. The rover receives signals from satellites and the base station to calculate grades and find points on the job site. This is where the correction factor created before is used, these rovers are calibrated for precision. Additionally, a data collector is used, this device is a small tablet that allows constructors to view and collect data on the site. Engineers create 3D models of the site from CAD files which are uploaded into the system. For heavy equipment the concept is the same with the exception that the rover is attached to the equipment and gives grades directly to the machine user interface.



Figure 1- GPS rover and data collector at work in Avenal, CA

SmartGrade altered the wiring and additional equipment needed when using GNSS in a machine (See Figure 2). SmartGrade heavy equipment comes GNSS ready from the factory. All that is required is to upload the 3D file into the machine and it is ready for operation. The main advantage of this is that all technology is integrated into the machine for performance, avoiding the need for extra wiring and masts.



Figure 2- New SmartGrade Motor Grader, fully integrated with GPS (John Deere)

Methodology

The approach I have taken for this research study is to focus on a local heavy civil construction company, Brough Construction, Inc based out of Arroyo Grande, California. I will analyze and highlight their experience on the use of this technology in the field through a specific case study. The project I will be focusing on includes the traditional GPS system as part of their project delivery method. The information obtained will be qualitative data as I will conduct an interview with the business owner and get his input and experience with the use of this technology. I will be focusing on the successes and efficiency of these systems in the field. Nobody can provide a better understanding of how this system helps or hinders a project than the people involved with this system. Many contractors, especially

smaller scaled companies are doubtful of the recent new technologies that emerge thus avoid taking the risk of investing time and efforts into these new technological trends. I hope this interview conducted with this heavy civil contractor is helpful and persuades those skeptical contractors to make an investment and see the benefit of this resource. I will pose questions that are targeted to highlight the GPS system and obtain information about advantages and disadvantages, cost, time, and how it is used in the field. Another topic where this individual will be asked about is the technology of SmartGrade. Jeffrey Brough, President of Brough Construction, Inc. attended a weeklong training at the John Deere facility in Illinois where he was introduced to this SmartGrade technology. He was the individual that sparked my interest in this after not seeing much research previously conducted since it's a fairly new concept. Some questions posed to him will relate to his reasons for attending this training, what was learned, determining if he will attend more training in the near future, and if he feels that this SmartGrade technology would be beneficial to him and his business. Through these interview questions, I will discover how general contractors feel towards this technology and conclude if they feel like this is something that they should invest in.

Another part of my methodology will be an interview with the Director of Construction Positioning Technology at John Deere, Kevin Murphy. Kevin works internally at John Deere and will be able to provide qualitative data. This research will aim to provide a better understanding of what this technology is used for, and which type of contractors would benefit more. Kevin is an expert who deals with this technology on a daily basis and is qualified to provide his professional opinion on the usefulness and efficiency of this technology. I will also obtain information that is practical for those contractors that are on the fence about obtaining and implementing this technology. I suspect this information will help contractors form a better decision of whether these systems can become an asset to their company or if they should remain using other traditional methods. Kevin and his expert knowledge will be able to provide us with some insight about this technology and inform those contractors that need these technological advancements to become more efficient and competitive. Like any other technology, issues always arise. I hope that with this interview, I can acquire information that is valuable so I can differentiate the advantages against the disadvantages and see if it is worth the time and money to invest into these types of rising trends. How unfortunate to invest in something that fails during operations or worse to not be used in the appropriate manner by its field operators, hindering the efficiency and effectiveness of the company.

With the two interviews I expect to find differentiating points of view between what a field person/contractor states compared to what a sales representative anticipating a commission check has to say. It is vital to include these two different perspectives to highlight the topic in a well-rounded manner examining different points of view. Jeffrey Brough of Brough Construction, Inc. will be able to provide information about this with a contractors and business owner perspective. Heavy civil construction is a sector within the construction industry that is a fast paced and dynamic environment with changes occurring often on the jobsite. Jeffrey Brough will help us understand if this technology can keep up with these constraints. General contractors in this industry hopefully can connect easily with Jeffrey regarding the aspects of this technology. On the other hand, we will review what insight Kevin Murphy provides regarding the technology's performance and capabilities. He will provide information that can facilitate the understanding of what this technology can do without that field insight and business owner standpoint but a more technical point of view. After conducting both of these interviews we will see what kinds of advantages and disadvantages exist throughout this technology. I am eager to find information that is valuable and helpful to those that are indecisive. I hope to educate my audience on the numerous benefits, advantages, and disadvantages in order to execute a sound decision on whether or not this resource is of interest to them and their business.

By utilizing this methodology, the goals of this case study and interview are to:

- Provide an understanding of GPS technology and SmartGrade usage in the heavy civil sector
- Explore the advantages and disadvantages in the use of this technology
- Analyze any issues or benefits seen in the field by users of these systems
- Examine what is needed to acquire and implement this technology

- Identify risks or responsibilities in the use of this technology
- Provide new knowledge to general contractors and seek areas that are in need of future research

Below you will see the interview questions posed to Kevin Murphy from John Deere about GPS and SmartGrade in the industry along with his responses.

GPS System Questions

How is this GPS technology used in the industry?

GPS technology is used by using GPS satellites, radio, and onboard computers to give a real time position on the corner of the cutting edge of a machine or the tip of a GPS rover rod. This will show you where you are on the project site in reference to a 3D model.

What sizes and types of companies come to you to inquire about GPS?

The smallest size that I ever sold to was a customer that didn't even have a bulldozer when they first invested in the technology. The largest is a company who possesses hundreds of machines. From the smallest to the largest, it benefits them all, but it benefits the smaller companies, sometimes more since less management is needed to manage the system.

What is the size of investment a company must take to use this?

For the GPS, you have to have a GPS base station, a base and rover, so the investment there is about \$40,000. On a machine you can kind of consider about \$60,000 to equip a machine with GPS. The rule of thumb is about \$100,000 for your first base station, rover, and machine. That cost has been pretty consistent for about the last fifth teen years. The technology has advanced, but like a lot of technologies, the cost pressure for the pricing is always downward.

What training is needed to use this? Any software or prior experience to use this?

No on the software, because when people initially get into this, it's easy to subcontract out the 3D model building. For prior experience, it's best if you already know how to do your job without the technology. I think competency is the only level that we need to get to. The user interface in the system is simple enough to use if you know what you're doing. We can get a new customer going in about 4 to 6 hours of on-the-field training.

How can this technology make a jobsite run more efficient? What are the benefits?

The biggest benefit for efficiency is no rework. The equipment is designed to get you to grade in grading applications. This system will not allow you to grade deeper than needed. Some operators that don't have this technology run into issues when they go too deep. You can't just go back and throw dirt on top of the existing ground, you won't get the compaction, so you must rip it up, bring the material in and then regrade it. It's pretty much doubling your work for your finishing costs. Another benefit is the elimination of a surveyor or a grade checker for certain situations. There will be less people at the jobsite which will increase efficiency and reduce labor costs. Generally, we'll see in terms of efficiency on a machine if you go from a bare machine that has no technology on it, to a machine that has automatics incorporated into it. You'll see around a fifty percent increase in productivity.

What kinds of issues do you see in using this? Any drawbacks?

The only thing I've seen as a drawback is that users begin to just accept the answer that the technology is giving them without going ahead and doing the basic work that they need to do including simple construction methods. People should not rely on technology like this is supposed to do your job for them. People still need to use common sense.

How reliable are these instruments in the field?

The instruments in the field are reliable. We are accurate with just the GPS system ranging between about four hundredths vertically to two hundredths horizontally. There are opportunities where someone can go in and punch in a wrong number, like a rod height. But in that case, you are going to be off two meters and you are going to catch that. You are never off just a little bit unless your data is bad.

Do contractors come to you and are they sometimes hesitant to get this kind of equipment implemented in their company? Why are they so hesitant about it?

Yes, I think the biggest reason is they've been doing it one way for so long that they don't see the need to change. The other thing is price, watching costs. Company owners begin to think of what else they could spend \$100,000 on. The difference is I can guarantee that the \$100,000 investment that they make will pay for itself in six months.

*SmartGrade Questions***What is the amount of investment needed?**

To incorporate SmartGrade technology onto the machines since they are all electric over hydraulic controls, customers are only looking at about \$60,000. Wiring for this technology is easy to install.

Is training required?

I've never spent more than probably two hours with a new customer on this technology. This technology is a learning by doing process. It takes about fifteen minutes to get the customer moving on the machinery, showing them the screen, the user interface, and getting them to relax and not be afraid to touch a button or ask a clarifying question. By the end of the day, they are usually significantly more productive and pretty comfortable with getting started the next day. We also have the ability to troubleshoot if there's something wrong or they are confused about something remotely. Simply logging on the machine and seeing what they are doing, and both the customer and the dealer can transfer files back and forth.

What types of contractors would be the most fit and would benefit the most from this?

Contractors that are looking to buy a new machine and if this technology is available would be the most fit. These contractors should absolutely be investing in this, I cannot imagine them not. It is a guarantee that you are going to get a full return on your investment.

What are the drawbacks and advantages you see?

The only drawback I see is that you cannot move the technology from machine to machine the way some contractors would prefer to. Regarding the advantages I see the following: increased performance, increased efficiency, and lower cost of all those components compared to the traditional system.

Do you think this technology will eventually eliminate the need for a skilled operator?

No, it won't eliminate skilled operators at all, what it will do is change their skill set. With this technology operators that are equal in terms of their ability to run equipment without it are separated by how much they utilize the technology and how much they choose to learn on their own on how to best benefit them.

*General Questions***Where can interested contractors go to receive additional information or training?**

The best place to start is YouTube, many interested individuals have found helpful information on the internet. John Deere and Topcon in particular have the best training sites and programs in the industry. Topcon has a full training center in Livermore, CA.

Can this technology affect the safety of employees?

Initially it was suspected to increase safety on a job site because you have fewer people on the ground. But after critical thinking it is also true that it affects job site safety because we have screens on the equipment, you have to train guys to not look at that screen. You want the operator looking at the cutting edge of whatever he's running because that's where he needs to focus and observe to ensure the area is clear of any potential collisions (Murphy, 2022).

Below we will see the case study on Brough Construction, Inc. in regards to this technology in the industry.

Case Study

Brough Construction, Inc is a heavy civil construction company located in Arroyo Grande, CA, twenty-five minutes south of the Cal Poly, San Luis Obispo campus. The company holds a class A general engineering license since its incorporation in 2006. Brough Construction, Inc. not only serves the central coast, but also completes projects in the central valley, ranging from as high north in Fresno, CA to the southernmost part of Kern County in California. Brough Construction has been able to build a successful central valley crew and a central coast crew that complete jobs that include storm drain, water, sanitary sewer, roadway, and sitework improvements. These projects all range from \$100,000 to \$10,000,000 in monetary value. The company currently employs about fifty to seventy people.

Brough Construction, Inc. recently completed a project for the City of Avenal. The project was completed in early March 2021 and was titled San Joaquin Street Road Project Phase III. The project consisted of providing asphaltic concrete (AC), aggregate base (AB), removing subgrade for an area of 23,425 square yards, removing and replacing 2,500 square feet of concrete curb, gutter, sidewalk, handicap ramps, along with upgrading fire hydrants, water services, and precast concrete boxes. GPS was used throughout the duration of this job, and it is a perfect example of what types of projects this system is good at.

The following are the exact interview questions asked to Jeffrey Brough, along with his responses.

When did you acquire the GPS system?

In 2019, we had a project for Shea Homes in Nipomo, CA. We had utilities we needed to install in previously graded pads and our contract made us responsible to put everything back to grade. I knew I could get a model, so I went ahead and got the equipment. I first leased everything with a dozer and then went ahead and purchased everything.

What made you want to use this? What convinced you?

This Nipomo job got me to use it, we had 200 acres of digging that needed to be put back efficiently. I did not want to do it because of the acquisition cost of it. I also did not know how to use it, so I took a quick course on it. What convinced me was that I knew that we were behind trying to keep up with our competition. The competition was already using it, they were being more efficient, and so therefore we had to be able to compete.

Was the investment you made on this product worth it?

Absolutely. Currently, we probably only use fifth teen percent of what it can do right now, but what we found is that on some small jobs we can verify grades on the fly. It definitely made it worth it.

In regards to the Avenal Project, what did you use GPS for and could you have done this without it?

This job had predesigned crowns for the roadway. It was not a constant percentage from gutter lip to crown. We were able to build a model off of their design crowns and then grade off of that. We did it for two reasons. Firstly,

for speed of the road grading. Secondly, to minimize our material overages. GPS allowed for the opportunity to be exactly on grade and not have material overages. I could not have done this without it.

Any issues you experienced at the jobsite in Avenal with this technology?

Yes, we had trouble because we had the overhead power lines. We had to learn how to try to get away from those to make it work. To fix this, we could only work on one section of the road and then move the base station to another location because we were getting interference from power lines.

What advantages did you see?

The advantages we experienced were efficiency and overall costs. We eliminated a person on the ground as a grade checker and minimized material overages.

In regards to the training you received at the training center in Illinois, tell me a bit about it. What did you learn, was it worth your time?

That was a sales pitch for John Deere to sell me their SmartGrade equipment. They do see a need that there's not a lot of people teaching what they do. Topcon, a GPS company, is not owned by John Deere; however, they do have a business relationship. Topcon training center is where they teach about the software. John Deere is having to teach it out of attrition since they are selling a product that goes on their machines. The training opened my eyes to what we can do with that stuff. It was worth my time.

Do you feel you are more comfortable with GPS?

Yes, I feel more comfortable with GPS, but it's something that you need to be using all the time. Many of my superintendents are picking up on it as well. I hope when you (Cristian Zarate-Ramirez) graduate you will be able to take the lead on this stuff.

Would you invest in a SmartGrade machine? Why or why not?

I would consider it if we got into more grading situations. The only difference between the SmartGrade machine over anything else is that the components are all built into it. They are not aftermarket add-ons, and, in the future, we won't have the option of having add-ons, they are just going to be SmartGrade. As of right now I do not grade enough to go and say, I need that SmartGrade skid steer. I do own a built-in skip and drag, so I guess I would invest in it, but that's the only way that it came off the line. I believe that when it's time for me to purchase a new dozer, I will not have an option. It'll just be a SmartGrade (Brough, 2022).

Analysis of Data

From these interviews with Kevin Murphy and Jeffrey Brough, many things were concluded about both GPS technology and SmartGrade. We can determine that this technology has come to modernize the construction industry along with increasing the productivity and efficiency of the contractors using it. The initial investment can draw contractors away from investing in the technology but the positive aspects definitely out way the negative. The interview with Jeffrey Brough gave us an understanding of how efficient his company was in his grading operations for the City of Avenal project. Kevin Murphy gave us an expert perspective and answered questions contractors still have on what these machines and equipment can do for their business's benefit. He expressed how this new technology makes construction companies stronger and the various benefits they can reap from implementing this technology within their business.

Positive Aspects of this Technology

A benefit we learned through these interviews was the efficiency of completing a grading task. Projects can become complex in all sorts of ways. The project encountered by Brough Construction included pre-designed crowns on the roadway. Using this technology, they were able to use a motor grader to grade without having material overages or rework. Also, time was saved along with increased speed progression which is vital for meeting project milestones. Another thing is the accuracy we can obtain from these systems. Contractors can be confident that the data given is within tolerances. This technology eliminates the need for a grade checker for a company, which can highly reduce labor costs. In terms of SmartGrade, we learned that this technology eliminates the need for all the cabling and brings in a high-performance integrated machine. Training is fairly simple and available to everyone. The initial investment can be high to some, but a major advantage is the guaranteed return on equity in a short amount of time.

Negative Aspects of this Technology

Like anything in this world there is good and there is bad. This technology can also have some flaws. A major flaw we learned is the interference with the power lines at the jobsite. This can be an issue in roadway construction where overhead power lines are very prominent. Another issue found is relying too much on the data. Many operators can become so dependent on this that they lose the foundational knowledge of construction methods. It is best to be cautious and use common sense in trying to accomplish tasks at the jobsite. Safety is also something that is affected, we see that screens are incorporated into the machines which can distract operators and unnecessarily cause accidents. Lastly, the initial cost can be a bit elevated for some at first, which is totally understandable.

Future Research

This technology has changed how we build, however there is more to do to make our industry efficient and sustainable. We are moving towards autonomous machines. Equipment without operators inside the machine. We see a lot of this in the agriculture industry already. This is something that needs to be researched further to accommodate a construction jobsite. Another area that must be researched is the ability to see what is out in front of us during grading operations. For example, if you are trying to grade to a certain pad elevation and there isn't any material onsite, the blade is going to work, but there's just an air void underneath it. Being able to speed up using artificial intelligence and measuring where the material is as we move around is one of the benefits that needs more research (Murphy, 2022).

Conclusion

Without a doubt this technology has come to revolutionize the traditional contractor's abilities and its means/methods to a more technological involved business. The GPS system and SmartGrade technology make us smarter, more efficient, and better competitors in the industry, especially in heavy civil construction. It is difficult to accept new changes, but we need to realize that the construction industry is an industry of continuous learning that we must acquire in order to become a successful builder. This technology continues to make efforts to improve how we do mass excavations and earthmoving to the simplest thing as locating a point on a jobsite. There is no reason to use a traditional process when this technology exists to make our lives easier.

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