Integration of Autonomous Equipment in the Heavy Civil Industry

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The heavy civil industry plays a pivotal role in shaping the infrastructure landscape, with construction equipment serving as the backbone of any project. In an industry that is constantly looking for ways to improve efficiency, productivity, and safety, autonomous construction equipment has emerged as an innovative solution to help improve these factors on a heavy civil project. The purpose of this paper is to present an in-depth look at the current state of new technology involving autonomous construction equipment, and how prevalent it is in today's heavy civil industry. Qualitative interviews that were completed with a project manager, superintendent, and a foreman that work for Toro Enterprises were used to help emphasize where autonomous equipment is at related to a smaller heavy civil company, and if it's worth it for them to implement this equipment into their everyday work. With autonomous equipment being a relatively new technology, future research that can be studied is cost-benefit analysis, initial investment costs, maintenance expenses, potential productivity gains, and how it can work side by side with BIM.

Key Words: Autonomous, Heavy civil, Equipment, Construction

Introduction

In recent years, there has been a remarkable rise in unmanned operations, surpassing the expectations of many. With companies like Tesla cutting-edge advancements now allow cars to navigate roads without the need for human intervention, and soon the rapid growth and enhancement of autonomous technology encompasses every industry, including construction. Companies like Built Robotics, Komatsu, Caterpillar, Bobcat, and many more are actively developing solutions to eliminate the need for operators in equipment, paving the way for autonomous technology implementation on excavators, skid steers, dozers, and other machinery.

Autonomous heavy civil construction equipment offers significant benefits in terms of both safety and productivity. With autonomous equipment, the risk of accidents and injuries is reduced since there is no human operator exposed to potential hazards. The reliance on advanced sensors, cameras, and
artificial intelligence enables autonomous machinery to detect and respond to its surroundings with precision and accuracy. This can eliminate human error and potentially enhance overall site safety. Furthermore, autonomous equipment can operate continuously without fatigue, allowing for round-the-clock productivity and potentially reducing project timelines. These machines can follow pre-programmed routes, perform repetitive tasks consistently, and optimize workflows, leading to increased efficiency and output.

This paper's purpose aims to examine the level of interest among heavy civil general contractors who heavily rely on extensive heavy equipment in adopting autonomous construction equipment as a potential replacement to human operated machines that have been used for many years. By obtaining a comprehensive understanding of their perspectives, this study intends to assist contractors in making informed decisions regarding the compatibility of autonomous construction equipment with their companies.

**Literature Review**

*History of Heavy Equipment*

The urbanization and territorial expansion in the United States propelled the Second Industrial Revolution. This transformative period witnessed the emergence of innovative machinery, including Benjamin Leroy Holt's combine harvester and steam engine tractor in 1880 and 1890, respectively. John Froelich further contributed to agricultural progress in 1892 with the invention of a gasoline-powered tractor featuring both forward and reverse gears. These agricultural advancements laid the foundation for the development of contemporary construction equipment as written (Heavyequipmentcollege.com, 2018). The same article says “In the 1920s, bucket wheel excavators emerged as powerful mining tools, revolutionizing the extraction of valuable minerals. This decade also witnessed the rise of heavy machine companies, with established ones merging and expanding, like Holt, which eventually became Caterpillar. Additionally, important construction machinery, like the bulldozer with continuous metal tracks, was invented during this period and continues to be widely utilized today.” (Heavyequipmentcollege.com, 2018). Heavy civil equipment has come a long way since these times, and autonomous equipment is ahead of its time.

*Productivity*

Built robotics writes the machine uses less fuel and moves more efficiently, which prolongs the life of the machine, reduces maintenance, and prevents unnecessary wear and tear. On average, a robotic piece of equipment from Built runs at the same speed and responsiveness as one being used manually by a person.” (Manufactures, 2021). This is another reason autonomous construction equipment is growing, because of the increased productivity. While autonomous equipment can be seen as expensive over the long run there can be seen benefits to costs, and one article writes While autonomous hauling system implementation would cost on average “$13 million at a site with 10 trucks and 15 ancillary vehicles, the total benefits are calculated to be $19 million. This indicates that investment into autonomous technology ultimately pays off.” (Manufactures, 2021) These benefits are
seen from the longer production hours, reduced load, and unit cost of 15%, and improved tire life of 40%. All these factors can be optimized when using autonomous software on equipment, and thus improve the productivity of these machines, which helps with cost on a project.

**Safety**

In the 13 years of autonomous equipment operation, between Komatsu and Caterpillar, they have moved over 5 billion tons of material, and Caterpillar alone has logged over 42 million miles with zero hauler-related incidents or lost time injuries. In contrast, a recent department of mines study analyzed the deaths of 52 miners over the past 12 years, finding worker fatigue and inexperience with mining risks to be the biggest cause of accidents. In a report that CAVCOE coauthored, they predicted that with full deployment of autonomous and connected vehicles, 80 percent of traffic collisions, fatalities and injuries could be eliminated. Autonomous machines can perform remote or difficult work, which helps keep people out of harm’s way. (Manufactures, 2021). In the *article Driverless Dozers and The Dawn of Autonomous Vehicle Technology in Construction* the author writes, “‘Operators historically have had tough jobs,’” Van Hampton said. “‘You’re driving something that’s off-road, so your neck, arms, and hands get tired. More construction is being done at night nowadays, too, so operators take little micro naps while they’re working. All this increases risk on projects. Automating safety—for instance, by making machines smart enough to detect if the operator is falling asleep, then wake them up—can reduce those risks.” (Alderton, 2021).

**Methodology**

Data collection for the study on autonomous construction equipment in the heavy civil industry was conducted through a series of interviews with key personnel including a project manager, superintendent, and foreman from Toro Enterprises. The interviews were structured around a set of predetermined questions that directly pertained to the topic at hand. The questions explored various aspects such as the advantages and challenges of using autonomous equipment, the impact on project timelines and productivity, safety considerations, and the potential effects on the workforce. By interviewing individuals occupying different roles within the chain of command, a quality understanding of the subject matter was obtained, allowing for an analysis of the implications and feasibility of autonomous construction equipment in the heavy civil industry. The following questions were asked to help further the investigation of this project:

- What are the main advantages of utilizing autonomous construction equipment in comparison to traditional manual operated machinery?
- What are potential challenges or limitations associated with implementing autonomous construction equipment on site?
- How would the integration of autonomous equipment impact project timelines, productivity, and overall project efficiency?
- What safety measures and protocols would need to be installed to ensure the safe operation and interaction of autonomous construction equipment with workers and the surrounding environment?
How does the adoption of autonomous construction equipment impact the workforce, and job roles within the construction industry?

Results

What are the main advantages of utilizing autonomous construction equipment in comparison to traditional manual operated machinery?

This question was asked to get an idea of the gentleman’s thoughts about autonomous equipment compared to how they run jobs with manually operated equipment. One of the project managers answered, “It can easily enhance efficiency by being able to work nonstop, and obviously operators of our heavy civil equipment are going to need breaks which decreases overall efficiency slightly.” The superintendent for Toro answered “It would likely increase efficiency with projects that involve grading and excavation, because laborers could make a mistake which would lead to rework. Autonomous equipment could lead to higher quality and minimize mistakes.” Their comments regarding this question were like many of the claims autonomous equipment companies make regarding the increase of efficiency and productivity.

What are potential challenges or limitations associated with implementing autonomous construction equipment on site?

When asking this question during the interview the project manager responded, “One potential challenge would be the initial investment required to purchase and integrate the autonomous machinery into our existing day to day operations.” Toro already has many pieces of manually operated construction equipment, and to integrate autonomous equipment into their system it would require a large investment, because this new equipment is not cheap. Potentially if they were to decide to gradually purchase equipment and use it on a few projects then they could slowly get accustomed to using it. It sounded like fully committing to autonomous equipment did not make sense for their company now.

Another challenge the foreman mentioned was “Having to train or hire new workers to be able to maintain the equipment, and to able to properly set it up on a jobsite would be expensive. Also relying on the technology that could potentially malfunction or glitch during a project could potentially delay a project days or even weeks.” Maintaining the equipment as well as hiring new workers who know how to properly set it up is another cost that seems to add a bit of risk for Toro.

How would the integration of autonomous equipment impact project timelines, productivity, and overall project efficiency?

When discussing this question, the superintendent for Toro Answered, “Autonomous equipment can help eliminate downtime from the operator who typically run this sort of equipment, and over the course of a project this will add up to increase the overall productivity which would then lead to a
shorter timeline for some projects.” This seemed like a common theme throughout the interview process, and the downtime was one thing the people being interviewed mentioned more than once. Autonomous equipment has superiority over manually operated equipment, because if it is fueled up it can run nonstop compared to a human that needs to use the restroom, eat food, and sleep.

The project manager made another interesting point when asked this question “The autonomous equipment is very precise, accurate, and consistent which would lead to faster completion for construction activities. With the autonomous equipment being able to focus on specific tasks these would reduce the need for manual labor, and laborers would be able to focus their work on other tasks.” Adding autonomous equipment to the equation for a given project seems to be more efficient then manually operated equipment, and this correlates with quicker project timelines.

**What safety measures and protocols would need to be put into place to ensure safe operation and interaction of autonomous equipment with workers and the surrounding environment?**

With safety being one of the main priorities on any jobsite this question was important to gain insight into the opinions of people who work around heavy equipment daily. When asked this question the foreman for Toro responded, “proper training programs must be established to educate workers on the specific operational requirements and safety precautions associated with autonomous equipment.” With the integration of autonomous equipment if workers such as laborers were not trained properly with this new technology, then this could add some potential risks on the jobsite. This factor would have to be considered when deciding whether to invest in this equipment.

The foreman brought up another great point about safety, and said “Clear communication channels, including signage and designated communication systems, should be established to facilitate effective communication between autonomous machines and workers.” Signage is common and necessary throughout any construction project, and when bringing autonomous equipment into the equation new signage should be created. With new signage saying, “Caution autonomous equipment at work”, or something along those lines this can raise awareness to anybody working on the jobsite. Hopefully by adding some type of signage this can help minimize the dangers of autonomous equipment.

**How does the adoption of autonomous equipment construction equipment impact the workforce and job roles within the construction industry, and are there any concerns regarding job displacements?**

This is a main concern with any autonomous equipment in any industry, and the concern being that some people could potentially lose their jobs to this new technology. The project manager for Toro answered “While autonomous equipment can help productivity with certain tasks, it won’t necessarily result in job displacements. It may shift the workers’ focus to become more technical with the autonomous equipment which could result in more training. There is also always going to be the need
for manual labor for certain task autonomous equipment cannot complete.” There are certainly some activities that autonomous equipment isn’t capable of yet, so laborers completing manual labor will always be needed.

The superintendent responded to this question saying “It’s important to provide training opportunities for workers to help them adapt with this new technology. Otherwise then autonomous equipment could potentially take people out of jobs, so if people do not evolve alongside this new technology, then they could get left behind.” If companies decide to invest in this new technology, then people who run the equipment manually shouldn’t have anything to fear. If they are willing to adapt alongside this technology, then they should worry about being replaced.

**Conclusion**

In conclusion, autonomous construction equipment offers numerous benefits that can significantly transform the heavy civil industry. The integration of autonomous machinery enhances operational efficiency, improves precision and accuracy, and enhances safety on construction sites. However, it is important to acknowledge that smaller heavy civil companies may face challenges in adopting this technology. The high initial investment costs, the need for specialized training, and the potential disruption to existing workflows make it difficult for smaller companies to embrace autonomous construction equipment. Nonetheless, with the right support, collaboration, and strategic planning, smaller companies can gradually explore opportunities to adopt this technology, benefiting from increased productivity, improved project outcomes, and a competitive edge in the evolving construction landscape.

**Future Research**

With autonomous construction equipment in the heavy civil industry, there are many areas for future research that can further expand people's understanding and address existing knowledge gaps. One area of exploration could focus on the long-term cost-benefit analysis of adopting autonomous machinery, considering factors such as initial investment costs, maintenance expenses, and potential productivity gains. Another area of interest is the integration of autonomous equipment with Building Information Modeling (BIM) technology, investigating how these technologies can work side by side to optimize project planning, coordination, and resource allocation. Exploring the human factors aspect of autonomous equipment, such as worker acceptance, training requirements, and job design, is also an important area for future research. By pursuing these directions, future studies can contribute to the continuous advancement and successful implementation of autonomous construction equipment in the heavy civil industry.
References

