Case Study: Diesel Powered Loaders Compared to Electric Loaders in Heavy Civil Construction

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As the construction sector evolves, the environmental consequences of greenhouse gasses have become a significant issue. Numerous contractors are transitioning to electric-powered systems, which offer more energy-efficient methods for heavy machinery, enhanced productivity, and construction equipment that meets new and improved emission standards. This paper aims to examine the viability of heavy civil construction firms transitioning from traditional diesel-powered wheel loaders to electric wheel loaders. Given the competitive and saturated market in road construction, many contractors have already started investing in electric systems. This results in cost savings in terms of fuel efficiency and operating expenses compared to conventionally fueled loaders. Semi-structured personal interviews with heavy equipment experts, as well as primary and secondary sources, were used to conduct qualitative research for this report. Despite the potentially higher initial cost of switching to an electric system, it will result in lower operating costs and environmental impacts in the future.

Key Words: Efficiency, Cost Savings, Heavy Civil Construction, Machinery, Electric

Introduction

The history of heavy construction machinery is a fascinating journey that began in 1886. Benjamin Leroy Holt, a pioneer in the field, invented the first combine harvester for agriculture. This was a significant development in the industry, marking the beginning of a new era in construction and agriculture. Four years later, Holt introduced another groundbreaking invention: a steam engine tractor. These inventions laid the foundation for the development of heavy equipment, particularly in the heavy civil industry (Johnson, 2017).

John Froelich, another innovator in the field, invented the gas-powered tractor in 1892. This invention played a crucial role in shaping the future of heavy equipment, especially in the heavy civil industry (Johnson, 2017). These two machines revolutionized the landscape of heavy machinery used in many of today’s construction projects. Before these machines were invented, labor-intensive methods were employed to transport materials and aggregates. This resulted in slower production rates and longer construction durations. One of the limitations of this period was that these machines were primarily designed for agricultural purposes.

In 1901, Benjamin Holt managed to incorporate the track technology initially seen on a commercial machine known as the Lombard Steam Log Hauler into his gas-powered track-type tractor. By integrating the continuous track technology of the Steam Log Hauler and creating more track-type machines, now known as crawlers, Holt gave birth to the “Caterpillar”. These technological advancements marked a significant turning point for all heavy equipment. The improvements extended beyond agriculture, leading to the production of metal track military equipment that would be used on tanks and other vehicles during World War I (Kolt, 2018).

The popularity of the track-type tractor during World War I led to the emergence of different types of heavy equipment machinery. In the 1920s, the first bulldozer and bucket wheel excavator were manufactured. This period
was known for its mining operations throughout the United States, and these machines had a significant impact. As heavy machinery became increasingly popular, many companies like Holt’s, now known as “Caterpillar”, began to establish and grow. As a result, this heavy equipment became an essential part of economic growth post World War II. As the economy expanded, the need for new construction emerged. Heavy equipment like the bulldozer was crucial to earthwork and mining operations that took place as a result of the economic expansion (Kolt, 2018).

As the demand for the production of more and more heavy equipment increased, so did the technological advancements of the equipment. The Interstate Highway project was fully underway, and the heavy equipment market was thriving. Hydraulic systems gained popularity over cable-operated controls. During the 35-year period of highway construction, the new sophisticated hydraulic system made its way to the United States, replacing the cable-operated system. As a result, manufacturers began producing heavy equipment with the new technological advancements.

The completion of the Interstate Highway Project that occurred over the past three decades led to a significant decrease in demand for heavy equipment in the 1980s. As a result, many companies merged to form larger and stronger companies, but many did not survive the recession. It wasn’t until the 1990s that these companies began to face new environmental regulations. These regulations forced all heavy equipment manufacturers to modify their engines to reduce their carbon footprint.

Since these environmental regulations were enacted, there has been an increase in the design and innovation of cleaner powered heavy equipment. In May 2007, Komatsu launched the world’s first electric forklift truck, followed by the world’s first electric excavator in May 2008. This marked a significant shift in the industry towards more environmentally friendly and sustainable practices (R. Stevenson, 2010). The introduction of electric machinery not only reduced the carbon footprint of heavy equipment but also led to increased efficiency and productivity in the construction industry. This trend continues today, with more and more companies investing in electric machinery to meet their construction needs while also contributing to environmental sustainability. The transition from traditional machinery to electric machinery represents a significant step forward in the construction industry, paving the way for a more sustainable and efficient future.

**Background**

*Hydraulic Wheel Loader*

The hydraulic wheel loader, a four-wheeled earthmoving machine, is a key player in various sectors such as construction, agriculture, and industrial cleanup projects. This machine employs an arm to elevate and lower its bucket, while a bell crank is utilized to open and close the bucket. Wheel loaders have the capability to lift a wide array of materials, including debris, gravel, soil, dirt, and pallets. (Wheeled Up)

The operation of a wheel loader is relatively simple. The machine works by digging a front-mounted bucket into the ground, scooping up, and transporting materials. Similar to other lifting devices, this front-mounted bucket carries objects with an internal hydraulic system. Operators also have the ability to adjust a load in midair to better leverage its weight.

The engine of the wheel loader powers both the hydraulics and the transmission. These, in turn, move the front attachment (such as a bucket, forks, sweeper, etc.) to manipulate the material being handled, and the wheels or tracks to move the machine around the jobsite and through nearly any kind of terrain.
The design of a wheel loader offers numerous advantages, explaining its widespread use across industries. Some of the benefits offered by a wheel loader include strong versatility to perform a diverse set of jobs, high maneuverability to move around a worksite nimbly and swiftly, a simple design that can lead to reduced maintenance costs, less impact on working surfaces than other machines, and a wide range of sizes and attachments to fit numerous applications. (Lee and Shaw, 2019)

Different attachments provide new tools for working with materials; a wide range of sizes are designed for certain applications, articulation offers more maneuverability, and other customizations fit specific circumstances. One of the most notable differences in wheel loaders is how lifts are loaded and managed by the loader’s arm, with the most common designs for the arm and its linkage being Z-bar linkage and parallel-lift linkage.

![Wheel Loader and Parts](image)

**Figure 1. Wheel Loader and Parts (VeriTread)**

*Electric Performance in Wheel Loaders*

Fully electric wheel loaders are a marvel of modern engineering. They operate using a battery that powers two separate electric motors. One motor is dedicated to the drive system, which controls the movement of the loader, while the other powers the working hydraulics, which operate the loader’s arm and bucket. The power is automatically provided by the respective motor, depending on the task at hand. This intelligent power distribution helps to minimize energy consumption, making the loader more efficient. (Volvo, 2021)

Mechanically, electric loaders function similarly to their traditional counterparts. The primary difference lies in the power source. Instead of a diesel engine, they use an electric motor. This motor powers the hydraulic pump, which is responsible for operating the loader’s various functions. The hydraulic pump generates a flow of hydraulic fluid, which is then directed to hydraulic cylinders and motors through a series of valves. The pressurized fluid causes the cylinders and motors to move, which in turn operates the loader’s arm and bucket.

The arm of the loader, which is controlled by the hydraulic system, can lift and lower the bucket. The bucket itself can be opened and closed using a bell crank mechanism, also controlled by the hydraulics.

In a nutshell, the electric motor provides the power, the hydraulic system controls the movement, and the loader’s arm and bucket carry out the work. This efficient system allows the electric wheel loader to perform a variety of tasks, from lifting and moving materials to digging and grading.
Advantages of Electric Powertrain Systems

Fully electric powertrains are known for their zero emissions. Unlike traditional internal combustion engines that emit harmful gases, electric powertrains produce no tailpipe emissions. This makes them an environmentally friendly choice, contributing significantly to the reduction of greenhouse gases and air pollution.

Additionally, electric powertrains offer improved fuel economy. They are highly efficient, converting a larger percentage of the electrical energy from the grid to power at the wheels. This results in a better “fuel” economy compared to conventional internal combustion engines, translating to cost savings for the user in the long run.

Thirdly, electric powertrains provide instant torque. Electric motors can deliver their maximum torque instantly from a standstill. This characteristic leads to quick acceleration, making electric vehicles responsive and fun to drive. Electric powertrains are characterized by their simplicity and reliability. They have fewer moving parts compared to internal combustion engines, which means there is less that can go wrong. This results in lower maintenance costs and an increased lifespan for the vehicle. (Volvo, 2021)

Lastly, the use of regenerative braking in electric powertrains enhances efficiency. When the vehicle is braking or going downhill, the electric motor operates as a generator, converting the kinetic energy back into electrical energy, which is then stored in the battery for later use. This process reduces wear on the braking system and increases the overall efficiency of the vehicle.

Objectives

- Investigate the environmental consequences of acquiring both types of wheel loaders for roadway construction.
● Evaluate the operating and ownership expenses associated with both electric powertrain wheel loaders and conventional diesel wheel loaders.

● Assess the practicality of heavy civil contractors transitioning to electric powertrain wheel loaders.

● Offer new knowledge to roadway contractors on the procurement costs of an electric powertrain wheel loader.

Methodology

To ensure the most accurate results, I conducted a thorough review of existing literature through semi-structured interviews and the use of primary and secondary sources. This approach helped me delve deeper into the complexities of the research topic. With the insights gained from this comprehensive review, I’m now in a position to evaluate the ownership and operating costs of both types of heavy machinery by calculating a rate of investment. Conducting interviews with knowledgeable professionals really helped me understand the industry’s viewpoint on such a new technology. I was able to ask the questions that normal research could not. I was able to greatly expand my own understanding of electric machinery and its real world capabilities. Moreover, I can provide contractors with insights on the feasibility of transitioning to an electric system in heavy civil construction, with a specific focus on roadway construction.

Case Study

For this case study, I’m concentrating on numerous roadway construction firms, but I was fortunate to gather information from Skanska Heavy Civil Construction. Skanska, headquartered in New York, New York, specializes in all facets of heavy civil construction. Their work encompasses dams, underground tunnels, roadways, and bridges. My focus will be on their roadwork operations to gain insights into their future investments in heavy equipment. This study will center on the Bobcat T7X, a model manufactured by Bobcat that is available in both diesel and fully electric versions. Skanska, being an innovative company, has both versions of this machine at several of their job sites nationwide.

Data Collection

Utilizing both primary and secondary sources, I was able to gather valuable information about the functionality of both electric and conventional wheel loaders. This gave me a practical understanding of each type. However, this information alone wasn’t sufficient to fulfill my objective of providing roadway contractors with a feasibility report on the use of electric machines. As I aimed to be well-informed enough to convincingly propose the idea of transitioning to fully electric-powered heavy equipment to contractors, I conducted several interviews with different project team members within Skanska’s Seattle office. This gave me a deeper understanding of the purchasing, operating, and ownership costs of both the conventional and electric versions of the Bobcat T7X wheel loaders.
One of my initial interviews was with Dillan Quigley, a Senior Project Engineer with Skanska Construction. Dillan, with his extensive experience tracking weekly cost reports on the company’s heavy machinery fleet within the L300 Link Extension project in Seattle, provided accurate information about the ownership and operating costs of both the conventional and electric T7X wheel loaders. This information enabled me to perform a precise life cycle analysis of each machine. Additionally, I gathered information on upfront costs, life expectancy, routine maintenance checks, and the estimated hourly use per week.

During our conversation, Dillan raised several points that I hadn’t previously considered. One such point was the potential benefit of renting equipment for smaller projects when company equipment wasn’t available. This was a factor I had to consider when performing my calculations and assessing the value of these machines. After gathering sufficient information, I found it relatively straightforward to obtain prices for new wheel loaders. I also started looking for used wheel loaders on the market that met basic requirements, including being in operational condition and not damaged.

To gain a better understanding of the Bobcat T7X, I conducted a phone interview with Sunbelt Equipment Co. in Southern California. Speaking with their General Manager, Sean Thomas, his knowledge and experience with this relatively new wheel loader provided valuable information on ownership costs for my life cycle analysis. As a service manager, he had a comprehensive understanding of maintenance costs, life expectancy, and operating costs, which greatly assisted me in evaluating the worthiness of purchasing an electric machine compared to a traditional diesel one.

A recurring point that I kept hearing about was the fact that the electric loader didn’t stay charged for a very long time. While it was reported that the functionality of the electric machine was extremely smooth and quiet, the need for consistent recharging was a hassle and something that the field workers really disliked. Considering the long working days in the field, it is a hindrance for workers to have to constantly run batteries back and forth from charger to machine.

*Operating and Ownership Costs*

After collecting and analyzing data, I conducted a comprehensive life cycle analysis of both the conventional and electric Bobcat T7X wheel loaders. This allowed me to provide roadway contractors with a detailed cost breakdown for both powertrain options. To ensure the accuracy of my calculations, I utilized the net present value formula, which estimates the monetary value that the purchase of these wheel loaders would bring to the company. To further validate this value, I calculated the depreciation of the wheel loader using the life expectancy and salvage value data that I gathered from internet research and interviews.

Following extensive market research, I identified two comparable 2023 models. The first is the 2023 Bobcat T7X diesel wheel loader, a brand-new model retailing at $230,000. Due to its novelty, it’s being sold through a waitlist program, with certain contractors, including Skanska, getting early access. The 2023 electric T7X loader, on the other hand, is priced at a hefty $250,000, which includes a charger for the machine. As previously mentioned, these two machines share similar mechanics, with the key difference being their powertrain (traditional vs. electric).
After conducting my calculations, I obtained the following results:

<table>
<thead>
<tr>
<th></th>
<th>2023 Bobcat T7X Diesel Wheel Loader</th>
<th>2023 Bobcat T7X Electric Wheel Loader</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purchase Price</strong></td>
<td>$230,000</td>
<td>$250,000</td>
</tr>
<tr>
<td><strong>Operating Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>$1,900 per month</td>
<td>Electricity: $800 per month</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$615 per month</td>
<td>Maintenance: $1,100 per month</td>
</tr>
<tr>
<td>Repairs</td>
<td>$790 per month</td>
<td>Repairs: $910 per month</td>
</tr>
<tr>
<td><strong>Total Monthly Cost</strong></td>
<td>$3,305</td>
<td><strong>Total Monthly Cost</strong>: $2,810</td>
</tr>
<tr>
<td><strong>Ownership Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment Cost</td>
<td>$4,245</td>
<td>Equipment Cost: $5,755</td>
</tr>
<tr>
<td>Depreciation</td>
<td>$945</td>
<td>Depreciation: $1,400</td>
</tr>
<tr>
<td><strong>Total Monthly Ownership Costs</strong>: $5,190</td>
<td><strong>Total Monthly Ownership Costs</strong>: $7,155</td>
<td></td>
</tr>
<tr>
<td><strong>Net Cost</strong></td>
<td>$8,495</td>
<td><strong>Net Cost</strong>: $9,965</td>
</tr>
</tbody>
</table>

After crunching the numbers on operating and ownership costs, it’s clear that the electric T7X loader comes with a steeper initial price tag. Maintaining the electric system also tends to be more costly, as the replacement parts are not only more expensive but also require more labor to install compared to traditional parts.

That said, there are definite savings to be had in the power department. With diesel prices on the rise, particularly in places like Seattle, the potential for fuel cost savings is a compelling reason to opt for an electric loader. However, as my tables above illustrate, every other cost category for the electric loader is higher than its diesel counterpart, which is something I anticipated. This mirrors what we see in the auto industry when comparing electric cars to their gasoline-powered equivalents. You could potentially save over $1,000 a month on fuel, but if the battery or any major electric parts fail, you’re looking at a substantial repair bill.

Depreciation is another key factor to consider. The relatively new electric loader depreciates at a faster rate, which is understandable. The used market for these machines is still getting used to electric models, and many people are hesitant to buy a used one due to concerns about potentially expensive battery-related repairs. Over time, and depending on how the loader is used and the nature of the construction operations, the electric wheel loader could potentially offer greater cost savings, especially if fuel prices continue to climb and electric parts become more commonplace and less expensive to repair. However, on a monthly basis, the traditional wheel loader saves the owner $1,470, which is a significant difference.
Due to the electric powertrain system, repairs and maintenance tend to be pricier than for the diesel wheel loader. In theory, if the electric Bobcat were to stay in good working order for many years and avoid any major breakdowns, the costs could even out. But as things stand, owning an electric loader is more expensive and, in the opinion of some, more inconvenient than owning a traditional diesel one.

Conclusion

Based on the findings from our research and calculations in this case study, I would advise Skanska Construction and other roadway contractors against investing in the Bobcat T7X electric wheel loader over its diesel-powered counterpart. The life cycle analysis and other qualitative data suggest that transitioning to an electric powertrain system would not be a sound investment for many roadway contractors in Seattle, Washington, and across the country.

Field tests conducted on both versions of the Bobcat T7X wheel loaders have shown that, despite its quieter operation and lack of fuel requirements, the electric wheel loader is significantly more expensive. As the heavy civil construction industry increasingly prioritizes sustainability and shows interest in transitioning to electric machinery, companies like Skanska Construction across the US are in need of heavy construction equipment that can enhance productivity and reduce costs.

In summary, fully electric technology remains relatively inefficient in meeting the demands of heavy civil loaders. While it holds promise as a viable investment for smaller-scale projects or those emphasizing environmental standards, the current high cost associated with electric heavy loaders renders them impractical for most situations. As the technology matures and costs decrease, we may witness a more widespread adoption of electric loaders across construction sites. However, for now, the balance between environmental benefits and economic feasibility remains a delicate one.

Future Research

Sustainability and green building practices are gaining significant traction within the construction industry. This trend is largely driven by a growing awareness of environmental issues and the potential for long-term cost savings. As part of this shift, electric machinery is expected to become increasingly prevalent in construction operations.

The use of electric machinery aligns with sustainable practices as it reduces the reliance on fossil fuels, thereby decreasing carbon emissions. Moreover, electric machinery often operates more quietly, contributing to noise pollution reduction which is a key point for many public jobs located in suburban or inner city locations.

However, despite these advantages, the adoption of electric machinery in the construction industry is still in its early stages. High upfront costs, expensive maintenance, and concerns about battery life and power capacity are among the challenges that need to be addressed.

Given these factors, it’s crucial for more research to be conducted to further improve the efficiency, cost-effectiveness, and reliability of electric machinery. As advancements are made, construction companies should keep a close eye on the development of electric machinery. Staying informed will enable them to make strategic decisions about when and how to integrate these technologies into their operations for maximum benefit. In the long
run, the shift towards electric machinery could play a pivotal role in creating a more sustainable and environmentally friendly construction industry.
References


