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ENVIRONMENTAL AND ECONOMIC COST EVALUATION OF AUTONOMOUS TRUCK CORRIDORS: CASE STUDY: I-35 (OKLAHOMA CITY–DALLAS)

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1. Introduction

The transportation sector is a major contributor to greenhouse gas emissions and air pollution, with heavy-duty and medium-duty trucks contributing 25% of the global CO_2 emissions related to transportation (Tiseo 2024). As global efforts to combat climate change intensify, there is growing interest in developing more sustainable freight transportation systems. This has led to increased research and investment in alternative propulsion technologies for trucks, including electric batteries and overhead catenary systems. Additionally, the rapid advancement of autonomous driving technology has opened up new possibilities for optimizing truck operations and reducing labor costs. However, the adoption of these new technologies requires careful consideration of their economic viability, environmental benefits, and infrastructure requirements. This is particularly important for long-distance freight corridors, which form the backbone of many countries' logistics networks.

This case study presents an environmental and economic cost comparison of different types of trucks operating on a 200 mi roadway along the I-35 corridor between Oklahoma City, Oklahoma, and Dallas, Texas. Different scenarios are evaluated featuring both human drivers and autonomous vehicles using conventional engines, overhead cable lines (OCL), and batteries. One of the systems evaluated—referred to as an autonomous truck corridor (ATC)—involves the implementation of a dedicated lane and specialized infrastructure, including passive protection devices, masts, catenary wires, etc., with OCL to power the trucks that operate on the corridor. These trucks operate using electricity supplied by overhead feedlines running along the road, offering a sustainable and efficient alternative to conventional trucks. The findings suggest that by using autonomous trucks with internal batteries and a 50 mi long overhead cable for battery charging, this system can result in potential cost savings of over 50% and a carbon footprint reduction of over 40% relative to conventional trucks.

The key to the success of this system lies in the dedicated infrastructure that must be developed specifically for the vehicles that use it. Unlike regular roadways, the lanes designated for OCL trucks require a significant investment in overhead cable systems that deliver continuous power to the trucks, allowing them to operate over long distances without relying on internal combustion engines or large batteries. Figure 1 illustrates a typical OCL truck, manufactured by a German company (Conway 2019), along with a potential location for a dedicated lane that could be constructed to accommodate such trucks. This dedicated infrastructure ensures seamless and efficient operation, facilitating the adoption of OCL trucks on major highways and further contributing to reduced emissions and operational costs.

Tobias Ohls, 2016, Scania/DHM Bergendahl Professional (top); Institute for Transportation (bottom)

Figure 1.Typical ATC truck manufactured in Germany (top) and a potential location where a dedicated lane can be constructed (bottom)

Figure 2 illustrates various approaches to dedicating lanes and building the necessary infrastructure for an ATC along existing roads. In the left-hand diagram, a central lane is designated for ATC vehicles and is separated from existing road traffic by physical barriers to ensure safety and lane integrity. The center diagram shows a two-lane configuration where ATC lanes are placed on both sides of the road and are separated from regular traffic by lane markings. In the right-hand diagram, a central median is constructed to further separate ATC vehicles from regular road traffic, providing additional space and safety buffers. These designs highlight different options for integrating ATC lanes into existing roadways while maintaining traffic flow for conventional vehicles.

2. Methodology

2.1. Overview of Assumptions and Scenarios

Table 1 outlines the different scenarios investigated in this case study and explains the assumptions for each. Several of the scenarios feature different lengths of overhead power lines to assess the impact of this parameter on the results. It is noteworthy that the overhead line scenarios involve dedicated infrastructure systems designed to charge trucks while they travel a specific distance, requiring the construction of dedicated roadways and bridges.

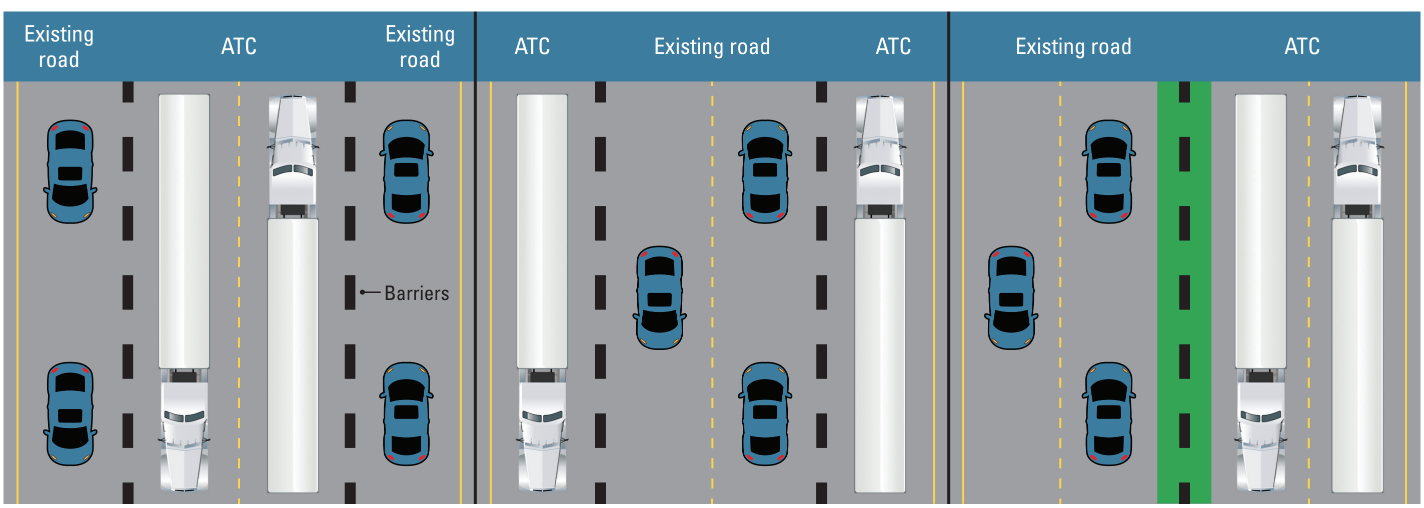

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Figure 2. Different ways of dedicating lanes for an ATC

For the scenarios where trucks use overhead power lines and batteries, the trucks leave their starting place with a fully charged battery and then attach themselves to overhead lines along the journey that will recharge their batteries as they drive. The trucks can then detach from the charging lines and continue their journey with the power needed to drive to their destination. This means that the overhead power lines would be placed approximately midway between the starting place and destination. This placement is feasible because, according to the U.S. Department of Transportation (U.S. DOT 2023), it takes 45 minutes to recharge the battery of an electric vehicle. This means that the trucks' batteries could be recharged over an approximately 50 mi segment while the trucks are traveling at highway speeds.

All scenarios except the one involving conventional trucks assume that the trucks are autonomous, meaning that they operate without drivers and navigate the highways independently of human intervention. This assumption is crucial for understanding the economic impact of these scenarios, as driverless trucks can significantly reduce labor and operational costs compared to conventional trucks, which require human drivers. By removing the need for drivers, these trucks offer potential cost savings.

2.2. Data Collection

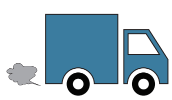
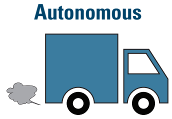
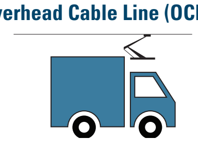
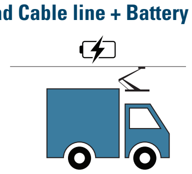
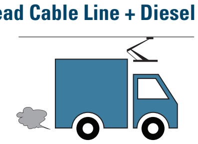
Data were obtained from publicly available sources, including the Oklahoma Department of Transportation (ODOT 2023, FHWA 2023), the U.S. Energy Information Administration (EIA) (U.S. EIA 2024a, 2024b, 2025), and websites compiling gas and electricity prices (Way.com n.d.) and battery production costs (Carlier 2023). Table 2 shows the bidirectional truck volumes and speeds for the study corridor. Two truck volumes are reported. The high truck traffic forecast indicates the reported number of trucks on I-35 in all of Oklahoma in 2022, and the low truck traffic forecast indicates the number of trucks measured between Dallas and Oklahoma City in 2022.

Table 2. General information for the analysis

High Truck Traffic Forecast (Number of Trucks on I-35 in Oklahoma)[1]	8,300 per day
Low Truck Traffic Forecast (Number of Trucks Only between Oklahoma City and Dallas)[2]	2,025 per day
Average Truck Speed on Highway	60 mph

[1] FHWA 2023 [2] ODOT 2023

Table 1. Scenarios and their corresponding assumptions

Truck Type	Scenario	Assumptions
Conventional 	Conventional	Conventional diesel trucks on I-35 (Oklahoma City–Dallas) traveling 200 mi
Autonomous 	Autonomous	Autonomous diesel trucks traveling 200 mi
Overhead Cable Line (OCL) 	200-OCL	Autonomous electric trucks running by 200 mi OCL
Overhead Cable line + Battery (OCLB) 	150-OCLB	Autonomous trucks with internal batteries, 150 mi charging by OCL and 50 mi running by battery
	100-OCLB	Autonomous trucks with internal batteries, 100 mi charging by OCL and 100 mi running by battery
	50-OCLB	Autonomous trucks with internal batteries, 50 mi charging by OCL and 150 mi running by battery
Overhead Cable Line + Diesel (OCLF) 	150-OCLF	Autonomous trucks running 150 mi by OCL and 50 mi using diesel
	100-OCLF	Autonomous trucks running 100 mi by OCL and 100 mi using diesel
	50-OCLF	Autonomous trucks running 50 mi by OCL and 150 mi using diesel

2.3. Calculation of CO_2 Emissions

There are two primary types of CO_2 emissions for trucks:

1. **Tailpipe emissions.** CO_2 from the consumption of diesel fuel
2. **Upstream emissions.** CO_2 from the production and distribution of diesel fuel or electricity

The total CO_2 emissions for a given truck are obtained by adding these two types of emissions as follows: *Total CO_2 Emissions = Tailpipe Emissions + Upstream Emissions*.

For the scenarios in this case study, these emissions were calculated by making several assumptions (Table 3) and gathering the needed information.

Table 3. Assumptions used to calculate tailpipe and upstream emissions

Truck	Tailpipe Emissions	Upstream Emissions
Conventional/ Autonomous	CO_2 from fuel consumption	CO_2 from fuel supply (upstream, refining and distribution)
OCL/OCLB	No tailpipe emissions	CO_2 from electricity production + CO_2 from battery cell production + CO_2 from OCL infrastructure construction
OCLF	CO_2 from fuel consumption	CO_2 from electricity production + CO_2 from infrastructure construction + CO_2 from fuel supply (upstream, refining and distribution)

2.3.1. Tailpipe Emissions

For Conventional, Autonomous, and OCLF trucks, the total CO_2 emissions from tailpipes were calculated using equation (1). (For OCLF trucks, the fuel consumption is calculated only for the distance without OCL.)

$$\text{Total } CO_2 \text{ per truck} \left(\frac{t}{y}\right) = \frac{Annual\ average\ mileage}{Fuel\ efficiency} \times CO_2 from\ fuel\ consumption \quad \textbf{(1)}$$

where

- **Annual average mileage** is the total distance traveled by a truck in a year in miles. It is assumed that a truck travels only 200 mi/day and therefore 73,000 mi in a year. Based on Federal Highway Administration (FHWA) highway statistics, the annual mileage for a Class 8 truck is 69,169, which is very close to the assumed mileage (AFDC 2024).
- **Fuel efficiency** is the fuel efficiency of the truck in miles per gallon (MPG).
- **CO_2 from fuel consumption** is the amount of CO_2 emitted per gallon of fuel consumed **(tCO_2/gal)**.

2.3.2. Upstream Emissions

For Conventional trucks, upstream CO_2 emissions were calculated using equation (2):

$$Total\ CO_2\ per\ truck = annual\ average\ fuel\ consumption\ per\ truck \times CO_2\ from\ fuel \quad \textbf{(2)}$$

where

- **Average annual fuel consumption per truck** is the total fuel consumed by a truck in a year (gallons).
- **CO_2 from fuel supply** is the amount of CO_2 emitted per gallon of fuel (tCO_2/gal).

For Autonomous trucks, upstream CO_2 emissions were calculated using equation (3):

$$Total\ CO_2\ per\ truck \left(\frac{t}{y}\right) = annual\ average\ fuel\ consumption\ per\ truck \times CO_2\ from\ fuel + length\ of\ the\ highway \times 2 \times CO_2\ from\ construction\ of\ dedicated\ pavement\ and\ bridges \div number\ of\ trucks \quad \textbf{(3)}$$

where

- **Average annual fuel consumption per truck** is the total fuel consumed by a truck in a year (gallons).
- **CO_2 from fuel supply** is the amount of CO_2 emitted per gallon of fuel (tCO_2/gal).
- **CO_2 from construction of dedicated pavement and bridges** is the amount of CO_2 emitted per mile per lane (t/mile/lane).

For OCL trucks, equation (4) was used:

$$Total\ CO_2\ per\ truck \left(\frac{t}{y}\right) = average\ annual\ electricity\ consumption\ per\ truck \times CO_2\ from\ electricity\ consumption\ per\ truck + total\ CO_2\ per\ truck\ after\ the\ lifetime\ of\ the\ infrastructure \quad \textbf{(4)}$$

where

- **Average annual electricity consumption per truck** is the total electricity consumed by a truck in a year **(kWh)**.
- **CO_2 from electricity production** is the amount of CO_2 emitted per kilowatt-hour of electricity produced (tCO_2/kWh).
- **Total CO_2 per truck after the lifetime of the infrastructure** is the CO_2 emissions associated with the construction and maintenance of the OCL infrastructure (tCO_2).

For OCLB trucks, the equation includes additional terms for battery production, as shown in equation (5):

$$Total\ CO_2\ per\ truck\ \left(\frac{t}{y}\right) = average\ annual\ electricity\ consumption\ per\ truck \times CO_2\ from\ electricity\ production + CO_2\ emissions\ for\ battery\ production \times capacity\ of\ battery \times number\ of\ batteries + total\ CO_2\ per\ truck\ after\ the\ lifetime\ of\ the\ infrastructure\ based\ on\ the\ length\ of\ OCL \qquad (5)$$

where

- **CO_2 emissions for battery production** is the amount of CO_2 emitted per kilowatt-hour of battery capacity produced (tCO_2/kWh).
- **Capacity of battery** is the total battery capacity (kWh).
- **Number of batteries** is the total number of batteries in the truck's lifetime.

For OCLF trucks that use a combination of fuel and electricity, equation (6) was used:

$$Total\ CO_2\ per\ truck\ \left(\frac{t}{y}\right) = average\ annual\ fuel\ consumption\ per\ truck \times CO_2\ from\ fuel\ supply + average\ annual\ electricity\ consumption\ per\ truck \times CO_2\ from\ electricity\ production + total\ CO_2\ per\ truck\ after\ the\ lifetime\ of\ the\ infrastructure\ based\ on\ the\ length\ of\ OCL \qquad (6)$$

All of the parameters above are shown in Table 4.

2.4. Calculation of the Cost of Each Truck

The costs of the different truck types evaluated in this case study are outlined below, with detailed explanations of each variable used in the cost calculations. These trucks were chosen to provide several possible solutions for transportation along the study corridor. A conventional truck that is powered by diesel fuel with a human driver was chosen to serve as a basis of comparison for all other scenarios. In addition, several types of autonomous vehicles were chosen. Autonomous vehicles that use diesel fuel are simply referred to as autonomous trucks in this case study. Autonomous trucks that use overhead power lines are referred to as OCL trucks. Other versions of this type of autonomous truck use a combination of overhead power lines and batteries (referred to as OCLB) or overhead power lines and diesel fuel (referred to as OCLF).

The cost for each type of truck was calculated as follows:

- **Conventional** = cost of truck + total maintenance cost + total fuel cost + total cost of driver
- **Autonomous** = cost of truck + total maintenance cost + total fuel cost + cost of dedicated pavement and bridges
- **OCL** = cost of truck + total maintenance cost + total electricity cost + infrastructure cost per truck + cost of pavement and bridges

Table 4. Parameters used to calculate equations (1) through (5)

Parameter	Value	Unit
Annual average mileage	73,000	mi
Fuel efficiency (conventional)[1]	12.84	MPG
Fuel efficiency (autonomous)[1]	13.07	MPG
CO_2 from fuel consumption[2]	0.01018	t/gal
CO_2 from fuel supply[3]	0.002431	t/gal
Average electricity consumption of truck per mile[4]	2	kWh/mi
CO_2 from electricity production in Oklahoma[5]	0.000176	(t/kWh)
CO_2 from infrastructure construction for overhead power lines[6]	834.8	t/mi
CO_2 from construction of dedicated pavement, and bridges[7]	2,250	t/mi/lane
CO_2 emissions for battery cell production[8]	0.075	t/kWh
Lifetime of the infrastructure[6]	35	year
Lifetime of the truck[4]	10	year
Lifetime of the battery[9]	5	year

[1] *TuSimple n.d.*
[2] *U.S. EPA and NHTSA 2010, IPCC 2006*
[3] *Moretti et al. 2017*
[4] *Ramshankar et al. 2023*
[5] *U.S. EIA 2024a, 2025*
[6] *Hanesch et al. 2022*
[7] *Aryan et al. 2023*
[8] *Carlier 2023*
[9] *Nationwide 2024*

- **OCLB** = cost of truck + total maintenance cost + total electricity cost + infrastructure cost per truck + total battery cost (based on the battery capacity for OCL length) + cost of dedicated pavement and bridges
- **OCLF** = cost of truck + total maintenance cost + total electricity cost (based on the length of OCL) + infrastructure cost (based on the length of OCL) + total fuel cost (based on the length of the distance without OCL) + cost of pavement and bridges

The components used in the cost calculations are explained as follows:

- **Cost of truck.** The initial purchase cost of the truck. This varied for a conventional, battery-powered, or OCL-based truck.
- **Total maintenance cost.** The cumulative maintenance expenses over the truck's operational period.
- **Total fuel cost.** The total cost of fuel consumed by the truck.
- **Total cost of driver.** The cumulative cost of hiring a driver.
- **Cost of dedicated pavement and bridges.** The additional costs associated with adapting infrastructure (pavement and bridges) that autonomous and OCL trucks use for traveling to and from a destination.
- **Total electricity cost.** The cumulative cost of electricity consumed by the truck.
- **Infrastructure cost per truck.** The cost of constructing and maintaining the OCL infrastructure, allocated per truck, that OCL trucks use for traveling to and from a destination. The cost breakdown of the required infrastructure is given in Table 5.
- **Total battery cost.** The cost of batteries required for OCLB trucks, based on their capacity and the length of the OCL.
- **Total fuel cost (based on the length of the distance without OCL).** The cost of fuel for distances where the truck cannot use the OCL infrastructure.

By breaking down the costs into these specific components, the total cost of ownership for each type of truck could be calculated over its operational lifetime. This detailed approach allowed an assessment of the economic feasibility of adopting various truck types and their associated infrastructure requirements.

All of the parameters for each component included in the cost of a truck are shown in Table 6.

Table 5. Breakdown of the construction costs of the OCL infrastructure

Component	Cost ($/mi)
Energy feed point[1]	8,000
Feed lines from energy feed point to substation[1]	400,000
Substation[1]	480,000
Masts[1]	640,000
Catenary wire[1]	960,000
Passive protection devices[1]	320,000
Project planning, tendering, etc.[1]	280,800
Pavement and bridges[2]	2,500,000
Total	**5,588,800**

[1] Ramshankar et al. 2023
[2] Compass International Inc. 2024

Table 6. Parameters for calculating the costs of the trucks

Parameter	Value	Unit
Diesel fuel cost[1]	3.60	$/gal
Electricity cost[2]	0.0828	$/kWh
Maintenance cost per truck[3]	15,000	$/year
Truck cost (conventional)	182,000	$
Truck cost (OCL and autonomous)[4]	300,000	$/truck
Total cost of infrastructure[5]	5,588,800	$/mi
Cost of battery[6]	157	$/kWh
Cost of driver in Oklahoma[7]	107,800	$/year

[1] Nationwide 2024
[2] Barr 2024
[3] U.S. EIA 2024b
[4] ECG Business Intelligence 2022
[5] Ramshankar et al. 2023
[6] Spiller 2023
[7] Indeed.com 2025

3. Results

3.1. Carbon Footprint

Based on the equations for each type of truck, Figure 3 presents the CO_2 emissions generated in each scenario over a span of 35 years for 2,025 and 8,300 trucks per day. These graphs highlight the significant reduction in CO_2 emissions achieved by various truck types compared to conventional trucks. Table 7 shows the percent reduction in CO_2 emissions for each scenario after 35 years and the corresponding breakeven point, which describes the point where the CO_2 emissions saved offset the initial CO_2 investment required to adopt the technology.

Table 7 displays the difference in the carbon emissions associated with each truck type compared to the conventional truck. The table also shows the breakeven point in years, indicating when each truck can offset the investment in CO_2 emissions required to adopt the technology.

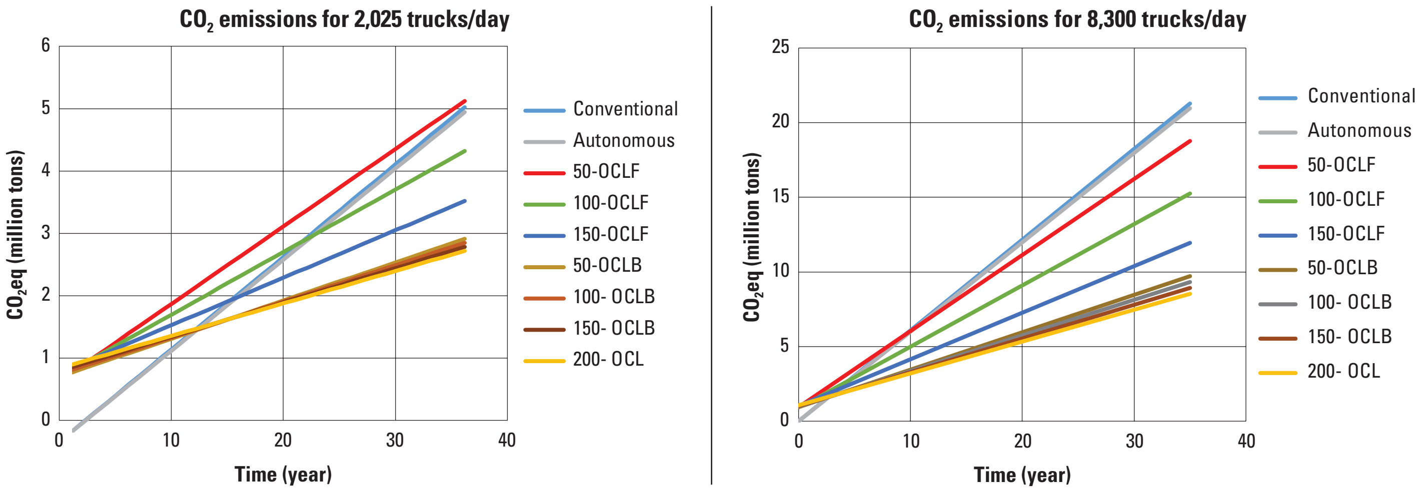


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Figure 3. CO_2 emissions in each scenario for 2,025 and 8,300 trucks/day

Table 7. Difference in the carbon emissions associated with each truck type compared to the conventional truck after 35 years

Truck Type	Type of Energy Used to Power the Truck	Carbon Footprint (tCO_2 of 2,025 Trucks/Day)	Percent Carbon Cost Difference versus Conventional after 35 Years	Breakeven (Years)	Carbon Footprint (tCO_2 of 8,300 Trucks/Day)	Percent Carbon Cost Difference versus Conventional after 35 Years	Breakeven (Years)
Conventional	Diesel	5,192,303	—	—	21,282,030	—	—
Autonomous	Diesel	6,014,340	+15.8	—	21,862,480	+2.7	—
200-OCL	Electricity	2,888,438	-44.3	12	8,532,800	-59.9	3
150-OCLB	Electricity and Battery	2,952,729	-43.1	11	8,925,651	-58.2	3
100-OCLB	Electricity and Battery	3,017,304	-41.8	11	9,319,663	-56.2	3
50-OCLB	Electricity and Battery	3,081,879	-40.6	11	9,713,675.5	-54.3	3
150-OCLF	Electricity and Diesel	3,689,049	-28.9	15	11,943,655	-43.8	4
100-OCLF	Electricity and Diesel	4,490,370	-13.5	21	15,253,973	-28.3	5
50-OCLF	Electricity and Diesel	5,291,690	+1.9	—	1,8771,175	-11.8	6

The results show that the 200-OCL trucks have the lowest CO_2 emissions, which are 44% and 60% lower than those of conventional trucks for 2,025 and 8,300 trucks/day, respectively. The OCLB and OCLF trucks (except for 50-OCLF) also show a significant reduction in carbon footprint, with CO_2 emissions ranging from 14% to 58% lower than those of conventional trucks. The data show that as the length of the overhead cable is reduced for the OCLF trucks, the carbon savings also decrease, and CO_2 emissions even increase relative to conventional trucks when the length of the OCL becomes 50 mi. Autonomous trucks that run solely on diesel fuel show an increase in CO_2 emissions of nearly 16% compared to existing trucks.

It is important to note that although the OCL infrastructure does entail initial CO_2 costs for creating the infrastructure, the rate of CO_2 emissions is substantially reduced in subsequent years, and the CO_2 costs for this initial production are offset. It is worth noting that these CO_2 emissions include the construction of overhead power line, masts, and dedicated roads and bridges.

Overall, these results show the significant potential of OCL, OCLB, and OCLF trucks to reduce CO_2 emissions.

3.2. Financial Costs

The financial costs for each scenario were calculated over the 10-year life of the trucks used in those scenarios. Figure 4 shows the cost data for each scenario for 2,025 and 8,300 trucks per day. Table 8 provides the percent difference in cost for each truck relative to the conventional truck and the breakeven point (in years) at which the cost saved offsets the initial cost of adopting the technology.

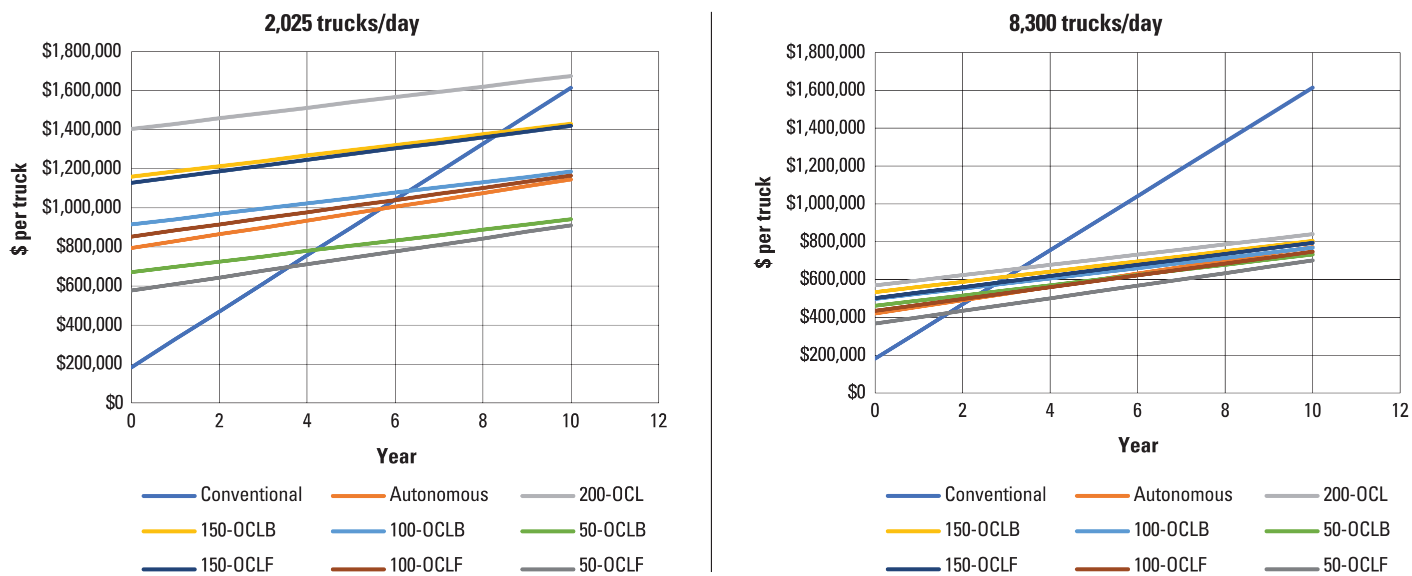

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Figure 4. Cost per truck in each scenario for 2,025 and 8,300 trucks/day

Table 8. Difference in the financial cost of each truck type compared to the conventional truck

Truck Type	Type of Energy Used to Power the Truck	Cost per Truck ($) (2,025 Trucks/Day)	Percent Cost Difference versus Conventional	Breakeven (Years)	Cost per Truck ($) (8,300 Trucks/Day)	Percent Cost Difference versus Conventional	Breakeven (Years)
Conventional	Diesel	$1,614,673	—	—	$1,614,673	—	—
Autonomous	Diesel	$1,144,898	-29.1	6	$771,553	-52.2	3
200-OCL	Electricity	$1,674,848	+3.7	—	$840,228	-47.9	4
150-OCLB	Electricity and Battery	$1,430,258	-11.4	9	$804,293	-50.2	4
100-OCLB	Electricity and Battery	$1,185,668	-26.5	7	$768,358	-52.4	3
50-OCLB	Electricity and Battery	$941,078	-41.7	4	$732,423	-54.6	2
150-OCLF	Electricity and Diesel	$1,419,805	-12.1	9	$793,839	-50.8	3
100-OCLF	Electricity and Diesel	$1,164,761	-27.8	6	$747,450	-53.7	3
50-OCLF	Electricity and Diesel	$909,717	-43.6	4	$701,062	-56.6	2

For the lower volume of truck traffic (2,025 trucks per day), the life-cycle cost was lower than that of the conventional truck for all of the scenarios investigated except for the 200-OCL truck. For the higher volume of truck traffic (8,300 trucks per day), all of the scenarios showed cost savings between 48% and 56% relative to the conventional truck. Also, these savings were not impacted by the length of the overhead cable or the method used to power the trucks. These variables were not sensitive for the higher truck volume because the infrastructure costs are divided by a larger number of vehicles, and the savings in driver salaries becomes more significant as the number of trucks using the system increases.

When the volume of trucks is lower, the method and infrastructure to power the trucks become more important factors in the cost calculations. For example, when the length of the overhead cable is 100 mi, the costs of an OCLF or OCLB truck are similar to those of an autonomous truck that uses diesel fuel only. This means that the cost of an overhead cable of this length is offset by the fuel savings from using the electricity provided by the cable. As the overhead cable length increases, the cost of the overhead power line is not compensated by the fuel savings. However, it is important to note that when a 50 mi overhead cable line is used, the reduced initial costs of the overhead line combined with the reduction in the cost of the fuel can provide a savings of 42% if the trucks use the overhead line and internal batteries. The cost reduction is 44% if the trucks use the overhead line and diesel fuel. This is an important finding because both of these scenarios also showed the highest amount of financial savings for the higher truck volume and the lowest breakeven point for both the higher and lower truck volumes.

4. Comparing the Carbon Footprint and Financial Costs

4.1. Autonomous Truck

While autonomous trucks offer significant cost savings relative to conventional trucks, they also increase CO_2 emissions and ultimately carbon footprint due to the need to construct a new lane for these trucks. Additionally, autonomous trucks still rely on diesel fuel to operate on highways, which further contributes to CO_2 emissions.

4.2. 200-OCL Truck

This type of truck has the lowest carbon footprint and is economical for both the lower and higher truck volumes. Specifically, the cost of this truck for 2,025 trucks per day is 3.7% higher than that of the conventional truck, whereas the cost is nearly 58% lower for 8,300 trucks per day. This disparity highlights the importance of truck volume in calculations of infrastructure costs. When truck volumes are near 8,300 trucks per day, then the infrastructure costs are not significant, but they become more important when truck volumes are closer to 2,025 trucks per day.

4.3. 150-, 100-, and 50-OCLB Trucks

While all of the OCLB trucks show good performance in terms of reduced CO_2 emissions and reduced costs relative to the conventional truck, the 150- and 100-OCLB trucks become less beneficial at lower truck volumes. However, the 50-OCLB truck provides a balance of economic savings and a reduced carbon footprint. By using 50-OCLB trucks, the length of dedicated infrastructure that must be constructed is decreased, and this saves costs.

4.4. 150-, 100-, and 50-OCLF Trucks

Similar to the OCLB trucks, the length of the overhead line affects both the carbon footprint and costs of OCLF trucks. The reduction in CO_2 emissions is almost the same for both the lower and higher truck volumes; however, a higher volume of trucks is more economical, especially when the length of dedicated infrastructure is 100 or 150 mi. Additionally, the breakeven point decreases by one-third to one-half at higher truck volumes.

4.5. Summary

Overall, this analysis underscores the importance of considering both environmental and economic factors when selecting truck types for long-term sustainability in freight transportation. Despite the initial costs, investing in OCL infrastructure proves to be a suitable choice for substantial long-term benefits. The analysis of CO_2 emissions and costs is summarized in Table 9.

Table 9. Analysis of CO_2 emissions and costs for all truck types

Truck Type	Carbon Footprint Percent Savings in CO_2 emissions		Percent Savings in Financial Costs		Comments
	2,025 Trucks/Day	8,300 Trucks/Day	2,025 Trucks/Day	8,300 Trucks/Day	
Conventional	—	—	—	—	The baseline with the highest carbon footprint and cost.
Autonomous	-15.8%	-2.7%	29.1%	52.2%	Shows an increase in CO_2 emissions compared to conventional trucks. Achieves a significant cost reduction of 29.1% for 2,025 trucks/day and 52.2% for 8,300 trucks/day, with breakeven points of 6 years and 3 years, respectively.
200-OCL	44.3%	59.9%	3.7%	47.9%	Exhibits the most substantial reduction in carbon emissions, approximately 44% to 60% lower than conventional trucks for both 2,025 trucks/day and 8,300 trucks/day. Interestingly, has a 3.7% higher cost per truck for 2,025 trucks/day but a significant reduction of 48% for 8,300 trucks/day, with breakeven points of 9 and 4 years, respectively.
150-OCLB	43.1%	58.2%	11.4%	50.2%	Demonstrate significant reductions in carbon emissions, ranging from 42% to 58% compared to conventional trucks. Show cost reductions ranging from 11% to 42% for 2,025 trucks/day and 52% to 54% for 8,300 trucks/day, with breakeven points generally within 4 to 9 years. **The 50-OCLB is the most beneficial and recommended scenario.**
100-OCLB	41.8%	56.2%	26.5%	52.4%	
50-OCLB	**40.6%**	**54.3%**	**41.7%**	**54.6%**	
150-OCLF	28.9%	43.8%	12.1%	50.8%	Display reductions in CO_2 from 12% to 44%. Demonstrate significant cost savings, particularly the 50-OCLF variant, which shows a 43.6% reduction in cost for 2,025 trucks/day and 56.58% for 8,300 trucks/day, with a breakeven point of just 6 years for 8,300 trucks/day. These scenarios have a larger carbon footprint because the trucks use diesel fuel instead of batteries.
100-OCLF	13.5%	28.3%	27.8%	53.7%	
50-OCLF	-1.9%	11.8%	43.6%	56.6%	

5. Recommendations

The following recommendations are based on the scenarios investigated in this case study using data available as of spring 2024 for the 200 mi I-35 corridor between Dallas, Texas, and Oklahoma City, Oklahoma.

5.1. Higher Volume of Truck Traffic

When the truck volume is 8,300 trucks per day, all scenarios show cost savings of 48% to 57% compared to conventional diesel trucks. However, in the carbon footprint analysis, the scenarios that rely either entirely on overhead power lines or a mixture of overhead power lines and batteries show a 58% to 64% reduction in carbon footprint. Implementing these scenarios on roads with high traffic volumes shows significant promise for cost savings and a reduction in carbon footprint.

5.2. Lower Volume of Truck Traffic

When the truck volume is 2,025 trucks per day, the differences among the different scenarios are larger. At this volume, scenarios that feature overhead power lines or a combination of overhead power lines and batteries show the most significant reduction in carbon footprint. The infrastructure costs for the overhead power lines and dedicated infrastructure also become costlier given the smaller number of trucks that use the system. By reducing the length of the dedicated infrastructure, however, the initial costs can be reduced.

OCL trucks will use batteries that will be charged before leaving their point of origin. The trucks can be charged while maintaining their speed using the 50 mi of overhead power lines and dedicated infrastructure. By only using 50 mi of overhead power lines, the initial infrastructure costs can be minimized. This makes the use of 50 mi of overhead power lines in combination with battery-powered trucks an exciting combination that works well for both higher and lower volumes of truck traffic.

5.3. Overall Recommendation

The scenario that uses 50 mi of overhead power lines shows the best performance in terms of carbon footprint and financial cost. This scenario provides savings of almost 58% and 63% in carbon emissions and 42% and 55% in financial costs.

This scenario features a set of dedicated overhead lines that are 50 mi long where battery-powered autonomous trucks can be charged as they drive. These lines can be thought of as charging stations that the trucks can use while they are in motion. These dedicated charging lanes should be positioned approximately 75 mi from the trucks' starting point. Since only 50 mi of dedicated infrastructure needs to be created, the logistical challenges of finding the space and constructing the infrastructure are reduced.

6. Future Work

This work would benefit from the following additional analysis:

- **A sensitivity analysis of the different input variables.** For example, Oklahoma and Texas use a significant amount of renewable wind energy. This reduces the cost and carbon footprint of the energy that would be used to power the trucks traveling on the ATC. How would the findings of this case study change in locations where this is not the case?
- **Investigation of the minimum charging time needed for electric trucks.** The minimum charging length investigated in this work was 50 mi. Charging technology may be available to shorten that time period, which would allow a shorter length to be used for the overhead cable lines.
- **Investigation of a wider number of truck traffic volumes and roadway lengths.** More detailed analysis should be done to understand the most likely locations for the ATC. The present analysis used a minimum of 200 mi and 2,025 trucks per day. As the number of trucks per day decreases, the recommendations may change. The minimum number of trucks per day where an ATC is beneficial should be found. Additionally, the sensitivity of the analysis to the length of roadway should be investigated.

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