WHITE PAPER

MEASURING WHAT MATTERS

A standardized framework for the real cost of autonomous trucking

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Executive summary

Autonomous trucking is set to enter commercial deployment as soon as 2025, offering a transformative solution to persistent industry challenges such as driver shortages, high turnover, and escalating logistics costs. Its potential lies in continuous, cost-efficient freight operations that improve supply chain access and reliability.

Successful adoption, however, requires integration across a complex transportation value chain that extends beyond autonomous driving technology.

To enable meaningful evaluation between technologies and business models, BCG has developed the Cost Per Mile (CPM) Framework for autonomous trucking—a standardized, holistic metric capturing all relevant operational costs. BCG's CPM framework provides an objective, common language for cost that empowers all stakeholders to make informed and data-driven decisions.

By offering a consistent benchmark, BCG's CPM empowers stakeholders: technology providers can showcase performance, fleet operators can assess ROI, shippers gain pricing clarity, and investors and regulators can evaluate viability and risk. Broad adoption of our CPM framework will accelerate commercialization by enabling transparent comparisons, driving cost improvements, and aligning incentives across the autonomous trucking value chain.

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The long-term potential of the autonomous trucking industry

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1. https://www.ttnews.com/articles/aurora-full-self-driving; https://www.ttnews.com/articles/bot-auto-driverless-pilot-2025; https://www.houstonpublicmedia.org/articles/technology/2025/05/12/521130/two-companies-begin-testing-driverless-commercial-trucks-in-houston-area/.
2. Autonomous trucks leverage hub-to-hub ("H2H") operations. In a H2H operation, self-driving trucks operate between "hubs" which are located nearby origin and final destination. Human-driven vehicles handle the first and last legs of the journey, i.e., from origin point to 1st hub and last hub to destination.
3. https://matrackinc.com/usa-truck-driver-shortages; https://www.smart-trucking.com/freight-shortage-2023/

Why the industry needs a standardized efficiency metric

The autonomous trucking industry requires careful coordination across the transportation value chain

Autonomous trucks rely on advanced sensors and artificial intelligence to operate safely and reliably on public highways. Autonomous driving technology is only one element of the autonomous trucking value chain, however. Integrating these vehicles into existing supply chains will require changes across multiple aspects of logistics operations.

For example, consider a transportation operator adopting autonomous trucking to serve a retailer customer. To this operator, the switch does not end with the purchase of new hardware and software, or with changes to workforce requirements and driver hours[4]. The operator will also require access to additional technically skilled labor to maintain the fleet. And if an autonomous truck stops in the middle of the road, it needs resources and infrastructure to "rescue" the stranded vehicle.

In commercial operations, technology will be just one component of a much larger autonomous trucking value chain. That value chain includes:

- Vehicle, component, and technology suppliers: Produce and supply vehicles, trailers, and autonomous driving components[5]
- Technology companies: Develop the software and hardware technology stack design, and provide assembly and integration services
- Maintenance & support services: Provide the personnel, skills and infrastructure to ensure vehicle uptime
- Transportation operations: Responsible for dispatching and managing trucks on the road, interfacing with shippers, and ensuring logistics performance
- Shippers & receivers: Companies and individuals shipping and receiving freight

The various elements of this value chain may be the responsibility of different industry participants. Today's autonomous trucking players are pursuing two basic models:

Vehicle-as-a-Service (VaaS) players focus exclusively on developing autonomous truck hardware and software platforms. They integrate this technology with trucks from OEM partners and offer it to fleet operators or carriers through subscription, licensing, or per-mile fees. This capital-light model enables rapid growth, high margins, and broad deployment across existing fleets, while allowing customers to retain operational control and integrate autonomy into their existing logistics networks.

4. E.g., Route planning with regards to trip length, frequency, refueling, loading and unloading, and additional time for human-in-the-loop activities (e.g., break times for human-driven legs of the trip, human-led inspections, etc.)
5. E.g., sensors, servers and communication devices, redundancy brakes, steering, etc. Also includes the financing aspects of the value chain to finance purchase of high-value equipments

Transportation-as-a-Service (TaaS) players manage the entire transportation value chain, from developing self-driving technology to operating and maintaining the truck fleet. They purchase trucks and components from OEM and Tier 1 suppliers. Retrofitting trucks with autonomous systems is typically done by players themselves or in partnership with OEMs. This vertically integrated approach ensures complete control over safety, performance, and customer experience. However, it is highly capital- and operations-intensive. TaaS providers must scale physical infrastructure such as terminals, maintenance, and support staff along with technology, which limits flexibility but enables tighter performance oversight.

The industry needs a holistic and standardized metric of cost and operational efficiency

The transportation industry has multiple participants. They include component suppliers, vehicle manufacturers, technology players, transportation & maintenance service providers, shippers (i.e., customers of the industry who have transportation needs), investors, regulators, and insurance underwriters.

For all industry participants, varied business models and the lack of uniform performance benchmarks make it difficult to evaluate the true costs and benefits of the shift to autonomous trucking. Nor can they easily compare the relative costs of different offerings. This lack of clarity makes it difficult to ensure fair pricing, gauge technological readiness, evaluate return on investment, assess policy needs, or underwrite risk accurately.

Progress is only possible if it is measurable. If autonomous trucking is to compete with conventional approaches at-scale, the industry needs a standardized way to measure its true costs and operational impact. Identifying a standard metric helps industry participants to clearly and quantitatively identify the tipping point where autonomous vehicles offer real benefits. Such a metric should be consistent and auditable across providers, business models and technology types, shifting the focus of the discourse from isolated, “flash” demonstrations to business practicality and viability.

Current practice indicates a clear need to develop a standardized metric that assesses the true real-world operational cost impact of this emerging technology. Regardless of the technology provider’s business model, the ultimate price borne by final payers in the industry (shippers and receivers) includes the entire cost of the transportation value chain. Therefore, the cost impact of autonomous trucking is not a simple trade-off between a reduction in driver wages and an increase in vehicle cost. Instead, the impact extends deep into operations to include autonomous trucking’s impact on:

- Inspection, maintenance, and repair cost, both labor and non-labor (e.g., parts, consumables)
- Costs associated with roadside failures due to autonomous driving systems failure (e.g., rescue driver time, towing, security, contractual damage)
- Remote assistance operations cost
- Final mile delivery cost in a hub-to-hub model
- Infrastructure cost (e.g., additional maintenance equipment)
- Insurance cost

The optimal efficiency metric should be determined by cost drivers throughout the value chain. Each stage of that value chain includes different business models and unique cost drivers, but the holistic end-to-end view will be what drives the economics. In this paper we present such a metric: BCG’s Cost Per Mile (CPM) framework for autonomous trucking.

BCG's CPM Framework

Introducing the BCG CPM Framework

BCG has drawn on deep expertise in the trucking, logistics, shipping and freight and autonomous technology sectors to develop a framework with the objective of measuring and comparing these costs. The CPM Framework combines these vantage points to capture a holistic view across the different stages of the value chain.

The CPM Framework articulates the full set of costs that are required to operate a well-run, at-scale autonomous trucking operation. The framework is supported by a concrete value tree, which defines a set of input variables, and the calculation logic that transforms those variables into CPM. Appendix II provides a detailed breakdown of this calculation logic.

Selecting the right metric that captures cost and operational efficiency

The transportation sector uses various metrics of cost and operational efficiency. Of these, cost per mile (CPM) is best suited to be a standard measure across the industry. CPM is a well-established standard in the trucking industry. Its prevalence provides several benefits:

- CPM is a straightforward benchmark that is intuitive and familiar to industry stakeholders, encouraging wider adoption across the industry
- There is a high likelihood that players already have the right data available to calculate CPM
- Simply put, CPM is a measure of operational efficiency, where the total relevant cost of operating an autonomous fleet is included as a numerator, and is divided by the total number of actual driven miles as a denominator.

$$\text{Cost per Mile (CPM)} = \frac{\text{(Total cost of owning and running an autonomous trucking operation)}}{\text{(Total miles driven)}}$$

CPM offers several advantages over other operational metrics, such as cost per weight and cost per distance-weight:

- Cost per weight, which measures the total cost to move a unit of freight weight, is useful in weight-constrained operations. However, it does not account for volume and distance, which can skew accuracy for shorter, high frequency freight movements with low weights.
- Cost per distance-weight measures the total cost to move a unit of freight weight across a defined distance. It adds the additional layer of weight consideration to cost-per-mile, normalizing cost across freight types and providing a comprehensive measure of cost efficiency. However, the level of granularity required, and the complexity of the calculation makes this metric less intuitive. Data needed for this calculation is not commonly tracked among industry players, making it less practical for industry-wide adoption

Key guiding principles of the CPM Framework

In the development of the CPM Framework, BCG has followed a set of guiding principles:

1. Comprehensiveness

CPM should reflect the voices of all industry participants, from cutting-edge technology developers to truck operators, shippers and retailers, investors, and insurance underwriters. These voices, when distilled to a logical framework, ensure coverage of a holistic gamut of drivers that captures all components of the cost of autonomous trucking operation

2. Objectivity

CPM should be objective and free of bias favoring one category of industry participant over others. Objectivity is critical in ensuring that the CPM can act as a trustworthy and industry-standard method of understanding the true cost of running an autonomous trucking operation.

3. Practicality

Theoretical completeness must be balanced with practicality and usability. There should be a clear logic that allows users to capture accurate inputs, as well as a clear calculation logic that explains how those inputs are transformed into the standardized metric.

4. Prevention of gaming

CPM is calculated based on captured operational data. A robust calculation should minimize fluctuations based on selective repurposing, exclusion or inclusion of operational data. Examples of such data manipulation include, but are not limited to:

- Deploying autonomous fleets exclusively in "easier" use cases (e.g., simple routes that don't match the needs of most users, such as LA-Dallas)
- Excluding critical operational inputs (e.g., taking long time for pre-trip calibration but excluding that time from CPM calculations)
- Basing input data from higher-performing parts of the fleet (e.g., excluding older vehicle data to deflate maintenance demand)
- Basing input data on a limited period to capture favorable outcomes (e.g., focusing on periods with good weather conditions)
- Including non-revenue generating, non-available miles into CPM calculations to inflate the denominator

The optimal efficiency metric should be determined by cost drivers throughout the value chain. Each stage of that value chain includes different business models and unique cost drivers, but the holistic end-to-end view will be what drives the economics. In this paper we present such a metric: BCG's Cost Per Mile (CPM) framework for autonomous trucking.

5. Operational focus

The CPM Framework should measure the day-to-day operational cost of running an autonomous trucking business. It should exclude costs not directly related to operations (e.g., interest rates). However, there are two categories of costs that should be reported alongside CPM Framework, given their significance.

- **R&D:** R&D is a significant nonoperating cost in the autonomous mobility industry. In the self-driving taxi sector, for example, Waymo and Tesla each invested over $10B in upfront R&D costs[6]. Given their size, R&D costs should be reported separately alongside CPM to allow benchmarking by investors and industry analysts.

- **Personal injury:** While personal injury claims could have tangible financial impact for an autonomous trucking player, the frequency and value of these claims is highly dependent on factors outside of day-to-day autonomous trucking operations (e.g., litigation and settlement outcomes, insurance coverage, allocation of liability). These costs are instead best represented as one-time write-offs.

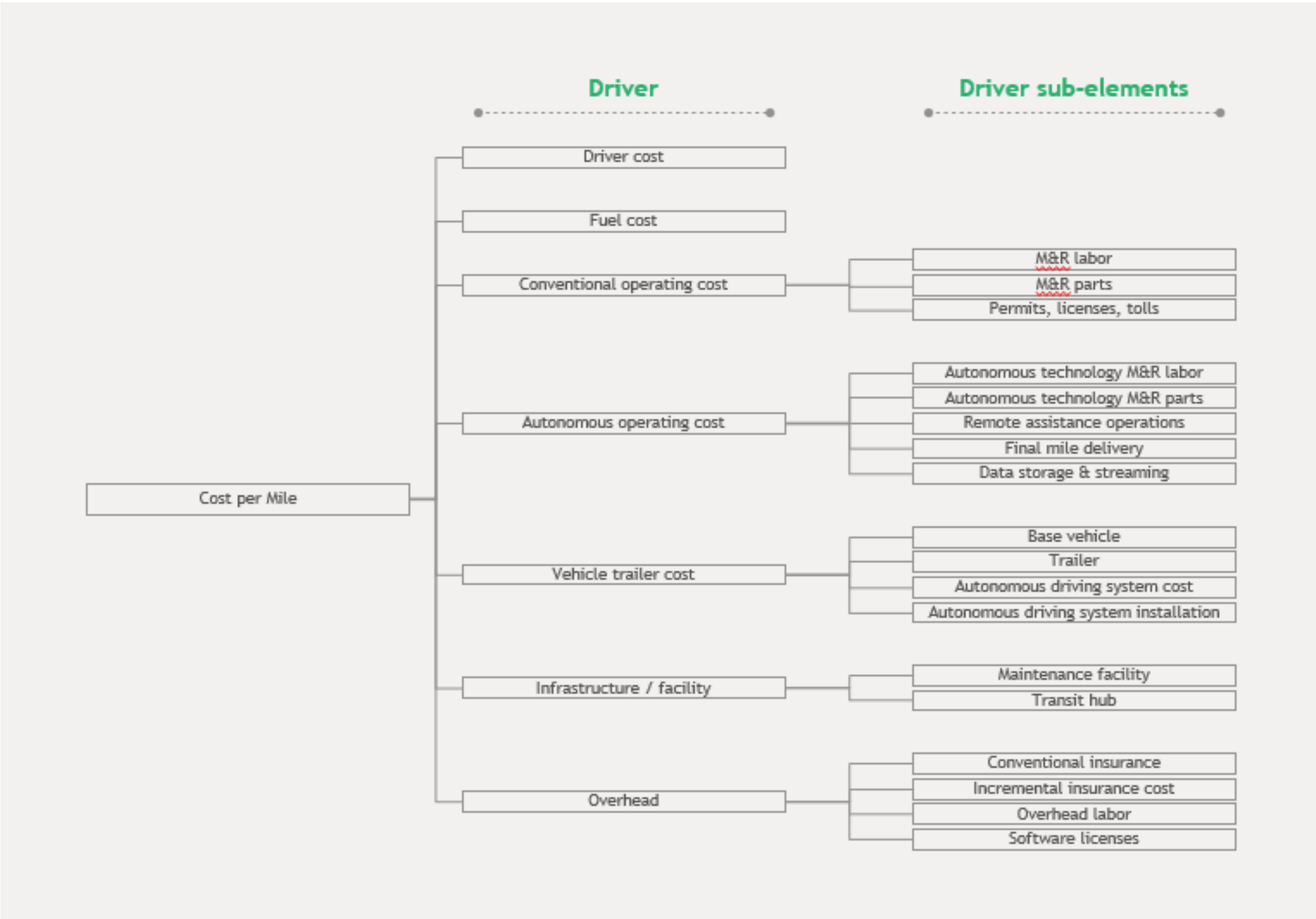
Drivers of the CPM Framework

The CPM Framework aims to comprehensively capture the full gamut of costs that are relevant to operating an autonomous trucking fleet, because autonomous trucking industry requires careful coordination across the transportation value chain

These include the seven cost categories below:

EXHIBIT 1

Key drivers and sub-drivers of Cost per Mile[7]



6. Waymo press releases. Waymo raised $5.5B in 2020 and $5.6B in 2024; CNBC, *Why investors are divided on Tesla's turn to robots and self-driving cars* (Apr. 16, 2025)
7. "M&R" stands for Maintenance and Repair, and includes all costs associated with inspection, maintenance, repair, and related activities

1. Driver cost

This is the cost associated with human drivers. Typically, this is the largest single cost component of a conventional trucking operation[8]. These costs include driver wages, benefits, and workers' comp. They also include recruitment costs, driver "idling" costs during loading/unloading, autonomous system tuning, etc., and the emergency cost of drivers for "rescue" operations associated with on-the-road autonomous technology failure.

2. Fuel cost

Fuel costs are typically the second largest cost component in a conventional trucking operation[9]. While autonomous trucks typically use identical or similar internal combustion engines to conventional trucks, studies have shown that autonomous trucking technology can result in 10 to 15 percent fuel savings[10]. Such savings come from optimized vehicle handling behavior (e.g., steering, braking) and enhanced speed control allowing vehicles to drive longer distances in the optimal speed band (55 to 65 mph)[11].

3. Conventional operating cost

Operating costs associated with any kind of trucking operations may include: the labor and non-labor costs of regular maintenance, inspection, and repair, licenses required to operate trucks, and the tolls and fees incurred while operating the vehicle

4. Autonomous trucking operating cost

Incremental operational costs that are unique to an autonomous fleet. These costs may include:

- **Autonomous technology inspection, maintenance, and repair cost** directly related to autonomous trucking operations. This cost includes labor (skilled technicians and engineers) and non-labor (e.g., replacement cameras and sensors)

- **Rescue costs** associated with on-the-road autonomous technology failure, which can incur additional towing, roadside security, and potential penalties for shippers

- **Remote assistance cost**, which is primarily the labor cost of remote assistance operators who monitor trucks to ensure smooth operation and provide emergency disengagement where necessary

- **Data storage and streaming cost**, associated with handling the large amounts of data required for autonomous driving, including on-vehicle and back-end data storage, and transfer between the two

- **Final mile delivery cost**. Current autonomous trucking operations rely on a hub-to-hub (H2H) model, where driverless operations occur only on the highway between "transit hubs."[12] The first and final leg of the journey (starting point to hub; hub to ending point) is handled by human drivers and incurs additional cost

8. American Transportation Research Institute (2024), An Analysis of the Operational Costs of Trucking
Waymo press releases.
9. Ibid.
10. Aurora (2024). The Sustainability Opportunity of Autonomous Trucking; https://www.tusimple.com/wp-content/uploads/2021/01/UCSD-Fuel-Study-Press-Release.pdf
11. https://www.tusimple.com/wp-content/uploads/2021/01/UCSD-Fuel-Study-Press-Release.pdf
12. Transport Topics (2024), Autonomous Trucks Reshaping the Freight Industry

5. Vehicle cost

This is a broad range of costs associated with the comprehensive vehicle platform required for a truck to drive autonomously. It includes:

- **Autonomous technology inspection, maintenance, and repair cost** directly related to autonomous trucking operations. This cost includes labor (skilled technicians and engineers) and non-labor (e.g., replacement cameras and sensors)
- **Rescue costs** associated with on-the-road autonomous technology failure, which can incur additional towing, roadside security, and potential penalties for shippers
- **Base vehicle & trailers:** Base hardware required for trucking operations. Almost all autonomous trucking players rely on existing truck and trailer OEMs to produce the base vehicle
- **Autonomous driving hardware kit ("AD Kit"):** The suite of additional hardware required for the truck to operate autonomously. This includes sensors (camera, LiDAR, radar), communications devices (antennae, network switches), computation hardware, and redundancy systems (steering, brakes). The cost to install AD Kits is also calculated separately

6. Infrastructure & facility cost

This cost category includes cost of maintenance, storage, and parking facilities to effectively operate a fleet. While these cost categories are generally well known, the prevalence of the H2H model in autonomous trucking will likely increase transit hub space demand for autonomous trucking operations.

7. Overhead cost

This category includes costs directly related to the day-to-day operation of autonomous truck fleets. A key component in this category is insurance, where autonomous trucking may incur a different premium profile than conventional trucking.

Key Variables and Standardized Constants

The BCG CPM Framework distinguishes "Key Variables" and "Standardized Constants" to focus on the cost drivers relevant to player competency.

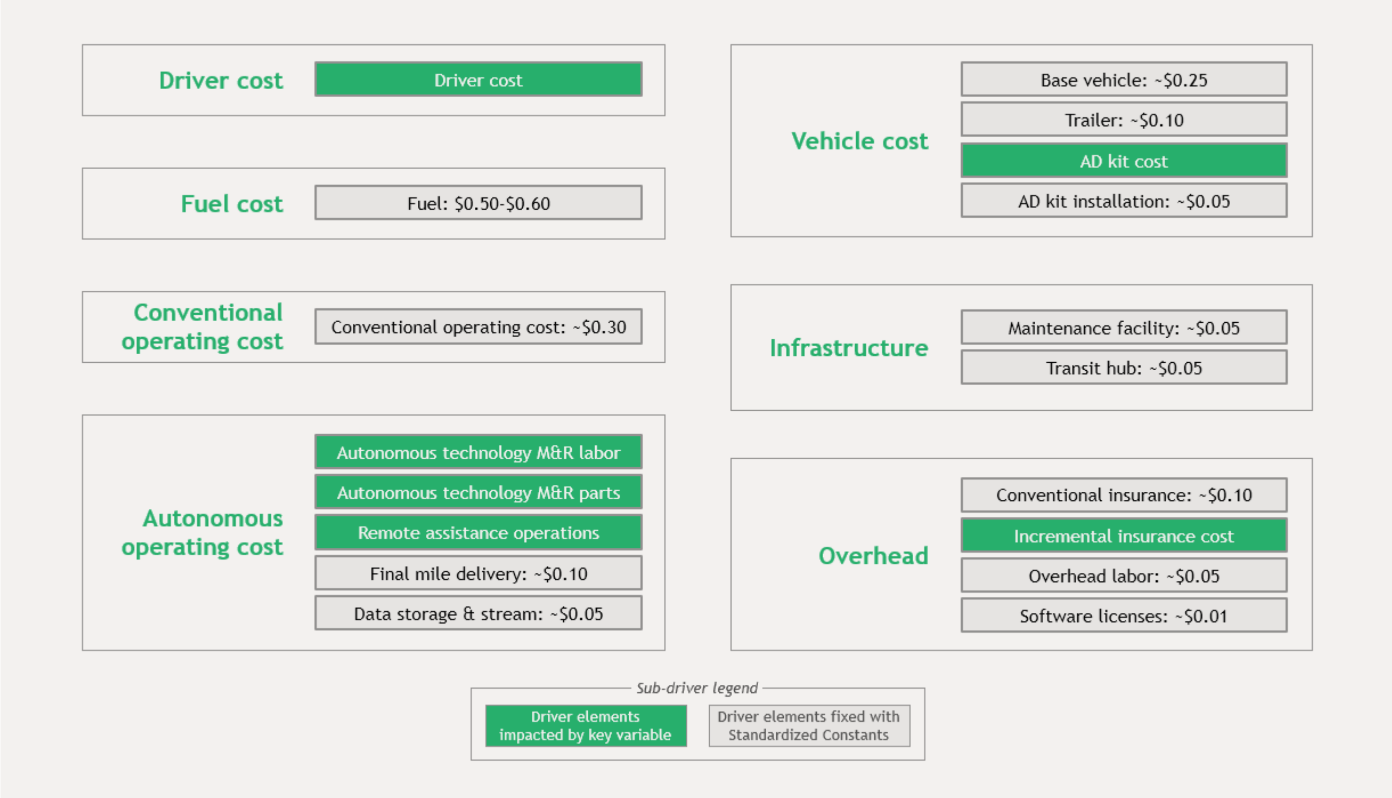
Key Variables are input variables that have a significant impact on CPM outcome, and which vary between autonomous trucking players' technical and operational maturity. For example, each autonomous truck type uses a unique set of AD Kit, with total reliability, performance, and cost differentials that have a meaningful impact on CPM.

These variables become active inputs into the CPM Framework. Figure 2 below maps which components of the CPM will be impacted by each key variable. Appendix I of this document explains how the Key Variables are used to calculate the relevant cost drivers.

Standardized Constants are any input that is not key variable. These are cost components which are either well-established industry standards that do not vary significantly between players, or costs that do not have a significant impact on CPM outcome. For ease of calculation and to minimize "gaming", these inputs are treated as static assumptions in the CPM Framework. Figure 2 below shows how driver elements whose values are fixed using Standardized Constants. Appendix II of this document lists the Standardized Constants used in the framework.

EXHIBIT 2

Impact of Key Variables and standardized constants in CPM driver elements[13]



Deep-dive discussions of Key Variables

The CPM Framework designates six key variables. As discussed in Section 3.5., these variables are selected for their significant impact on CPM and their variability among autonomous trucking players. Each variable may influence several CPM cost drivers.

1. AD Kit cost

This is the cost associated with human drivers. Typically, this is the largest single cost component of a conventional trucking operation[8]. These costs include driver wages, benefits, and workers' comp. They also include recruitment costs, driver "idling" costs during loading/unloading, autonomous system tuning, etc., and the emergency cost of drivers for "rescue" operations associated with on-the-road autonomous technology failure.

- **Measure by:** Average cost of autonomous driving kit
- **Cost drivers impacted:** AD Kit cost
- **Why it varies and why it matters:** AD Kit is a source of high variability between autonomous trucking players. Each player makes strategic decisions about the types and number of components, overall kit design, off-the-shelf or proprietary components, outsourced or in-house assembly processes, and other design and operational factors. Current AD Kit costs range from $100K to $250K per vehicle.[14]

13. See footnote number 2 for M&R definition
14. Global Market Insights (2025), Top 5 Challenges Autonomous Truck Industry Contenders are Facing in 2025; BCG interviews with industry participants; PatentPC (2025), The Cost of Self-Driving Technology: How Much Do AV Components Really Cost?

2. Total driver hours

- **Measure by:** Number of total driver hours driven
- **Cost drivers impacted:** Driver cost
- **Why it varies and why it matters:** Reducing total driver hours is one of the key value propositions of autonomous trucking. Driver wages for long-haul trucking operations have increased by more than 6 percent per year[15] due to labor shortages. Reducing driver hours not only affects driver wages, which accounts for 40 percent or more of conventional trucking CPM[16], it also affects overall vehicle availability by removing time associated with driver-related constraints (e.g., rest breaks, sleeping on overnight routes). The ability to reduce driver hours is primarily dependent on the autonomous driving technology maturity of each player. Operational decisions also play a role: in densely populated areas or on complicated routes, truck operators may decide to put a driver behind the wheel, for example. In contrast, driver cost is set as a standardized constant (see *Appendix II*) that reflects the weighted average driver wage per hour to avoid cost differences based on localities.

3. Total Autonomous technology M&R labor hours

- **Measure by:** Number of total autonomous technology engineer hours worked
- **Cost drivers impacted:** Autonomous technology M&R labor[17]
- **Why it varies and why it matters:** Engineers and technicians skilled at inspecting, maintaining, and repairing autonomous trucks are critical cost components that will have a significant impact to autonomous trucking operations, accounting for up to 60 percent of the total incremental costs of autonomous trucking[18]. Technically mature players will require fewer engineer hours for these activities. Determining technician hour requirements is both a technological and operational decision. Operationally savvy players will evaluate the optimal number of engineer and technician hours based on their impact on other aspects of the operational cost (e.g., increased risk of roadside failures, increased inspection hours for lower maintenance hours). In contrast, the M&R labor cost per hour is set as a standardized constant (see *Appendix II*) that reflects the weighted average cost per hour to avoid cost differences based on localities.

4. Total cost of parts used for repair

- **Measure by:** Total cost of autonomous technology parts used during repair
- **Cost drivers impacted:** Autonomous technology M&R parts[19]
- **Why it varies and why it matters:** Maintaining and repairing the technology components of autonomous trucks may require high value parts as well as skilled labor. A trucking-grade LiDAR can cost more than $20K, for example.[20] Players with AD Kit designs that result in lower durability or a high roadside incident rate may incur higher repair parts cost.

15. Bureau of Labor Statistics
16. American Transportation Research Institute (2024), An Analysis of the Operational Costs of Trucking
17. See footnote number 2 for M&R definition
18. BCG projections based on CPM Framework; BCG interviews with industry participants
19. See footnote number 2 for M&R definition
20. BCG interviews with industry participants

5. Remote assistance operator demand

- **Measure by:** Average number of remote operators needed per vehicle
- **Cost drivers impacted:** Remote assistance operations
- **Why it varies and why it matters:** Remote assistance operators monitor vehicles in real time and disengage autonomous driving in edge cases, complex scenarios, or system handoffs the AV cannot resolve alone. The combination of each player's technical maturity and proportion of driver-out operations determines the demand for remote assistance operators. While pilot-stage operations deploy approximately one remote operator for every two vehicles, highly mature players can achieve a ratio of up to 1:10[21]. In contrast, remote operator cost per operator is set as a standardized constant (see Appendix II) that reflects the weighted average remote operator cost per operator to avoid minor cost differences based on localities.

6. Frequency of incidents, failures, and disengagement

- **Measure by:** Total number of incidents[22], total number of autonomous technology failures, number of disengagements per 1,000 miles
- **Cost drivers impacted:** Autonomous technology M&R labor[23], Incremental insurance cost
- **Why it varies and why it matters:** Incidents, failures, and disengagements collectively represent the stability and predictability of an autonomous driving technology. These factors are also affected by operational decisions: higher investment in AD Kit or in maintenance can reduce number of incidents, for example. On-the-road failures and incidents such as collisions result in a rescue operation that incurs additional costs. These costs include driver hours, towing, roadside security, and customer penalties for late or missed deliveries.[24] The frequency of incidents and disengagements may also be used by insurance underwriters when determining the insurance premium for autonomous trucking operations.[25]

21. Ibid.; Madadi, B. et al. (2023), An Agent-Based Discrete Event Simulation of Teleoperated Driving in Freight
22. Incidents are defined as events that result in property damage
23. See footnote number 2 for M&R definition
24. However, because CPM Framework measures the operational cost of operating autonomous trucks, it does not include the cost of personal injury or property damage that results from accidents.
25. TruckingDive (2024), Fleets, insurers face big unknowns in the transition to autonomous trucks; BCG interviews with industry participants

CPM will benefit all industry participants, but a coordinated approach is required to drive industry-wide benefits

Benefits of BCG CPM Framework adoption

As an industry-standard measure, the BCG CPM Framework is expected to provide tangible benefits to all constituents of the industry, including:

Autonomous trucking technology players

The BCG CPM Framework creates a credible performance benchmarking system, quantifying cost-competitiveness using consistent, standardized metrics that enable apples-to-apples comparisons between players. It provides a standard metric in which players can ground their performance so that customers and other stakeholders have a clear view of their offering. Players can use CPM to highlight performance differentiators, such as technology stack complexity and maturity, compute power requirements, operational efficiency, and fuel economy.

Transportation service providers

Fleet operators, which manage trucking operations between customer distribution centers, can use CPM as benchmark to compare autonomous driving system players when selecting products and services. They also can use CPM as a metric to compare cost tradeoffs compared to human driving and assess the ROI associated with adopting autonomous technology in their operations.

Shippers (i.e., customers of the industry who have transportation needs)

Shippers gain a transparent pricing benchmark that clarifies the value tradeoffs between autonomous and human trucking. This will help to build trust in autonomous trucking providers, enabling informed decisions about the adoption of autonomous trucking.

Investors

Venture capitalists, marquee auto players (e.g., the venture arms of large auto conglomerates), and other investors providing capital into the industry gain a common lens with which to compare autonomous trucking players and evaluate their maturity and commercial viability.

Regulators

Regulators and policymakers at all levels of the government can use a standardized CPM to clarify the economic case for autonomous trucking and assess where policy, infrastructure or legal intervention may be needed to support commercialization, safety, or industry growth.

Insurers

Insurance underwriters benefit from a clearer understanding of the operational risks and cost exposures tied to autonomous vehicle performance, particularly as it relates to safety and accident risk. Over time, CPM benchmarking can support more accurate underwriting, as insurers tailor their offerings to the risk-adjusted cost profiles of different ADS providers' business models.

Pathway to industry-wide adoption

The CPM Framework provides the foundation for credible, data-driven decision-making across the entire industry. Driving industry-wide adoption of the CPM Framework requires concerted participation of all industry stakeholders, however.

1. Autonomous technology purchase & investment decisions

Buyers of autonomous technology—Transportation operators (VaaS) and shippers (VaaS, TaaS) —as well as investors (e.g., VCs) can create powerful incentives for industry-wide adoption of the CPM Framework. Buyers should use the CPM metric as a benchmarking tool when comparing carriers and modes: evaluate which logistics partners consistently deliver the lowest CPM adjusted for service levels. Investors should integrate CPM metrics into due diligence for autonomous trucking investments by requiring companies to provide a clear calculation of their current cost-per-mile and key assumptions (uptime, support costs, etc.).

2. Operational evaluation & planning

Encouraging stakeholders to deploy the BCG CPM Framework as an internal assessment and planning tool can drive further adoption. Fleet operators can identify cost drivers (e.g., sensor maintenance or remote operations) and prioritize day-to-day operational improvements accordingly. Shippers can use the metric to optimize route planning, contract terms, and performance targets. Technology providers can use the their offerings' CPM performance to inform future technology roadmaps and allocate development resources effectively.

3. Industry-wide discourse:

Finally, continuous exposure of CPM metrics in public and industry forums will reinforce the Framework's place as a common language for all industry stakeholders. Collaborating through industry forums, shipper councils, and peer groups will ensure consistent measurement practices. Sharing anonymized data or best practices between industry participants can help raise overall efficiency, expand adoption, and accelerate commercialization of autonomous trucking.

Conclusion

The future of autonomous trucking depends not only on technological innovation, but also on the ability of all industry stakeholders to evaluate that innovation with clarity, consistency, and credibility. The BCG CPM Framework offers a standardized, comprehensive, and objective measure of operational efficiency. By capturing the full range of real-world costs involved in autonomous freight, the CPM Framework empowers each stakeholder—from technology developers to investors—to make informed, data-driven decisions that reflect the true economic impact of autonomy.

Industry-wide adoption of the BCG CPM Framework will foster greater transparency, encourage fair comparisons between technologies and business models, and drive continuous cost and performance improvements. Just as importantly, it will build trust in the autonomous trucking ecosystem by providing shippers, regulators, and insurers with a reliable lens to assess value, viability, and risk.

As the industry moves from pilot programs to scaled deployment, each participant across the transportation value chain must play a role. The BCG CPM Framework is an important first step in this movement, offering a common language that unites this complex, evolving value chain.

Appendix I: Calculation logic for drivers affected by Key Variables

A. Driver Cost

$$\text{Driver cost} = \frac{\text{Driver FLC per Hour} \times \text{Driver Hours}}{\text{Total fleet miles driven}}$$

Driver FLC per hour= Driver wages+benefits+recruiting costs

Where:

Key Variables used as an input

- Driver hours

Basic operational characteristics

- Total fleet miles driven

Standardized Constant (see ***Appendix II***)

- Driver wages
- Driver benefits
- Driver recruiting costs

B. Autonomous technology inspection, maintenance, and repair cost ("AD M&R cost")

$$\text{AD M\&R Cost} = \frac{\text{(AD M\&R labor cost + Total cost of autonomous driving system parts used for repair}}{\text{Total fleet miles driven}}$$

Where:

Key Variables used as an input

- Engineer hours
- Technician hours
- AD M&R parts cost

Basic operational characteristics

- Total fleet miles driven

Standardized Constant (see *Appendix II*)

- Engineer FLC
- Technician FLC

C. Remote assistance operations

$$\text{Remote assistance operations} = \frac{\text{\# of remote operators} \times \text{Remote operator FLC} \times \text{Total fleet hours driven}}{\text{Total fleet miles driven}}$$

Where:

Key Variables used as an input

- # remote operators (to operate the fleet)
    - E.g., For a fleet of 20 trucks, if ratio of operators-to-fleet is 1:2, this value should be 10. If the ratio is 1:10, the value should be 2.

Basic operational characteristics

- Total fleet miles driven
- Total fleet hours driven

Standardized Constant (see *Appendix II*)

- Remote operator FLC

D. AD Kit cost

Variable is directly factored into CPM calculation as a key variable (AD Kit Cost), without further formula.

E. Incremental insurance cost

$$\text{Incremental Insurance multiplier} = \left(\frac{M_{Trad.}}{M_{Auto.}}\right)^{a} \times \left(\frac{C_{Trad.}}{Auto.}\right)^{b} \times (1+Dxk)^{c}$$

$$M_{Trad.} = \frac{\text{Number of incidents}}{\text{Total fleet miles driven}}$$

Where:

Key Variables used as an input

- Number of incidents
    - $M_{Auto.}$: # miles between incidents for autonomous trucks
- *D:* # of disengagement per 1,000 miles.

Basic operational characteristics

- Total fleet miles driven

Standardized Constants (see *Appendix II*)

- $C_{Trad.}$: Avg. claims value per incident for traditional trucks
- $C_{Auto.}$: Avg. claims value per incident for autonomous trucks

- *k*: Disengagement-to-risk translation constant (currently 10-20%)

    - *For example, if k=0.1, then each disengagement per 1,000 miles would raise the expected risk by 10%. Insurers calibrate k based on what fraction of disengagements are assumed would result in an incident.*

- *a, b, c*: Boundary condition multiplier to set lower/upper bounds on autonomous insurance premium relative to traditional trucking

    - *For example, if autonomous trucks are shown to be 30% more likely to encounter incidents (M_{Trad} / M_{Auto} ratio of 1.3), the insurance multiplier does not increase by 30%*

    - *Current best practice range: 0.3-0.5*

Appendix II: Summary of Standardized Constants

Assumption	Value	Source / rationale
Driver Cost		
Base year driver salary / hour. (2025)	$34.2	BCG expertise & Bureau of Labor Statistics
Benefits % salary	24%	ATRI (2024), An Analysis of the Operational Costs of Trucking
Driver recruiting cost per driver	$7,700	Industry benchmarks from publicly available data and BCG expertise
Driver churn per year	72%	Churn for large carriers; from ATA reports and publicly available data
Pre-trip inspection hours per trip	0.166… hrs.	Average from expert input; 10 minutes per trip spent on pre-trip inspection
Routine autonomous driving technology inspection hours per trip	0.0833… hrs.	Average of expert input; 5 mins per trip
Miles before overnight rest	700 mi.	BCG expertise & publicly available data on long-haul trucking patterns
Overnight trucking premium	167%	Based on BLS data and expert interviews, reflects industry night-shift premium range
Fuel Cost		
Miles per gallon (MPG) below optimal speed	4.9 mi.	Department of Energy (DOE); average fuel efficiency for trucks driving 25–35 mph
MPG at optimal speed	6.0 mi.	DOE; reflects peak fuel economy at 55–65 mph
MPG above optimal speed	4.3 mi.	DOE; captures fuel efficiency decline at 65–75 mph
Miles per hour (MPH) below optimal speed	30 mi.	DOE; Midpoint of 25–35 mph low-efficiency speed band
MPH at optimal speed	60 mi.	DOE; Midpoint of 55–65 mph most efficient speed band
MPH above optimal speed	70 mi.	DOE; Representative midpoint of 65–75 mph band where efficiency declines
% of hours driven below optimal speed	30%	Assumed based on typical time spent in urban, low-speed, or congestion-prone segments
% of hours driven at optimal speed	55%	Reflects portion of highway miles in long-haul routes typically driven at fuel-efficient speeds
Fuel cost per gal.	$3.2	DOE
Operating Cost (autonomous)		
Base year SW engineer salary / yr. (2025)	$149,500	BCG expertise & Bureau of Labor Statistics
Benefits % salary	24%	ATRI (2024), An Analysis of the Operational Costs of Trucking
Base year HW engineer salary / yr. (2025)	$165,500	BCG expertise & Bureau of Labor Statistics
Benefits % salary	24%	ATRI (2024), An Analysis of the Operational Costs of Trucking
Base year technician salary / yr. (2025)	$75,189	BCG expertise & Bureau of Labor Statistics
Benefits % salary	24%	ATRI (2024), An Analysis of the Operational Costs of Trucking

Total working day / year	365	Assumed federal holidays, vacations, and weekends are all counted towards paid days off
Total working hour / day	8	Assumed 8-hour workday
Inspection hour / vehicle / day	0.72 hrs.	Based on industry norms for daily pre-trip and post-trip checks in commercial fleets operating AV systems
Maintenance hour / vehicle / day	0.90 hrs.	Reflects average maintenance effort in autonomy-enabled fleets
Repair hour / vehicle / day	0.18 hrs.	Estimated from typical unscheduled repair needs in heavy-duty operations with AV-related hardware
Rescue operation avg. driving MPH	65 mi.	Driving at higher speed than optimal speed to respond to failure (~65-70mi. on highways)
Rescue vehicle dispatch distance	25%	Based on 1500 mile route assumption; if a truck comes to a failure, a dispatched driver will have to travel from the starting hub or the ending hub, whichever is closer to the location of the truck. The distance the driver needs to travel is between 0-50% of the total route distance
Avg. recovery distance (long leg)	75%	Based on 1500 mile route assumption; if a truck stops prior to half point, the driver who have recovered the vehicle have to drive 50-100% of the remaining route
Avg. recovery distance (short leg)	25%	Based on 1500 mile route assumption; if a truck stops after the half point, the driver who have recovered the vehicle have to drive 0-50% of the remaining route
Safety/security personnel cost per rescue	$1,500	From expert interview; flat rate assumption per failure for on-site 3rd party services
Towing fee per rescue	$1,200	Flat towing fee: $1,200 based on $978 TX max for 25K+ vehicles + ~$200 AV handling buffer
Probability of in-lane AV failure	10%	Based on expert input; represents the estimated share of rescue-requiring AV failures where the vehicle becomes stranded in-lane or otherwise obstructs traffic and towing services are required
Weighted avg. value per container	$150,000	Insurance industry expert interviews & BCG expertise
Sensitive delivery %	15%	Ibid.
Nonsensitive delivery penalty	2%	Ibid.
Penalty occurrence %	50%	Ibid.
Remote assistance FTE FLC / yr. (2025)	$69,480	BCG expertise & Bureau of Labor Statistics
Throughput KB per second	3,750 kb	Equivalent to 30 Mbps; reflects typical AV data stream rates
Connection count	1	Assumes one active connection per vehicle stream
$ per GB streamed	$0.06	Based on average cloud data pricing
Storage req (GB) per vehicle per hour	40 GB	Estimated based on average data logging requirements
$ per GB stored	$0.04	Reflects long-term cold storage pricing for fleet-scale data
Final mile leg per trip	2 legs	Expert interviews; assumes drayage operations at origin and destination points
Final mile miles per leg	17.7 mi.	Expert interviews; based on average terminal-to-destination distance in freight networks
Final mile cost per mile	$4	Expert interviews; reflects averages cost of local delivery operations
Operating Cost (conventional)		
Maintenance & repair cost per mile (conventional truck)	$0.206	ATRI (2024), An Analysis of the Operational Costs of Trucking
Tire cost per mile	$0.045	Ibid.
Toll cost per mile	$0.034	Ibid.

License cost per mile (conventional truck)	$0.009	Ibid.
Base insurance cost per mile (conventional truck)	$0.099	Ibid.
Vehicle Cost		
Total expected vehicle lifetime (years)	5 yrs.	Expert interviews; based on industry average for Class 8 trucks
Lifetime miles per vehicle	800,000 mi.	Expert interviews; reflects typical Class 8 diesel truck lifespan
Cost per vehicle	$187,999	Based on published pricing for Freightliner Cascadia models
Cost to install AD Kit (e.g., labor)	$10,000	Expert interviews & BCG research; includes labor and integration
Truck-to-trailer ratio	2.6 trailers per truck	ATRI (2024), An Analysis of the Operational Costs of Trucking and expert interview input
Cost per trailer (reefer)	$60,000	Based on average market pricing from BCG research
Cost per trailer (dry)	$40,000	Average dry van trailer pricing from BCG research
# of reefer trailers % total trailers	15%	Assumed fleet mix based on industry averages and BCG expertise
Infrastructure Cost		
Annual lease per sqft (2025)	$11.17/sqft	2025 Class A Industrial space lease cost / sqft / yr
# sqft required per truck	660	Assumes 15×40 ft per truck with ~10% buffer for maneuvering
# maintenance bays per truck	0.05	Assumes one bay per 20 trucks based on fleet facility benchmarks
# vehicle storage per truck	0.02	One storage space per 50 trucks; assumes shared hub usage
Parts storage sqft per truck	105 sqft	Estimated from BCG research on fleet support facilities
Tire storage sqft per truck	30 sqft	Estimated from BCG research on fleet support facilities
Tools & fluids storage sqft per truck	40 sqft	Estimated from BCG research on fleet support facilities
Non-storage space % storage space	50%	Assumes ~70% of space used for maintenance and storage; 15-20% for maneuvering, and 10-15% for office, etc.
# hubs per route	2 / route	Assumes origin and destination hubs with no intermediate stops
Rent price per hub per month	$250 / mo.	Based on expert interviews & BCG research
% routes hub-to-hub (i.e., not P2P)	100%	Assumes all autonomous routes operate within a hub-to-hub network
% routes operating in hub-to-hub (non-autonomous)	36.4%	LTL trucking total volume % total trucking volume (assuming LTL leverages hubs)
Overhead Cost		
Average miles per incident (non-autonomous)	1,350,000 mi.	Insurance industry expert interviews & BCG expertise
Avg. autonomous truck incident claims value % traditional	1.3	Ibid.
Disengagement-to-risk translation constant	0.1	Ibid.
Boundary condition (miles / incident)	0.4	Ibid.
Boundary condition (claims value)	0.4	Ibid.

Boundary condition (disengagement risk)	0.4	Ibid.
Cybersecurity annual license per vehicle	$1,700 / vehicle	BCG research, Estimated based on typical enterprise cybersecurity licensing for safety-critical AV systems
Remote operations SW license per mile	$0.004 / mi.	BCG research, reflects usage-based software licensing common in remote support operations
Base year S&M salary / yr. (2025)	$70,000	BCG expertise & Bureau of Labor Statistics
Base year G&A salary / yr. (2025)	$65,000	Ibid.
Base year HR salary / yr. (2025)	$75,000	Ibid.
Base year Finance salary / yr. (2025)	$80,000	Ibid.
Base year IT salary / yr. (2025)	$85,000	Ibid.
Base year Dispatcher salary / yr. (2025)	$70,000	Ibid.
Sales & marketing FTE per truck	0.8 / truck	Based on expert input & BCG research on typical staffing ratios for fleet-based operations
G&A FTE per truck	0.8 / truck	Ibid.
HR FTE per truck	0.5 / truck	Ibid.
Finance FTE per truck	0.6 / truck	Ibid.
IT FTE per truck	0.7 / truck	Ibid.
Dispatcher FTE per truck (autonomous)	0.1 / truck	Expert input & BCG research; assumes 1 dispatcher per 20 AV trucks
Dispatcher FTE per truck (non-autonomous)	0.1 / truck	Expert input & BCG research; assumes 1 dispatcher per 15 conventional trucks
% S&M time spent on pilot	4.2%	Expert input & BCG research; assumes ~20 minutes spent per day
% G&A time spent on pilot	0.6%	Expert input & BCG research; assumes ~20 minutes spent per week
% HR time spent on pilot	4.2%	Expert input & BCG research; assumes ~20 minutes spent per day
% Finance time spent on pilot	0.6%	Expert input & BCG research; assumes ~20 minutes spent per week
% IT / cybersecurity time spent on pilot	4.2%	Expert input & BCG research; assumes ~20 minutes spent per day
% Dispatcher time spent on pilot (autonomous)	12.5%	Expert input & BCG research; assumes ~60 minutes spent per day
% Dispatcher time spent on pilot (non-autonomous)	16.7%	Expert input & BCG research; assumes ~80 minutes spent per day

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