Autonomous heavy-duty vehicles in logistics: market trends, opportunities, and barriers

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Abstract. This paper presents a comprehensive market research study focused on identifying opportunities and barriers for the adoption of autonomous heavy-duty vehicles (AHDVs) in the logistics industry. The methodology employs a qualitative approach, utilizing workshops, questionnaires, interviews, and social media polls to collect primary and secondary data. The empirical findings highlight both the current landscape and the future trends in AHDVs, fleet management, and logistics. The study reveals the importance of safety, technological readiness, regulatory challenges, and infrastructure development as key barriers, while also showcasing potential benefits like increased safety, reduced costs, and improved efficiency. Furthermore, a quadrant analysis prioritizes these opportunities and barriers for strategic decision-making. The article concludes by discussing the implications of the findings and the broader context of autonomous vehicles in logistics.

Keywords: Autonomous Heavy-Duty Vehicles (AHDVs), Logistics, Barriers, and opportunities

1 Introduction

The integration of autonomous heavy-duty vehicles (AHDVs) represents a transformative shift within contemporary logistics and transportation. With the potential to enhance operational efficiencies in global delivery networks, AHDVs have emerged as catalysts for reshaping supply chain dynamics, logistics strategies, and material handling. Amid these advancements, navigating challenges becomes crucial.

AHDVs, endowed with autonomous capabilities, hold promise for streamlining material flow paradigms. Yet, their integration is impeded by multifaceted challenges, requiring an understanding of market dynamics, legal complexities, and technological advancements.

This paper explores the landscape of AHDVs in logistics, shedding light on market dynamics and insights for integration. Rooted in a comprehensive three-year market analysis, it delves into AHDVs' interaction with logistics through literature reviews, workshops, interviews, and desk research.

Research question: **"What are the significant market trends, barriers, and opportunities associated with the integration of autonomous heavy-duty vehicles within the logistics sector?**"

By examining market trends, barriers, and opportunities, this study contributes to understanding AHDVs' role in logistics and aids stakeholders in navigating their integration.

2 Methodology

The methodology employed in this study adheres to a qualitative approach, as recommended by established research practices for a thorough investigation of the integration of autonomous heavy-duty vehicles (AHDVs) within the logistics domain. Creswell (2013) posits that such an approach is ideally suited for capturing the multifaceted perspectives, experiences, and insights of stakeholders, enabling an in-depth exploration of the research problem. Our research journey encompassed distinct phases, including problem definition, research design, data collection, analysis, and reporting, as outlined by Sekaran (2003).

The initial phase, Problem Definition and Objective Setting, focused on elucidating market trends, barriers, and opportunities to facilitate informed decision-making at both consortium and partner levels. In the Research Design and Approach phase, a qualitative research method was selected for its exploratory nature, which accommodates comprehensive data collection and analysis. This included both primary and secondary data

gathering for a holistic understanding, as Denzin and Lincoln (2011) advocate for such an approach in achieving a holistic exploration of the research phenomenon.

Data Collection was a crucial phase, involving structured surveys, questionnaires, interviews, workshops, and social media polls. These techniques were meticulously utilized to gather specific opinions and insights from professionals, experts, and practitioners within the industry. As detailed in Table 1, the diversity of our data collection methods enabled us to amass a broad and in-depth range of perspectives. Neuman (2013) highlights that employing a variety of data collection methods enriches the data pool and enhances the credibility of the findings. A rigorous analysis of secondary data, including scholarly works, reports, and business publications, was also conducted to establish a comprehensive contextual framework, bolstering the primary data's authenticity.

In the Data Analysis phase, we first transcribed interviews and surveys to accurately capture key insights. Following this, an open-coding technique was employed to identify preliminary themes and patterns, in line with grounded theory (Charmaz, 2006). This step led to a thematic analysis, as described by Braun & Clarke (2006), where codes were grouped into broader themes, revealing recurrent relationships and insights. We ensured accuracy and consistency through the constant comparison method (Glaser & Strauss, 1967), comparing themes across various data sources. The final stage involved interpreting these themes in light of our research goals, providing a nuanced understanding of our findings.

Finally, in the Reporting and Communication phase, the findings were presented in alignment with our research goals, supplemented by literature and direct quotes. The implications were discussed to foster a nuanced discourse on AHDVs in logistics, and the outcomes of the analysis were shared with partners to enhance the overall project outcomes.

Data Collection Method	**Focus**	**Participants**	**Method Description**
Social Media Polls (LinkedIn)	Automation in logistics operations to AVs market readiness	234 responses	Weekly polls to gather insights on different automation topics
Workshop	Drivers, barriers, and opportunities for AHDVs in logistics	Various consortium partners, around 36 (manufacturers, research institutes, consultancy firms, etc.)	Interactive survey using Mentimeter and collaborative session using Metroretro
Online Survey (Mentimeter)	Identification of barriers, opportunities, and drivers of automated HDVs in logistics	16 partners	Survey to identify barriers, opportunities, and drivers
Interviews with Project Partners	Barriers and opportunities to connected and autonomous HDVs in real logistics operations	11 key opinion leaders (ports, civil aviation, fleet management, automotive industry)	In-depth interviews for first-hand data on market dynamics

Table 1: Data Collection Methods

3 Findings

3.1 Trend Analysis

Regarding trends, the authors did a preliminary analysis focusing on two main sources: (1) the DHL Logistics Trend Radar (5th Edition) and (2) the Trendmanager expert database (see www.trendmanager.com). The DHL Logistics Trend Radar is based on over 13,000 DHL customers, partners, and employees who visit the DHL Innovation Centers every year, providing DHL experts with invaluable feedback to develop the DHL Logistics Trend Radar. The Trendmanager tool helps companies and projects, as AWARD, to identify and systematically monitor the trends that are relevant for them.
Furthermore, interviews with project partners of the EU H2020 project AWARD (All Weather Autonomous Real logistics operations and Demonstrations - https://award-h2020.eu/) regarding AHDVs were conducted.

The trend radars revealed multiple relevant trends. For example, the trendmanager tool identified 16 megatrends (see Fig. 1) related to “Autonomous vehicles in logistics” and 11 connected macrotrends. In general, both trend analysis tools provided similar aspects. Self-driving vehicles combined with intelligent infrastructure- and (fleet) management components as well as sustainable logistics are core trends.

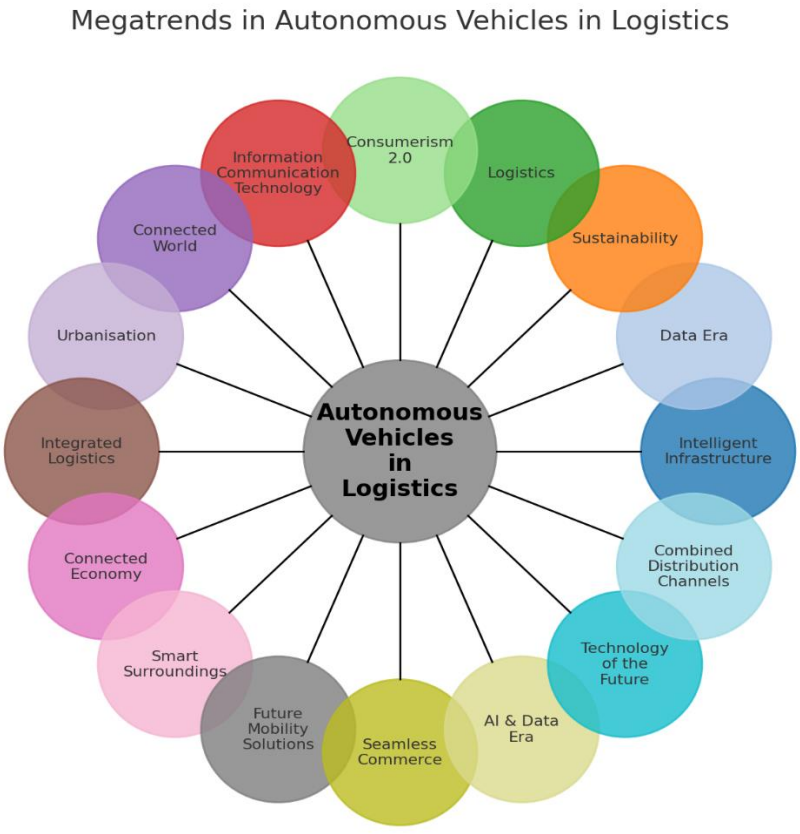

Fig. 1: 16 Megatrends identified related to autonomous vehicle in logistics.

In the market analysis context, an initial competitive landscape analysis was performed based on the Porter’s Five Forces (1979). Based on the four AWARD use cases (Hub-to-hub, Port, Airport, Forklift), the main outcome for the five forces (Supplier Power, Buyer Power, Threat of New Entry, Threat of Substitution and Competitive Rivalry) is the following. Low supplier power due to not yet ready products, low buyer power due to limited demand of just the innovators in the market, medium to high risk of new market entrants due to a lot

of possible new technology players, low risk of substitution based on the limited number of available products and finally the competitive rivalry is based on a competition between high innovative companies and R&D projects.

3.2 Opportunities and Barriers Analysis

Opportunities Analysis: Some of the main opportunities identified are:
Enhanced Safety: A paramount opportunity arising from AHDVs lies in their potential to enhance safety within logistics operations. AHDVs, equipped with advanced sensors and real-time data processing capabilities, hold the promise of minimizing human errors and reducing the likelihood of accidents. This translates into a safer working environment, safeguarding human lives, and minimizing the risk of costly disruptions (Roland Berger, 2016).
Cost Reduction: The integration of AHDVs carries the potential for substantial cost reduction in both transportation and labor. AHDVs' capacity for optimized route planning and efficient driving behavior can lead to decreased fuel consumption and operational expenses. Additionally, the elimination of the need for human drivers can result in significant labor cost savings, making logistics operations more financially viable.
Resource Optimization: AHDVs' continuous operation and ability to adhere to driving-hour regulations offer opportunities for enhanced resource utilization. This translates to improved vehicle and driver utilization, thereby increasing the overall efficiency of logistics operations. The potential for extended driving hours and reduced downtime can lead to more streamlined and productive supply chain management (Roland Berger, 2016).
Customer-Centric Supply Chains: AHDVs have the potential to reshape supply chains into customer-centric entities. By mitigating factors such as driver rest periods and human-caused accidents, AHDVs enable more streamlined material flow and efficient service delivery. This can lead to improved customer satisfaction, reduced delays, and enhanced overall supply chain performance (Neuweiler & Riedel, 2017).

Barriers Analysis: Some identified barriers are:
Technological Barriers: Technological immaturity poses a significant challenge to deploying AHDVs in non-protected environments, particularly when inadequate infrastructure is present. Challenges like GPS connectivity issues and the lack of reliable 5G networks hamper AHDV scalability. Integrating diverse sensors such as LiDAR, cameras, and radar, crucial for safe AHDV operations, presents another hurdle.
Security and Safety: Ensuring safety in AHDV operations encompasses preventing collisions with pedestrians and vehicles and implementing emergency stop systems. Robust cybersecurity measures are essential to safeguard AHDVs from cyber threats and unauthorized access. Ethical considerations also arise, with the challenge of defining AI decision-making in unavoidable accidents.
Infrastructure and Regulatory Challenges: The insufficiency of adequate infrastructure for mass commercialization of AHDVs without excessive investment remains a barrier. Regulatory frameworks lack uniformity, posing complexities across various jurisdictions. The EU's requirement for a driver's continuous responsibility on public roads hampers AHDV adoption. Establishing criteria to verify the safety of AHDV systems for licensing is also an unresolved concern.
Liability and Ethical Concerns: Liability attribution in case of accidents involving AHDVs remains unclear1. As automation advances, liability is expected to shift from drivers to manufacturers1. However, issues may arise during the transition phase when both human drivers and automation systems control vehicles1. Ethical challenges arise from AHDVs' decision-making in inevitable accident scenarios.
Employment and Organizational Changes: The transition to AHDVs could disrupt employment structures, necessitating new skills and training for maintaining and operating autonomous systems. The restructuring of roles and responsibilities poses a potential barrier.
Privacy and Economic Factors: Privacy concerns linked to data collection and potential cyber-attacks on AHDV systems introduce additional complexities. High manufacturing costs, significant infrastructure investment, and the expenses associated with training qualified personnel are formidable economic barriers.

Quadrant Analysis of opportunities and barriers.

The quadrant analysis of barriers and opportunities for Automated Heavy-Duty Vehicles (AHDVs) integration in logistics reveals a comprehensive landscape. The analysis unveils a multi-faceted picture, showcasing the interplay between barriers and opportunities in the dynamic logistics environment.

The identified barriers reflect the complexity of AHDV integration, spanning technological, regulatory, safety, security, ethical, and economic dimensions. These challenges underscore the need for robust technological maturity, standardized regulations, enhanced safety measures, and ethical decision-making frameworks. While certain barriers may eventually evolve into opportunities with technological advancement and growing acceptance, immediate action is required to mitigate concerns related to safety, liability, infrastructure, and workforce restructuring.

The opportunities landscape aligns with the transformative potential of AHDVs, highlighting avenues for enhanced efficiency, reduced costs, and increased sustainability. Technological advancements in connectivity, sensors, and AI drive the expansion of AHDVs' applications. Collaboration among stakeholders, regulatory adjustments, and safety measures create opportunities to establish AHDVs as a safe and reliable logistical solution. Furthermore, evolving societal attitudes towards sustainability and automation open doors for embracing AHDVs in supply chain operations.

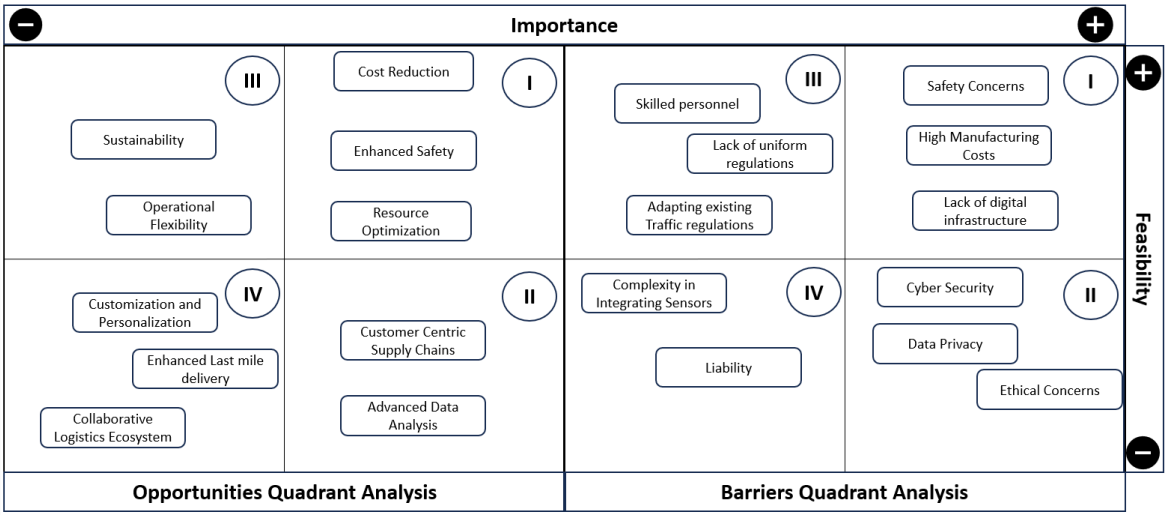

Fig. 2. Quadrant Analysis of Opportunities for Autonomous Heavy-Duty Vehicles in Logistics

4 Conclusion

In conclusion, this comprehensive market research study has elucidated how the logistics sector might adapt to the advent of autonomous heavy-duty vehicles (AHDVs). Our multifaceted research approach, which included workshops, questionnaires, interviews, and social media polls, has offered a detailed picture of the current state and potential of AHDVs in logistics. Significantly, the thematic analysis of our interviews was pivotal in bringing to light the specific challenges and opportunities within the sector. This investigation not only highlighted key drivers and barriers but also shed light on varied stakeholder perspectives, which have been crucial in forming our strategic recommendations for the adoption of AHDVs.

The insights gained underscore the transformative potential of AHDVs in logistics, echoing findings from previous studies such as those by Marsden et al. (2018) and Kim et al. (2022). The integration of AVs in logistics and the rise of Logistics 4.0 present a landscape replete with both opportunities and challenges. Economic and business model shifts, as anticipated by Clements & Kockelman (2017) and Fritschy & Spinler (2019), further corroborate our conclusions regarding the market impact of AVs. Additionally, the

technological and social challenges we identified resonate with concerns regarding public perception and manoeuvrability in logistics centers, as noted by López-Lambas & Alonso (2019).

Our study's findings emphasize the critical aspects affecting the integration of AHDVs, including safety, technological readiness, legal issues, and infrastructure development. While challenges like technological maturity, security concerns, and regulatory hurdles persist, the potential benefits of AHDVs in improving safety, reducing costs, optimizing resources, and developing customer-centric supply chains are significant.

The quadrant analysis of opportunities and barriers that we conducted offers a dynamic perspective on the AHDV landscape in logistics, underlining the need for proactive measures to address challenges and capitalize on emerging opportunities. To realize the full benefits of AHDVs in the logistics industry, collaborative efforts among stakeholders, regulatory adaptations, and a commitment to safety and sustainability are imperative.

Through this study, we contribute a comprehensive understanding of the various dynamics influencing the adoption of autonomous vehicles in logistics. As the sector continues to evolve, stakeholders must remain adaptable and forward-thinking to harness the revolutionary potential of AHDVs fully.

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