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A Foresight Study on Adoption of Autonomous Long-Haul Trucks among Logistics Industry in Malaysia

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Abstract

Autonomous long-haul trucks (ATs), one of the most cutting-edge technologies available today, significantly contributed to the development of logistics companies. In the coming years, the advent of autonomous long-haul trucks is poised to revolutionize the logistics and transportation industry, presenting a monumental game-changer with far-reaching implications. However, research on the adoption of Autonomous Long-Haul Trucks among logistics companies in Malaysia is limited. Hence, this study seeks to analyze the primary factors driving the Autonomous Long-Haul Trucks and to study the future image of their adoption within logistics companies in Malaysia. In this study, both qualitative and quantitative methods are used. STEEPV analysis applied as a foresight methodology. A questionnaire was used to identify the primary issues and drivers, as well as the impact-uncertainty analysis that corresponds to the adoption of autonomous long-haul trucks technology in the future. Among 275 distributed questionnaires to employees in Malaysian logistics companies, only 63 responded, resulting in a 38.89% response rate. The study identified legal and regulatory framework and technological advancements as the top two key drivers, showing the highest impact and uncertainty. Based on the findings of the study, four scenarios emerged were revolutionized transportation innovation, reduced efficiency, slow technological adoption, and safety and security risks.

1. Introduction

Trucks play a crucial role in a multifaceted logistical network that encompasses inland waterways, roads, air, and rail transit. Given their pivotal role in moving freight between ports, deports, airports, and rail terminals, the global supply chain and logistics markets heavily depend on trucks. Not only are trucks the most cost-effective and swift mode of transportation, but they also offer unparalleled adaptability for the majority of goods and freight (ACEA, 2021).

The logistics sector is currently undergoing a profound transformation driven by digitalization and other technological advancements. These innovations have the potential to significantly reduce the cost of shipping products over land (S&P Global, 2022). The main mode of transportation in the logistics market is using trucks in land transport. Globally, the trucking industry is grappling with an aging workforce and a labor crisis, as highlighted by Kim *et al.* (2022). Consequently, to reshape the logistics sector, there has been a notable emergence and revolution in autonomous truck logistics, marking a substantial impact on the overall logistics landscape, as reported by Tank Transport (2023).

According to Madhavan *et al.* (2006), "autonomous trucks" refers to vehicles that will be operated by satellites and cutting-edge GPS systems (Global Positioning Systems). To develop an autonomous truck, many sensors, a fuel control system, real-time processing, and live traffic feeds from cameras are all necessary (Vyacheslav, 2021). According to Daimler Truck Company (2019), companies that are totally devoted to autonomous trucking can experience an increase in safety because the systems do not get fatigued or lose focus. By allowing trucks to run longer, it will improve logistics performance and assist society in managing the expanding volume of freight, especially during periods of extreme driver shortages. Moreover, autonomous trucks exhibit substantial market and growth potential, with the added benefit of enhancing service revenues (Daimler Truck, 2023).

The researcher has pinpointed key advantages for contemporary transportation firms as they integrate autonomous trucks (ATs) onto highways. Foremost among these benefits is the potential for ATs to reduce operational expenses while simultaneously increasing capital expenditures, thereby reshaping the financial landscape for businesses. Additionally, Chottani *et al.* (2018) highlighted that ATs offer a promising solution to the industry's capacity issues, providing an opportunity for truck original equipment manufacturers (OEMs) to make advancements downstream and enter the transportation sector. Consequently, the disruptive impact of autonomous trucks on the logistics supply chains of retailers is already evident, with expectations for this influence to grow in the future, according to Vyacheslav (2021).

1.1 Research Background

The transportation and logistics sectors are on the brink of a major transformation, as autonomous vehicles (AVs) rapidly advance from the realm of science fiction to practical reality (Mansour, 2023). According to the market research conducted by Fortune Business Insights (2023), the size of the global market for autonomous trucks (ATs) was valued at USD 30.70 billion in 2022 and is projected grow from USD 33 billion in 2023 to USD 67.73 billion by 2030 at a CAGR of 10.8 percent between 2023 to 2030.

A transformative trend with the potential to reshape future transportation demands and planning requirements is the emergence of autonomous trucks. This trend stands out for its ability to provide not just safety solutions but also to enhance mobility, thereby significantly amplifying supply chain efficiency and dependability. For autonomous long-haul trucks to achieve success and yield positive outcomes, industry experts and the government need to collaborate on a comprehensive roll-out strategy. This strategy should encompass all phases of autonomous truck technology, ranging from assisted driving and remote control to fully autonomous operations (Imthiaz, 2023).

Khan's (2023) forecast that the future of Pakistan's logistics and transportation industry will be shaped by the integration of autonomous trucks with a strong emphasis on safety. Based on US Department of Transportation's National Highway Traffic Safety Administration (NHTSA) statistics, 94% of car crashes are a result of human error (Future Bridge, 2020). Despite this statistic, autonomous trucks hold the potential to markedly reduce the incidence of road accidents by eliminating human error. Beyond the crucial aspect of saving lives, this advancement would also contribute to cost reduction associated with accidents, encompassing medical expenses and property damage (Khan, 2023).

Moreover, autonomous trucks offer a distinct advantage in enhancing efficiency. Autonomous trucks can optimize their routes and ease traffic congestion by communicating with other trucks and infrastructure. This would result in faster and more efficient deliveries, which would benefit both businesses and consumers (Khan, 2023). Furthermore, in terms of consumer benefits, the deployment of autonomous trucks has the potential to create added value by significantly reducing delivery times, as emphasized by Bedell in 2019. Lastly, autonomous trucks would be able to operate around the clock, further increasing operational efficiency and reducing operating costs (Khan, 2023).

1.2 Problem Statement

The evolution of logistics organizations has been considerably influenced by autonomous trucks (ATs), one of the most cutting-edge technologies accessible today (Collie *et al.*, 2022). In a few years, autonomous trucks will be a reality, which will significantly alter the whole transportation business (Ribeiro, 2021).

The integration of autonomous trucks in developed economies comes with a multitude of benefits, encompassing heightened operational efficiency, improved safety measures, lowered transportation expenses, and an overall boost to environmental sustainability (Menzies, 2022). Based on previous study, it was found that developed nations have actively embraced and implemented autonomous semi-trucks, marking a substantial transformation in the logistics industry. As stated by autonomous trucking website (TuSimple), a leading American autonomous trucking company set to offer autonomous semi-truck solutions, their technology is projected to be operational by 2024 (Banker, 2021).

However, the shift from conventional trucks to autonomous counterparts introduces a set of challenges and considerations that demand attention. These include navigating regulatory frameworks, addressing infrastructure needs, managing workforce concerns, and gauging public acceptance (Zarif et al, 2021).

Governments and regulatory bodies must formulate comprehensive rules, guidelines, and standards to ensure safe and responsible deployment of autonomous trucks on public roads (Mutabazi, 2023). Additionally, addressing issues related to cybersecurity, data privacy, and safety certifications is equally crucial in navigating the landscape of autonomous truck deployment (Mutabazi, 2023).

Roads and transportation systems must integrate advanced technologies, such as 5G networks and smart sensors, to facilitate seamless communication between vehicles and traffic management centers. (Edwards, 2023). In terms of workforce concerns, autonomous trucks have led to concerns about job displacement among millions of truck drivers (Debusmann, 2021). Likewise, most non-specialized long-distance drivers could be replaced by autonomous trucks, resulting in a projected loss of 294,000 trucking jobs (Viscelli, 2018). Transparent communication like pedestrians' interaction with driverless trucks, public education, and proof of the advantages and safety of self-driving trucks must all be provided to increase public trust and confidence in autonomous technology (Mutabazi, 2023). By addressing these factors, logistics companies aiming to introduce autonomous truck technology can mitigate challenges related to public acceptance (Khan, 2023).

Considering the highlighted advantages and challenges, there is an opportunity to conduct a foresight study on the adoption of autonomous long-haul trucks among the logistics industry in Malaysia. Moreover, the limited of information and studies on autonomous trucks manufacturers in Malaysia is a contributing factor to lower demand and insufficient infrastructure, hindering the adoption of autonomous trucks in the country. To enhance the global competitiveness of the Malaysian logistics industry, the imperative and essential adoption of autonomous long-haul trucks is obvious.

Therefore, to achieve the research objectives the issues, challenges, and trends of autonomous long-haul trucks (ATs) among logistics industries is determined. Furthermore, the key drivers of autonomous long-haul trucks (ATs) among logistics industries also determined. Consequently, the future image of autonomous long-haul trucks (ATs) among logistics industries is identified.

1.3 Scope of the Research

The foresight study was carried out keeping in view the time horizon of 10 years in the future, which is from the year of 2023 to 2033. The current research focuses on each resource or information related to the trend of autonomous trucking in logistics industry. All the related information and data collected from various sources such as news, blogs, journals, articles, and from all kinds of research materials corresponding to autonomous long-haul trucks were analyzed and evaluated. The respondent of this study consists of Malaysian Hauliers Companies. Malaysian Hauliers Company is a company employed in the transport of goods and materials by road in Malaysia.

1.4 Significance of the Research

This study could contribute to knowledge on the autonomous long-haul trucks adoption among logistics industry in Malaysia. Autonomous long-haul trucks will have a huge impact on the supply chain operations through autonomous trucks adoption. It is because AI will automate everything from shipping operations to long-haul deliveries. This study also contributes to the literature on importance of autonomous long-haul trucks adoption and foresight study. By identifying key issues and drivers in employing autonomous long-haul trucks in the logistics industry, the research aims to shed light on future trends within Malaysia. This research was carried out and aimed to identify the issues and drivers of employing autonomous long-haul trucks among logistics industry and to study the future trend of autonomous long-haul trucks in Malaysia. This study could benefit the government in making policy and enhance autonomous long-haul trucks adoption in logistics industry. Hence, the government can develop manufacturing policy or incentives that consider implementing autonomous long-haul trucks in their training and development program in the future.

2. Research Methodology

This chapter covers a researcher's approach to provide reliable, valid results to address the objectives of this study. In this research, both qualitative and quantitative methods were used to analyze and interpret data. The qualitative data is analyzed by means of STEEPV method, while the quantitative data is analyzed using means of an Impact-Uncertainty analysis on the writing of scenario.

2.1 Research Design

Research design is an important component in conducting the research. The research design is a data collecting and analysis framework (Cooper *et al.*, 2006; Ghauri and Grønhaug, 2005). In this research, both qualitative (STEEPV analysis) and quantitative (descriptive analysis) approaches were used to analyze and interpret the data. STEEPV analysis was used to identify the future trend and to classify the issues and drivers on future usage of autonomous long-haul trucks. Descriptive analysis using SPSS software was used to analyze data collected from the questionnaire.

2.2 Data Collection

Data collection is a process of collecting information from all the relevant sources to find answers to research problems and evaluate the outcomes. The data collection of this research is composed of primary data and secondary data collection.

The primary research definition refers to research that has involved the collection of original data specific to a particular research project (Gratton & Jones, 2010). Researcher collects the data through questionnaire by using Google Form application. The questionnaire is given to the logistics companies employees to gather relevant information in Malaysia.

Secondary research entails the synthesis or summarization of previously published and structured data and literature. Researchers conduct secondary research by utilizing and analyzing data obtained from primary research sources (Bouchrika, 2023). The secondary data will be collected through several sources such as articles, journal articles, news, government-related articles, etc. The use of existing data is more economical and expedient than obtaining original data.

2.3 Population, Sample Size, and Sampling Technique

Research population is defined as a specific collection of individuals or objects which is the central focus of a scientific question. In this study, the respondents comprise Malaysian Hauliers Companies engaged in the transportation of goods and materials by road within Malaysia, with a specific interest in their plans to adopt autonomous trucks. According to the Association of Malaysian Hauliers (2022) data, there are a total of 275 logistics companies, constituting the target population for this research within the logistics industry in Malaysia.

The sample size of this study was determined by using Krejcie & Morgan (1970) table. According to the table Krejcie & Morgan, 162 logistics companies were chosen as samples for this study. This study used a purposive sampling method. It is a non-probability sampling technique commonly used in mixed methods research. This approach aims to select information-rich cases and optimize the utilization of limited research resources (Nikolopoulou, 2022). This involves identifying and choosing individuals or organizations with specialized knowledge or experience about a phenomenon of interest (Cresswell & Plano Clark, 2011).

2.4 STEEPV Method

According to Black (2021), the STEEPV method can analyze the past and predict the future. Social, technological, economic, environmental, political, and values is the abbreviation for STEEPV. It is utilized for future logistics industry discussions regarding autonomous truck drivers and trends. In addition, the STEEPV approach is a form of content analysis that refers to articles, journals article, books, and newspapers.

2.5 Impact-uncertainty Analysis

Impact-uncertainty analysis will be utilized to identify the most uncertain and consequential drivers in implementing autonomous trucks among logistics company in Malaysia. In this study, descriptive analysis is used to identify the key driving force. The drivers were listed according to importance, impact, and uncertainty. The top two key drivers with the highest level of impact and level of uncertainty have been selected to develop scenario analysis.

2.6 Scenario Building

The scenario building was developed using the top two key drivers from the impact-uncertainty analysis. The future image of events and trends of autonomous long-haul trucks among logistics industry were broken down into four distinctive alternative scenarios regardless of favorable or unfavorable outcomes. At the end of the study, its implications and recommendations were discussed. These alternative scenarios represent the four possibilities that might happen from 2023 to 2033.

3. Literature Review

This chapter provides an overview of the Autonomous Long-Haul Trucks (ATs), concept, and trends in the research report. The purpose of the literature review was to ensure that it could be correlated with the topic of this research, which was to identify the issues and drivers, analyze the challenges, threats, and uncertainty surrounding the adoption of ATs in logistics transportation.

3.1 Autonomous Long-Haul Trucks

Autonomous long-haul trucks are commercial vehicles that use artificial intelligence to automate everything from cargo yard operations to long-distance deliveries (Bruke, 2021) and operate securely without human intervention. It is ideally suited for the middle mile of delivery, such as highway driving (Lmad, 2022). ATs is controlled and propelled by sensors and software based on artificial intelligence (Crystal, 2023). It uses a combination of cameras, sensors, and advanced algorithms to navigate its environment autonomously. Typically, they are equipped with a variety of technologies, including LiDAR, radar, GPS, and computer vision systems, which allow them to perceive and respond to their surroundings (Tanktransport, 2023).

3.2 Advantages of Autonomous Long-Haul Trucks (ATs)

Autonomous long-haul trucks offer a wide range of applications and may be used to benefit the industry overall. There are various advantages gained from adopting autonomous long-haul trucks in logistics industry. This study stressed the major advantages for logistics sector which were boost supply chain efficiency, lower transportation expenses, and safety.

3.2.1 Boost Supply Chain Efficiency

Autonomous long-haul trucks can boost supply chain efficiency with vehicle connectivity (Tanktransport, 2023). By using vehicle-to-vehicle (V2V) communication, called autonomous trucks platooning, it can exchange information and communicate critical data such as speed, location, the direction of travel relative to other vehicles on the road, braking, and loss of stability (Delvens, 2023). This allows them to coordinate their movements, optimize traffic flow, and decrease the likelihood of collisions. In the logistics industry, platooning is multiple autonomous trucks that travel in close proximity to reduce air resistance and increase fuel efficiency. This can result in substantial fuel savings and reduced greenhouse gas and CO2 emissions (Tanktransport, 2023).

3.2.2 Lower Transportation Costs

Fuel costs comprise a significant portion of trucking companies' operating expenses, which trickle down to manufacturers and ultimately the consumer. However, with the option to implement vehicle platooning with automated trucks, fuel consumption can be reduced by 10% (Redwood, 2016). Next, autonomous vehicles have the potential to reduce logistics companies' insurance premiums (Tanktransport, 2023). As autonomous and other intelligent technologies develop and there are fewer accidents, policyholders' auto fleet insurance premiums could decrease (Greenwald, 2023).

3.2.3 Safety

Autonomous long-haul trucks can minimize human error in trucking and prevent accidents proactively (Tanktransport, 2023). The U.S. National Highway Traffic Safety Administration states automated vehicles have the potential “to save lives and reduce injuries” since “94% of serious crashes are due to human error” (Goddu, 2022). With autonomous trucks driving during off-peak traffic hours, the risks caused by driver fatigue can be markedly reduced (Freightwaves, 2017). Autonomous trucks also can automatically maintain a safe following distance, adjust their speed according to traffic conditions, and brake promptly in response to obstacles (Tanktransport, 2023).

3.3 Disadvantages of Autonomous Long-Haul Trucks (ATs)

As the adoption of autonomous trucks is still an emerging technology in the business market and logistics sector, there is still uncertainty information about the technology. Therefore, technology adoption encounters numerous challenges.

3.3.1 Legal framework and regulations

Legal framework and regulations are one of the most essential requirements before autonomous trucks can be widely adopted (Lee, 2023). The authority should consider the difficulty in determining who is responsible in the event of an emergency or collision. In fact, with the development of autonomous trucks, the responsibility for accidents clearly shifts from drivers to the corporations designing and developing these trucks. In light of the prevalence of autonomous trucks on public roads, it is imperative that laws be revised. A policy that addresses the concerns of potential customers must be clear and concise (Singh & Saini, 2021).

3.3.2 Loss of Job

Many truck drivers who have been operating vehicles for decades will lose their jobs when autonomous trucks replace human truck drivers (Pauline, 2020). If the process of automation matures, truck drivers will be supplanted (Lien, 2022). This is due to the fact that autonomous trucks can change lanes and accelerate or decelerate without a human operator present (Rose & Hach, 2022). Even though the younger generation of truck drivers are willing to work around the clock, they lack the necessary knowledge and experience to operate a truck (Pauline, 2020).

3.3.3 Security issues

The logistics company's practice of autonomous trucks is hampered by security concerns. As software operates autonomous trucks, it is simple for hackers to compromise the software and create delivery vulnerabilities, such as overriding the controls. Even if a human supervisor is present in an autonomous truck, software hacking cannot be detected by the driver alone (Pauline, 2020).

3.4 STEEPV Analysis

In this section, all issues, challenges, and trends from the STEEPV analysis. STEEPV analysis was used to identify the key terms of autonomous long-haul trucks adoption in logistics companies. From the STEEPV analysis, it was determined that technological variables have the most influence on the adoption of automated long-haul trucks, while political factors have the least.

3.5 Drivers of Issues, Challenges, and Trends

This research has identified major issues, challenges, and trends for the future image of Autonomous Long-Haul Trucks in logistics industry. A total of 15 drivers of issues, challenges, and trends have been identified as depicted in Table 1.

Table 1 *Drivers of issues, challenges, and trends*

No	Issues, Challenges, and Trends	Drivers
1	Driver shortage, Truck driver scarcity, Driven shortage, Labor shortage, Driver shortage	Workforce Requirement
2	Autonomous driving concerns, Human-free operation, Human-free autonomous trucking	Autonomy Revolution
3	Accident reduction, Reduction of fatalities, Safety	Safety Management
4	Decrease driving time, Increase efficiency, Time efficiency	Operational Efficiency
5	Gender equality, Job loss concern	Societal Impact
6	Expertise in artificial intelligence and vehicle control systems recruitment	Talent Acquisition
7	Rigorous testing for building public confidence in autonomous vehicles, Public education campaigns for trust in autonomous vehicles, Public acceptance, Public trust	Trust Development
8	Autonomous trucks and AI integration, AI automation, Artificial intelligence automation, AI/ML	AI Integration
9	Advanced technology for enhanced logistics efficiency and security, Advanced technology for safe and efficient self-driving trucks, Advanced sensor data for early problem detection	Technology Advancements
10	Levels of vehicle automation, Sensing technologies and decision-making in autonomous trucks	Automation Progression
11	Strategic partnership and unique technology in autonomous trucking, Shared technology foundation of autonomous cars and trucks	Collaborative Innovation
12	Real-time data analysis and enhanced decision-making in AVs, Real-time data and traffic management	Real-time Analytics
13	Autonomous cargo handling, Sensor-based automation in truck operations	Cargo Automation
14	Legal and technological challenges, Legal liability, Federal regulatory framework, Regulatory frameworks	Legal & Regulatory Framework
15	Improved driver quality of life and job satisfaction, Job displacement	Work-life Balance

4. Data Analysis and Results

This chapter analyzes the mean value of importance, impact, and uncertainty of drivers from STEEPV analysis. The data collected were analyzed by the SPSS to obtain overall demographic data and the mean value of each driver. The top two highest drivers of mean value will define most uncertainty and impact on autonomous long-haul trucks adoption, and it will be used in the next chapter of scenario analysis process.

4.1 Survey Return Rate

Based on Table 2, the population of Malaysian Hauliers Companies is identified 275. From this population, a sample size of 162 respondents was selected for the study. The distribution of 275 sets of valid questionnaires was conducted through various channels, including email, personal calls, and social media platforms such as WhatsApp and LinkedIn, utilizing the Google Form format. The survey return rate yielded 63 responses out of the 275 valid questionnaires, resulting in a response rate of 38.89%.

Table 2 *Survey return rate*

Population	275
Sample Size	162
Questionnaire Returned (Valid)	63
Questionnaire Distributed	275
Response Rate (%)	38.89%

4.2 Reliability Analysis

A reliability test was done in the real study to verify this research. This research was using Cronbach's Alpha value to test the questionnaire data consistency and reliability. Table 3 showed the result of Cronbach's Alpha value for Level of Importance, Level of Impact, and Level of Uncertainty pertains in good reliability as the value is consistency over 0.8 in real study, therefore, the study was reliable and could be continued.

Table 3 *Reliability analysis*

Factors	Pilot Test		Real Study		N of Items
	Cronbach's Alpha Value	Number of Respondents	Cronbach's Alpha Value	Number of Respondents	
Level of Importance	0.820	15	0.853	63	45
Level of Impact	0.774		0.831		
Level of Uncertainty	0.811		0.857		

4.3 Demographic Analysis

Table 4 *Demographic respondent*

No	Characteristics	Category	Frequency	Percentage (%)
1	Gender	Male	49	77.8
		Female	14	22.2
2	Age	Below 30 Years Old	12	19.0
		31-40 Years Old	21	33.3
		41-50 Years Old	19	30.2
		51 Years Old & above	11	17.5
3	Race	Malay	24	38.1
		Chinese	29	46.0
		Indian	9	14.3
		Other	1	1.6
4	Educational Level	SPM/O-Level	5	7.9
		STPM/Matriculation/ Foundation/Diploma	14	22.2

		Bachelor's Degree	40	63.5
		Doctorate Degree	2	3.2
		Others	2	3.2
5	Number of Employees	< 10 people	9	14.3
		10 – 19 people	5	7.9
		20 – 29 people	7	11.1
		30 – 39 people	6	9.5
		> 40 people	27	42.9
6	Working Experience	Below 3 Years	11	17.5
		3 – 5 Years	7	11.1
		6 – 8 Years	8	12.7
		9 Years & above	37	58.7
7	Energy Sources	Natural gas	2	3.2
		Fuel	61	96.8
		Electric	-	-
		Hybrid (Combination of electric and fuel)	-	-
8	Knowledge on Autonomous	Yes	41	65.1
	Trucks	No	22	34.9
9	Future Plan to Implement	Yes	41	65.1
	Autonomous Trucks	No	22	34.9
10	Prediction Timeline to Implement	Immediately	2	3.2
	Autonomous Trucks	4 to 6 years from now	15	23.8
		7 to 9 years from now	17	27.0
		In a decade	29	46.0

The demographic analysis encompassed the comprehensive profiling of respondents, covering variables such as gender, age, race, educational level, number of employees, working experience, energy sources, knowledge levels, future plan, and projected timelines for the implementation of autonomous long-haul trucks within the logistics industry in Malaysia. A total of 63 participants contributed to this study, revealing a prevailing male majority (77.8%), with the predominant age group being 31-40 years old (33.3%). The demographic breakdown indicated a significant representation of Chinese respondents (46%), individuals holding a bachelor's degree (63.5%), and a substantial portion employed in companies with more than 40 employees (42.9%). Most of the employees have been working for 9 years and above (58.7%). The study also highlighted that the major energy source for trucks in logistics companies was traditional fuel (96.8%). The majority of 41 respondents exhibit knowledge about autonomous trucks in the logistics industry and express intentions to implement autonomous trucks into their future plans. In contrast, the remaining 22 respondents do not share this inclination. Most of the respondents (29%) have predicted the timeline to implement autonomous trucks in logistics industries is in a decade.

4.4 Descriptive Analysis of Driver

This section discussed fifteen drivers who had been voted based on three aspects: importance, level of impact, and level of uncertainty. The approach of impact-uncertainty analysis was constructed to determine the top driver which contributed highest impact and uncertainty in the future. Out of fifteen drivers, only eight were selected based on the highest mean score.

4.4.1 Mean of drivers based on level of importance

Table 5 *Mean value of the top eight leading drivers based on importance*

No	Drivers	Mean
D1	Legal and Regulatory Framework	4.2698
D2	Technology Advancements	4.1905
D3	Trust Development	4.1746
D4	Cargo Automation	4.0000
D5	Collaborative Innovation	3.9683

D6	AI Integration	3.9524
D7	Real-time Analytics	3.9524
D8	Automation Progression	3.9206

The mean values in Table 5 indicate the overall rating scale by the respondents answered based on their evaluation and opinion, and those drivers have the potential to create a new future for the logistics industries. The next step is to find out the highest mean value in descending order. Out of fifteen drivers listed in this study, only eight were chosen based on the highest mean in level of impact and level of uncertainty. All the data collected will be utilized in the subsequent impact and uncertainty analysis.

4.4.2 Mean of drivers based on level of impact-uncertainty

Table 6 *Mean value of the top eight leading drivers based on impact-uncertainty*

No	Drivers	Mean Value	
		Impact	Uncertainty
D1	Legal and Regulatory Framework	4.0635	4.0635
D2	Technology Advancements	4.0794	3.9048
D3	Trust Development	4.0000	3.8413
D4	Cargo Automation	3.8095	3.8571
D5	Collaborative Innovation	3.7619	3.6825
D6	AI Integration	3.9841	3.5714
D7	Real-time Analytics	3.8413	3.8524
D8	Automation Progression	3.9683	3.8730

Table 6 demonstrates a comparison of the mean values for the top eight leading drivers based on their levels of impact and uncertainty. The main purpose of this analysis is to identify the drivers with the highest outcomes concerning both impact and uncertainty. Specifically, the top two drivers showing the highest impact and uncertainty will be emphasized. To enhance clarity, a graph depicting the impact-uncertainty analysis based on these top eight leading drivers is presented below.

4.5 Impact-Uncertainty Analysis

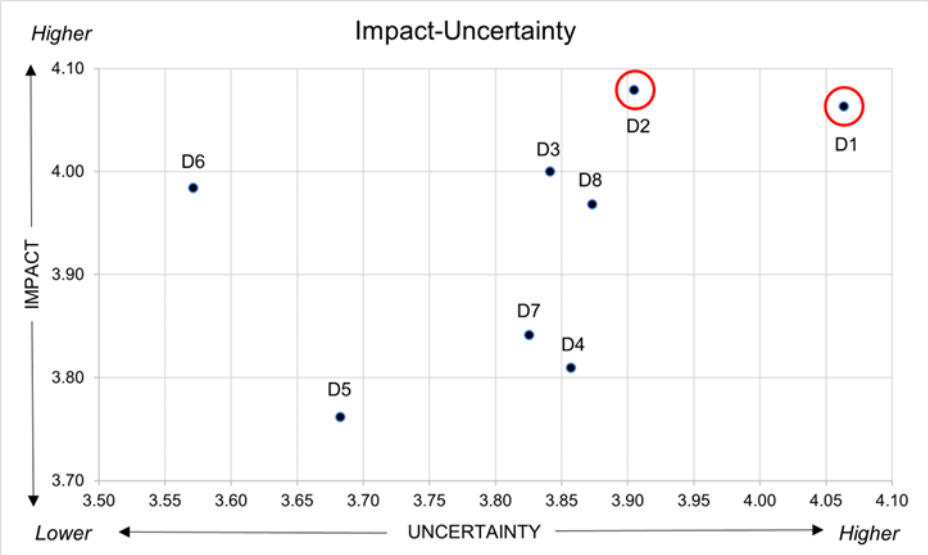

Fig. 1 *Impact-uncertainty analysis*

The Impact-Uncertainty Analysis result is illustrated in Fig. 1. The decision will be based on the two most significant impacts and uncertainty driver. Coordinate D1 (4.0635, 4.0635) for Legal and Regulatory Framework and Coordinate D2 (3.9048, 4.0794) for Technology Advancement were selected. This is because D1 is the driver with the highest level of uncertainty whereas D2 is the driver with highest level of impact. Hence, these two key drivers were chosen as the top key drivers and will be used to construct scenario-building analysis.

5. Discussion, Recommendation and Conclusion

5.1 Discussion based on First Research Objective

The primary objective of this research is to use STEEPV analysis to identify issues, challenges, and trends in the adoption of autonomous long-haul trucks within the logistics industry. This strategic tool facilitates the evaluation of relevant data in a simplified manner. Given the absence of autonomous trucking technology in Malaysia, it is imperative for logistics professionals to proactively understand the advantages, issues, and challenges before contemplating adoption. This comprehension is vital for the successful integration of autonomous long-haul trucks into the Malaysian logistics landscape, with fifteen drivers identified for accomplishing the second objective.

5.2 Discussion based on Second Research Objective

The second objective is to identify key drivers for adopting autonomous long-haul trucks in the Malaysian logistics industry. Fifteen drivers were identified through STEEPV analysis, which played a crucial role in aligning factors influencing the industry with the future adoption of autonomous trucking technology. These drivers, selected based on impact-uncertainty analysis, will determine the feasibility and reliability of integrating autonomous long-haul trucks in the logistics sector in the future. Two primary key drivers, deemed the most impactful and uncertain, emerged from the evaluation of autonomous trucking technology for the logistics industry.

5.3 Discussion based on Third Research Objective

The third objective is to study the future trends of autonomous long-haul trucks in Malaysian logistics industry. Four scenarios, based on the top two key drivers (D1: Legal and Regulatory Framework and D2: Technology Advancements), were identified from impact-uncertainty analysis. These scenarios outline potential trajectories of autonomous long-haul truck adoption from 2023 to 2033. Based on Figure 2, the scenarios depict different possibilities for the future of autonomous long-haul truck adoption, ranging from revolutionary transportation innovation to safety and security risks. These outcomes will be analyzed to determine the favorability or unfavourability of the proposed future image of autonomous long-haul truck adoption in the logistics industry.

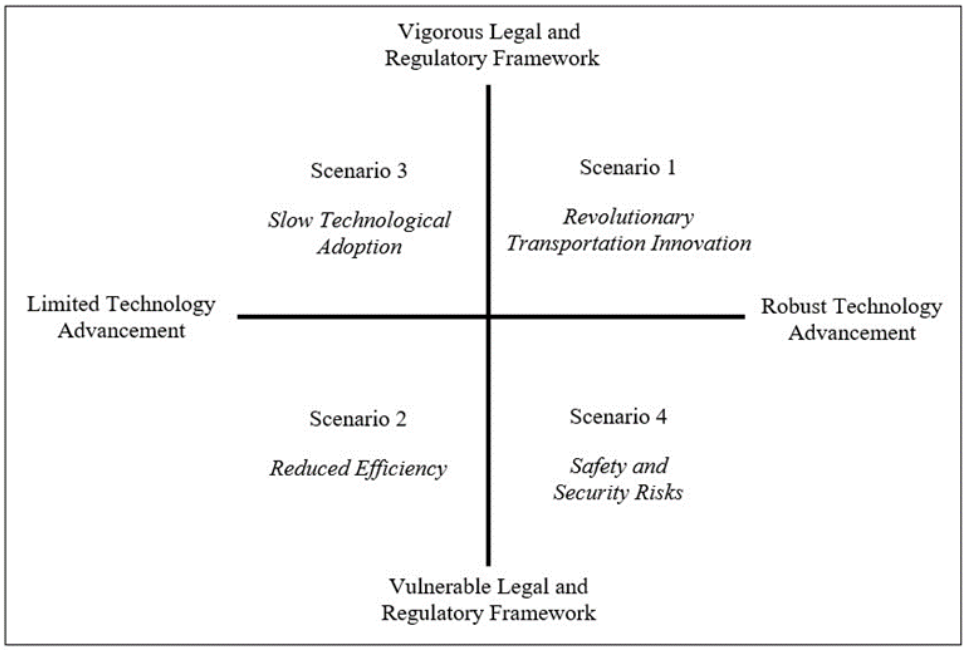

Fig. 2 *Future scenario analysis*

The Future Scenario Analysis is portrayed in Fig. 2, outlines four potential outcomes based on two key drivers, Legal and Regulatory Framework and Technology Advancements. Among these scenarios, revolutionary transportation innovation stands out as the most favorable, while reduced efficiency emerges as the least desirable. The scenario of slow technological adoption, coupled with safety and security risks, presents a mixed outlook, with potential for either positive or negative impacts on the adoption of autonomous long-haul trucks within the logistics industry in Malaysia.

5.3.1 Scenario 1: Revolutionary Transportation Innovation

The first scenario takes place where there is a vigorous legal and regulatory framework aligned with robust technology advancement. This synergy paves the way for revolutionary transportation innovation, signifying a new era of normalization where autonomous long-haul trucks emerge as the predominant logistics transport medium. This evolution aims to automate transportation processes, enhancing flexibility and sustainability in operations, as highlighted by Serheichuk (2021). This scenario drives transport logistics into a transformative era marked by innovative transportation practices.

In terms of robust technological advancements, the level of technological sophistication in autonomous truck systems plays a crucial role in determining the advancement of logistics companies. Companies that invest in research and development to develop advanced sensors, artificial algorithms, and computer vision capabilities have a higher chance of success in logistics industries (TireTrack Expert, 2023). By using AI algorithms and machine learning, it can help in designing and improving autonomous systems for trucks. These technologies are also able to process and analyze vast amounts of data from sensors, cameras, and other sources to make real-time decisions and responses. These systems aid in comprehending and mapping the surroundings, detecting obstacles, predicting traffic patterns, and ensuring secure and efficient navigation.

The potential transformation of people's lives by self-driving trucks is contingent on a robust legal and regulatory framework. Such a framework instils confidence among individuals to embrace autonomous trucks in the transportation industry, fostering positive attitudes and trust among the public, industry stakeholders, and policymakers. For example, Rio Tinto, a mining company, has been using autonomous trucks for more than a decade to run safer, more efficient, and low-cost operations. They are removing driver errors and improving safety by increasing the automation of trucks, drills, and trains (GMG Group, 2021).

For social view, with the vigorous legal and regulatory framework and robust technology advancement, the adoption of autonomous long-haul trucks has the potential to influence various aspects of society, employment, also directly improves public safety. By implementing the autonomous long-haul truck, it can reduce fatal crashes, better speed control and shorter reaction times to other drivers and objects (TuSimple, 2022). For example, logistics transport companies can develop fail-safe systems and redundancy measures that can prevent accidents from occurring (Arrow Truck Sales, 2023).

Considering the vigorous legal and regulatory framework and significant technological breakthroughs, the scenario is ideal for the broad deployment of autonomous long-haul trucks in the logistics business. The strong regulatory environment enables secure and standardized implementation, reducing risks and increasing industry confidence. At the same time, advances in high-end technology contribute to the smooth integration of autonomous features, optimizing route planning, strengthening safety protocols, and increasing operational efficiency.

5.3.2 Scenario 2: Reduced Efficiency

This is the most undesirable and worst scenario for the future of adoption autonomous long-haul trucks in logistics industries in Malaysia. The deficient regulatory environment, characterized by vulnerable legal and regulatory framework measures and limited technological advancement hinder the seamless integration of autonomous features, impeding the potential for efficient and safe freight transportation. Also, the absence of cutting-edge technology hampers the deployment of advanced autonomous systems in trucking, resulting in a reliance on conventional, manually operated trucks.

Limited technological advancement will stop people improving and they can just adopt conventional trucks in logistics transportation. This scenario might cause many challenges to logistics transportation such as transportation costs, shipping speed and truck capacity, and shipment visibility (Track Record, 2023). Adopting conventional trucks might have the effects drivers' fatigue. It impairs a driver's alertness, concentration, and reaction time, significantly increasing the risk of accidents.

The truck will also be susceptible to delays caused by traffic jams, road construction and weather conditions. Traffic jams, especially on access to cities and industrial estates, can lead to delays in delivery. Additionally, the production of fossil fuels for trucks contributes to air pollution and further exacerbates climate change (Scale Climate Action, 2023). However, professionals are encouraged to increasingly develop and rely on technology, so that it can assist to anticipate these incidents or choose alternative routes (Noatum Logistics, 2021).

The vulnerable legal and regulatory framework further exacerbates the inefficiency of autonomous long-haul trucks, as unclear guidelines and a lack of standardized safety protocols deter companies from investing in and adopting autonomous trucking. For example, Shah *et al.* (2020) mentioned that the data-driven nature of autonomous trucks raises a new set of legal problems to be solved. A few of the key legal challenges include privacy issues, cyber security threats and motor accident injury insurance reform. All these challenges will offer an insight into some of the complexities that will need to be resolved before automated vehicles are ready for wholesale rollout.

Thus, the overarching impact is a logistics landscape that falls behind in terms of technological advancement, resulting in a missed opportunity to enhance efficiency, reduce environmental impact, and stay globally competitive in the evolving landscape of transportation and logistics in Malaysia.

5.3.3 Scenario 3: Slow Technological Adoption

This scenario occurred when there is vigorous legal and regulatory framework but limited technology advancement towards the adoption of autonomous long-haul trucks in logistics industries, Malaysia. It refers to strong legal and regulatory frameworks that take primacy in a logistics transportation sector with little technology innovation. While the potential for the deployment of autonomous long-haul trucks exists, the absence of cutting-edge technology poses a challenge, hindering the logistics industry from fully realizing the benefits of innovative transportation systems. It could result in a lack of transparency, slow communication, and manual processes, which hinder the growth of the logistics ecosystem in Malaysia.

Limited technological advancement poses several challenges, with one notable consequence being an extended timeline for the implementation of autonomous trucks. It could result in delayed or reduced adoption of autonomous trucks by the trucking industry and society, which could affect the competitiveness and profitability of the sector. In addition, low technology advancement may raise increased or unresolved risks and uncertainties for the safety and security of autonomous trucks, as well as the legal and social implications of their operation. For example, Sofman (2023) explained that there are a few fundamental physical barriers to going driverless today. Many autonomous trucks lack the redundant safety features built into trucks that provide a fallback if the brakes or steering fails.

Logistics transport also will miss or diminish opportunities for achieving the potential benefits of autonomous trucks, such as lower emissions, higher efficiency, and better mobility. Despite high regulatory environment, limitation of technology advancement may discourage collaboration between industry stakeholders, slowing down progress in autonomous truck adoption and impeding the industry's ability to harness the full spectrum of benefits offered by cutting-edge technologies. As a result, logistics companies face increased operational costs, reduced overall productivity, and a limited ability to meet the evolving demands of a rapidly changing market (Sukriti, 2019).

While there are hurdles to overcome, such as technology limitations and the establishment of comprehensive regulatory frameworks, the outlook for autonomous long-haul trucks is undeniably promising. As technology advances nowadays and public trust grows with the robust legal and regulatory framework, logistics companies can expect to witness the widespread integration of autonomous trucks into their transportation systems.

5.3.4 Scenario 4: Safety and Security Risks

This vulnerability in the legal and regulatory structure will cause various problems especially concerning data privacy and security risks in Malaysia's logistics transportation sector. While high technology advancement leads to a paradigm shift, revolutionizing the transportation landscape. The advanced trucks, equipped with cutting-edge sensors, artificial intelligence, and connectivity will enhance logistics operational efficiency, safety, and cost-effectiveness. This is an ideal situation for an organization to implement the autonomous trucking technology in Malaysia, yet it must be aware of the legal issue.

The adoption of robust technology advancement for autonomous trucking has brought utmost advantage for logistics transportation. It has the potential to reduce traffic congestion and road accidents in developing countries, Malaysia. Autonomous trucks are equipped with real-time data collection, where it can generate vast amounts of data about road conditions, traffic patterns, and infrastructure. This real-time data can be harnessed to improve transportation planning and decision-making (Raizada, 2023). Alexander (2021) claimed that autonomous long-haul trucks are safer because of advances in complex systems of braking and spatial awareness. Levy (2022) reported that when a human driver activates, the trucks can automatically adjust their own speed to maintain a given diving distance from the trucks in front of it by using the adaptive cruise control.

However, a vulnerable legal and regulatory framework for autonomous long-haul trucks can lead to several detrimental consequences. As reported by Naveed (2023), the legal and public perception aspects of autonomous truck operations are significant obstacles that must be addressed before a substantial number of self-driving trucks are implemented. Autonomous trucks operate using vehicle-to-vehicle communication, also called truck platooning, sensors, and high-definition maps. All of this allows them to learn from other vehicles and maximize safety. But all this information amounts to a significant collection of personal data, including data on the location of a truck's driver.

As autonomous trucks rely heavily on interconnected systems and data exchange, cyber risk can arise where the truck is being operated and a malicious actor takes control of the truck or surrounding infrastructure. Another risk is hackers gaining unauthorized access to the data generated by automated trucks themselves (Shah *et al.* 2020). So, even the rise of autonomous trucks poses cybersecurity risks as their software can be hacked, leading to a loss of control over the truck and potentially damaging property and employees (Wombolt *et al.* 2023).

Autonomous truck cutting-edge technology allows for tremendous progress and potential commercialization in logistics transportation despite a weak legal and regulatory framework. However, weak legal guidelines create challenges for the autonomous trucking industry, including the risk of accidents, uncertainties in liability attribution, and a lack of standardized regulations across jurisdictions. Without a robust regulatory emphasis on

safety standards, liability protocols, and operational guidelines, the industry faces hurdles. To overcome these issues, it is crucial for Malaysia's government to strengthen and clarify legal frameworks, ensuring the safe and responsible integration of autonomous trucks into the future logistics landscape.

5.4 Limitation of Study

There are a few limitations that occur while completing the research during the process of this research. First, the size of the population is too small to represent on the autonomous trucks in logistics industries in Malaysia. There are no studies conducted in Malaysia on the adoption of autonomous trucks in logistics industries in Malaysia. Therefore, certain logistics transportation workers in Malaysia do not understand the perception of this modern technology. The next limitation is lacking cooperation from respondents. Most respondents refused to participate in the research survey due to company confidentiality since this may cause inconvenience or harm the image of an organization. Finally, the results may not apply to other countries because there are a variety of demographic factors that will influence how respondents interpret the use of autonomous trucks in logistics industries. The result of the study reflects that both legal and regulatory framework and technology advancement must be taken into deliberation in implementing autonomous trucks among logistics industries in Malaysia.

5.5 Recommendation for Future Study

The primary aim of this study was to determine the future image of autonomous long-haul trucks adoption in recruitment and selection in Malaysia for the next 10 years or decades. However, Malaysia currently has not widely identified and developed the implementation of autonomous long-haul trucks within the logistics sector. To commence, an interview session can be conducted during data collection. This will encourage the respondents to have a better understanding of the application of autonomous long-haul trucks among logistics industries. Consequently, they will be able to provide insightful responses to open-ended inquiries, which will contribute to the researcher's understanding of the research issue at hand. As autonomous trucking technologies shift transportation roles, proactive education, change management, and skill development become crucial. Comprehensive training programs must be provided to help employees operate autonomous systems. The benefits, safety measures, and ethical issues of autonomous long-haul truck adoption must be communicated to ensure a successful and widely accepted by logistics industry.

5.6 Recommendation for Autonomous Long-Haul Trucks Adoption in Logistics Industries

The four possible scenarios derived from the top two key drivers identified by the impact-uncertainty study had both positive and negative consequences for the growth of autonomous long-haul trucks adoption among logistics industries in Malaysia. To ensure the ongoing advancement of autonomous long-haul trucks of logistics companies' objectives, it is essential to come up with a solution and strategy to combat the fragile regulation framework towards long-haul trucks technology advancement that emerged during scenario building analysis.

5.7 Conclusion

In conclusion, this study has been identified the issues and drivers on the adoption of Autonomous Long-Haul Trucks among logistics industry in Malaysia. Conducting a foresight study on the adoption of autonomous long-haul trucks in Malaysia's logistics industries will unveil emerging trends that could shape the future of transportation over the next decade or beyond. Additionally, this research offers novel insights and perspectives from respondents, contributing new knowledge and information regarding the development of autonomous long-haul truck adoption in Malaysia's logistics sector.

The top two key drivers, identified through impact-uncertainty analysis, have been used in constructing a scenario-building analysis. This approach has led to the development of four scenarios aimed at determining the future landscape of autonomous truck adoption within the logistics industries. Legal and regulatory framework and technological advancement have strong relationship in shaping future of autonomous long-haul trucks adoption in logistics industries, Malaysia. These two key drivers have the potential to create an ideal scenario labeled "Revolutionary Transportation Innovation," wherein the logistics transportation landscape undergoes transformation using autonomous long-haul trucks. However, these same drivers also cause the risk of leading to three adverse scenarios in the future, namely "Reduced Efficiency," "Slow Technological Adoption," and "Safety and Security Risks." In essence, it is crucial to acknowledge that every new technology comes with challenges and limitations. Therefore, both the public and private sectors should collaborate and offer support to foster the development of this new future technology in Malaysia.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** L.W.R. and N.K.K.; **data collection:** L.W.R.; **analysis and interpretation of results:** L.W.R. and N.K.K.; **draft manuscript preparation:** L.W.R. and N.K.K. All authors reviewed the results and approved the final version of the manuscript.

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