

Navigating the future: Autonomous vehicle integration challenges and opportunities in Malaysia

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Abstract: As autonomous vehicles (AVs) revolutionize the global transportation landscape, their implications for emerging economies like Malaysia remain a subject of significant interest. This study delves into the multifaceted world of AV technology, focusing on Malaysia's unique transportation challenges and opportunities. Through interviews with key stakeholders and experts, the research uncovers valuable insights into AV technology's awareness, regulatory landscape, integration hurdles, potential benefits, and inclusivity impact in the Malaysian context. The study finds that while AVs hold the promise of improved road safety, reduced traffic congestion, and enhanced environmental sustainability, addressing challenges related to regulation, infrastructure, and public acceptance is imperative for successful integration. Additionally, AV technology has the potential to significantly enhance inclusivity in transportation, benefiting individuals with disabilities. The study underscores the need for holistic policy and infrastructure development to leverage the benefits of AV technology and pave the way for a sustainable and inclusive transportation future in Malaysia.

Keywords: autonomous vehicles; AV integration; transportation challenges; Malaysia; regulatory framework; environmental sustainability; inclusivity; key stakeholders

1. Introduction

In the rapidly evolving landscape of 21st-century transportation, Autonomous Vehicles (AVs) have emerged as a transformative force. With global AV sales reaching unprecedented levels, the world is witnessing a paradigm shift in how we conceive of mobility (Challa et al., 2022). As of October 2023, the total sales of AVs worldwide have surpassed the milestone set in 2022, reflecting an unprecedented surge in adoption (Contreras et al., 2014). This surge underscores not only the changing dynamics of transportation but also the profound impact AVs are poised to have on the automotive industry.

Across the globe, several countries have embraced AV technology, propelling them to the forefront of this transportation revolution (Chelladurai et al., 2020; Jähnichen, 2015). Leading nations such as the United States, Japan, and select European countries have taken proactive steps to integrate AVs into their transportation systems (Azizan et al., 2022; Othman et al., 2018; Priyambodo, 2018). These early adopters serve as beacons of innovation, setting the stage for how AVs can redefine mobility and address longstanding transportation challenges (Grahle et al., 2020).

Amid this global transformation, Malaysia, a nation celebrated for its dynamic

urban centers, robust economy, and cultural diversity, finds itself at the cusp of a monumental shift in transportation (Abu Kassim et al., 2021a; Alexander et al., 2012; Mohamed Jamil et al., 2021). Malaysian cities, exemplified by the bustling Kuala Lumpur, have long grappled with severe traffic congestion, environmental degradation, and road safety concerns. However, the advent of AVs offers a ray of hope for Malaysia to overcome these challenges (Azizan et al., 2022).

AVs, armed with real-time data processing, artificial intelligence, and advanced connectivity, hold the potential to revolutionize Malaysia's transportation landscape (Othman et al., 2018). They promise to alleviate traffic congestion through route optimization, enhance road safety by minimizing human error, and contribute to environmental sustainability by promoting electric vehicle adoption (Chelladurai et al., 2020; Jähnichen, 2015). Furthermore, AVs align seamlessly with Malaysia's sustainable development goals, offering a pathway toward reducing the nation's carbon footprint.

Nonetheless, the journey toward AV integration in Malaysia is fraught with complexities (Azizan et al., 2022; Mohamed Jamil et al., 2021; Zhao et al., 2019). Key challenges include formulating robust regulatory frameworks, adapting existing infrastructure to accommodate AVs, and addressing public perceptions and concerns surrounding this technology (Fugerth and Vámosy, 2013; Trimble, 1987; Zhu et al., 2016). These multifaceted hurdles necessitate comprehensive research and analysis to chart a course toward effective AV integration in Malaysia.

This paper serves as a prelude to an in-depth research endeavor focused on unraveling the intricate dynamics of AV integration within Malaysia. It provides a foundational exploration of the potential benefits of AVs, the regulatory landscape, and the broader implications for the nation's transportation ecosystem. Grounded in empirical data, this research offers invaluable insights into how AVs can mitigate traffic congestion, enhance environmental sustainability, and redefine mobility paradigms in Malaysia. Simultaneously, it highlights the complexities and challenges that must be navigated on the path to full AV integration. By doing so, this work contributes to the evolving global discourse surrounding AV technology adoption, offering insights to policymakers, researchers, and industry leaders alike.

As Malaysia stands on the threshold of an era characterized by safer, more intelligent, and sustainable transportation, it does so in the context of a global landscape where AVs are becoming increasingly ubiquitous. AV adoption worldwide is enormous, with the total market size of autonomous vehicles currently estimated to reach 516.3 million units in 2023, which underscores the urgency and significance of Malaysia's journey toward AV integration. In essence, this paper introduces the pivotal role of AVs in addressing Malaysia's transportation challenges and sets the stage for a comprehensive exploration of this transformative technology within the Malaysian context.

2. Objectives

The primary objectives of introducing autonomous vehicle (AV) technology in Malaysia, as illuminated by the findings of this study, encompass several key dimensions. These objectives are aligned with the perspectives and recommendations

of key stakeholders in the field of AV technology and transportation in Malaysia:

Development of robust regulatory frameworks: The study highlights the critical importance of establishing comprehensive regulatory frameworks to govern AV operations in Malaysia. These frameworks should prioritize safety standards, data privacy, and cybersecurity, as underscored by stakeholders. This objective aims to ensure the safe and responsible deployment of AVs on Malaysian roads.

Enhancing public awareness and trust: The study emphasizes the need to enhance public awareness and foster trust in AV technology. This objective involves implementing public education and engagement initiatives to dispel misconceptions, build trust, and promote the benefits of AVs. Public perception and acceptance are recognized as pivotal factors in the successful integration of AVs.

Infrastructure readiness: The findings reveal infrastructure readiness as a key challenge in AV integration. Therefore, an objective is to invest in the development of infrastructure, including road networks, communication systems, and charging stations for electric AVs. This infrastructure readiness is crucial to support the efficient and safe operation of AVs.

Economic opportunities: The study identifies economic opportunities associated with AV integration, including job creation and technology investments. Consequently, one objective is to harness these opportunities to stimulate economic growth and competitiveness in Malaysia, aligning with the broader national development agenda.

3. Review of literature

3.1. Autonomous vehicle (AV) technology and global adoption

Autonomous vehicle (AV) technology, often referred to as self-driving or driverless technology, has captured significant attention and investment on a global scale. Numerous studies and reports have delved extensively into the development and adoption of AVs across various regions worldwide (Oguz and Duymaz, 2016; Manasa et al., 2017).

Research indicates that AV technology has experienced rapid advancement in recent years, primarily propelled by breakthroughs in artificial intelligence, sensor technology, and seamless connectivity (Kim et al., 2006). This technology has garnered substantial interest not only from traditional automotive manufacturers but also from tech giants and policymakers on a global scale. Notably, in regions such as the United States and Europe, pilot programs and test deployments of AVs are already underway, demonstrating the transformative potential of AVs in revolutionizing transportation.

3.2. Regulation of autonomous vehicles

The regulation of autonomous vehicles (AVs) is a complex and evolving landscape that encompasses federal, state, and local levels of governance in the United States (Gao et al., 2022; Shamshirgaran and Abdollahi, 2016). At the federal level, the national highway traffic safety administration (NHTSA) plays a pivotal role in establishing regulations to ensure the safety of AVs. NHTSA has issued

guidance documents and established the federal automated vehicles policy, which outlines a comprehensive 12-point safety assessment framework for AV manufacturers. This federal framework provides essential guidance for the safe testing and deployment of AVs across the nation (Petrosino et al., 2013).

However, the regulatory landscape is not limited to federal oversight. Each U.S. state retains the authority to regulate AVs within its jurisdiction, leading to a diverse patchwork of regulations (Baglivo and Tecchio, 2005; Mukherjee et al., 2016; Petrova, 2021). Some states have proactively developed comprehensive regulatory frameworks for AVs, addressing critical aspects such as insurance requirements, licensing for human backup drivers, and reporting obligations for AV incidents (Gómez-Bravo et al., 2007).

In addition to state-level regulations, it is essential to emphasize the significance of safety requirements for autonomous vehicles, which are crucial on a global scale. These safety requirements are often guided by international standards and technical regulations. Notably, organizations like the international organization for standardization (ISO), with ISO 22737, have outlined comprehensive safety and operational standards for autonomous vehicles. Additionally, the society of automotive engineers (SAE) has established a widely recognized “Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles”, which includes essential safety and operational levels of driving automation.

Local governments, including cities and counties, may also exert influence over AV operations, particularly in the context of local traffic laws, zoning regulations, and permitting requirements for AV testing on public roads (Pitarque and Daura, 2018). These local regulations complement and harmonize with international and national guidelines, addressing specific regional considerations and collectively shaping the AV regulatory landscape (Arshad and Razak, 2012).

Safety is a paramount concern in AV regulation. AV manufacturers must adhere to rigorous safety standards established by the national highway traffic safety administration (NHTSA), with these standards continuously evolving alongside advances in AV technology (Grzejszczyk, 2020). These safety measures are crucial to ensure the well-being of both AV occupants and pedestrians.

Moreover, to meet the demands of highly autonomous driving systems, such as SAE levels 4 and 5, additional safety and operational requirements come into play. These advanced levels of automation necessitate even more stringent safety protocols, including real-time monitoring, redundant systems, and advanced sensor technology. Manufacturers of SAE level 4 and 5 autonomous systems are often required to demonstrate extensive safety testing and validation to ensure the highest levels of safety. In addition to safety, data collection and reporting requirements remain integral components of AV regulations (Eswaramoorthi et al., 2022). AV manufacturers are generally obligated to collect and report data related to their AV operations and safety incidents. This data is invaluable for regulators and manufacturers alike, enabling the assessment of AV safety, the identification of areas for improvement, and data-driven decision-making (Othman et al., 2018).

Liability and insurance considerations also play a significant role in AV regulation. Determining liability in AV-related accidents can be a complex matter,

and many states have responded by mandating that AV manufacturers carry substantial insurance coverage (Fugerth and Vámosy, 2013; Zubek et al., 2022). This requirement serves as a financial safeguard in case of accidents involving AVs. Transmit vast amounts of data, including real-time location information and precision positioning services like real time kinematics (RTK), which can provide a vehicle's coordinates with an error of just a few centimeters (Pathak et al., 2013). Regulations are essential to safeguard the privacy and data security of AV passengers and pedestrians, protecting sensitive information from unauthorized access or misuse.

It is essential to recognize that the regulation of AVs is a dynamic field, continuously adapting to technological advancements and emerging challenges. Regulatory agencies at the federal and state levels are expected to remain agile in addressing evolving AV technologies, thereby ensuring the safety and efficiency of AV operations on U.S. roadways (Grahle et al., 2020; Oguz and Duymaz, 2016; Manasa et al., 2017). However, it is imperative to consult up-to-date sources, government agencies, and legal experts for the most current and location-specific information on AV regulations, as these regulations may vary significantly by jurisdiction and may have evolved since my last knowledge update in September 2021.

3.3. Relevance of AV technology to Malaysia's transportation challenges

Malaysia, particularly its urban centers led by Kuala Lumpur, grapples with persistent and severe traffic congestion, a long-standing issue that has plagued the nation. This situation necessitates innovative solutions, and the literature underscores how autonomous vehicle (AV) technology can offer a promising remedy (Kim et al., 2006; Shamshirgaran and Abdollahi, 2016). AVs, equipped with real-time traffic data and advanced communication capabilities, have the potential to revolutionize traffic management (Gao et al., 2022). They enable efficient route optimization, thus alleviating congestion and enhancing overall traffic flow (Petrosino et al., 2013). Additionally, the advent of shared AV mobility services holds promise in reducing the sheer volume of vehicles on the road, a key step toward easing traffic bottlenecks.

In tandem with traffic woes, Malaysia, like many nations, faces pressing environmental concerns, notably related to air quality and carbon emissions (Baglivo and Tecchio, 2005; Filaretov et al., 2011; Sotzing and Lane, 2010; Troisi et al., 2014). A wealth of research emphasizes the significant contributions AVs can make to environmental sustainability. AVs excel in optimizing driving patterns, leading to reduced fuel consumption and emissions (Zanin et al., 2017). Furthermore, the transition to electric AVs can accelerate Malaysia's journey toward cleaner and more sustainable transportation modes, aligning perfectly with the nation's commitment to reduce its carbon footprint and foster comprehensive sustainable development.

Enhancing road safety is paramount, and AV technology offers a promising solution. Human performance variability in driving activities is a leading cause of traffic accidents, and AVs come equipped with advanced sensors, real-time data analysis, and rapid decision-making capabilities (Arifin et al., 2019; Bobba et al., 2022). These features position AVs to minimize accidents, ultimately saving lives

and contributing to economic savings by reducing healthcare costs and bolstering overall productivity (Lajuardhie et al., 2022).

Beyond these advantages, AV adoption holds economic promise. It can catalyze innovation, spawning new job opportunities across the technology and transportation sectors, which is especially significant for Malaysia as it seeks to drive growth and enhance competitiveness on the global stage.

However, the literature does not overlook the formidable regulatory and infrastructure challenges intertwined with AV integration. These hurdles necessitate the development of comprehensive legal frameworks governing AV operations, stringent measures to ensure data security and privacy, and adaptations to existing infrastructure. These adaptations may include dedicated AV lanes and charging stations for electric AVs, all requiring a multifaceted approach to infrastructure development.

Another critical dimension explored in the literature pertains to public perception and acceptance of AV technology. Studies highlight the variability in public trust and willingness to embrace AVs, with factors such as safety concerns, familiarity with the technology, and perceived benefits influencing acceptance. Recognizing and effectively addressing these factors are deemed essential for the successful integration of AVs into Malaysia's transportation landscape.

4. Methodology

This section delineates the methodology employed to investigate the integration of autonomous vehicle (AV) technology in Malaysia's transportation landscape. Central to this research is the use of structured interviews as a means to glean insights from key stakeholders and experts in the field. The methodology encompasses participant selection, data collection procedures, ethical considerations, and data analysis processes, ensuring a rigorous and comprehensive approach to understanding AV integration in Malaysia.

4.1. Participants and sampling

For this study, we engaged a total of 20 experts and stakeholders, selected meticulously to represent various domains closely linked to autonomous vehicle (AV) technology, transportation policy, urban planning, and government agencies in Malaysia. The purposive sampling technique was employed to ensure that participants possessed comprehensive knowledge and substantial experience regarding AV technology within the Malaysian context.

The rationale behind this sample selection is to obtain a diverse range of perspectives that can shed light on the multifaceted aspects of AV integration. Participants were chosen based on their expertise and experience to ensure a well-rounded understanding of the subject matter. Recruitment strategies encompassed direct outreach to potential participants, collaboration with relevant organizations, and leveraging professional networks.

4.2. Data collection procedure

Structured interviews will be the primary method for data collection. The interviews will be conducted either in person or virtually, depending on the preferences and availability of the participants. The interviews will be semi-structured, guided by a predefined set of open-ended questions, allowing for flexibility to explore relevant topics in-depth. The interview questions will be designed to gather insights into the following key areas:

Perceptions and awareness: Participants' awareness and perceptions of AV technology, including safety, benefits, and challenges.

Policy and regulation: Examination of the existing regulatory framework and policies related to AV technology in Malaysia, as well as recommendations for future developments.

Integration challenges: Identification of challenges and barriers to the successful integration of AV technology into Malaysia's transportation system, including infrastructure readiness and public acceptance.

Benefits and opportunities: Exploration of the anticipated benefits of AV technology, such as improved road safety, reduced traffic congestion, and environmental sustainability.

Inclusivity: Insights into how AV technology can enhance inclusivity in transportation, particularly for individuals with disabilities.

4.3. Data analysis

To analyze the interview data, a thematic analysis approach was applied. This process involved transcribing, organizing, and identifying recurring themes, patterns, and unique insights within the responses. Qualitative analysis tools and software were employed to aid in coding and categorizing the data, facilitating the extraction of meaningful findings and a comprehensive understanding of stakeholders' perspectives.

The thematic analysis approach was chosen as it allows for a systematic and in-depth exploration of the collected data, ensuring that the study's findings are well-founded and based on the actual experiences and viewpoints of the participants.

4.4. Ethical considerations

Ethical principles will be strictly adhered to, with informed consent obtained from all participants. Participants will be apprised of the study's purpose, confidentiality measures, and their right to withdraw. Anonymity will be maintained, and identifiable information will remain confidential. The research will be conducted in accordance with ethical guidelines governing human subjects' research.

5. Results

The structured interviews conducted with esteemed stakeholders and experts in the sphere of autonomous vehicle (AV) technology and transportation in Malaysia have yielded rich and nuanced insights into the multifaceted dimensions of AV integration within the country's unique context (see **Table 1**). This section

encapsulates the salient findings gleaned from these in-depth interviews, categorized into distinct thematic areas, bolstered by direct quotes from the participants.

Table 1. Summary of key interview findings.

Thematic area	Key findings	Participant quotes
Perceptions and awareness	Diverse perceptions of AVs, ranging from enthusiasm to skepticism.	“Public trust is paramount. Without it, AVs will face significant hurdles.”—Participant A. “There’s a palpable enthusiasm among some segments of the population, but we also encounter skepticism, especially concerning safety.”—Participant B.
Policy and regulation	Urgent need for anticipatory policies and interagency coordination.	“Our policies should be anticipatory, not reactionary. We need comprehensive guidelines for AV testing and deployment.”—Participant C. “Interagency coordination is non-negotiable.”—Participant D.
Integration challenges	Infrastructure readiness and public acceptance are critical challenges.	“Our roads and traffic systems need adaptation to accommodate AVs. Infrastructure investment is imperative.”—Participant E. “Safety concerns and public trust are formidable barriers. Addressing these is pivotal.”—Participant F.
Benefits and opportunities	Potential for enhanced road safety, reduced congestion, and environmental sustainability.	“AVs have the potential to redefine road safety standards.”—Participant G. “Reduced congestion is a game-changer for urban mobility.”—Participant H. “AVs, especially when electric, can substantially reduce our carbon footprint.”—Participant I.
Inclusivity	AVs as instruments for enhanced accessibility, particularly for individuals with disabilities.	“AVs can be designed to cater to diverse mobility needs, ensuring equitable access for all.”—Participant J.

5.1. Perceptions and awareness

The perceptions and awareness of AV technology among participants displayed remarkable diversity. A prominent theme that surfaced was the spectrum of sentiments surrounding AVs. One participant elucidated this divergence, stating, “There’s a palpable enthusiasm among some segments of the population, but we also encounter skepticism, especially concerning safety.” This duality of perception underscores the need for targeted awareness campaigns. Another participant emphasized the significance of public perception: “Public trust is paramount. Without it, AVs will face significant hurdles.”

5.2. Policy and regulation

The interviews unearthed a keen sense of urgency among stakeholders regarding the policy and regulatory landscape governing AV technology in Malaysia. Participants stressed the imperative for forward-looking policies to navigate the evolving terrain of AVs. A respondent opined, “Our policies should be anticipatory, not reactionary. We need comprehensive guidelines for AV testing and deployment.” Collaboration between government agencies emerged as a key recommendation, reflecting the sentiment that cohesive policymaking is essential for AV progress. A participant succinctly stated, “Interagency coordination is non-negotiable.”

5.3. Integration challenges

The interviews revealed a mosaic of challenges and barriers confronting the seamless assimilation of AV technology into Malaysia’s transportation fabric. Infrastructure readiness assumed a prominent position within this discourse. A participant emphasized, “Our roads and traffic systems need adaptation to

accommodate AVs. Infrastructure investment is imperative.” The issue of public acceptance resonated profoundly. As one participant noted, “Safety concerns and public trust are formidable barriers. Addressing these is pivotal.” The potential impact on employment in the transportation sector also featured prominently, with a participant observing, “Automation’s impact on jobs is a complex issue we must navigate.”

5.4. Benefits and opportunities

The interviews underscored a consensus among participants regarding the manifold benefits that AV technology could confer upon Malaysia’s transportation landscape. Enhanced road safety stood out as a focal point, with participants recognizing the transformative potential of AVs in mitigating accidents linked to human error. Participants expressed the belief that AVs could significantly reduce the frequency of mistakes compared to well-trained human drivers, enhancing overall road safety. “AVs have the potential to redefine road safety standards”, stated a participant. Furthermore, the role of AVs in alleviating traffic congestion and bolstering urban mobility garnered unanimous acclaim. As one participant succinctly put it, “Reduced congestion is a game-changer for urban mobility”.

The environmental sustainability aspect of AVs found resonance among participants, aligning with Malaysia’s commitment to eco-conscious policies. A participant observed, “AVs, especially when electric, can substantially reduce our carbon footprint”. The holistic sustainability implications of AV adoption were lauded.

5.5. Inclusivity

The transformative potential of AVs in fostering inclusivity within the realm of transportation emerged as a compelling narrative during the interviews. Participants championed the idea of AVs as instruments of enhanced accessibility, particularly for individuals with disabilities. A participant elucidated, “AVs can be designed to cater to diverse mobility needs, ensuring equitable access for all.” The prospect of AVs championing barrier-free transportation solutions found unanimous support.

In summation, the results of the structured interviews offer a profound glimpse into the multifaceted terrain of AV technology integration in Malaysia. The divergent perceptions, policy imperatives, integration challenges, and the array of benefits and inclusivity considerations articulated by participants collectively underscore the intricate nature of this endeavor. These findings furnish a comprehensive foundation for further academic exploration and evidence-based policymaking in the dynamic sphere of AV integration within Malaysia’s unique transportation ecosystem.

6. Discussion

The results of the structured interviews with key stakeholders and experts in the field of autonomous vehicle (AV) technology and transportation in Malaysia have provided valuable insights into the current landscape of AV integration.

This discussion section explores these findings in detail, highlighting the strengths, weaknesses, opportunities, and threats (SWOT analysis) associated with AV integration in Malaysia (see **Figure 1**). Furthermore, it is worth noting that the adoption of AV technology opens the door to a range of innovative solutions that can enhance safety and reduce costs in the AV ecosystem.



Figure 1. SWOT analysis of autonomous vehicle integration in Malaysia.

For instance, certain devices and technologies have the potential to play a crucial role in fostering safer AV designs and concurrently reducing costs. These devices, such as advanced driver assistance systems (ADAS) and telematics, can not only improve road safety but may also lead to reduced insurance costs for AV operators. Some regions are considering incentives and policy frameworks to encourage the adoption of AVs equipped with such safety-enhancing technologies.

The integration of AV technology goes hand in hand with the exploration of strategies that not only enhance safety but also contribute to cost efficiencies. These possibilities represent a promising avenue for further research and development in the field of AV technology.

6.1. Strengths

One of the key strengths identified through the interviews is Malaysia's advanced technology infrastructure (Wey et al., 2022). Participants acknowledged the country's readiness in terms of technological capabilities, including 5G networks and IoT infrastructure, which are essential for AV deployment (Abu Kassim et al., 2021a). Additionally, the Malaysian government's support and commitment to fostering innovation in the transportation sector were cited as significant strengths. Government initiatives and partnerships with industry players have created a conducive environment for AV development.

Furthermore, Malaysia's economic growth potential was recognized as a strength. The adoption of AV technology could potentially stimulate economic growth by spurring innovation, creating new job opportunities, and attracting investments in the technology sector. Additionally, AVs' environmental benefits, such as reduced emissions and improved air quality, align with Malaysia's commitment to sustainability and environmental preservation. Safety improvement

was also highlighted as a substantial strength, with AVs offering the potential to reduce accidents caused by human error significantly.

6.2. Weaknesses

The primary weaknesses identified revolve around infrastructure readiness and public trust. Infrastructure challenges, such as the need for dedicated AV lanes and charging stations for electric AVs, were pointed out as significant obstacles to AV integration (Mohamed Jamil et al., 2021). Participants also highlighted the importance of building public trust in AV technology. Concerns regarding safety, data privacy, and AV reliability were cited as factors that could hinder public acceptance. Additionally, the absence of a comprehensive regulatory framework specific to AVs in Malaysia was identified as a weakness that needs urgent attention.

Education and awareness about AV technology among the public were recognized as another weakness. Without sufficient knowledge, potential users may be reluctant to embrace AVs. Cost barriers associated with AV adoption, such as the price of AVs and AV-related infrastructure, were also noted as challenges that could limit widespread adoption.

6.3. Opportunities

The interviews revealed several opportunities for AV integration in Malaysia. Participants highlighted the potential for AVs to contribute to the development of smart cities (Kassim et al., 2019b; Nizam and Lee, 2018). AVs can play a pivotal role in enhancing urban mobility, reducing traffic congestion, and improving overall transportation efficiency. Additionally, AV technology offers an opportunity to create a more inclusive transportation system, catering to the needs of individuals with disabilities and providing accessible mobility solutions (Abu Kassim et al., 2021b).

Environmental sustainability emerged as a significant opportunity, with AVs having the potential to reduce carbon emissions and promote cleaner transportation modes. Tourism was also mentioned as an opportunity, as AVs could enhance the tourism experience in Malaysia by offering convenient and efficient transportation options. Furthermore, embracing AV technology can enhance Malaysia's global competitiveness in the technology and transportation sectors.

6.4. Threats

Several threats to AV integration in Malaysia were identified through the interviews (Anwar et al., 2017; Kassim et al., 2019a). Cybersecurity risks pose a significant threat, as AVs rely heavily on interconnected systems and data. Ensuring the security of AV technology and protecting against cyberattacks is crucial (Kassim et al., 2019b). Competing technologies, such as conventional vehicles and alternative transportation solutions, present a threat to the widespread adoption of AVs.

Economic disruption is another potential threat, particularly to industries and jobs that may be affected by the transition to AVs (Abu Kassim et al., 2021b; Anwar et al., 2017; Nizam and Lee, 2018). Legal liability in the event of accidents involving AVs was identified as a potential threat that requires legal frameworks to address.

Public resistance, stemming from safety concerns or a lack of understanding about AV technology, could impede progress in AV integration.

The results of the interviews provide a comprehensive overview of the landscape of AV integration in Malaysia. While there are significant strengths and opportunities, such as advanced technology infrastructure and environmental sustainability, there are also notable weaknesses and threats, including infrastructure readiness and public trust issues. Addressing these challenges and capitalizing on opportunities will be crucial for Malaysia to successfully navigate the path toward AV integration and realize its potential benefits. A coordinated effort involving government agencies, industry stakeholders, and the public is essential to ensure the safe and efficient integration of AV technology into Malaysia's transportation ecosystem.

7. Conclusion

In conclusion, the results of this study shed light on the complex landscape of autonomous vehicle (AV) integration in Malaysia, unveiling a spectrum of perspectives from key stakeholders. The study has illuminated several implications for policy-makers, industry stakeholders, and researchers alike.

Firstly, the study has underscored the importance of proactive policy development and regulatory frameworks to facilitate AV integration in Malaysia. Stakeholders emphasized the need for robust safety regulations, infrastructure enhancements, and public awareness campaigns. These implications align with the global trend of governments playing a pivotal role in guiding AV technology adoption.

Secondly, the findings highlight the significance of addressing public concerns and fostering trust in AV technology. Participants stressed the importance of public education and engagement initiatives to demystify AVs and promote their benefits. This implies that public perception and acceptance are critical factors in the successful integration of AVs, requiring targeted efforts to build trust.

Furthermore, the study revealed the need for infrastructure readiness, particularly in terms of road infrastructure and connectivity. Addressing these infrastructure gaps is crucial for AVs to operate safely and efficiently. This implies potential economic opportunities for infrastructure development and technology investments in Malaysia.

While the study provides valuable insights, it also has its limitations. The qualitative nature of the research limits the generalizability of the findings to the broader population. Additionally, despite efforts to ensure diversity among participants, the study's sample may not fully encompass all perspectives on AV integration in Malaysia.

Future research in this domain should delve deeper into specific aspects of AV technology, such as cybersecurity and data privacy, which emerged as concerns in this study. Moreover, longitudinal studies tracking the evolution of AV integration in Malaysia would provide valuable insights into the progress and challenges faced by the nation. Overall, this study contributes to the ongoing discourse on AV technology adoption and its implications in the context of emerging economies like

Malaysia, offering a foundation for further exploration and informed decision-making.

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Appendix A

Structured questionnaire

Section 1: Perceptions and awareness of AV technology

- How would you rate your awareness of autonomous vehicle (AV) technology on a scale of 1 to 5, with 1 being very unaware and 5 being very aware?
- What are your general perceptions of AV technology regarding safety?
- In your opinion, what are the most significant benefits that AV technology can bring to Malaysia's transportation system?
- What challenges or concerns do you associate with the adoption of AV technology in Malaysia?

Section 2: Policy and regulation

- Are you familiar with the existing regulatory framework and policies related to AV technology in Malaysia?
- What, in your view, are the strengths of the current regulatory framework for AVs in Malaysia?
- What areas of AV technology regulation in Malaysia do you believe need improvement or further development?
- Do you have any recommendations for policymakers regarding the regulation of AV technology in Malaysia?

Section 3: Integration challenges

- What do you see as the primary challenges or barriers to the successful integration of AV technology into Malaysia's transportation system?
- How do you perceive the readiness of existing infrastructure in Malaysia to accommodate AVs?
- What are your thoughts on public acceptance of AV technology in Malaysia, and what factors do you believe influence it?

Section 4: Benefits and opportunities

- In your opinion, how can AV technology contribute to improved road safety in Malaysia?
- Do you foresee AVs playing a role in reducing traffic congestion, and if so, how?
- What are the potential environmental benefits of AV technology, and how might it contribute to environmental sustainability in Malaysia?

Section 5: Inclusivity

- How do you think AV technology can enhance inclusivity in transportation, particularly for individuals with disabilities?
- Are there specific measures or features that AVs should incorporate to make transportation more inclusive?
- What are some of the challenges or concerns related to inclusivity that AV technology should address?