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A Foresight Study of Autonomous Mobile Robots (AMRs) for Logistics Sector in Malaysia

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Abstract

In recent years, the logistics industry has seen a rise in the incorporation of AMRs to optimize operations. It has become increasingly helpful and promising because of its capacity to travel in an environment without the assistance of mechanical or electrical guiding devices. The purpose of this research study is to investigate how AMRs are being used in Malaysia's logistics industry. The objective is to identify the drivers, problems, and future trends of AMRs in this Sector. The study collects and analyzes data using a mixed-methods approach, including STEEPV analysis and questionnaires. This research aims to help AMRs gain acceptance and be successfully implemented in Malaysia's logistics sector by achieving its objectives. This research entails a comprehensive examination of the factors influencing the adoption of AMRs in the logistics sector, employing the STEEPV analysis framework. Subsequently, this research used SPSS analysis to present the outcomes of AMRs issues and drivers within the logistics sector. The target respondents were selected are the managers of freight forwarders logistics company in Johor. 170 questionnaires were distributed via Gmail, yielding a 45.88% survey return rate, and identified 'Risk and safety' and 'Labour Cost' as the top two drivers. Furthermore, scenario analysis was conducted based on these drivers, yielding four potential future outcomes from 2023 to 2033. This study aims to enhance awareness among future researchers and stakeholders regarding AMR adoption in the logistics industry, with in-depth findings discussed in subsequent sections..

1. Introduction

The foresight research on AMRs for the logistics industry in Malaysia summarizes in the first section of this chapter. The study found that using AMRs boosts productivity and offers the logistics sector several advantages. In this study, the researcher looks at the drivers, problems, and potential uses of AMRs in Malaysia's logistics industry as well as the likely trajectory of their adoption in the future. Additionally, this study intends to identify STEEPV elements that affect AMRs for the Malaysian logistics sector to analyze its main drivers. Thus, the goal of this study will be to ensure that Malaysia's logistics industry can completely accept the future trends of AMRs.

1.1 Research Background

The logistics industry is increasingly integrating autonomous mobile robots (AMRs) in an effort to optimize operations (Ben *et al.*, 2018). AMRs promote corporate efficiency by using robots and artificial intelligence to

improve logistical and supply chain processes (Ben *et al.*, 2018). AMRs provide for material transportation and inventory management, enabling for the optimization of human resources and participation in value-added activities (Fragapane *et al.*, 2021). AMRs easily handle complicated logistical environments thanks to their autonomous route selection, revolutionizing the sector to satisfy consumer needs and guaranteeing on-time delivery (FLEXQUBE, 2022).

By 2027, the worldwide AMR market is anticipated to have grown at a compound yearly growth rate of 16.8%, valued at $34.65 billion (Allied Market Research, 2020). The inclusion of cutting-edge technology in these devices is what is driving the use of AMRs in logistics. The extensive integration of self-governing mobile robots raises worries about safety, security, worker adaptation, and laws, yet these issues may be successfully resolved in the future (Hyland, 2023). Therefore, if Malaysia is to achieve Industrial Revolution 4.0 in the next years, self-governing mobile robots in logistics would be a key component (Bahrin *et al.*, 2016).

1.2 Problem Statements

The deployment of Autonomous Mobile Robots (AMRs) in logistics in Malaysia faces challenges that hinder successful implementation. These challenges include technological limitations, limited resources in AMR devices, and a lack of expertise in software development and data analytics (Recotvet, 2019; Ling *et al.*, 2020; Divisions, 2022). Additionally, regulatory frameworks and guidelines are essential to ensure the safe operation of AMRs in logistics (Tipping & Peter, 2016; Leenes *et al.*, 2017).

On the positive side, AMRs have the potential to enhance efficiency and productivity in the logistics sector by automating tasks and minimizing errors (Wijemanne, 2022; Sunol, 2022). They offer flexibility and scalability, allowing logistics companies to adapt to changing customer needs (Warehouse Automation, 2023). AMRs also improve inventory management by providing real-time tracking and optimization (Jessica, 2023).

In conclusion, while AMRs can bring significant benefits to the Malaysian logistics industry, addressing technological challenges, enhancing expertise, and establishing clear regulatory frameworks are necessary steps to fully leverage their capabilities and achieve automation and resilience in the industry.

Therefore, to achieve the research objectives the issues, challenges, and trends of AMRs for logistics sector in Malaysia is determined. Furthermore, the key drivers of AMRs for logistics sector in Malaysia also determined. Consequently, the the future image of AMRs for logistics sector in Malaysia is identified.

1.3 Scope of the Study

The foresight study, encompassing the ten-year period from 2021 to 2031, rigorously examines the STEEPV factors influencing AMRs within the logistics sector, with a specific focus on Malaysia. Through an exhaustive literature review, the research systematically addresses the prevalent issues, challenges, and evolving trends pertaining to AMRs in the logistics domain. Diverse and pertinent data sources, including journals, books, conference proceedings, and other relevant repositories, were meticulously curated to inform the analytical framework. The study is delimited to industries operating within the logistics sector that actively utilize AMRs. The survey, targeting managers of freight-forwarded logistics companies with expertise in AMR deployment, was administered to systematically collect data for subsequent in-depth analysis, with the overarching goal of constructing future scenarios grounded in the discerned patterns and insights.

1.4 Significance of the Study

This study aims to identify and investigate the drivers and issues of AMRs in Malaysia's logistics sector and the future adoption trend of these robots. It can illuminate the advantages and disadvantages of using these robots in the Malaysian logistics sector, raise Malaysians' understanding of the possible advantages and difficulties AMRs offer in logistical operations, and create the groundwork for further study. This research shows how the adoption of AMRs in the logistics sector has been affected by uncertainties and how it affects organizational performance outcomes.

2. Research Methodology

This section elaborates on the methodology utilized to gather and analyze data to address the research question and objectives of the investigation. The study employs quantitative and qualitative methodologies, including STEEPV analysis and questionnaires, to facilitate data analysis and interpretation. Besides, this section also explains the research design utilized in the investigation, explicates the foresight procedure, and evaluates the population and sampling methodology. Ultimately, the data analysis is explicated, and the research instrument is scrutinized. This chapter plays a crucial role in ensuring the study's objectives are achieved during data collection.

2.1 Research Design

The research design serves as a blueprint for the desired study, acting as the framework that connects all elements of a research project (Akhtar, 2016). It offers researchers an effective strategy for enhancing suitable study strategies and methodologies for the best results (McCombes, 2021). In order to obtain and evaluate comprehensive data for this research, researcher will use a mixed-methods approach that integrates quantitative and qualitative techniques. The STEEPV analysis serve as part of the qualitative technique to investigate the key influences, unknowns, difficulties, and trends around AMRs in logistics. The final list will be created by combining the main problems and factors discovered during STEEPV research. A survey technique is employed for the quantitative approaches, and a questionnaire was sent to chosen respondents. The reliability and accuracy of the measuring device were tested in a pilot study, and then data are gathered and analyzed using the Statistical Package for Social Science (SPSS) program. The next step involves foresight research using impact-uncertainty analysis and scenario analysis.

2.2 Foresight Process

Foresight entails systematic data collecting and analysis to provide fresh and diversified viewpoints on emerging trends (Voros, 2003). This study's goal is to look at the possibilities and consequences that might arise from the use of AMRs in the logistics industry. The STEEPV analysis and horizon scanning should be included in this section.

2.2.1 Horizon Scanning

Horizon scanning is a thorough procedure that includes identifying important drivers, analyzing pertinent data, and assessing future trends, according to the National Academies of Sciences, Engineering, and Medicine (2020). Determining an organization's readiness for impending changes or dangers is crucial since it helps with policy development and proactive decision-making by highlighting requirements and gaps. Horizon scanning entails researching a vast array of sources, such as journals, novels, articles, and publications, to acquire diverse perspectives and insights, thereby improving the accuracy of the process. For policies to be successful, horizon scanning must be done consistently (National Academies of Sciences, Engineering, and Medicine, 2020).

Horizon scanning is being used as a study approach to examine logistical solutions for AMRs. Using horizon scanning approaches, researchers can find upcoming technology, regulatory frameworks, market trends, and other essential elements related to antimicrobial resistance. According to the National Academies of Sciences, Engineering, and Medicine (2020), this method allows researchers and decision-makers to proactively identify possible barriers and devise strategies to maximize the advantages of AMRs in the logistics sector.

2.2.2 STEEPV Method

The STEEPV analysis is a framework that comprises six key factors, namely Social, Technological, Economic, Environmental, Political, and Values. These factors serve as a fundamental basis for initiating strategic discussions concerning the future. STEEPV method consists of 10 steps which are data marking, data listing, data classification, data identification, comparative theme, repeating steps, data inspection, reviewing, data merging, and final confirmation.

2.3 Population and Sampling

2.3.1 Sampling Method

Sampling is the process of choosing a small sample from a larger population in order to determine the likelihood that an inevitable fact, event, or outcome will occur (Acharya *et al.*, 2013). Sampling methods can be divided into two categories: probability and non-probability. In this study, the researcher selects samples based on their preferences or subjective evaluations using a non-random sampling technique. As it is easier to collect data from respondents and finish the project on time, purposeful sampling saves time and money throughout the research process.

2.3.2 Population

Population refers to the entire group of individuals, events, or objects that the researcher wishes to examine (Banerjee & Chaudhuri, 2010). The logistics organizational in Johor are chosen as the population for this study. According to Federation of Malaysian Freight Forwarders (FMFF, 2023) report, there have 260 logistics companies in Johor.

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2.3.3 Sample Size

Taherdoost (2016) explains that sampling is the process of selecting enough correct elements from the population to generalize them to the population elements. Purposeful sampling aims to select a portion of the total population from the survey as a representative of the survey and analysis and then infer the general situation based on this portion of the sample. a sample size of 155 respondents out of a population of 260 (KENPRO, 2012). The respondent for this research are the managers of logistics company in Johor, as these organizations are actively involved in logistics operations.

2.4 Research Instrument

A research instrument refers to the instruments used to collect data. In this study, a questionnaire is utilized as the main research instrument owing to its effectiveness in terms of cost and time as well as its capacity to provide respondents anonymity (Zohrabi, 2013). The survey questionnaire method is used to collect quantitative data, employing a large population of respondents and multiple survey questions to investigate ideas, attitudes, decisions, and other characteristics (Zohrabi, 2013). The questionnaire approach provides a broad variety of possibilities, assuring a representative sample for targeted results and important decision-making.

The questionnaire for this study is administer online, and questions are crafted considering existing literature to predict the trend of AMRs in the logistics sector. The acquired data is analyzed using the Statistical Package for the Social Sciences (SPSS), and the questionnaire structure consists of four parts. Part A of the survey inquired about basic demographics such respondent's age, gender, race, employment status, and location of operation. Parts B, C, and D used the Likert scale to evaluate the relevance, effect, and degree of ambiguity of AMRs in Malaysian logistics.

2.5 Pilot Test

A pilot test is a test that aims to provide reliable findings. For a high-quality research study on the difficulties, problems, and trends of AMRs in the transport sector in Malaysia, the project needs to be well-designed and carried out. The right sample size must be determined not to offer sufficient power for hypothesis testing but to evaluate the feasibility of participant recruiting or research design. A pilot study can also evaluate all other aspects of the preliminary study, saving participants and researchers time and money. Cronbach Alpha should be 0.70 or above, which is regarded as good (Taber, 2017).

Table 1 *Cronbach's Alpha rule of thumb*

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

2.6 Analysis of Data

2.6.1 Descriptive Analysis

Descriptive analysis is a statistical technique used to summarize and describe data, showcasing relationships, patterns, and trends. It is particularly useful in identifying data outliers and elucidating correlations between variables. This study used SPSS statistics software to generate descriptive statistics, including frequency, percentage, and average, from questionnaire data.

2.6.2 Impact Uncertainty Analysis

This research's analysis plays a crucial role in the researcher's decision-making process, as it helps evaluate the potential impacts of research outcomes and identifies sources of ambiguity that may affect the reliability and relevance of the findings (Johansen *et al.*, 2014). In this study, a mixed-method data analysis approach that combined qualitative and quantitative methods is used to analyze the data to adopt impact-uncertainty analysis, a technique used to evaluate the effects and implications of a study while considering the associated uncertainties (Johansen *et al.*, 2014). The purpose of this research is to identify prospective AMR trends in logistics, with drivers chosen based on their considerable effect and potential impact on future growth, with each demonstrating varied degrees of impact and uncertainty.

2.7 Scenario Analysis

This study utilizes scenario analysis to predict future outcomes of AMRs for logistics sector in Malaysia. According to Balaman (2019), scenario analysis is a useful technique in research since it helps researchers to investigate and evaluate the long-term effects and results of many speculative future scenarios or occurrences. With the objective of understanding their possible influence on study findings and conclusions, this approach entails creating and analyzing several hypothetical scenarios depending on different assumptions or factors (Balaman, 2019). Scenario analysis in the current research is based on the first two drivers discover in the impact-uncertainty analysis. In order to predict and evaluate potential future AMR trends, the researcher creates four alternate scenarios, each having either good or negative consequences.

3. Literature Review

This session discusses the methodology used for collecting and analyzing data to answer the research question and objectives of this study. It uses quantitative and qualitative methods, such as STEEPV analysis and questionnaires, to make the data analysis and interpretation. It also provided an explanation of the research design employed in the study, a description of the foresight process, and an analysis of the population and sampling methodology. Finally, it explained the analysis of the data and analyzes the research instrument. This session is critical in ensuring the study goals were met throughout the data-collecting process.

3.1 Autonomous Mobile Robots

The incorporation of robotics has a significant impact on the development of modern logistics systems, with their extensive adoption becoming a critical factor in determining competition and future inter-enterprise operations trends (Ben *et al.*, 2018). AMRs in logistics are equipped with advanced features such as path planning, navigation, information integration, and autonomous decision-making, which significantly improve the efficiency and intelligence of contemporary logistics (He *et al.*, 2020). Nevertheless, one of the primary challenges in employing AMRs is assuring their efficient navigation in outdoor environments and accurate achievement of intended destinations, which requires high-precision trajectory tracking control (Li *et al.*, 2016). Li *et al.* (2016) state that control methods play a crucial role in attaining this level of control for mobile robotics.

As stated by Karabegovi *et al.* (2018), packaging and wrapping are regular jobs that robots do in the logistics industry. AMRs, such as cooperation robots, inventory transportation robots, scalable storage picking robots, and autonomously guided vehicles (AGVs), are created for a variety of uses and operational requirements (Tek, 2022).

3.2 Logistics in Malaysia

Logistics management is a vital component of supply chain management that entails the strategic planning, execution, and monitoring of the efficient movement and storage of products, services, and knowledge from origin to destination to meet customer demands (The Council of Supply Chain Management Professionals, 2023). In Malaysia, logistical planning significantly depends on the growth of multimodal transportation networks, with the well-connected sea, air, land, and rail infrastructure supporting the flow of goods within and outside the nation (Project Management Office, 2019). Ministry of Transport Malaysia (2015) states that crucial locations such as Port Klang and Kuala Lumpur International Airport (KLIA) are essential in facilitating logistics operations.

Third-party logistics (3PL) providers, who provide various services such as transportation, storage, freight forwarding, and value-added services, further improve the efficient operation of the supply chain in Malaysia (Wahab *et al.*, 2021). (Sohail & Sohal, 2003) These third-party logistics (3PL) providers leverage their expertise, networks, and technological capabilities to deliver customize logistics solutions that accommodate Malaysian businesses' diverse requirements. Additionally, as there is a growing need for effective last-mile delivery, organized shipment fulfillment services, and improved reverse logistics procedures, online shopping has significantly impacted the nation's logistics management framework (Viu-Roig & Alvarez-Palau, 2020). According to Meidut-Kavaliauskien *et al.* (2014), the e-commerce industry places a heavy emphasis on quickness, adaptability, and user experience to meet online consumers' expectations.

3.3 STEEPV Analysis

The STEEPV analysis framework is often used to assess the numerous elements that might influence the deployment and success of a certain technology. In this section, all recognized AMR-related problems and factors have been grouped according to the relevant social, technological, economic, environmental, political, and value categories.

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3.4 Table of Driver Related to Merged Issues, Trends, and Challenges

After integrating essential terms pertaining to the issues and drivers of AMRs in logistics sector, ten comprehensive issues and drivers were identified. These exhaustive issues and drives will be incorporated into the data collection questionnaire. Table 2 lists the issues and drivers that have been integrated.

Table 2 *Driver related to merged issues / trends / challenges*

No.	Issues / Trends / Challenges	Drivers
1	Labour supply to meet the demand for jobs that require physical effort Shortage of workforce effect businesses in Asia are considering adopting AMRs Lack of highly qualified workers	Labour supply
2	Implementing AMRs on employee retention and work satisfaction AMRs system promote collaboration and communication across different organizational Implementing AMRs changes in employment patterns and job	Cultural attitudes
3	Heightened uncertainty and intricate interdependencies in the AMRs system impact human interactions Autonomy on human emotions and the perception of AMRs Potential risks and safety concerns Workplace safety	Risks and safety
4	Excessive energy consumption AMRs consume a significant amount of energy AMRs adoption accelerates resource utilization and depletion	Energy usage
5	Implementing AMRs changes in employment patterns and job displacement Navigate independently Self-navigating system	Labor automation
6	Heightened uncertainty and intricate interdependencies in the AMRs system impact human interactions" Innovation and efficiency of cloud computing for AMRs Advance technology for real-time data Complex technologically	Technological advancement
7	Shortage of high-qualify workforce effect labor cost increase Lack of highly qualified workers Workforce displacement can impact the decline labor cost	Labor cost
8	Decreased the human error Enhanced assembly process for improved productivity Low battery life affects the performance Decreased the human error Real-time data processing	Productivity performance
9	Enhancing their performance through iterative improvements Workforce displacement affect decline of gross domestic product (GDP) Rising demands Reduce material waste Increase in market growth	Economy Growth
10	Market value of AMRs increased High initial costs Lack of funds Large capital expenditure	Cost and funding

4. Data Analysis and Findings

This chapter provides a thorough discussion of the data analysis and conclusions about the utilisation of Autonomous Mobile Robots (AMRs) in Malaysia's logistics industry. The data was gathered and analysed using the Statistical Package for the Social Sciences (SPSS) software, using a distributed questionnaire sent via email to logistics managers in Johor. The investigation included demographic observations, detailed categorizations, and evaluations of the potential effect and uncertainty. The demographic data was represented using frequency, percentage, and cumulative percentage, while the prioritisation of issues was determined by calculating the

mean and standard deviation. For impact-uncertainty analysis, the drivers and problems with the highest mean were chosen from the top 50 percent. This selection was made to assess their potential effect and unpredictability in the future. This approach facilitated the identification of the most influential and unpredictable components for scenario analysis, establishing the foundation for developing strategies that tackle the most crucial elements defining the future of AMRs in Malaysia's logistics business.

4.1 Pilot Test Result

This research used Cronbach's Alpha values calculated using SPSS to perform a pilot test on a sample of 78 respondents to evaluate the questionnaire's reliability. The results of the study were encouraging although the Level of Importance demonstrated a satisfactory degree of dependability (α = 0.761), suggesting that its items were consistently aligned, additional improvements are possible. On the other hand, the Level of Impact (α = 0.842) and Level of Uncertainty (α = 0.869) showed high reliability, above the criterion of 0.8. This indicates a greater internal consistency across the items used to assess these variables. The strong Cronbach's Alpha values indicate a greater level of reliability in measuring the effect and uncertainty elements, emphasising their stability and dependability for assessing the examined constructs.

Table 3 *Reliability of pilot test*

Factors	Cronbach's Alpha Value
Level of Importance	0.761
Level of Impact	0.842
Level of Uncertainty	0.869

4.2 Actual study

The reliability of the actual study also has been conducted. The result of the reliability of the actual study is shown in the table below. According to the Table 4, Cronbach's Alpha Value for the Level of Importance is (α = 0.748), and the Level of Impact is (α = 0.774). These two factors are indicative of an acceptably reliable measurement; however, room for refinement persists to bolster its consistency. Besides that, Cronbach's Alpha value for the Level of Uncertainty is (α = 0.809) and is categorized as better reliability because Cronbach's Alpha value is above 0.8.

Table 4 *Reliability of actual study*

Factors	Cronbach's Alpha Value
Level of Importance	0.748
Level of Impact	0.774
Level of Uncertainty	0.809

4.3 Survey Return Rate

This research targeted 260 respondents from Malaysia's logistics sector, with 155 actively engaged managers from Johor participating in the survey via Google Forms. This web-based platform streamlined data organization and analysis, offering efficiency and cost savings by eliminating paper-based distribution and manual data entry. Out of 200 surveys distributed via email, the study achieved a response rate of 45.88%, indicating significant engagement from the surveyed logistics company managers.

Table 5 *Survey return rate*

Population	260
Sample	155
Questionnaire Returned	78
Questionnaire Distributed	170
Percentage	45.88%

4.4 Demographic Analysis

This section examines the demographics of study participants using seven questionnaire items covering gender, age, race, education level, occupation sector, work experience, number of employees, and which specific AMR technologies are currently used or considered for implementation. Visualized through pie charts with percentages, this approach enhances data accessibility and understanding.

4.4.1 Respondents Demographics Information

In summary, the analysis of the respondent data reveals a predominantly male participant group comprising 62.8% of the total, with females accounting for 37.2%. Age-wise, the largest segment falls within the 19 to 29 years old category (55.1%), followed by the 30 to 39 years old category (34.6%). Ethnically, Malays constitute the largest group (48.7%), followed by Chinese (41%) and Indians (10.3%). Educationally, a substantial majority hold degree-level qualifications (74.4%), with smaller proportions having master's (7.7%) or Ph.D. degrees (1.3%). Occupationally, the government sector is most represented (50%), followed by the private sector (35.9%) and self-employed individuals (14.1%). Regarding experience, 48.7% have 1-5 years, 37.2% have 5-10 years, and 3.8% have less than a year of experience, while 10.3% have extensive experience. The majority are associated with companies with 51 to 100 employees (53.8%), and in terms of AMRs technology, Inventory Transportation Robots are the most mentioned (37.2%). This comprehensive analysis provides valuable insights for data-driven decision-making in future research and projects.

4.5 Descriptive Analysis of the Drivers

This section presents a descriptive analysis of AMRs related issues in Malaysia's logistics sector. Respondents used a Likert scale in Parts B, C, and D of the questionnaire to rate these issues based on importance, impact, and uncertainty. SPSS software was used to analyze the data for mean and standard deviation. The top fifty percent of drivers with the highest mean levels of impact and uncertainty were selected for scenario analysis, employing an impact-uncertainty analysis method to identify primary factors driving future uncertainty and impact.

4.5.1 Mean of Drivers in Corresponding with Importance

The mean value of each driver was determined using a rating scale to which respondents provided their evaluations and opinions. Table 6 below was showed the mean of the first five leading Drivers based on level of importance.

Table 6 *Mean of the first five leading drivers on importance*

No	Drivers	Mean
1	Risks and safety	4.4103
2	Technological advancement	4.3462
3	Productivity performance	4.2949
4	Labor cost	4.2436
5	Labor automation	4.2179

4.5.2 Mean of Drivers in Corresponding with Impact

The Table 7 below showed that Mean of the five leading drivers on Level of Impact.

Table 7 *Mean of the five leading drivers on level of impact*

No	Drivers	Mean
1	Risks and safety	4.3590
2	Technological advancement	4.2692
3	Productivity performance	4.2949
4	Labor cost	4.2949
5	Labor automation	4.1410

4.5.3 Mean of the Drivers in Corresponding with Level of Uncertainty

The Table 8 below showed that the Mean of the five leading drivers on Level of Uncertainty.

Table 8 *Mean of the five leading drivers on Level of uncertainty*

No	Drivers	Mean
1	Risks and safety	4.3718
2	Technological advancement	4.3718
3	Productivity performance	4.2949
4	Labor cost	4.3974
5	Labor automation	4.3077

4.6 Impact Uncertainty Analysis

Table 9 shows the mean value of the top five leading drivers based on the level of uncertainty and level of impact. The purpose of identifying the top five leading drivers based on the level of uncertainty and level of impact in research is to highlight critical research areas with the potential for significant breakthroughs but also with inherent issues and drivers. Fig. 2 shows the top two drivers were identified which have the highest impact and uncertainty to the future AMRS for logistics sector in Malaysia. First, the statement "risks and safety (DI) has the highest impact and uncertainty (4.3718, 4.3590) while labor cost (D4) has the second highest impact and uncertainty (4.3974, 4.2949).

Table 9 *Mean of the five leading drivers on level of impact and uncertainty*

No	Drivers	Mean	
		Uncertainty	Impact
D1	Risks and safety	4.3718	4.3590
D2	Technological advancement	4.3718	4.2692
D3	Productivity performance	4.2949	4.2949
D4	Labor cost	4.3974	4.2949
D5	Labor automation	4.3077	4.1410

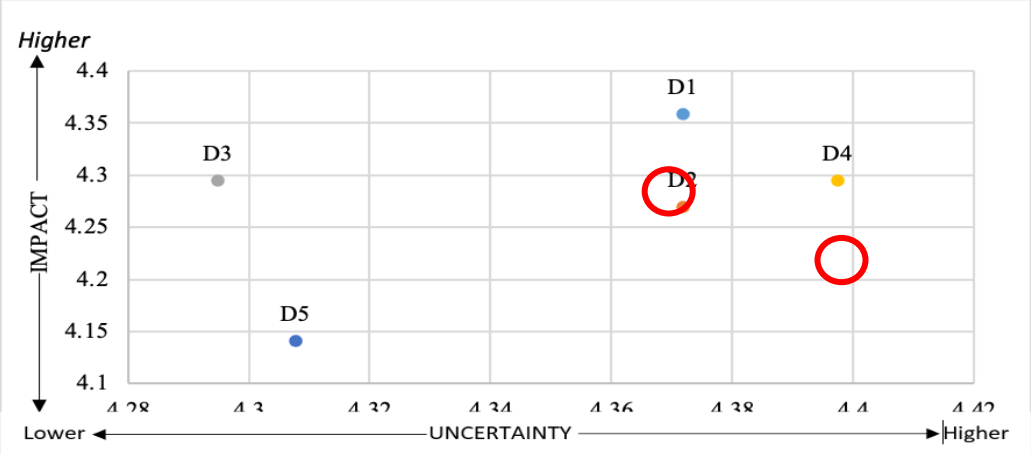

Fig. 2 *Impact uncertainty analysis*

5. Discussion, Recommendation, and Conclusion

This chapter will create the scenario analysis using the top two drivers that were analyzed based on the impact-uncertainty analysis in the previous chapter. By conducting a scenario analysis, one can ascertain the anticipated outcome of four distinct alternative scenarios involving the top two variables to assess the trends of AMR in the logistics industry of Malaysia within the next five to ten years.

5.1 Discussion on First Research Objective

The study of first objective is to identify the issues, challenges, and trends of AMRs for logistics sector in Malaysia. Firstly, labor supply plays a significant role in shaping the adoption of AMRs. While these robots offer automation and enhanced efficiency, concerns have arisen about potential job displacement and the need to retrain the current workforce (Manyika & Sneader, 2018). To address these concerns, it is imperative to implement reskilling initiatives and training programs to ensure a smooth transition to automation.

Secondly, the development of cultural attitudes towards technology is another crucial driver. Public perception of AMRs and technology, in general, greatly influences their adoption. To foster a positive perception and overcome cultural resistance, initiatives focused on public education and awareness are necessary (Huang & Liao, 2015). Building trust and showcasing the advantages of AMRs can help integrate them seamlessly into the workforce (Addup Networks Private Limited, 2023).

Thirdly, the driver of risk and safety is essential for the widespread acceptance of AMRs. Ensuring the safety of both human laborers and infrastructure is paramount. This requires the development of efficient risk mitigation plans, the implementation of strong safety procedures, and the establishment of precise standardization standards (Kaplan & Mikes, 2012). Collaborative efforts among government, industry, and research institutions can accelerate the development of comprehensive safety frameworks (Deng *et al.*, 2023).

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Furthermore, environmental sustainability is a critical consideration. The energy usage of AMRs symbolizes concerns related to environmental factors in logistics. To promote long-term sustainability, it is vital to explore renewable energy sources like solar charging stations and optimize AMR energy usage through intelligent routing (Federation of Malaysian Manufacturers, 2023). Striking the right balance between automation and human labor is also crucial, as complex decision-making still requires human supervision and intervention (Real-time Network, 2023).

Additionally, the rapid technological advancements in AMR technology require continuous adaptation and investment in cutting-edge solutions (Yang & Gu, 2021). Staying competitive necessitates staying updated on technological developments and exploring opportunities for additional automation and optimization (Ironhack, 2023).

Financial considerations, such as the initial cost of obtaining and maintaining AMRs, represent a major barrier. Organizations must carefully assess the cost-benefit ratio and explore diverse funding alternatives, including private partnerships and government grants (Fragapane *et al.*, 2021). To justify these early expenses, demonstrating a strong return on investment (ROI) is essential (Britt, 2022). Maximizing operational efficiency requires optimizing human operator training and streamlining existing procedures (Javaid *et al.*, 2021).

In conclusion, the implementation of AMRs in the Malaysian logistics sector is a complex and continuously developing process, influenced by various drivers and challenges. A comprehensive strategy is necessary to consider technological advancements, labor dynamics, economic impacts, and environmental sustainability. By efficiently addressing these factors through collaborative efforts, Malaysia can harness the potential of AMRs to revolutionize the logistics sector, fostering expansion, innovation, and enhanced competitiveness in the future.

5.2 Discussion on Second Objectives

This study has established three primary objectives. The second objective of the research is to determine the primary factors that contribute AMRs in the logistics sector in Malaysia. The two primary drivers have been chosen based on the impact-uncertainty analysis. Both drivers have the most significant impact and uncertainty based on the user and the developer of the AMRs review. “Risk and safety” and “Labour cost” have the highest mean in level of impact and uncertainty.

The future integration of Autonomous Mobile Robots (AMRs) in Malaysia's logistics sector hinges on the careful consideration of risk and safety factors. Highlighting the significance of safety in decision-making processes, stringent safety protocols and regulations are emphasized as critical components (Dunakin, 2019; Konica Minolta, 2023). AMRs, equipped with advanced obstacle detection and avoidance systems, offer a pathway to enhance human laborer safety and reduce accidents, contributing not only to increased productivity but also fostering an improved workplace atmosphere (Reynolds, 2023). Optimized safety standards may further elevate the efficiency of logistics operations, leading to expedited deliveries, reduced operating expenses, and heightened competition, attracting investments and driving advancements in the industry (Damini, 2023).

However, the adoption of AMRs also poses challenges, particularly in terms of labor dynamics and costs within the logistics sector. While these robotic systems promise efficiency and cost-effectiveness by automating repetitive tasks, their integration may lead to changes or replacements in traditional manual roles, potentially causing employee dissatisfaction (Romaine, 2023; Holzer, 2022). The uncertainties surrounding the speed of technology adoption, the extent of automation implementation, and regulatory developments add complexity to the equation, influencing the overall impact of AMRs on workforce requirements and industry dynamics.

5.3 Discussion on Third Objectives

The third objective is to determine the future trends of AMRs in the Malaysian logistics industry. The objective is to identify the future trends that will drive change, as well as the future environment and market for AMR adoption in the Malaysian logistics industry. This objective also requires identifying the forces that can change the future of AMRs in the Malaysian logistics industry. The Fig. 3 represents future trends in AMR adoption, four alternative scenarios were generated. These four alternatives represent four scenarios that could occur between 2023 and 2033.

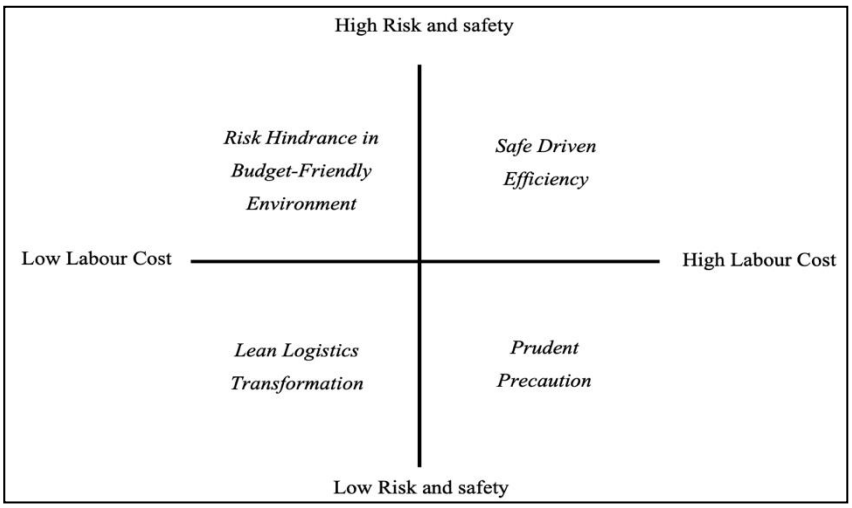

Fig. 3 *Development of Four Scenario Analysis*

5.3.1 Scenario 1 "Safe Driven Efficiency"

Scenario 1, referred to as "Safety-Driven Efficiency" in Fig. 3, envisions a landscape characterized by stringent safety measures alongside high labor costs. This scenario has the potential to transform the logistics business by not only reducing accidents but also fostering a workplace that prioritizes employee well-being.

By giving top priority to safety through advanced AMRs, operational disruptions can significantly decrease, while employee morale, productivity, and efficiency can soar (Safety Line, 2023). The establishment of comprehensive safety protocols, as suggested by the World Economic Forum report (2023), may require significant investments in specialized equipment and training. However, the potential benefits of reduced downtime and injuries may outweigh the initial costs, resulting in sustained financial savings and improved operational resilience.

While the initial impact of this approach might strain profit margins due to expensive labor, strategic measures such as leveraging technology to reduce reliance on costly human labor can offset these expenses (Feng, 2020). Additionally, focusing on market segments that highly value safety can allow companies to command higher prices, thus alleviating the financial burden associated with safety-focused strategies (Huang & Zhong, 2023).

In addition to the financial benefits, a safety-first strategy enhances a company's brand image (Srinivasan & Kurey, 2014). Companies that demonstrate a strong commitment to employee well-being can gain a competitive edge in an era where consumers prioritize ethical behavior. The market value of such branding and consumers' willingness to pay a premium for products from companies with impeccable safety records are evident (Agrawal, 2016).

To fully realize the advantages of Safety-Driven Efficiency in the integration of AMRs in logistics, strategic investments in automation and technology are essential (Raza *et al.*, 2023). These investments aim to reduce the need for costly physical labor while strengthening safety measures. Proactive risk management systems and a safety culture can empower employees, leading to fewer accidents and the implementation of a more cost-effective safety approach (Naji *et al.*, 2021).

In conclusion, despite high labor costs, Scenario 1 offers a compelling vision for the future of the logistics industry, emphasizing safety through AMRs. Safety-driven efficiency can become a lasting competitive advantage with strategic planning and innovative solutions, even in the face of challenges like initial financial pressures and potential operational slowdowns. Through skillful negotiation of trade-offs and the adoption of innovative approaches, the logistics sector can harness the revolutionary potential of an AMR-enabled safety-centric culture.

5.3.2 Scenario 2 "Lean Logistics Transformation"

Scenario 2, titled " Lean Logistics Transformation" envisions the Malaysian logistics industry characterized by reduced labor expenses, controlled safety risks, and lowered operational risks. Here, AMRs aim to capitalize on their cost-effectiveness while managing the challenges associated with limited safety features.

In this scenario, the focus is on customizing AMRs for maximum operational efficiency and cost reduction. Simple, cost-effective AMRs models are deployed to handle routine logistics tasks, even at the expense of advanced safety measures. The emphasis shifts towards economic considerations, occasionally leading to operational challenges.

The Supply Chain Reviews (2020) highlight the trade-offs involved in cost-driven logistics strategies. While prioritizing cost-effectiveness can optimize operations, it may also involve compromising on safety precautions. This aligns with the expectations in Scenario 2, where reduced safety features are anticipated due to cost reduction.

AMRs in Scenario 2 require businesses to balance cost-effectiveness with operational efficiency carefully. While initial investments may be lower, long-term viability could be compromised by operational issues resulting from reduced safety features. However, strategic integration of AMRs can optimize logistics operations, streamline repetitive tasks, and reduce labor-related expenses (Addup Networks Private Limited, 2023).

Furthermore, Arthur A. Thompson, Jr's critiques (1984) emphasize the immediate financial consequences of cost-focused initiatives in industries. While reduced safety investments may impact profit margins in the short term, alternative cost-cutting strategies and targeting market segments with lower safety demands can mitigate these effects.

In summary, Scenario 2, "Lean Logistics Transformation" foresees a landscape where AMRs prioritize cost-effectiveness over stringent safety protocols in the logistics industry. While this approach may offer immediate cost savings and operational simplification, it may raise concerns about long-term sustainability and safety. Striking a balance between these trade-offs will be crucial to harness the cost benefits of AMRs while maintaining operational reliability and safety in the logistics sector.

5.3.3 Scenario 3 “Risk Hindrance in Budget-Friendly Environment”

Scenario 3, titled " Risk Hindrance in Budget-Friendly Environment " presents a unique challenge for the future of the logistics industry in Malaysia. It revolves around the dilemma of dealing with heightened risks while also benefiting from cost-effective labor. This scenario envisions a conflict between the desire for cost savings and the need for stringent safety regulations, potentially leading to operational complexities and legal issues.

AMRs in this scenario operate in an environment where low labor costs are enticing to businesses, but strict safety measures remain crucial. Finding a solution to reconcile these conflicting dynamics proves to be a significant challenge. According to Rvj (2022), industries with low labor costs may struggle to uphold stringent safety standards, which can result in operational disruptions. This aligns with the anticipated outcomes in Scenario 3, where the pursuit of cost reduction may clash with rigorous safety protocols.

Under Scenario 3, the logistics industry's future with AMRs requires a delicate balance between cost benefits and safety precautions. While low labor costs may be attractive, obligations for safety and regulatory compliance can hinder operational efficiency. As noted by Bill Black (2017), scholarly studies emphasize that implementing strict safety protocols in low-cost environments may lead to operational complications and potential opposition from safety authorities, compromising overall effectiveness.

Adhering to stringent safety standards in a cost-conscious setting presents significant challenges, as illustrated in Scenario 3. Organizations may require assistance in navigating the complexities of maintaining rigorous safety protocols in the face of enticingly low labor expenses, potentially resulting in operational disruptions and regulatory noncompliance.

In conclusion, Scenario 3, " Risk Hindrance in Budget-Friendly Environment" highlights the intricate dilemma that businesses must address: striking a balance between the allure of inexpensive labor and the necessity of strict safety regulations. Effectively managing this situation will necessitate innovative approaches and strategic compromises to uphold critical safety standards, maximize cost savings, ensure operational efficiency, and comply with regulatory requirements in the logistics industry.

5.3.4 Scenario 4 “Prudent Precaution”

Scenario 4, titled " Prudent Precaution " envisions the future of AMRs in Malaysia's logistics industry characterized by low risks, moderate safety concerns, and high labor costs. This scenario emphasizes finding a delicate equilibrium between cost reduction and safety, albeit with safety standards somewhat lower than in safety-focused scenarios.

In this context, AMRs are expected to provide a moderate solution that balances the imperative to cut labor costs with the need for safety precautions. Striking this balance between cost-effectiveness and maintaining acceptable safety standards presents inherent complexities and challenges for industries (Tamers *et al.*, 2020). This aligns with the anticipated outcomes in Scenario 4, where cost reduction may take precedence over substantial investments in safety measures.

Scenario 4 demands that the logistics industry navigate the intricacies of cost-sensitive safety measures concerning AMRs. While cost reduction is essential due to high labor expenses, businesses aim to uphold a reasonable level of safety to ensure uninterrupted operations. This strategy may involve targeted investments in AMRs that offer a balance between safety and efficiency improvements.

As noted by Inlogsys (2023), sectors facing significant labor expenses often struggle to strike a balance between implementing safety protocols and minimizing financial consequences. While the logistics industry

seeks to maintain an adequate level of safety precautions, the associated expenses in achieving this equilibrium may pose challenges in terms of immediate financial gains.

In conclusion, Scenario 4 outlines a future in the logistics industry where companies seek to achieve a balance between safety concerns and costly labor expenses by implementing "Prudent Precaution" measures for AMRs. The primary objective is to optimize expenditures while maintaining an acceptable level of safety, thus balancing operational reliability and cost-effectiveness. The ability to uphold fundamental safety standards in the logistics environment while harnessing the advantages of AMRs hinges on the effective management of this delicate equilibrium.

5.4 Limitation of study

This foresight study offers significant perspectives on the possible incorporation of AMRs in Malaysia's logistics industry. However, the pointed-out constraints emphasize the necessity of continued investigation, wider data gathering, and flexible approaches to handle unanticipated technological breakthroughs and contextual intricacies for a more thorough comprehension and efficient application of AMRs in the ever-changing logistics landscape.

5.5 Recommendation

5.5.1 Recommendation for future study

Further research in Malaysia's logistics sector on AMRs should focus on longitudinal studies to monitor real-time AMRs application and its consequences, specifically evaluating long-term operational, environmental, and economic impacts across various logistics segments. Additionally, comparing adopting organizations with non-adopters can offer valuable insights. A detailed examination of socio-cultural factors impacting AMRs adoption, through surveys or interviews with stakeholders, can provide a comprehensive understanding of the obstacles and facilitators influencing AMRs implementation in Malaysia's logistics sector.

5.5.2 Recommendation For AMRs In Logistics Sector.

This scenario analysis offers insights into the future of AMRs in Malaysia's logistics sector. Stakeholders should collaborate on comprehensive training programs focused on AMR operation and maintenance for logistics professionals. Pilot programs, facilitated through partnerships between logistics firms and technology providers, should be prioritized to apply AMR capabilities practically and refine infrastructure. Ongoing monitoring of AMR-specific technological advancements is crucial to adapt strategies for seamless integration and long-term efficiency in Malaysia's logistics sector.

5.6 Conclusion

In conclusion, this research aims to investigate the future trends of AMRs in Malaysia's logistics sector, addressing the associated issues, challenges, trends, and key drivers. The research approach involves foresight methodology, SPSS analysis, SPEEEV analysis, and impact-uncertainty analysis. From the impact-uncertainty analysis, the top two drivers have been identified and incorporated into scenario analysis, resulting in four future adoption scenarios for AMRs in logistics.

The adoption of Autonomous Mobile Robots (AMRs) in the logistics sector in Malaysia is intricately linked to the dual considerations of risk and safety, as well as labor costs. A positive correlation exists between these factors, giving rise to an optimal scenario termed "Safety-Driven Efficiency," wherein society exhibits a heightened interest in deploying AMRs for logistics operations. This scenario envisions a future where safety measures and cost-effectiveness synergize, fostering an environment conducive to the widespread adoption of AMRs.

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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:*** *C.J.Q., and A.S.;* ***data collection:*** *C.J.Q.;* ***analysis and interpretation of results:*** *C.J.Q., and A.S;* ***draft manuscript preparation:*** *C.J.Q., and A.S. All authors reviewed the results and approved the final version of the manuscript.*

References

Acharya, A. S., Prakash, A., Saxena, P., & Nigam, A. (2013). Sampling: Why and how of it? *Indian Journal of Medical Specialities*, *4*(2), 330–333. Research Gate.

Addup Networks Private Limited . (2023, May 8). *The benefits of using autonomous mobile robots (AMRs) in warehouse operations*. Www.linkedin.com. https://www.linkedin.com/pulse/benefits-using-autonomous-mobile-robots

Agrawal, A. J. (2016, January 25). *How Much Do Consumers Care About Product Safety When Buying Products?* Forbes. https://www.forbes.com/sites/ajagrawal/2016/01/25/how-much-do-consumers-care-about-product-safety-when-buying-products/?sh=394cb4b55f9f

Akhtar, I. (2016, September). *Research Design*. ResearchGate; www.researchgate.net. https://www.researchgate.net/publication/308915548_Research_Design

Alatise, M. O., & Hancke, G. P. (2020). A Review on Challenges of Autonomous Mobile Robot and Sensor Fusion Methods. *IEEE Access*, *8*, 39830–39846. https://doi.org/10.1109/access.2020.2975643

Anbalagan , L., & Nur Syazreen , A. (2023). A systematic review on recent advances in autonomous mobile robot navigation. *Engineering Science and Technology, an International Journal*, *40*, 101343. https://doi.org/10.1016/j.jestch.2023.101343

Aoki, S., Yonezawa, T., & Kawaguchi, N. (2022). RobotNEST: Toward a viable testbed for IoT-Enabled environments and connected and autonomous robots. *IEEE Sensors Letters*, *6*, 2. IEEE. https://doi.org/10.1109/LSENS.2021.3139624

Arora, K. (2023, March 26). *Use of Last Mile delivery technology to improve customer satisfaction*. Www.linkedin.com. https://www.linkedin.com/pulse/use-last-mile-delivery-technology-improve-customer-ketan-arora

Aspers, P., & Corte, U. (2019). *(PDF) What is Qualitative in Qualitative Research*. ResearchGate. https://www.researchgate.net/publication/331387557_What_is_Qualitative_in_Qualitative_Research

Automation, S. (2022, November 28). *Autonomous Mobile Robots: Trends and Challenges*. Www.scio-Automation.com; SCIO Automation. https://www.scio-automation.com/update/autonomous-mobile-robots-trends-and-challenges

Baba, J., Sichao, S., Nakanishi, J., Kuramoto, I., Ogawa, K., Yoshikawa, Y., & Ishiguro, H. (2020). *Teleoperated Robot Acting Autonomous for Better Customer Satisfaction*. https://doi.org/10.1145/3334480.3375212

Bahrin, M. A. K., Azli, N. H. N., Talib, M. F., & Othman, M. F. (2016). Using autonomous robots to drive supply chain innovation A series exploring Industry 4.0 technologies and their potential impact for enabling digital supply networks in manufacturing. In *ResearchGate*. https://www.researchgate.net/publication/304614356_Industry_40_A_review_on_industrial_automation_and_robotic

Balaman, Ş. Y. (2019). *Scenario Analysis - an overview | ScienceDirect Topics*. Www.sciencedirect.com. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/scenario-analysis#:~:text=Scenario%20analysis%20is%20the%20process

Banerjee, A., & Chaudhury, S. (2010). Statistics without tears: Populations and samples. *Industrial Psychiatry Journal*, *19*(1), 60–65. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3105563/

Ben , G., Steve J., P., & Dr. Dirk, M. (2018). *ARTIFICIAL INTELLIGENCE IN LOGISTICS A collaborative report by DHL and IBM on implications and use cases for the logistics industry 2018*. DHL Customer Solutions & Innovation. https://ftp.idu.ac.id/wp-content/uploads/ebook/ip/BUKU%20LOGISTIK%204.0/DHL/glo-core-trend-report-artificial-intelligence.pdf

Bill Black. (2017, July 18). *Balancing cost against safety. Why the scales should be one-sided.* Www.linkedin.com. https://www.linkedin.com/pulse/balancing-cost-against-safety-why-scales-should-one-sided-bill-black

Britt, P. (2022, April 24). *How to Manage Your Autonomous Mobile Robot Return on Investment*. Robotics 24/7. https://www.robotics247.com/article/how_to_manage_your_autonomous_mobile_robot_return_on_investment/

Business List. (2023). *Best Logistics in Johor Bahru, Malaysia - List of Logistics Companies Malaysia*. Www.businesslist.my. https://www.businesslist.my/category/logistics/city:johor-bahru

bznadmin. (2022, January 18). *Autonomous Mobile Robots (AMR): How they work and how they can become part of a warehouse*. Modula. https://www.modula.eu/blog/autonomous-mobile-robots-amr-how-they-work-and-how-they-can-become-part-of-a-warehouse/

Calitz, A., Poisat, P., & Cullen, M. (2017). The future African workplace: The use of collaborative robots in manufacturing. *SA Journal of Human Resource Management*. https://doi.org/10.4102/sajhrm.v15i0.901

Čech, M., Wicher, P., Lenort, R., Malčic, T., David, J., Holman, D., Staš, D., & Záruba, J. (2020). Autonomous Mobile Robot Technology For Supplying Assembly Lines In The Automotive Industry. *Acta Logistica*, *7*(2), 103–109. https://doi.org/10.22306/al.v7i2.164

Chen, Y., Yang, C., Song, B., Gonzalez, N., Gu, Y., & Hu, B. (2020). Effects of Autonomous Mobile Robots on Human Mental Workload and System Productivity in Smart Warehouses: A Preliminary Study. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *64*(1), 1691–1695. https://doi.org/10.1177/1071181320641410

Craye, C., Filliat, D., & Goudou, J.-F. (2016). *RL-IAC: An exploration policy for online saliency learning on an autonomous mobile robot*. 4877–4884. https://doi.org/10.1109/IROS.2016.7759716

Damini. (2023, January 25). *Minimizing Supply Chain Disruptions With Better Inventory Management*. Deskera Blog. https://www.deskera.com/blog/minimizing-supply-chain-disruptions-with-better-inventory-management/

Davila Delgado, J. M., Oyedele, L., Ajayi, A., Akanbi, L., Akinade, O., Bilal, M., & Owolabi, H. (2019). Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. *Journal of Building Engineering*, *26*, 100868. ScienceDirect. https://doi.org/10.1016/j.jobe.2019.100868

De Silva, V., Roche, J., & Kondoz, A. (2018). Robust Fusion of LiDAR and Wide-Angle Camera Data for Autonomous Mobile Robots. *Sensors*, *18*(8), 2730. https://doi.org/10.3390/s18082730

Deng, J., Sun, H., Zhang, Z., Cheng, J., & Huang, M. (2023). Recent Advances towards Safe, Responsible, and Moral Dialogue Systems: A Survey. *ArXiv:2302.09270 [Cs]*. https://arxiv.org/abs/2302.09270

Dolan, S. (2022, April 15). *The challenges of last mile delivery logistics and the tech solutions cutting costs in the final mile*. Insider Intelligence. https://www.insiderintelligence.com/insights/last-mile-delivery-shipping-explained/

Dunakin, C. (2019, July 25). *The biggest challenges of supply chain management*. 6 River Systems. https://6river.com/biggest-challenges-of-supply-chain-management/

Economic Planning Unit, Prime Minister's Department. (2021). National Fourth Industrial Revolution (4IR) Policy. https://www.ekonomi.gov.my/sites/default/files/2021-07/National-4IR-Policy.pdf

Faster Capital. (2023, June 20). *Affordability Assessment for Startups and Small Businesses*. Www.linkedin.com. https://www.linkedin.com/pulse/affordability-assessment-startups-small-businesses-fastercapital

Federation of Malaysian Manufacturers. (2023, October 26). FMM welcomes the launch of National Sustainability Policy 2023-2030. https://www.fmm.org.my/images/articles/publication/FMM_BIA_Apr-June2021.pdf

Feng, X. (2020). *The labour implications of technological upgrading in China*. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_764445.pdf

FLEXQUBE. (2022, April 6). *Plant Engineering | Optimize warehouse logistics with AMRs*. Plant Engineering. https://www.plantengineering.com/articles/optimize-warehouse-logistics-with-amrs/

Fragapane, G., de Koster, R., Sgarbossa, F., & Strandhagen, J. O. (2021). Planning and control of autonomous mobile robots for intralogistics: Literature review and research agenda. *European Journal of Operational Research*, *294*(2). https://doi.org/10.1016/j.ejor.2021.01.019

Fragapane, G., Hvolby, H.-H., Sgarbossa, F., & Strandhagen, J. O. (2021). Autonomous mobile robots in sterile instrument logistics: an evaluation of the material handling system for a strategic fit framework. *Production Planning & Control*, 1–15. https://doi.org/10.1080/09537287.2021.1884914

Fragapane, G., Ivanov, D., Peron, M., Sgarbossa, F., & Strandhagen, J. O. (2020). Increasing flexibility and productivity in Industry 4.0 production networks with autonomous mobile robots and smart intralogistics. *Annals of Operations Research*. Springer Link. https://doi.org/10.1007/s10479-020-03526-7

Ganiyu, I. O., Oyedele, O. O., & Derera, E. (2021). *Disruptions of the Fourth Industrial Revolution: Implication for Work-Life Balance Strategies*. Future of Work, Work-Family Satisfaction, and Employee Well-Being in the Fourth Industrial Revolution. https://www.igi-global.com/chapter/disruptions-of-the-fourth-industrial-revolution/265616

Garbacz, P., & Burski, B. (2014). The use of cloud computing in mobile robotics. *Problemy Eksploatacji*, *2*, 61–72. Research Gate. https://www.researchgate.net/publication/277897420_The_use_of_cloud_computing_in_mobile_robotics

Ghelichi, Z., & Kilaru, S. (2021). Analytical models for collaborative autonomous mobile robot solutions in fulfillment centers. *Applied Mathematical Modelling*, *91*, 438–457. https://doi.org/10.1016/j.apm.2020.09.059

Global Market Insights inc. (2023, April 17). *Autonomous Mobile Robot Market to hit $9 Billion by 2032*. GlobeNewswire News Room. https://www.globenewswire.com/news-release/2023/04/17/2647643/0/en/Autonomous-Mobile-Robot-Market-to-hit-9-Billion-by-2032-Says-Global-Market-Insights-inc.html

Gnambs, T., & Appel, M. (2019). Are robots becoming unpopular? Changes in attitudes towards autonomous robotic systems in Europe. *Computers in Human Behavior*, *93*, 53–61. https://doi.org/10.1016/j.chb.2018.11.045

Grover M.S., A. (2023, May 9). *Transforming Food Safety: How Autonomous Mobile Robots are Changing the Inspection Game*. Www.food-Safety.com; Food Safety Magazine. https://www.food-safety.com/articles/8567-transforming-food-safety-how-autonomous-mobile-robots-are-changing-the-inspection-game

Gudwin, R., Rohmer, E., Paraense, A., Fróes, E., Gibaut, W., Oliveira, I., Rocha, S., Raizer, K., & Vulgarakis Feljan, A. (2020). The TROCA Project: An autonomous transportation robot controlled by a cognitive architecture. *Cognitive Systems Research*, *59*, 179–197. https://doi.org/10.1016/j.cogsys.2019.09.011

Gue, K. R., Furmans, K., Seibold, Z., & Uludag, O. (2014). GridStore: A Puzzle-Based Storage System With Decentralized Control. *IEEE Transactions on Automation Science and Engineering*, *11*(2), 429–438. https://doi.org/10.1109/tase.2013.2278252

Gundlach, G. T., Bolumole, Y. A., Eltantawy, R. A., & Frankel, R. (2006). The changing landscape of supply chain management, marketing channels of distribution, logistics and purchasing. *Journal of Business & Industrial Marketing*, *21*(7), 428–438. Research Gate. https://doi.org/10.1108/08858620610708911

Hart, I. (2023, December 11). *Striking a balance between automation and human labour in food and drink industry*. IOT Insider. https://www.iotinsider.com/iot-insights/striking-a-balance-between-automation-and-human-labour-in-food-and-drink-industry/

He, C., Ma, R., Qu, H., & Gu, R. (2020). Research on Mobile Robot Positioning and Navigation System Based on Multi-sensor Fusion. *Journal of Physics: Conference Series*, *1684*(1), 012011. https://doi.org/10.1088/1742-6596/1684/1/012011

Hercik, R., Byrtus, R., Jaros, R., & Koziorek, J. (2022). Implementation of Autonomous Mobile Robot in SmartFactory. *Applied Sciences*, *12*(17), 8912. MPDI. https://doi.org/10.3390/app12178912

Holzer, H. J. (2022, January 19). *Understanding the impact of automation on workers, jobs, and wages*. Brookings; Brookings. https://www.brookings.edu/articles/understanding-the-impact-of-automation-on-workers-jobs-and-wages/

Huang, G. Q., Chen, M. Z. Q., & Pan, J. (2015). Robotics in ecommerce logistics. *HKIE Transactions*, *22*(2), 68–77. https://doi.org/10.1080/1023697x.2015.1043960

Huang, H., & Zhong, S. (2023). Application of Marxist-based science and technology theory in the ethical review of artificial intelligence robots. *Soft Computing*. https://doi.org/10.1007/s00500-023-08663-2

Huang, T.-L., & Liao, S. (2015). A model of acceptance of augmented-reality interactive technology: the moderating role of cognitive innovativeness. *Electronic Commerce Research*, *15*(2), 269–295. https://doi.org/10.1007/s10660-014-9163-2

Hyland, B. (2023, February 6). *5 key questions to consider when implementing AMRs*. Mobile Robot Guide. https://mobilerobotguide.com/2023/02/06/5-key-questions-to-consider-when-implementing-an-amr/

In, J. (2017). Introduction of a Pilot Study. *Korean Journal of Anesthesiology*, *70*(6), 601–605. https://doi.org/10.4097/kjae.2017.70.6.601

Industrial Quick Search. (2022). *Types of AGVs (Automatic Guided Vehicles)*. Www.iqsdirectory.com. https://www.iqsdirectory.com/articles/automated-guided-vehicle/types-of-agvs-automatic-guided-vehicles.html

Inlogsys. (2023, September 20). *Warehouse Automation vs. Manual Labor: A Cost-Benefit Analysis*. Medium. https://medium.com/@inlogsysltd/warehouse-automation-vs-manual-labor-a-cost-benefit-analysis-b456870d6963

Ironhack. (2023, May 24). *How to Stay Up-to-Date on Tech Trends and Innovations*. Www.ironhack.com. https://www.ironhack.com/gb/blog/how-to-stay-up-to-date-on-tech-trends-and-innovations

Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2021). Substantial capabilities of robotics in enhancing industry 4.0 implementation. *Cognitive Robotics*, *1*, 58–75. Sciencedirect. https://doi.org/10.1016/j.cogr.2021.06.001

Jenkins, A. (2020, December 10). *Warehouse Automation: The How, When & Why*. Oracle NetSuite. https://www.netsuite.com/portal/resource/articles/inventory-management/warehouse-automation.shtml

Johansen, A., Sandvin, B., Torp, O., & Økland, A. (2014). Uncertainty Analysis – 5 Challenges with Today's Practice. *Procedia - Social and Behavioral Sciences*, *119*, 591–600. https://doi.org/10.1016/j.sbspro.2014.03.066

Kaplan, R. S., & Mikes, A. (2012, June). *Managing Risks: A New Framework*. Harvard Business Review. https://hbr.org/2012/06/managing-risks-a-new-framework

Karabegović, I., Karabegović , E., Mahmić, M., & Husak, E. (2018). The application of service robots for logistics in manufacturing processes. *Advances in Production Engineering & Management*, 185–194. Research Gate. https://doi.org/10.14743/apem2015.4.201

KENPRO. (2012, August 25). Sample Size Determination Using Krejcie and Morgan Table. Kenya Projects Organization [KENPRO]. https://www.kenpro.org/sample-size-determination-using-krejcie-and-morgan-table/

Konica Minolta. (2023, August 18). *Two reasons why Autonomous Mobile Robots are the answer to workplace safety*. Konica Minolta. https://www.konicaminolta.com.au/news/blogs/two-reasons-why-autonomous-mobile-robots-are-the-answer-to-workplace-safety

Latikka, R., Savela, N., Koivula, A., & Oksanen, A. (2021). Attitudes Toward Robots as Equipment and Coworkers and the Impact of Robot Autonomy Level. *International Journal of Social Robotics*. https://doi.org/10.1007/s12369-020-00743-9

Leenes, R., Palmerini, E., Koops, B.-J., Bertolini, A., Salvini, P., & Lucivero, F. (2017). Regulatory challenges of robotics: some guidelines for addressing legal and ethical issues. *Law, Innovation and Technology*, *9*(1), 1–44. https://doi.org/10.1080/17579961.2017.1304921

Li, Q., Tang, Q., Chan, I., Wei, H., Pu, Y., Jiang, H., Li, J., *et al.* (2018), "Smart manufacturing standardization: Architectures, reference models and standards framework", Computers in Industry, Elsevier, Vol. 101 No. July, pp. 91–106. https://doi.org/10.1016/j.compind.2018.06.005

Li, Z., Deng, J., Lu, R., Xu, Y., Bai, J., & Su, C.-Y. (2016). Trajectory-Tracking Control of Mobile Robot Systems Incorporating Neural-Dynamic Optimized Model Predictive Approach. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *46*(6), 740–749. https://doi.org/10.1109/TSMC.2015.2465352

Lin , Z. H., & Xu, T. L. (2018). Application of Robot Technology in Logistics Industry. *Journal of Mechanical Engineering Research* . Research Gate. https://doi.org/10.30564/jmer.v1i1.116

Loganathan, A., & Ahmad, N. S. (2023). A systematic review on recent advances in autonomous mobile robot navigation. *Engineering Science and Technology, an International Journal*, *40*, 101343. Science Direct. https://doi.org/10.1016/j.jestch.2023.101343

Logistics Ministry of Transport Malaysia. (2015, March). *Logistics And Trade Facilitation Masterplan (2015-2020)*. The Ministry of Transport. https://www.mot.gov.my/en/Penerbitan%20Rasmi/Executive%20Summary%20Logistics%20and%20Trade%20Facilitation%20Masterplan.pdf

Malaysian Communications and Multimedia Commission (MCMC). (2023). 4Q 2022 Postal and Courier Services Infographic. In Official website of Malaysian Communications and Multimedia Commission (MCMC). https://www.mcmc.gov.my/skmmgovmy/media/General/Resources/P-C_BI-4Q.pdf

Malaysian Investment Development Authority. (2020, July 10). *E-Commerce: A Game Changer for Logistics Industry in Malaysia*. MIDA | Malaysian Investment Development Authority. https://www.mida.gov.my/e-commerce-a-game-changer-for-logistics-industry-in-malaysia/

Manyika, J., & Sneader, K. (2018, June 1). *AI, automation, and the future of work: Ten things to solve for*. McKinsey & Company. https://www.mckinsey.com/featured-insights/future-of-work/ai-automation-and-the-future-of-work-ten-things-to-solve-for

Martínez, B. H., & Herrero, P. D. (2010). Autonomous navigation of an automated guided vehicle in industrial environments. *Robotics and Computer-Integrated Manufacturing*, *26*(4), 296–311. https://doi.org/10.1016/j.rcim.2009.10.003

McCombes, S. (2021). *How to create a research design*. Scribbr; Scribbr. https://www.scribbr.com/methodology/research-design/

Meidutė-Kavaliauskienė, I., Aranskis, A., & Litvinenko, M. (2014). Consumer Satisfaction with the Quality of Logistics Services. *Procedia - Social and Behavioral Sciences*, *110*, 330–340. Science Direct. https://doi.org/10.1016/j.sbspro.2013.12.877

Mokhtar, S. S. M., Ramli, M. S. A., Abdul-Rashid, H. A., & Jaafar, H. I. (2022). Robots in the Malaysian manufacturing industry: Current status, trends, and future prospects. Robotics and Computer-Integrated Manufacturing, 74, 102184. Retrieved from https://www-sciencedirect-com.ezproxy.uthm.edu.my/science/article/pii/S0278612522001649?ref=cra_js_challenge&fr=RR-1

Nair, V. V., Kuhn, D., & Hummel, V. (2019). Development of an easy teaching and simulation solution for an autonomous mobile robot system. *Procedia Manufacturing*, *31*, 270–276. Science Direct. https://doi.org/10.1016/j.promfg.2019.03.043

Naji, G. M. A., Isha, A. S. N., Mohyaldinn, M. E., Leka, S., Saleem, M. S., Rahman, S. M. N. B. S. A., & Alzoraiki, M. (2021). Impact of Safety Culture on Safety Performance; Mediating Role of Psychosocial Hazard: An Integrated Modelling Approach. *International Journal of Environmental Research and Public Health*, *18*(16), 8568. https://doi.org/10.3390/ijerph18168568

NewMediaWire. (2023, April 17). *ARM Quantify Gains Popularity for Assisting in the Development of the AI Quantitative Investment Market*. Yahoo Finance. https://finance.yahoo.com/news/arm-quantify-gains-popularity-assisting-143504385.html

Oitzman, M. (2021, August 6). What's the difference between an AMR and an AGV? Mobile Robot Guide. https://mobilerobotguide.com/2021/08/06/whats-the-difference-between-an-amr-and-an-agv/

Oliff H., Liu Y., Kumar M., Williams M., Ryan M. (2020). Reinforcement learning for facilitating human-robot-interaction in manufacturing. Journal of Manufacturing Systems, 56(June), 326–340. https://doi.org/10.1016/j.jmsy.2020.06.018

Omotayo, A., & Melan, M. (2017). Factors Influencing the Information and Communication Technology (ICT) of Third Party Logistics in Malaysia. *Int. J Sup. Chain. Mgt*, *6*(2). https://ijis-scm.bsne.ch/ojs.excelingtech.co.uk/index.php/IJSCM/article/download/1788/1788-5685-1-PB.pdf

P&S Intelligence . (2023, January). *Autonomous Mobile Robots Market Size & Share Forecast, 2030*. Prescient&Stategic Intelligence. https://www.psmarketresearch.com/market-analysis/autonomous-mobile-robots-market

Panigrahi, P. K., & Bisoy, S. K. (2021). Localization strategies for autonomous mobile robots: A review. *Journal of King Saud University - Computer and Information Sciences*. https://doi.org/10.1016/j.jksuci.2021.02.015

Pasparakis, A., De Vries, J., & De Koster, R. (2023). Assessing the impact of human–robot collaborative order picking systems on warehouse workers. *International Journal of Production Research*, 1–15. https://doi.org/10.1080/00207543.2023.2183343

Paul. (2022, April 8). *Augmenting the Workforce with Autonomous Mobile Robots*. Supply Chain Asia. https://supplychainasia.org/augmenting-the-workforce-with-autonomous-mobile-robots/

Potluri, S., Mohanty, S. N., Mohammad, G. B., & Shitharth, S. (2022). Cloud Analytics for Industry 4.0. In *Google Books*. Walter de Gruyter GmbH & Co KG. https://books.google.com.my/books?hl=en&lr=&id=wISIEAAAQBAJ&oi=fnd&pg=PA121&ots=WOemATLcAc&sig=hIqbIW1LSCzDYk2T31YSqqjQFf8#v=onepage&q&f=false

Project Management Office. (2019). *National Transport Policy 2019-2030*. Kementerian Pengangkutan Malaysia. https://www.pmo.gov.my/wp-content/uploads/2019/10/National-Transport-Policy-2019_2030EN.pdf

Qian, J., Zi, B., Wang, D., Ma, Y., & Zhang, D. (2017). The Design and Development of an Omni-Directional Mobile Robot Oriented to an Intelligent Manufacturing System. *Sensors*, *17*(9), 2073. https://doi.org/10.3390/s17092073

Raza, Z., Woxenius, J., Vural, C. A., & Lind, M. (2023). Digital transformation of maritime logistics: Exploring trends in the liner shipping segment. *Computers in Industry*, *145*, 103811. https://doi.org/10.1016/j.compind.2022.103811

Real time network. (2023, October 24). *Industry 4.0: The Essential Role of Industrial Automation*. Www.linkedin.com. https://www.linkedin.com/pulse/industry-40-essential-role-industrial-automation-real-time-networks-d3foe

RECOTVET. (2019, September 3). *MALAYSIA INDUSTRY4WRD POLICY*. Sea-Vet. https://sea-vet.net/initiatives/571-industry4ward-policy

Reynolds, J. (2023, September 26). *Revolutionizing Warehouse Automation with AMRs | Future of Logistics*. InVia Robotics. https://inviarobotics.com/blog/revolutionizing-warehouse-automation-with-autonomous-mobile-robots-amrs/

Rhydderch, A. (2017, June). *(PDF) Scenario Building: the 2x2 Matrix Technique*. ResearchGate. https://www.researchgate.net/publication/331564544_Scenario_Building_The_2x2_Matrix_Technique

Robotnik. (2021, August 11). What is an autonomous mobile robot (AMR). https://robotnik.eu/what-is-an-autonomous-mobile-robot-amr-what-robotnik-arm-brings-to-your-business/

Rvj. (2022, December 29). *Manufacturing Challenges: How can You Overcome Them?* Deskera Blog. https://www.deskera.com/blog/manufacturing-challenges/

Safety line. (2023, July 30). *Does Safety Create a Productive and Safe Work Environment?* SafetyLine Lone Worker | Leaders in Work Alone Safety Monitoring. https://safetylineloneworker.com/blog/is-safety-productive#:~:text=Safe%20employees%20are%20happier%20and%20engaged%20in%20their%20work&text=With%20safeguards%20in%20place%2C%20employees

Schlechtriem, M. (2021, May 10). *A Guide to Warehouse Robots by Application*. Meili Robots. https://www.meilirobots.com/resources-list/robot-guide

SCM reviews. (2020, August 10). *Trade-offs in Supply Chain Management: The impact of Covid-19*. Www.scmr.com. https://www.scmr.com/article/trade_offs_in_supply_chain_management_the_impact_of_covid_19

Seegrid. (2023, July 20). *Autonomous Mobile Robots (AMRs): Leading the Charge for Efficient and Flexible Work*. Hub.seegrid.com. https://hub.seegrid.com/blog/autonomous-mobile-robots-amrs-leading-the-charge-for-efficient-and-flexible-work

Sense More. (2023, December 25). *The Key Factors Impacting ROI in Predictive Maintenance*. Google.com. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiZneCP7biDAxW8T2wGHbA-BmEQFnoECA4QAQ&url=https%3A%2F%2Fsensemore.io%2Fthe-key-factors-impacting-roi-in-predictive-maintenance%2F&usg=AOvVaw2bQ_OJJEw-61_sP6p16P_e&opi=89978449

Sohail, M. S., & Sohal, A. S. (2003). The use of third party logistics services: a Malaysian perspective. *Technovation*, *23*(5), 401–408. Academic.edu. https://doi.org/10.1016/s0166-4972(02)00003-2

Soltanov, M. (2023). *Investigating the Effectiveness of Natural Language Interfaces for Human-Robot Interaction*. Research Gate. https://doi.org/10.13140/RG.2.2.24329.31840

Soori, M., Arezoo, B., & Dastres, R. (2023). Artificial Intelligence, Machine Learning and Deep Learning in Advanced Robotics, A Review. *Cognitive Robotics*, *3*. Science Direct. https://doi.org/10.1016/j.cogr.2023.04.001

Spherical Insights. (2023, May). *Global Autonomous Mobile Robot Market Size, Forecast – 2032.* Spherical Insights. https://www.sphericalinsights.com/reports/autonomous-mobile-robot-market

Srinivasan, A., & Kurey, B. (2014, April). *Creating a culture of quality*. Harvard Business Review. https://hbr.org/2014/04/creating-a-culture-of-quality

Stucki, M. (2023, September). *2x2 Scenario Planning Matrix: A Step-by-Step Guide*. Futures Platform. https://www.futuresplatform.com/blog/2x2-scenario-planning-matrix-guideline

Taber, K. S. (2017). The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Research in Science Education*, *48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Taherdoost, H. (2016). Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research. *SSRN Electronic Journal*, *5*(2), 18–27. https://hal.science/hal-02546796/file/Sampling%20Method%20in%20Research%20Methodology;%20How%20to%20Choose%20a%20Sampling%20Technique%20for%20Research.pdf

Tamers, S. L., Streit, J., Pana-Cryan, R., Ray, T., Syron, L., Flynn, M. A., Castillo, D., Roth, G., Geraci, C., Guerin, R., Schulte, P., Henn, S., Chang, C., Felknor, S., & Howard, J. (2020). Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *American Journal of Industrial Medicine*, *63*(12), 1065–1084. https://doi.org/10.1002/ajim.23183

Tek, H. (2022, November 10). *Types of Autonomous Robots and Their Superior Functions (2022)*. Hy-Tek Intralogistic. https://hy-tek.com/resources/types-of-autonomous-robots/

The Council of Supply Chain Management Professionals. (2023). *SCM Definitions and Glossary of Terms*. Cscmp.org. https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx#:~:text=Logistics%20management%20is%20that%20part

Thompson, A. (1984, January). *Strategies for Staying Cost Competitive*. Harvard Business Review. https://hbr.org/1984/01/strategies-for-staying-cost-competitive

TiAMR, R. (2020, May 15). *What are the technological challenges affecting the advancement of mobile robotics?* Medium. https://medium.com/@robosera.info/what-are-the-technological-challenges-affecting-the-advancement-of-mobile-robotics-846909ff1ba0

Tipping, A., & Peter, K. (2016). Shifting patterns: The future of the logistics industry. In *PWC*. https://www.pwc.com/gx/en/transportation-logistics/pdf/the-future-of-the-logistics-industry.pdf

Tomohiro Umetani, Kondo, Y., & Tokuda, T. (2020). *Rapid Development of a Mobile Robot for the Nakanoshima Challenge Using a Robot for Intelligent Environments*. *32*(6), 1211–1218. Department of Intelligence and Informatics, Konan University. https://doi.org/10.20965/jrm.2020.p1211

University of Texas Arlington. (2023, March 15). *Subject and Course Guides: Quantitative and Qualitative Research: Understand What Quantitative Research Is*. Uta.edu. https://libguides.uta.edu/quantitative_and_qualitative_research/quant

Varshney, N. (2023, May 24). *Warehouse Automation: An Essential Imperative*. Apparel Resources. https://apparelresources.com/technology-news/manufacturing-tech/warehouse-automation-essential-imperative/

Viu-Roig, M., & Alvarez-Palau, E. J. (2020). The I mpact of E-Commerce-Related Last-Mile Logistics on Cities: A Systematic Literature Review. *Sustainability*, *12*(16), 6492. Research Gate. https://doi.org/10.3390/su12166492

Voros, J. (2003). A generic foresight process framework. *Foresight*, *5*(3), 10–21. https://doi.org/10.1108/14636680310698379

Wahab, S. N., Bahar, N., & Radzi, N. A. M. (2021). An inquiry on knowledge management in third-party logistics companies. *International Journal of Business Innovation and Research*, *24*(1), 124. https://doi.org/10.1504/ijbir.2021.111977

Wang, C. J., & Du, D. D. (2016). *Research on logistics autonomous mobile robot system*. 275–280. IEEE International Conference on Mechatronics and Automation, Harbin, China. https://doi.org/10.1109/ICMA.2016.7558574.

Wang, C., Tok, Y. C., Poolat, R., Chattopadhyay, S., & Elara, M. R. (2020). How to secure autonomous mobile robots? An approach with fuzzing, detection and mitigation. *Journal of Systems Architecture*, 101838. https://doi.org/10.1016/j.sysarc.2020.101838

Wijemanne, N. (2022, February 6). *How Autonomous Mobile Robots Can Solve Global E-Commerce Fulfillment Problems*. Robotics 24/7. https://www.robotics247.com/article/how_autonomous_mobile_robots_can_solve_global_ecommerce_fulfillment_problems#:~:text=Mobile%20robots%20are%20revolutionizing%20manufacturing

World Economic Forum. (2023). *The Global Risks Report 2023 18th Edition*. https://www3.weforum.org/docs/WEF_Global_Risks_Report_2023.pdf

Wu, J., Huang, Z., Guan, Y., Cai, C., Wang, Q., Xiao, Z., Zheng, Z., Zhang, H., & Zhang, X. (2011). *An intelligent environmental monitoring system based on autonomous mobile robot*. 138–143. https://doi.org/10.1109/ROBIO.2011.6181275

Yang, F., & Gu, S. (2021). Industry 4.0, a revolution that requires technology and national strategies. *Complex & Intelligent Systems*, *7*(7). Springer. https://doi.org/10.1007/s40747-020-00267-9

Yapp, E. (2020, March 16). *Malaysia's digital transformation efforts progress*. ComputerWeekly.com. https://www.computerweekly.com/feature/Malaysias-digital-transformation-efforts-progress-amid-challenges

Yazar, K. (2023, May 10). *What is a Collaborative Robot (Cobot)? | Definition from TechTarget*. WhatIs.com. https://www.techtarget.com/whatis/definition/collaborative-robot-cobot#:~:text=Yasar%2C%20Technical%20Writer-

Zhang, J., Yang, X., Wang, W., Guan, J., Ding, L., & Vincent C.S. Lee. (2023). Automated guided vehicles and autonomous mobile robots for recognition and tracking in civil engineering. *Automation in Construction*, *146*, 104699. https://doi.org/10.1016/j.autcon.2022.104699

Zohrabi, M. (2013). *Theory and Practice in Language Studies* (pp. 2–4). ACADEMY PUBLISHER. https://www.academypublication.com/issues/past/tpls/vol03/02/tpls0302.pdf#