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A Foresight Study on Automated Storage and Retrieval Systems in Warehouse Automation in Johor

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Abstract

With the rapid development of science and technology, many industries have begun to use automation technology and adopt intelligence to improve operational efficiency and reduce workplace accidents. Warehouse management systems have entered a new era, where automated storage and retrieval systems (ASRS) play a crucial role in warehouse automation. This advanced system utilizes the latest automation technologies to transform traditional warehouse management, enabling intelligent processing and efficient operations. As enterprises demand more intelligent warehouse solutions, ASRS is becoming increasingly important. However, there is limited research on ASRS implementation in Johor. This study aims to determine the trends, challenges, and key driving factors of ASRS in warehouse automation in Johor, Malaysia. It explores the future landscape of ASRS adoption by engaging key stakeholders in the Johor warehouse industry. Both quantitative and qualitative research methods were used, with data collection through surveys and analysis using the Statistical Package for the Social Sciences (SPSS). The STEEPV framework was applied to identify the significant drivers influencing ASRS development. The findings provide insights into the critical factors shaping ASRS adoption in Johor, highlighting opportunities and challenges for businesses. This study contributes to understanding how ASRS can enhance warehouse automation and offers recommendations for future improvements.

1. Introduction

Warehouse automation involves using technology, such as software systems, autonomous mobile robots, and data-capturing methods, to streamline and control inventory movement and organization. The goal is to reduce human involvement, optimizing efficiency, movement, dependability, and precision while minimizing labor-intensive tasks, human errors, and potential worker injuries (Turner *et al.*, 2020). Automation enhances modern logistics by improving efficiency, accuracy, and security. Tasks like inventory management, order picking, packaging, and transportation are automated using software systems, robots, and data capture tools, resulting in real-time tracking of goods, optimized storage space, and improved productivity and workplace safety (Surgeredev, 2023). Automation reduces errors, saves costs, and enhances work safety, allowing employees to focus on more valuable activities and promoting sustainable development (Johnson, 2024). Historically, warehouse management was manual, with workers using pen and paper to track inventory. The introduction of barcodes allowed for accurate inventory tracking and faster data input. RFID technology further revolutionized management by enabling real-time inventory tracking without line-of-sight requirements (Vecna Robotics, 2023; Higginbothem, 2023). Warehouse Management Systems (WMS) simplified operations by integrating inventory tracking, order execution, and picking optimization with barcode and RFID technologies (Erp, 2024). Advanced analytics and AI algorithms now optimize operations, forecast demand, and efficiently allocate resources, with AI-powered vision systems used for quality control and inventory tracking (Vecna Robotics, 2023). Automated Storage and Retrieval Systems (AS/RS) are increasingly used in logistics to improve customer experience, streamline processes, reduce costs, and enhance efficiency. These systems optimize warehouse operations, improve supply chain efficiency, and provide competitive advantages by eliminating manual labor, reducing errors, and maximizing storage capacity. Despite their benefits, these systems pose challenges that need addressing. A prospective study focuses on identifying and solving these problems in Johor's warehouses, emphasizing the importance of well- designed, user-centered AS/RS in warehouse innovation (Romaine, 2023; Christina Dube, 2024).

Warehouse automation, integrating advanced technologies like robotics, artificial intelligence (AI), and the Internet of Things (IoT), have transformed logistics operations by enhancing efficiency, accuracy, and productivity. Automated systems can perform repetitive tasks faster and more accurately than manual labor, reducing errors in picking, packaging, and sorting, and allowing for uninterrupted, round-the-clock operations. This improvement in efficiency boosts productivity, shortens turnaround times, and enhances order accuracy, leading to increased customer satisfaction and competitive advantages for businesses (Fatima *et al*., 2022; Ridolfi *et al*., 2019; Scullin, 2024). Cost reduction is another significant benefit of warehouse automation. By minimizing reliance on manual labor and optimizing space and energy utilization, automated warehouses can achieve substantial long-term savings despite the high initial investment. Automation reduces labor costs and mitigates the impact of labor shortages, while efficient inventory management through automation systems decreases waste and unnecessary expenses, contributing to overall cost efficiency (Armenta, 2021).

Automation also enhances workplace safety by reducing the risk of injuries. Machines take over dangerous tasks, minimizing the need for workers to operate in hazardous environments. Automated systems do not suffer from fatigue or distractions, reducing the likelihood of accidents. Additionally, advanced safety monitoring equipment in automated warehouses can detect and prevent potential hazards, further improving safety standards (Warehouse Automation, 2023).

Automated Storage and Retrieval Systems (AS/RS) significantly improve inventory management by providing real-time data on inventory levels, locations, and movements. This real- time data helps control inventory more effectively, reducing the chances of shortages or surpluses. By generating extensive data for analysis, AS/RS systems optimize inventory levels, enhance decision- making, and improve supply chain responsiveness. Accurate inventory management leads to timely order deliveries, reducing delays and cancellations, and ultimately improving customer satisfaction and operational efficiency (Bricz, 2022; Wikipedia contributors, 2024).

However, implementing warehouse automation presents challenges. The high initial investment required for automation systems can strain capital, especially for small and medium-sized enterprises. Technical complexity, including system integration, maintenance, and the need for skilled personnel, poses significant hurdles. Automation's impact on labor, including job reductions and the need for retraining, can lead to resistance from employees and unions. Additionally, security concerns, such as vulnerability to cyberattacks and data privacy issues, require robust measures to protect against threats. Overdependence on technology necessitates strong technical support and contingency plans to handle system failures and ensure continuity of operations (HWARobotics, 2024; Callier, 2024; Bricspac, 2024; Prime Robotics, 2023). Therefore, to achieve the research objectives, the trends, issues, and challenges of Automated Storage and Retrieval Systems in Johor are identified. Consequently, the key drivers of Automated Storage and Retrieval Systems in Johor are determined, and the future image of Automated Storage and Retrieval Systems in Johor is studied.

2. Literature Review

2.1 Warehouse Automation

Warehouse automation is the use of automated methods and modern technology to optimize workflow and improve productivity in warehouse settings. It aims to increase efficiency, reduce errors, and enhance customer satisfaction. Warehouse automation involves automating inventory movement into, within, and out of warehouses with minimal human intervention. This process eliminates labor- intensive tasks like repetitive physical work and manual data entry. Some associate warehouse automation with software, while others associate it with automated storage and retrieval systems (AS/RS). Complete warehouse automation involves automating various parts of the process, including software systems, data collection, storage, and retrieval.

2.2 Automated Storage and Retrieval System

Automated Storage and Retrieval Systems (ASRS) are commonly used in manufacturing and distribution centers to increase floor space, security, and output. These systems combine digital, robotic, and racking components to create customized warehouses that can handle a variety of products. The Warehouse Management System (WMS) oversees these systems, and they can accommodate warehouses of any size or number of locations. Options include Cube Storage, Autonomous Mobile Robots (AMRs), shuttles, cranes, elevators, vertical lift modules (VLMs), micro-, unit-, and mini-loads. The AS/RS system has no size restrictions and can accommodate warehouses of any size or number of locations. It is particularly popular in warehouses handling large volumes of cargo, where storage density is crucial due to space constraints or expense, and where items are not processed or changed.

2.3 Importance

Automated storage and retrieval systems significantly impact warehouse automation by maximizing vertical and horizontal space utilization and reducing the required warehouse area. These systems efficiently organize inventory on compact, easy-to-access shelves, allowing for optimal storage in smaller spaces. Automated warehouses also improve efficiency by reducing the time needed to find and retrieve items, speeding up operations, and improving accuracy. By replacing human labor with automatic machinery, the warehouse process becomes faster and simpler, leading to faster order fulfillment and better customer service. Automated warehouses also improve accuracy by minimizing human errors, resulting in more reliable inventory management and reducing the possibility of errors affecting warehouse operation and customer satisfaction. The implementation of automated warehouses also saves labor by reducing the demand for labor and freeing employees from heavy, tedious work. This allows them to focus on more complex and value-added activities in the warehouse. Security is another important advantage of implementing automated warehouses. By reducing the need for manual handling and lifting heavy objects, the risk of injury for employees is significantly reduced, ensuring a safe and efficient movement of goods and creating a safer working environment for employees. Overall, automated warehouse systems have the potential to significantly impact warehouse automation and its future.

2.4 Challenge

Warehouse automation is the use of automated methods and modern technology to optimize workflow and improve productivity in warehouse settings. It aims to increase efficiency, reduce errors, and enhance customer satisfaction. Warehouse automation involves automating inventory movement Automated Challenge of Automated Storage and Retrieval System. The implementation of Automatic Storage and Retrieval System (AS/RS) in a warehouse presents several challenges, including high initial investment, system complexity, integration with existing systems, maintenance requirements, adaptability to changes, and potential downtime.

The initial investment is significant, as it requires the purchase and installation of necessary facilities and equipment, such as shelves, retrieval machines, conveyors, and control systems. These upfront costs may be a significant obstacle for small enterprises or those with limited funds. Integration with existing systems is another challenge, as automated warehouse systems rely on complex hardware and software components. This can lead to compatibility issues, necessitating customized development and extensive testing before integrating ASRS with other business processes. This integration process can be time-consuming and may require major changes to workflow and itinerary. Regular maintenance is essential for the performance and prevention of failures, including routine inspections, software updates, and maintenance. Professional maintenance personnel or external service contracts are required, which can increase ongoing operating costs. Maintenance-related downtime can disrupt operations and affect productivity. Technical problems and failures are common in automated warehouse systems, leading to disruptions in operations, delayed order fulfillment, and potential revenue losses. Therefore, a sound emergency plan and backup system are crucial to maintain efficiency and reliability. Lastly, the adaptability of automated warehouses to business needs or changes in warehouse operation is another challenge. Once ASRS is installed, these systems are less flexible than manual systems, making it expensive to modify the existing automated warehouse to accommodate these changes.

2.5 STEEPV Analysis

By utilizing STEEPV analysis, the issues, challenges, trends and driver that influence the adoption of AI based smart shopping cart will be identified. Various sources, including journals, government articles, the internet, and non-governmental organizations, have identified changes and trends in AI and categorizing them as social, technological, environmental, economic, political, and value. STEEPV analysis and horizon scanning are used in this foresight study. A total of 72 issues and drivers have been identified and are being grouped into the six categories mentioned above.

Table 1 *Frequency of each category*

Factors	Frequency
Social	16
Technological	22
Environment	7
Economic	11
Political	4
Values	12
Total	72

The researcher has identified and concluded that a total number of 10 drivers after merging of 72 issues, challenges, and trends as the factors of the adoption of automated storage and retrieval system in automation warehouse in Table 2 below.

Table 2 *Key drivers extracted from STEEPV analysis*

No	Issues, Challenges and Trends	Drivers
1.	Incorporating accessibility features in Automated Storage and Retrieval Systems (ASRS) such as screen readers, voice commands, and tactile interfaces ensures that users with disabilities can interact with the system effectively, promoting equitable access and usability.	Digital Inclusion
2.	ASRS must address data privacy concerns through robust security measures and strict privacy policies. Implementing strong encryption, secure authentication, and obtaining customer consent for data usage are essential to protect sensitive information	Security Concerns
3.	Adopting ASRS offers businesses significant operational efficiencies by automating inventory management, reducing manual labor, minimizing errors, and speeding up the retrieval process. This leads to streamlined operations, cost savings, and increased productivity.	Operational Efficiency
4.	ASRS systems should provide clear information and real-time updates to users about their stored items, ensuring transparency and building trust. Effective communication about system operations and data handling practices reassures users that their concerns and preferences are valued.	Trust and Transparency
5.	With the rise of ASRS, it is crucial for governance frameworks to ensure the secure and ethical use of these technologies. Regulations should mandate the implementation of safety standards, data protection measures, and equitable access to ASRS for all users.	Governance Intervention
6.	Empowering users to customize their interaction with ASRS, such as setting preferences for notifications and retrieval methods, enhances their control over the process. Providing comprehensive information about how their data is managed increases consumer awareness and confidence.	Consumer Empowerment and Awareness
7.	The integration of ASRS requires workforce upskilling to manage and maintain these systems. Offering training programs for employees helps them acquire new skills, ensuring their job security and improving their employability in a technology-driven environment.	Workforce Consideration
8.	ASRS integrated with the Internet of Things (IoT) enables a connected and efficient storage environment. IoT integration allows for real-time monitoring, predictive maintenance, and seamless interaction between ASRS and other smart devices, enhancing overall system capability.	Technology Capability
9.	ASRS should be designed to support a diverse range of users and applications. This includes multilingual interfaces, customizable settings, and adaptable configurations to meet various operational requirements and cultural preferences.	Diversity and Inclusion
10.	Combining traditional manual storage methods with modern ASRS technology offers users flexibility. Businesses can cater to customers who prefer conventional methods while providing the benefits of automation to those seeking efficiency and speed, creating a balanced service model.	Traditional-Modern Fusion

3. Research Methodology

3.1 Research Design

The research design outlines the scheme of data collection and evaluation, focusing on descriptive research. Quantitative questionnaires were selected for data collection, which were analyzed and developed by STEEPV to determine the relevant driving factors of automatic storage and retrieval system in Johor automated warehouse. Questionnaires are distributed to potential respondents, who are the stakeholders of these systems. A preliminary test was carried out to verify the reliability and effectiveness of the instrument. Data were collected and analyzed by SPSS. The research design and implementation, including structured questionnaire, STEEPV analysis and scenario development, are closely related to the research objectives, ensuring effective identification of trends, problems, challenges, key drivers and future forecasts of the automatic storage and retrieval system in Johor automated warehouse.

3.2 Scope of the Study

This research focuses on the Automatic Storage and Retrieval System (AS/RS) industry in Johor, Malaysia, targeting stakeholders within the logistics sector. Respondents include workers with exposure to AS/RS systems and enterprises that have implemented them. Johor, a significant industrial hub with thriving sectors such as manufacturing, logistics, and electronics, was chosen as the research scope. The FMM College, established in Johor, provides comprehensive training for individuals across various industries. The college's Johor Branch offers practical enterprise courses, including "Effective Warehouse and Inventory Management," catering to the needs of the manufacturing and service sectors. The aim is to develop people's potential and skills at all levels. The study also focuses on aiding logistics enterprises in understanding future trends, benefits, and challenges of AS/RS, and identifying the main driving factors of automated storage and retrieval systems. By equipping logistics enterprises with a comprehensive understanding of the industry's future, particularly regarding automated warehouses, the study aims to enable the sector to leverage automation advantages. To assess the acceptance of automated warehouse systems, a questionnaire will be developed and distributed among Malaysians. The questionnaire is designed to ensure study validity. Respondents will be asked to fill out a Google Form survey based on random sampling to investigate the acceptance of automated warehouse implementation. The study aims to understand the acceptance of AS/RS by Johor warehouses in Malaysia and its impact on various industries. By employing questionnaires and Google Forms, the research seeks to gather valuable insights into the adoption of automatic three-dimensional warehouses in Johor.

3.3 Research Flow Chat

Fig. 1 shows the research flow for this study. There are three objectives that researchers need to achieve. This research used STEEPV analysis.

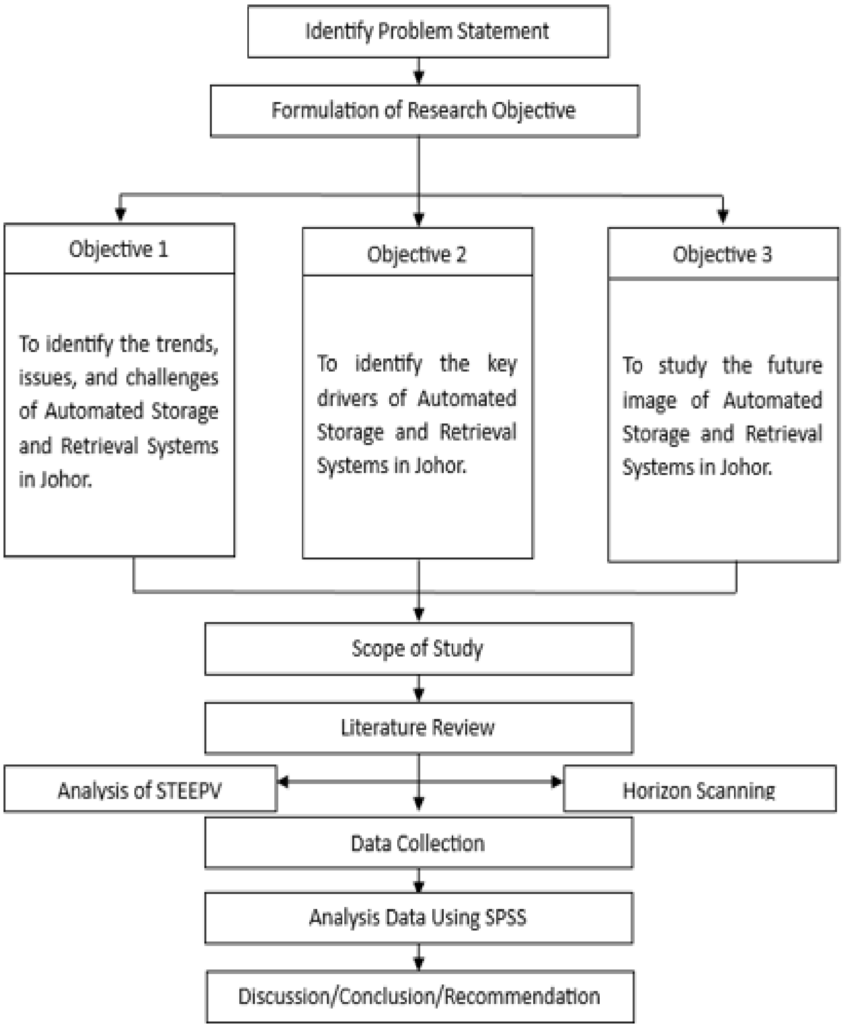

Fig. 1 *Research flowchart*

3.4 Foresight Process

Foresight process can be defined as systematic, participatory, future information collection and medium-and long-term scenario planning, so as to provide information for current decision-making and mobilize cooperative action. Fundamentally speaking, the forward-looking process includes prioritizing future priorities and using long-term thinking (the next 10 years) to support strategic decisions. Foresight process consists of several stages, first, horizontal scanning, data analysis by using STEEPV method, and finally, identifying the driving factors of automatic storage and retrieval system in Johor automatic warehouse.

3.5 Horizon Scanning

The goal of horizon scanning is to forecast Johor's employment during the ensuing 10 years (2024-2034). According to Grabtchak (2022), horizon scanning is a strategy to recognize early-stage indications of potentially important advancement through systematic testing on specific risk, threats, limitations, opportunities, and future advances. The approach focuses on the latest technology and its influence. The horizon scanning approaches also rely on desk research from a variety of sources, including the internet, journals, government and non-government resources, and research groups. The major goals are to identify persistent, changing, and unforeseen issues.

3.6 STEEPV Method

STEEPV analysis method is based on second-hand data. Previously collected research information can be used as second-hand information. It is different from the original data because the original data is information collected directly from the data source. The information used in this study is intended as a guide and reference point for conducting research. Journals and website articles are used in the secondary data collection of this study to learn more about the power behind the automatic storage and retrieval system in Johor automated warehouse.

3.7 Research Population and Sample

In order to make sure that the results of the study are accurate, trustworthy, and relevant to a larger population of interest, researchers must carefully identify their research population and use the most appropriate sampling procedure. According to the Department of Statistics Malaysia (DOSM), the estimated population of Johor is more than 4,000,000 by 2023. Krejcie & Morgan (1970) stated that the sample size of 384 is sufficient for a population that is 1,000,000 or more. In this case, the respondents will be selected using convenient sampling method and will involve 384 respondents.

Table 3 *Determining sample size method Krejcie and Morgan (1970)*

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size. *S* is sample size.

Source: Krejcie & Morgan, 1970

3.8 Sampling Method

According to Lindquist (1940), sampling is the process of selecting a representative sample from a population to determine its measurements and attributes. Sampling is the selection and matching of population units. Convenience sampling is a non-probability sampling technique in which units are chosen based on their convenience of access, such as geographic proximity or willingness to participate. The researcher chooses purposive sampling method to gather the quantitative data for this research.

3.9 Research Instrument

This study uses a questionnaire as a research instrument to gather, measure, and analyze data. The questionnaire consists of four sections: Section A, which measures demographic background, Section B, which explores the importance of factors and drivers towards automated storage and retrieval systems in selected warehouses in Johor, and Section C, which examines the impact of these factors and drivers. The Likert scale, a five-point rating scale, is used to measure respondents' decisions. Section D, on the other hand, examines the uncertainty of these factors and drivers. The questionnaire is structured in four sections, with each section measuring respondents' demographic background, factors and drivers, and their decision-making process. The Likert scale is designed to provide multiple response categories, allowing for a comprehensive understanding of the study's findings.

3.10 Data Collection

The systematic process of compiling information from observation or measurement can be called data collection (Bhandari, 2020). In order to test the prospective research on the automatic storage and retrieval system in the automatic warehouse selected by Johor, the original data and secondary data were used in the research. In the qualitative part of the research, researchers must collect second-hand information closely related to the research problem in order to achieve the research goal.

3.11 Primary Data

The original data were collected by using the questionnaire designed according to the analysis results of STEEPV. SPSS software will be used for analyzing data collection and will be used for impact-uncertainty analysis, as well as promoting the creation of scenarios to achieve the goal of this study, that is, a prospective study of the automatic storage and retrieval system in Johor automated warehouse.

3.12 Secondary Data

Any data set that has been compiled by a party other than the one that will be using it is referred to as secondary data. Secondary data sources let academics and data analysts create significant, high-quality databases that aid in issue solving (Hillier, 2022). Websites, journal articles, government documents, books, internal records, online databases, and other materials are used as secondary data sources. For researchers who are short on time and funding, using existing data offers a useful alternative. In this research, secondary data was used in order to identify issues and drivers that related to automated storage and retrieval systems in automation warehouses in Johor.

3.13 Data Analysis

Data analysis is a process of modifying, analyzing and cleaning up original data in order to obtain useful and relevant information to support enterprise decision-making (Kelley, K., 2023). By providing profound information and data, which are often displayed in charts, graphs, tables and graphs, this technology helps to reduce the risks related to decision-making. This study will use SPSS and basic regression analysis to evaluate the collected data.

3.14 Pilot Study

The purpose of the pilot study is to evaluate the feasibility of an expected comprehensive project before any large-scale quantitative study is carried out. Pilot studies are usually carried out in the population as similar as possible to the population under study rather than in the population that constitutes the final sample, in order to prevent prejudice (Simkus, 2023). Any mistakes found in the pilot test will be corrected. Until there are no errors and no adjustment is needed.

4. Data Analysis and Findings

4.1 Survey Return Rate

The study required a total of 384 respondents, and the questionnaires were distributed through WhatsApp and Telegram, face-to-face invitations and social media platforms. Table 4 below shows that 353 responses were collected from 384 samples, indicating that the response rate of this study reached 91.93%. The survey response rate is summarized in Table 4 as follows:

Table 4 *Survey return rate*

Population	Sample Size	Questionnaire Distribute	Questionnaire Returned	Percentage
4,000,000	1,000,000	384	353	91.93%

4.2 Reliability Test

Table 5 above shows that Cronbach's alpha is mainly used to evaluate internal consistency because it is suitable for three, four or five Likert scale items. Cronbach's alpha value is relatively easy to calculate, ranging from 0 to 1, indicating that the internal consistency is poor to very high. The above table shows that Cronbach's alpha coefficient exceeding 0.6 is necessary to evaluate the consistency between projects to measure a particular idea. If the value is lower than 0.6, it is likely that the formulated question is unclear and repetitive. Therefore, in order to ensure the reliability of the instrument, the issue must be reformulated or deleted.

Table 5: *Reliability coefficient value*

Cronbach's Alpha (α)	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 \geq \alpha \geq 0.8$	Good
$0.8 \geq \geq \alpha \geq 0.7$	Acceptable
$0.7 \geq \alpha \geq 0.6$	Questionable

0.6 ≥ α ≥ 0.5	Poor

4.3 Reliability in Pilot Study and Actual Study

At the beginning of the study, a pre-test was applied to evaluate the reliability of the problem; A total of 30 respondents participated in the pilot test. According to Table 6, Cronbach's α value is determined to be 0.965, and there are 30 respondents, which shows that the question has excellent internal consistency, indicating the reliability of the research and the potential for further research. In the real research, Cronbach's Alpha value dropped slightly to 0.957, with 353 responses, but it still remained in the excellent classification, indicating that the research is good and highly reliable.

Table 6 *Reliability test for pilot study and actual study*

	Cronbach's Alpha	Number of Items	Number of Respondents
Pilot Test	0.965	30	30
Real Study	0.957	30	353

4.4 Pilot Test Result

There are a total of 30 participants in this study, employed to test the pilot. The data results were presented in the form of Cronbach's Alpha values once the pilot test was completed. The Cronbach's Alpha value was determined using SPSS software. Table 7 showed Cronbach's Alpha value for the pilot test data in this study. The Cronbach's Alpha value for Level of Importance is 0.905, Level of Impact is 0.956, and Level of uncertainty is 0.969. The Cronbach's Alpha value for three Level was excellent because the Cronbach's Alpha Value for three Level was more than 0.9. Therefore, due to the Cronbach's Alpha value of 0.966 for the overall measure, three of the factors can be classified as excellent and highly reliable.

Table 7 *Reliability test for pilot study*

Factors	Cronbach's Alpha
Level of Importance	0.905
Level of Impact	0.956
Level of Uncertainty	0.969
Overall	0.965

4.5 Actual Study Result

A reliability analysis of the actual study has also been carried out. Table 8 showed Cronbach's Alpha value for the actual study data in this study. The Cronbach's Alpha value for Level of Importance is 0.876, Level of Impact is 0.880, and Level of uncertainty is 0.876. The Cronbach's Alpha value for Level of Importance, Level of Impact and Level of Uncertainty is categories as Good because the Cronbach's Alpha Value is between 0.8 and .09. The Cronbach's Alpha value for overall is 0.957, three of the factors can also be classified as acceptable and good. Hence, this study illustrates a good and high reliability of the variable.

Table 8 *Reliability test for the actual study*

Factors	Cronbach's Alpha
Level of Importance	0.876
Level of Impact	0.880
Level of Uncertainty	0.876
Overall	0.957

4.6 Demographic Analysis

In this section, we analyse and discuss information about the demographic background of customers and employees from the warehousing industry in Johor, Malaysia. The main purpose is to provide a clear background of the interviewee's background, including information related to their age group, gender and race, as well as other information related to the acceptance of warehouse automation technology, operation preference and warehouse management system based on artificial intelligence. Table 9 shows the summary of demographic analysis.

Table 9 *Summary of demographic analysis*

Demographic	Classification	Frequency (N)	Percentage (%)
Gender	Male	183	51.8
	Female	170	48.2
Age	Below 30 years old	79	22.4
	31-40 years old	143	40.5
	41-50 years old	79	22.4
	Above 50 years old	52	14.7
Race	Malay	123	34.8
	Chinese	86	24.4
	Indian	92	26.1
	Others	52	14.7
Position	Owner	8	2.3
	Manager	95	26.9
	Employee	258	70.8
Size of Company	Micro	77	21.8
	Small	168	47.6
	Medium	108	30.6
Years of Operation (years)	Last than 1 year	0	0
	1 – 5	79	22.4
	6 – 10	66	18.7
	11 – 15	156	44.2
	16 – 20	52	14.7
	More than 20	0	0
Utilization of Automated Storage and Retrieval System in Warehouse Automation	Yes	134	38.0
	No	219	62.0
Necessity of Implementing Automated Storage and Retrieval System in Warehouse Automation	Yes	233	66.0
	No	120	34.0
Necessity of Difficulty in Using the Automated Storage and Retrieval System in Warehouse Automation	Yes	225	63.7
	No	128	36.3

4.7 Mean of Drivers on the Level of Importance

The overall mean value of the level of importance for each driver is shown in Table 10 below. The highest mean value in the table is Technology Capability with a mean score of 4.18, indicating that enhancing technological capabilities is crucial for the implementation of Automated Storage and Retrieval Systems (ASRS) in warehouse automation.

Table 10 *Mean of drivers on level of importance in descending order*

No	Drivers	Mean
D8	Technology Capability	4.18
D1	Digital Inclusion	4.15
D9	Diversity and Inclusion	4.11
D4	Trust and Transparency	4.09
D6	Consumer Empowerment and Awareness	4.09
D7	Workforce Consideration	3.93
D5	Governance Intervention	3.92
D10	Traditional-Modern Fusion	3.92
D3	Operational Efficiency	3.89
D2	Security Concerns	3.85

4.8 Mean of Drivers on the Level of Impact

The overall mean value of the level of the effect for each driver is shown in Table 11 below. The highest mean value in the table is Governance Intervention, with a mean score of 4.19, indicating that it has the most significant effect on the implementation of Automated Storage and Retrieval Systems (ASRS) in warehouse automation.

Table 11 *Mean drivers on the level of impact in descending order*

No	Drivers	Mean
D5	Governance Intervention	4.19
D7	Workforce Consideration	4.16
D2	Security Concerns	4.12
D1	Digital Inclusion	4.09
D3	Operational Efficiency	4.05
D8	Technology Capability	4.04
D6	Consumer Empowerment and Awareness	3.97
D4	Trust and Transparency	3.94
D9	Diversity and Inclusion	3.86
D10	Traditional-Modern Fusion	3.84

4.9 Mean of Drivers on Level of Uncertainty

Following the calculation of the mean of the driver on the level of impact, the level of uncertainty is analyzed, and the mean value of each driver is determined. The highest mean value in Table 12 is Governance Intervention with a mean score of 4.19, indicating the highest uncertainty towards the implementation of Automated Storage and Retrieval Systems (ASRS) in warehouse automation.

Table 12 *Mean drivers on level of impact in descending order*

No	Drivers	Mean
D5	Governance Intervention	4.19
D10	Traditional-Modern Fusion	4.13
D4	Trust and Transparency	4.10
D3	Operational Efficiency	4.08
D6	Consumer Empowerment and Awareness	4.05
D8	Technology Capability	3.90
D1	Digital Inclusion	3.89
D7	Workforce Consideration	3.89
D2	Security Concerns	3.88
D9	Diversity and Inclusion	3.88

4.10 Impact-Uncertainty Analysis

Future impact and uncertainty of issues and drivers were being investigated based on mean value in descriptive analysis. Impact refers to the degree of effect by the major drivers towards the future of an area or a subject of concern while uncertainty refers to the level of possibility that related issues and drivers may happen in the future or not. The main purpose of the analysis is to determine the highest outcome in terms of impact and uncertainty. Table 13 shows mean value of leading drivers which is related to future Automated Storage and Retrieval System in Negeri Johor based on its impact and uncertainty. All data was used to construct impact and uncertainty analysis as shown in Fig. 2.

Table 13 *Mean of the leading drivers on the level of impact and uncertainty*

No	Drivers	Impact	Uncertainty
D1	Digital Inclusion	4.09	3.89
D2	Security Concerns	4.12	3.88
D3	Operational Efficiency	4.05	4.08
D4	Trust and Transparency	3.94	4.10
D5	Governance Intervention	4.19	4.19

D6	Consumer Empowerment and Awareness	3.97	4.05
D7	Workforce Consideration	4.16	3.89
D8	Technology Capability	4.04	3.90
D9	Diversity and Inclusion	3.86	3.88
D10	Traditional- Modern Fusion	3.84	4.13

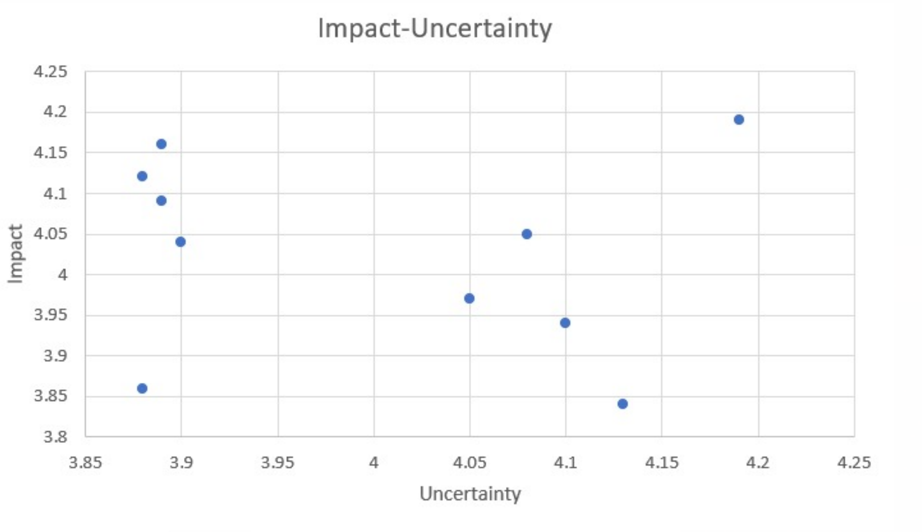

Fig. 2 *Impact-Uncertainty analysis*

5. Conclusion

This research aimed to identify challenges, key drivers, and explore the future image of ASRS in warehouse automation in Johor. With digitalization increasing globally, the study utilized various research methodologies such as foresight, STEEPV analysis, statistical analysis, impact- uncertainty analysis, and scenario building analysis to determine future key drivers and their importance, impact, and uncertainty level. The study found that high traditional-modern fusion and technological capability were crucial drivers for the future of ASRS in warehouses. A strong relationship between these drivers led to a positive forecast scenario of "Operational-Tech Synergy," while weaker relationships resulted in negative scenarios for technology and market development. These scenarios can offer insights for future researchers and organizations to support the growth and optimization of ASRS in warehouse automation.

The first objective of this study is to identify the trends, issues, and challenges of automated storage and retrieval systems in warehouse automation in Johor. This objective was achieved through the STEEPV analysis, which revealed that technological factors are the primary driver, followed by social, values, economic, political, and environmental factors. Understanding these trends, issues, and challenges is crucial for the future implementation and advancement of AS/RS technologies in warehouse automation.

The second objective of this study is to identify the key drivers of Automated Storage and Retrieval Systems (ASRS) in warehouse automation in Negeri Johor. Since developers and end users will be the primary stakeholders in ASRS implementation, issues and drivers will be crucial in confirming the technology and expanding the use of ASRS in warehouse automation in the future. Therefore, the comparison of the most influential and uncertain drivers would be based on the two top drivers that were chosen from the impact-uncertainty analysis. Both of the most impactful and uncertain drivers are discussed in this section which describes the impact of Automated Storage and Retrieval Systems (ASRS) in warehouse automation and the uncertainty of technology on future development. The section following provides a more detailed overview of the top two drivers.

The third objective of this research is to study the future image of Automated Storage and Retrieval Systems (AS/RS) in warehouse automation in Johor. This objective also needs to identify the forces that can change the future of AS/RS in warehouse automation. Four different scenarios would be formed to explore the future trends by using the scenario-building method, as shown in Fig. 3, with the corresponding drivers from the impact-uncertainty analysis. These scenarios would forecast the four different possibilities that might occur in the next ten years, which is from 2024 to 2034.

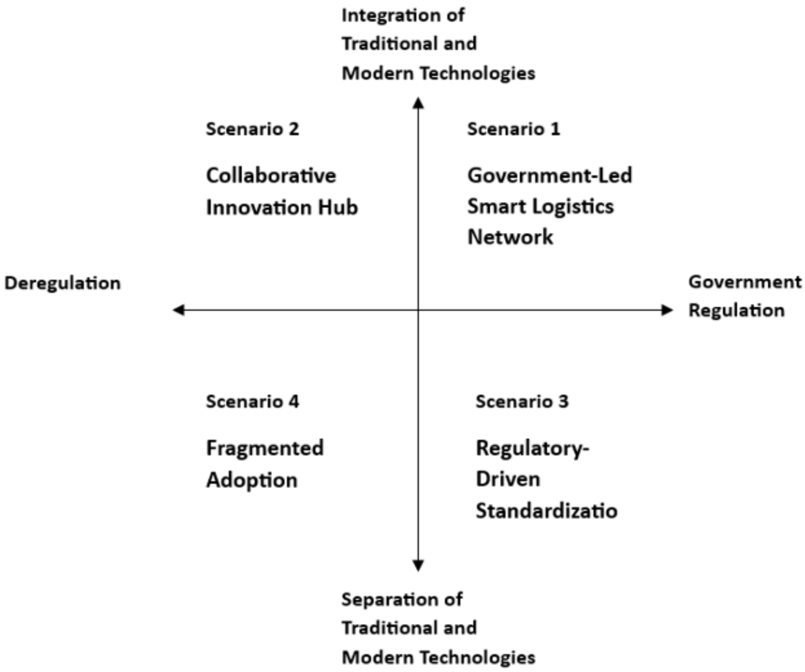

Fig. 3 *Development of four alternative scenarios*

Referring to scenario 1, Automated Storage and Retrieval Systems (ASRS) in warehouse automation in Johor experience a seamless integration of modern automation technologies with traditional warehouse management practices. This scenario represents a balanced approach where advanced ASRS technologies, such as robotic retrieval systems, AI-driven inventory tracking, and IoT-enabled warehouse monitoring, are introduced while preserving key elements of traditional warehouse operations, such as manual quality control, human oversight, and operational expertise. Rather than fully replacing traditional processes, there is a deliberate effort to integrate modern technology in a measured and incremental way. This approach ensures that warehouse workers and management teams are not overwhelmed by sudden technological changes while gradually adopting innovative solutions. The focus remains on enhancing operational efficiency, reducing errors, and improving overall warehouse productivity without disrupting established workflows.

Referring to scenario 2, the government takes a proactive role in shaping the future of logistics by creating a comprehensive framework for warehouse automation. Strong government policies and incentives are at the forefront of driving Automated Storage and Retrieval Systems (ASRS) adoption. These policies not only promote technological advancements but also provide subsidies to businesses that invest in these systems, easing the financial burden and accelerating the transition. Through regulatory frameworks and strategic partnerships with technology providers, the government ensures that warehouse operators have access to the latest innovations in automation. The overall aim is to enhance supply chain efficiency, reduce human error, and optimize storage capacity, while still maintaining a focus on economic growth and workforce stability. The integration of advanced ASRS technologies is guided by a clear roadmap that addresses both the technical and operational challenges of modernizing the logistics sector. Automated systems are introduced gradually, with a focus on minimizing disruptions to existing operations. For instance, automated retrieval and storage systems are deployed alongside traditional warehouse practices, allowing workers to adapt and transition at their own pace. The technology is tailored to complement the current infrastructure, ensuring that the implementation of automation is smooth and does not cause a sudden displacement of jobs. The workforce is gradually reskilled to operate and manage these advanced systems, promoting a sense of inclusivity and collaboration between automation and human labor.

Referring to scenario 3, the adoption of Automated Storage and Retrieval Systems (ASRS) in Johor is marked by a fragmented and inconsistent approach, largely due to minimal government support and a lack of coordinated efforts across the logistics sector. Without strong government policies or incentives, businesses are left to navigate the complexities of integrating automation into their operations on their own. Each warehouse operator makes decisions independently, leading to a lack of standardization and interoperability between different systems. This scattered approach creates inefficiencies in the broader logistics network, as each company may implement different ASRS technologies without aligning with industry best practices or shared technological standards. The absence of government intervention means there is little support in terms of financial subsidies or strategic guidance for companies considering ASRS adoption. This lack of a clear policy framework leaves many warehouse operators unsure about the long-term viability of investing in automation. As a result, only a few large companies with sufficient capital resources are able to afford the high initial costs associated with ASRS systems. Smaller warehouses, on the other hand, often struggle to make the leap to automation, either due to financial constraints or a lack of understanding of the potential benefits. This disparity in adoption rates between different types of businesses further exacerbates the fragmentation within the sector.

Referring to scenario 4, the government plays a dominant role in shaping the future of Automated Storage and Retrieval Systems (ASRS) implementation in Johor. A strong regulatory framework is established to ensure that all warehouses comply with strict standards and guidelines for the adoption of ASRS technologies. These regulations are designed to drive uniformity in system implementation across the region, ensuring that warehouses meet specific technical requirements and operational benchmarks. The government's active intervention is focused on ensuring that ASRS technologies are adopted for safety, efficiency, and sustainability, with little room for deviation from established standards. This top-down approach ensures that all warehouses, regardless of size or capacity, are held to the same operational and technological standards. However, while the regulations ensure a uniform approach to automation, the integration of ASRS technologies with traditional warehouse practices remains limited. Warehouse operators are primarily concerned with meeting compliance requirements, which often results in a focus on the bare minimum of automation needed to fulfill regulatory obligations. Traditional methods, such as manual handling, direct human oversight, and established workflow routines, are not fully integrated with the new automated systems. As a result, workers and management face friction as they continue to rely on old practices that are not optimized for the new automated technologies. The lack of a cultural shift towards modernization in warehouse operations means that employees may struggle to adapt to the technological changes, and automation may not be fully leveraged for its potential efficiency gains.

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Conflict of Interest

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

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

*The authors confirm contribution to the paper as follows: **study conception and design:** Tam Sau En, Mohd Zarir Yusoff; **data collection:** Tam Sau En; **analysis and interpretation of results:** Tam Sau En; **draft manuscript preparation:** Tam Sau En, Mohd Zarir Yusoff. All authors reviewed the results and approved the final version of the manuscript.*

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