FACTORS DETERMINING THE ADOPTION OF AUTOMATION IN LAST-MILE DELIVERY IN PENANG

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Abstract

Customer satisfaction, operational effectiveness, and service quality are all significantly impacted by last-mile delivery, the last phase of the logistics chain where products are delivered to ultimate customers. The swift expansion of e-commerce and rising urbanization in Penang, Malaysia, has intensified the demand for new solutions to improve last-mile operations. Automation technologies, including route optimization systems, autonomous delivery vehicles, and robotic handling equipment, present considerable promise to enhance speed, precision, and scalability in last-mile delivery operations. Nevertheless, the integration of automation in Penang's logistics sector is varying, necessitating a study of the factors which influence its acceptance. This study aims to examine the major factors influencing the adoption of automation in last-mile delivery operations across in Penang. The study analyses four key independent variable which is perceived usefulness, perceived ease of use, regulatory restrictions, and workforce readiness. A quantitative methodology was used, and data were gathered using standardised questionnaires given to 147 logistics professionals. Its reliability was tested by a pilot test, with Cronbach's alpha values surpassing the acceptable threshold for all constructs. Pearson correlation, multiple regression analysis, and descriptive statistics are used in the methodology to carry out the analysis. The findings show that the most important factors influencing the adoption of automation are workforce readiness and regulatory constraints, whereas perceived usefulness and perceived ease of use, despite having a positive correlation, did not reach statistical significance in the regression model. These results highlight how crucial regulatory constraint and workforce readiness are to the success of adoption of automation. For logistics companies, policymakers, and technology providers looking to improve operational efficiency while enabling digital transformation in Penang's logistics sector, this study provides useful insights.

Keywords: Automation Adoption, Last-Mile Delivery, Technology Acceptance Model

Abstrak

Penghantaran jarak terakhir memainkan peranan penting dalam menentukan kepuasan pelanggan, keberkesanan operasi dan kualiti perkhidmatan, kerana ia merupakan fasa terakhir dalam rantaian logistik di mana produk dihantar kepada pelanggan akhir. Perkembangan pesat e-dagang serta peningkatan kadar urbanisasi di Pulau Pinang, Malaysia telah meningkatkan keperluan terhadap penyelesaian baharu untuk menambah baik operasi penghantaran jarak terakhir. Teknologi automasi seperti sistem pengoptimuman laluan, kenderaan penghantaran autonomi dan peralatan pengendalian berasaskan robotik menawarkan potensi besar dalam meningkatkan kelajuan, ketepatan dan kebolehsuaian operasi penghantaran jarak terakhir. Namun begitu, tahap penerapan teknologi automasi dalam sektor logistik di Pulau Pinang masih berbeza-beza, sekaligus memerlukan kajian terhadap faktor-faktor yang mempengaruhi penerimaannya. Kajian ini bertujuan untuk mengenal pasti faktor utama yang mempengaruhi penerimaan automasi dalam operasi penghantaran jarak terakhir di Pulau Pinang. Empat pembolehubah bebas utama telah dianalisis dalam kajian ini, iaitu persepsi terhadap kegunaan, persepsi terhadap kemudahan penggunaan, kekangan peraturan dan tahap kesediaan tenaga kerja. Pendekatan kuantitatif telah digunakan dan data dikumpul melalui soal selidik berstruktur yang diedarkan kepada 147 profesional logistik. Kebolehpercayaan instrumen disahkan melalui ujian perintis, dengan nilai alpha Cronbach melepasi ambang kebolehterimaan bagi semua konstruk. Kaedah analisis melibatkan statistik deskriptif, analisis korelasi Pearson dan regresi berganda. Dapatan kajian menunjukkan bahawa kekangan peraturan dan kesediaan tenaga kerja merupakan faktor paling signifikan dalam mempengaruhi penerimaan automasi, manakala persepsi terhadap kegunaan dan kemudahan penggunaan walaupun berkorelasi positif, tidak menunjukkan signifikan dalam model regresi. Hasil ini menekankan peranan penting yang dimainkan oleh aspek peraturan dan kesediaan sumber manusia dalam memastikan kejayaan penerapan automasi. Kajian ini memberi panduan berguna kepada syarikat logistik, pembuat dasar dan penyedia teknologi dalam usaha meningkatkan kecekapan operasi dan mendukung transformasi digital dalam sektor logistik di Pulau Pinang.

Kata Kunci: Penerimaan Automasi, Penghantaran Jarak Terakhir, Model Penerimaan Teknologi

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Table of Content

List of Figure

List of Tables

List of Appendices

List of Abbreviation

SPSS	Statistical Package for Social Science
UUM	Universiti Utara Malaysia
TAM	Technology Acceptance Model
IV	Independent Variable
DV	Dependent Variable
PU	Perceived Usefulness
PEOU	Perceived Ease of Use

Chapter 1

1.1 Introduction

This chapter gives a summary of the research. It explains why this study should be conducted by looking at issue statements, research objectives, and research questions. The significance of the study and its contribution are also discussed. This chapter also provides an executive summary of important terms and ideas related to the subject of study. Finally, it outlines the conceptual framework of the research.

1.2 Background of the Study

In the contemporary digital economy, the swift ascent of ecommerce has altered consumer expectations, with customers requiring faster, reliable, and traceable delivery services. The escalating demand has exerted significant pressure on logistics companies to enhance efficiency and minimize delivery times. Last-mile delivery, which refers to the final stage in the supply chain where products are transported form a distribution centre to the customer's doorstep is widely known as the most complex and expensive part of the supply chain process. According to Exploration of the Challenges in the Last-mile Delivery in Supply Chain (2020) this stage can contribute to more than half of total logistics costs primarily due to operational inefficiencies, urban traffic congestion and failed delivery attempts. In response to these challenges, companies are increasingly adopting automation technologies to improve the efficiency and effectiveness of last-mile services. Technologies such as artificial intelligence driven route planning, autonomous delivery vehicles, automated parcel lockers and robotic sorting equipment are revolutionizing the way goods are delivered. The integration of automation into logistics operations has been shown to improve delivery responsiveness, reduce cost and enhance overall operational flexibility (Ghasemaghaei & Calic,2020). (Winkenbach et al.2016) emphasized that automation improves real time delivery and promotes more agile logistics networks. Notwithstanding the shown advantages, the incorporation of automation in last-mile delivery remains still developing, particularly in developing nations. In the Malaysian context, especially in Penang, an emerging logistics hub, the implementation of automation is still dispersed. Although some progressive organizations have begun to adopt automation, numerous others remain hesitant due to elevated implementation costs, a shortage of skilled labor, and ambiguity around regulatory compliance. Ismail and Nopiah (2022) assert that Malaysian logistics companies frequently encounter a disparity between technological accessibility and worker preparedness, hindering the digital transformation process. Researchers include Davis (1989) and subsequently Venkatesh and Davis (2000) have consistently highlighted that the adoption of new technologies hinges not solely on technical feasibility but also on human factors, particularly the perceived utility and ease of use of the technology. Chong and Ooi (2008) discovered that firms in logistics are more inclined to embrace technology when their personnel are well trained and proficient in its use. This underscores the need of personnel preparedness in conjunction with system architecture and infrastructural support. Considering the factors impacting the adoption of automation in last-mile delivery is crucial, especially in key places like Penang, given the evolving logistics market and the growing demand to digitise.

1.2 Problem Statement

Logistics companies in Penang continue to face challenges in managing last-mile deliveries, including traffic congestions, inaccurate addresses, unexpected delays and poor route planning (Chen et al., 2021). These issues often lead to missed delivery windows, dissatisfied customers, and higher operational costs. Although automation technologies offer effective solutions their adoption remains limited and inconsistent across the sector (Sanchez-Diaz et al., 2020). Despite the availability of tools like automated lockers and autonomous vehicles many companies are hesitant to adopt them. Even when the benefits are recognized in theory, the PEOU of technologies becomes another barrier. Some companies view on automation as technically complex, resource-intensive to implement or incompatible with their current system which leads to resistance among employees and the company. At the same time the PU of automation is how on how much it is believed to improve efficiency and performance and also plays role as companies may not fully understand or believe in the return on investment or performance gains particularly in local contexts. Additional barriers are caused by regulatory constraints especially when integrating new technology into the infrastructure public service (Blaska et al.,2022). Unclear policies, slow approval process or lack of supporting frameworks create uncertainties for business. The challenge is further compounded by the fact that companies may lack employees that are technologically savvy and well trained to operate or maintain automated systems which is pointing to the importance of workforce readiness. Without adequate training, digital literacy or confidence in automation, employees may resist change making adoption more difficult for them.The main factors influencing the adoption of automation in Penang's last-mile delivery sector are not adequately addressed by empirical data at the moment (Balaska et al., 2022). Hence, this study is timely and necessary to investigate the key factors influencing automation adoption in Penang's last-mile delivery landscape. By focusing on PU, PEOU, regulatory constraints and workforce readiness this study aims to bridge the current knowledge gap and provide practical, data driven insights. These insights can assist logistics provider, policymakers and technology stakeholders in overcoming adoption challenges and improving the overall efficiency, reliability and responsiveness of last-mile delivery services.

1.3 Research Questions

1. How does perceived usefulness effect the adoption of automation in last-mile delivery in Penang?
2. How does ease of use effect the adoption of automation technologies in last-mile delivery services within Penang?
3. How does regulatory constraints effect existing and potential regulatory constraints on the adoption of automation technologies for last-mile delivery within Penang?
4. To what extent does workforce readiness effect the adoption of automation technologies in last-mile delivery operations in Penang?

1.4 Research Objectives

1. Perceived usefulness effects the adoption of automation in last-mile delivery in Penang.
2. Perceived ease of use effect the adoption of automation technologies in last-mile delivery services.
3. To analyze the impact of regulatory constraints and policies on the adoption of automation technologies in last-mile delivery.
4. To determine the level of workforce readiness to support the adoption of automation in last-mile delivery.

1.5 Significant of study

This study holds both theoretical and practical significance, contributing to the existing body of knowledge and offering actionable insights for stakeholders in the last-mile delivery sector. The framework for comprehending how people adopt and utilise a technology can be acquired by the Technology Acceptance Model (TAM). The application of TAM is expanded in this study to the particular context of automation in Penang's last-mile delivery system.

1.5.1 Theoretical Significance

This study contributes to the theoretical development of TAM by applying it to the domain of last-mile delivery automation an area still underexplored in the Malaysian context. While TAM has been widely used in various sectors to explain user acceptance of technology, its relevance to logistics automation, particularly in Penang, has not been sufficiently studied (Wang et al.,2023). This research expands the scope of the TAM by analyzing the effects of how PU, PEOU, regulatory constraints and workforce readiness on the adoption of automation specifically within the logistics sector in

Penang. It also contributes a contextual dimension by incorporating local factors such as urban infrastructure, policy environments and the readiness of the workforce. Through this the study deepens the understanding of how environmental and cultural conditions influence technology acceptance, reinforcing the theoretical robustness and adaptability of the model across different regional contexts.

1.5.2 Practical Significance

This study offers practical guidance for industry practioners to adopt automation in last-mile delivery. By identifying key adoption factors, logistics companies and technology providers can make better decisions on system design, workforce planning and investment, improving implementation success and return on investment. For policymakers, findings highlight regulatory challenges that can either support or hinder automation. These insights can help shape effective policies that encourage innovation while addressing employment, safety and data privacy concerns. The study also underscores the importance of workforce readiness. Government agencies, HR teams and training institutions can use these findings to develop targeted programs that equip employees with skills needed for an automated logistics environment, ensuring smoother transitions and reduces disruptions.

1.6 Scope of Study

This study aims to identify the key factors affecting the adoption of automation technology in last-mile delivery operations in Penang, Malaysia. Penang, being a significant logistics hub, provides an appropriate environment for examining automation within the overall context of a developing nation. The study focusses on the perceptions and implementations of technologies by logistics and delivery companies, including AI-driven route optimisation, robotic sorting systems, autonomous delivery vehicles, and automated parcel lockers. The study integrates workforce readiness and regulations with PU and PEOU, guided by the Technology Acceptance Model (TAM). It utilizes an industry-

focused approach while also taking into account the opinions of other important

stakeholders, such as technology suppliers, employees, and lawmakers, in order to provide a thorough grasp of the potential and difficulties associated with automation adoption.

1.7 Definition of Key Terms

1.7.1 Last-mile Delivery

The last stage of delivery, in which items are delivered to the customer's location from a distribution center or transportation hub. It is frequently the most expensive and time-consuming link in the supply chain (Olsson et al., 2021).

1.7.2 Automation

Using machinery and technology to complete jobs with little assistance from humans. In order to increase operational efficiency, this comprises software-based delivery tools, automated sorting, robotics, and artificial intelligence (AI) systems (Onu & Mbohwa, 2019).

1.7.3 Perceived of Usefulness

The belief that using a specific technology will boost organizational results or job performance. (Vo et al., 2022) Users' assessments of the benefits automation offers to their work processes are reflected in it.

1.7.4 Perceived Ease of Use

The degree to which a person thinks using a particular technology will be simple and effortless. User-friendly technologies have a higher chance of being adopted (Wamba-Taguimdje et al., 2020).

1.7.5 Regulatory Constraint

Refers to the institutional, legal, or policy-related obstacles that could limit or make the adoption of automation technologies more difficult. (Baldwin & Lin, 2002) This includes a lack of standards or supporting infrastructure, ambiguous government regulations, and compliance obligations.

1.7.6 Workforce Readiness

Depending on their abilities, education, flexibility, and general technological proficiency, employees' readiness to embrace and use new technology. A prepared workforce is essential to the successful deployment of automation (Mekoth, 2022).

Chapter 2
Literature Review

2.1 Introduction

This chapter examines key factors influencing automation adoption in last-mile delivery, focusing on PU, PEOU, workforce readiness and regulatory constraints. These elements offer insight into challenges and drivers shaping adoption in Penang's logistics sector. Automation technologies such as autonomous vehicles and smart delivery systems can boost efficiency and meet rising customer demands (Mangiaracina et al.,2019). However regulatory constraint and workforce readiness remain obstacles (Lee et al.,2019; Mohammad et al.,2023). Grounded in Technology Acceptance Model, this review supports the development of effective strategies for successful automation integration.

2.2 Last-mile Delivery

Last-mile delivery is the final process in the supply chain which involves transporting goods from a distribution hub to the customer's location (Olsson et al.,2019; Singh,2018). As the point of direct customer interaction, it strongly influences satisfaction and loyalty (Singh,2018). Despite its importance, it is also considered one of the most costly, inefficient and environmentally taxing stages in logistics (Olsson et al.,2019). Research indicates that it can contribute significantly to overall supply chain costs (Olsson et al., 2019), mostly because of the challenges of delivering individual shipments to various locations within predetermined periods (Owens, 2023). Customers now anticipate faster, more cost-effective, and more flexible delivery alternatives, which has increased the demands and complexity of last-mile delivery as e-commerce has grown (Alverhed et al., 2024). Businesses have to fulfill these new requirements in order to stay competitive and retain customers (Singh, 2018). This has led to the emergence of what is commonly referred to as the "last-mile problem" (2024), which emphasizes the complexities, expenses, and fundamental inefficiencies of this last delivery segment. Depending on the location, these difficulties can differ greatly. For instance, traffic congestion and parking shortages are common problems in Penang's urban regions like George Town (2016), although more rural parts of the state may encounter difficulties because of the more extensive commutes and more residing populations.

2.3 Adoption of Automation in Last-Mile Delivery

The rise of e-commerce and increasing customer expectations have driven significant changes in how goods are delivered with automation playing a central role in transforming last-mile logistics (Data,2018; Mohammad et al., 2023). Technologies such as drones, delivery robots, autonomous vehicles and smart parcel lockers exemplify automation in this area. Integrating collaborative autonomous systems with traditional delivery modes like trucks , vans and bicycles can further support the shift towards fully automated delivery solutions (Behroozi & Ma,2023). Automation offers numerous benefits, including reduces labor costs, faster and more efficient deliveries, improved accuracy and enhanced customer satisfaction (Heid et al.,2018). Regulatory constraint, business planning, and technology investment decisions can all be influenced by an industry practitioner's understanding of technology adoption factors. The impact of regulatory constraints and laws, the technological complexity required, and stakeholders' perceptions of automation's usefulness and user friendliness all possess an essential role in the ease with which these benefits can be implemented.

2.3.1 Previous study on Adoption of Automation

Research on automation in last-mile deliveryhas largely focused on technological advancements. Studies highlight that tools like drones, AI based routing and delivery bots boosts efficiency, cut costs and enhance service quality (Mohammad et al.,2023). Automation also improves speed and accuracy while reducing reliance on manual labor (Heid et al.,2018). Likewise, incorporating robotics and artificial intelligence into last-mile delivery improves operational effectiveness but necessitates a significant financial outlay and technology infrastructure. Research on the adoption of automation in logistics has made extensive use of the Technology Acceptance Model (TAM).

Adoption is strongly influenced by PU (the degree to which automation increases efficiency) and PEOU (the degree to which automation is user-friendly), according to studies by Davis (1989) and Venkatesh & Davis (2000). Siegfried and Zhang (2021) discovered that logistics firms are more inclined to invest in automation in the last-mile delivery space if the technologies show a definite advantage in lowering operational inefficiencies and raising customer satisfaction. Adoption of automation is also greatly influenced by consumer perception. According to Cheng et al. (2021), adoption rates are impacted by safety, dependability, and privacy issues, underscoring the ongoing development of trust in automation, including drone and robot delivery. Similar trends were seen by Ee et al. (2024) in the automation of unmanned convenience stores, where consumers needed some time to get used to completely autonomous services.

The COVID-19 pandemic has influenced consumer adoption of autonomous delivery systems by increasing demand for contactless delivery options. Concerns over health have led to a move toward automation, which emphasizes the growing significance of non-human delivery options like robotic couriers and drones. Businesses that invest in automation must make sure that the good conduct, security, and reliability of these technologies full fill consumer expectations because safety is still their primary concern. Recent developments in technology highlight how automation is becoming more and more important in last-mile delivery. Robots are being tested in Brooklyn to speed up grocery deliveries and reduce costs. Similarly, Amazon is using robotics and AI to enhance delivery speed and reduce employee strain, reshaping job roles. As automation investments grow, broader adoption is expected, improving the sustainability and efficiency of last-mile logistics.

2.4 Perceived Usefulness

According to Davis (1989), PU is the extent to which a technology is thought to improve performance and efficiency in a certain task. It indicates how much companies and customers perceive automation may improve the logistics process, lower costs, and improve service quality in the context of last-mile delivery. Automation technologies that promise to increase customer satisfaction, reduce delays, and streamline operations include self-driving cars, drones, autonomous delivery robots, and AI-driven route optimization (Mohammad et al., 2023). Automation enhances order accuracy, minimizes human error, optimizes delivery routes, and uses less fuel (Heid et al., 2018). In order to stay competitive in the logistics industry, businesses that understand these benefits are more likely to engage in automation (Venkatesh & Davis, 2000). However, companies that do not see substantial efficiency improvements from automation could be reluctant to use these technologies because of worries about operational complexity, infrastructure preparedness, and high implementation costs (Ee et al., 2024). Businesses that view automation as a strategic benefit for enhancing operational efficiency and service delivery are more inclined to give it top priority in fiercely competitive marketplaces (Taylor et al., 2021).

2.4.1 Relationship Between Perceived Usefulness and Adoption of Automation in Last-Mile Delivery

Perceived usefulness refers to the degree to which a technology is believed to enhance performance and efficiency in a given task (Davis, 1989). Automation is more likely to be encompassed into logistics operations by companies that see its advantages for solving delivery inefficiencies and enhancing service quality (Siegfried & Zhang, 2021). Businesses using AI-based route planning systems, for example, report reduced fuel usage and faster deliveries, which reinforces their view of automation's benefits (Nabiha et al., 2020). According to Yuen et al. (2022), research indicates that shops who use autonomous delivery robots see a gain in urban logistics efficiency, which in turn leads to a greater investment in automation. However, especially in areas with low labor expenses and inadequate technological infrastructure, logistics companies may postpone or oppose adoption if they do not believe that automation is much more efficient than conventional delivery techniques (Ee et al., 2024). Thus, this study highlights the following hypothesis.

H1: Perceived usefulness has a significant relationship with the adoption of automation in last-mile delivery.

2.5 Perceived Ease of Use

Perceived ease of use (PEOU) refers to the extent to which individuals believe that adopting a technology will require minimal effort (Davis, 1989). PEOU has a significant impact on how last-mile delivery companies, delivery workers, and customers engage with automation technology like drones, autonomous automobiles, and AI-powered logistics systems. According to Venkatesh and Davis (2000), solutions that require less technical knowledge and connect easily with current systems are more likely to be implemented. On the other hand, if automation is seen as complicated, businesses could oppose its deployment because of worries about the learning curve for new technologies, operational disruptions, and training expenses (Siegfried & Zhang, 2021). On the other hand, if automation is seen as complicated, businesses could oppose its deployment because of worries about the learning curve for new technologies, operational disruptions, and training expenses (Siegfried & Zhang, 2021). To ensure smooth integration and operational effectiveness, logistics companies give priority to technologies for automation that complement present processes and require training (Heid et al., 2018).

2.5.1 Relationship Between Perceived Ease of Use and Adoption of Automation in Last-Mile Delivery

Perceived ease of use (PEOU) is a key factor in the acceptance of automation in last-mile deliveries. The Technology Acceptance Model (TAM) states that a technology's likelihood of being adopted rises with its usability (Davis, 1989). To be widely adopted in the logistics industry, automation solutions need to be simple to use and blend in with existing processes (Venkatesh & Davis, 2000). Concerns about operational disruptions and high implementation costs may cause businesses to delay adoption of automation if they believe it is complicated and necessitates significant training or improvements to the infrastructure (Siegfried & Zhang, 2021). Simplifying automation processes and ensuring user-friendliness are key strategies for accelerating adoption in last-mile delivery. Thus, this study highlights the following hypothesis.

H2: Perceived ease of use has a significant relationship with the adoption of automation in last-mile delivery.

2.6 Workforce Readiness

Workforce readiness is the extent to which employees have the skills, expertise, and adaptability needed to successfully implement and use automation technology. This involves being adept at using automated technologies like robotics, drones, AI-driven logistics platforms, and autonomous automobiles in the context of last-mile delivery. Automation is more likely to be implemented smoothly if the workforce is adaptable and technologically savvy (Schmidt et al., 2017). Employers may encounter opposition if their employees lack the required expertise, digital literacy, or adaptability, which could cause automation adoption to be delayed or fail (Chuang & Graham, 2020). Businesses may improve workforce readiness and make sure employees are ready for cooperation with automation technology by investing in training programs, upskilling initiatives, and implementing change approaches (Wamba et al., 2021). In addition to technical capabilities, workforce readiness includes individuals' perspectives and views regarding automation. Apprehension regarding job displacement, ambiguity surrounding new opportunities, and resistance to change might hinder adoption initiatives (Frey & Osborne, 2017). To tackle these problems, companies must cultivate a culture of digital change, assuring employees comprehend how technology enhances their work rather than replaces it. The shift to automated last-mile delivery operations can be facilitated and staff preparedness greatly increased by promoting an attitude of constant learning and adaptation.

2.6.1 Relationship Between Workforce Readiness and Adoption of Automation in Last-Mile Delivery

Workforce readiness plays a pivotal role in determining the success of automation adoption in last-mile delivery. A workforce that is technically skilled, adaptable, and open to digital transformation accelerates automation implementation by ensuring a smoother transition with minimal resistance (Schmidt et al., 2017). Employees who understand how to operate and collaborate with automation technologies contribute to higher efficiency, reduced operational disruptions, and better optimization of automated delivery processes (Chuang & Graham, 2020). On the other hand, low workforce readiness can significantly hinder automation adoption. If employees lack the necessary skills or perceive automation as a threat, companies may face resistance, resulting in slower adoption rates and inefficient utilization of automated systems (Frey & Osborne, 2017). Organizations that fail to invest in proper training and upskilling may also struggle with errors, system failures, and reduced productivity, negating the intended benefits of automation.To enhance workforce readiness, businesses must prioritize employee training, provide hands-on experience with automation technologies, and create an environment that supports digital learning and adaptation. Additionally, transparent communication about the benefits of automation and how it transforms job roles can help mitigate resistance and foster a positive approach to technological advancements (Wamba et al., 2021). In summary, workforce readiness is a critical determinant of automation adoption, as a well-prepared workforce facilitates seamless integration, while an unprepared one creates barriers to successful implementation. Thus, this study highlights the following hypothesis.

H3: Regulatory constraints have a significant relationship with the adoption of automation in last-mile delivery.

2.7 Regulatory Constraints

Regulatory constraints refer to the legal, policy, and compliance challenges that affect the implementation of automation in last-mile delivery. These constraints include government regulations on autonomous vehicles, drone deliveries, data privacy, cybersecurity, labor laws, and infrastructure requirements (Samouh et al., 2020). Many countries impose strict guidelines for deploying autonomous technologies to ensure safety, consumer protection, and compliance with existing transport regulations (Lee et al., 2019). For example, drone deliveries require airspace management policies, while autonomous ground vehicles must comply with traffic laws and pedestrian safety regulations (Nabiha et al., 2020). In Malaysia, regulatory uncertainties have slowed the adoption of automation in last-mile delivery, as businesses face unclear guidelines on operating autonomous logistics systems (Yuen, Wang, & Wong, 2022). Additionally, data security laws governing AI-driven logistics systems add another layer of complexity, as companies must ensure compliance with personal data protection regulations (Cheng et al., 2021). The lack of standardized policies across different regions further complicates automation adoption, leading to delays and increased operational costs for businesses seeking regulatory approval (Ee, Tan, & Low, 2024).

2.7.1 Relationship Between Regulatory Constraints and Adoption of Automation in Last-Mile Delivery

Regulatory constraints have a significant impact on the adoption of automation in last-mile delivery, often acting as a barrier to implementation. Strict legal requirements can discourage companies from investing in automation due to the uncertainty and complexity of compliance (Taylor, Roberts, & Green, 2021). When businesses face difficulties obtaining regulatory approvals for autonomous deliveries, they may delay or abandon automation projects in favor of traditional logistics solutions (Samouh et al., 2020). In contrast, countries with well-defined policies and supportive government initiatives have seen faster adoption of last-mile automation technologies. For instance, in the United States and parts of Europe, regulatory frameworks have been adapted to accommodate autonomous delivery systems, encouraging investment in automation (Siegfried & Zhang, 2021). In Malaysia, however, the absence of clear policies for autonomous deliveries has resulted in slow adoption, as companies hesitate to implement technologies without regulatory certainty (Nabiha et al., 2020). To accelerate adoption, governments need to establish standardized regulations, provide financial incentives for automation investments, and develop infrastructure to support emerging last-mile delivery technologies (Venkatesh & Bala, 2008). Addressing these regulatory constraints will create a more conducive environment for automation, leading to greater efficiency and innovation in last-mile logistics. Thus, this study highlights the following hypothesis.

H4: Workforce readiness has a significant relationship with the adoption of automation in last-mile delivery.

2.8 Underpinning Theory

This study is primarily underpinned by the Technology Acceptance Model (TAM), developed by Davis (1989), which explains user acceptance of technology by examining two key constructs which are PU and PEOU. TAM has been widely applied in various fields to understand behavioral intentions behind technology adoption, including logistics and supply chain management. In the context of this study, TAM helps explain how logistics companies and stakeholders assess automation in last-mile delivery based on its perceived benefits and ease of integration.

2.8.1 Technology Acceptance Model (TAM)

The PU construct in TAM refers to the degree to which an individual believes that using a particular technology will enhance job performance. In last-mile delivery automation, PU pertains to how logistics companies evaluate automation's potential to improve operational efficiency, reduce delivery costs, enhance service quality, and increase overall productivity. Studies such as Venkatesh & Davis (2000) and Siegfried & Zhang (2021) have emphasized that the greater the PU of a technology, the higher the likelihood of its adoption. If businesses recognize that automation—such as drones, autonomous vehicles, and AI-driven route optimization—can significantly streamline last-mile operations, they are more willing to integrate it into their logistics processes If automation systems are user-friendly, require minimal training, and integrate seamlessly with existing logistics operations, adoption rates are expected to increase. Conversely, if these technologies are difficult to implement, require extensive retraining, or disrupt current workflows, businesses may resist adoption (Venkatesh et al., 2003). Logistics companies are more inclined to adopt automation when they perceive it as intuitive, cost-effective, and compatible with their operational structure. Beyond PU and PEU, workforce readiness and regulatory constraint also plays a role in shaping adoption decisions. The ability of employees to adapt to new automation technologies influences how quickly and effectively businesses integrate automation into their last-mile delivery processes. By applying TAM, this study provides a theoretical foundation for understanding the key factors influencing automation adoption in last-mile delivery. The model suggests that logistics companies are more likely to integrate automation technologies when they perceive them as both useful and easy to use, while also considering workforce readiness. Thus, TAM serves as a guiding framework to analyze how these perceptions impact decision-making and technology adoption in logistics automation.

2.9 Research Framework

The research framework for this study is designed to examine the factors influencing the adoption of automation in last-mile delivery. The framework is developed based on existing literature, particularly the Technology Acceptance Model (TAM) in automation and logistics. The model identifies key independent variables that affect the dependent variable, providing a structured approach to understanding the adoption process delivery services.

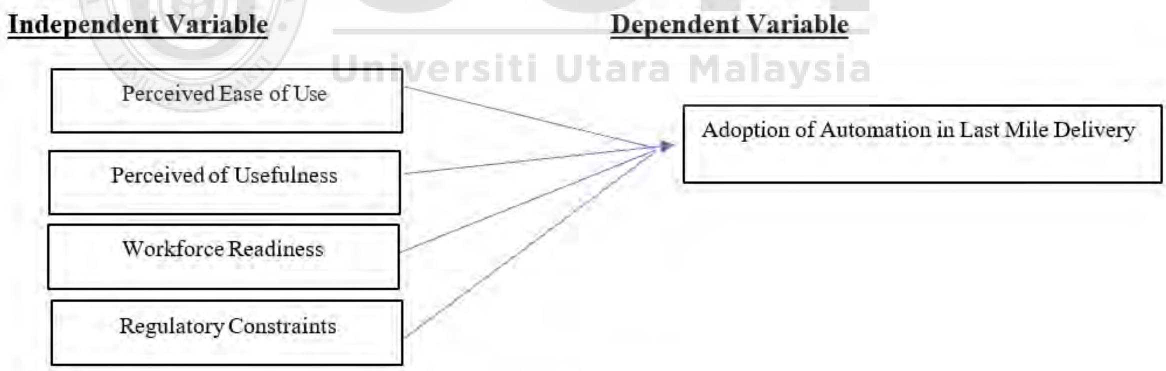

Figure 1: Research Framework

2.10 Hypotheses statements

Based on the research framework, the following hypotheses are proposed to examine the relationships between the independent and dependent variables:

H1: Perceived usefulness has a significant relationship with the adoption of automation in last-mile delivery.

H2: Perceived ease of use has a significant relationship with the adoption of automation in last-mile delivery.

H3: Regulatory constraints have a significant relationship with the adoption of automation in last-mile delivery.

H4: Workforce readiness has a significant relationship with the adoption of automation in last-mile delivery.

Chapter 3
Research Methodology

3.1 Introduction

This chapter outlines the research methodology used to examine factors influencing automation adoption in last-mile delivery within Penang's logistics sector. It introduces the study's theoretical foundation and provides a structured approach to analyzing key variables affecting adoption among logistics companies and technology providers.

3.2 Research Design

This study employs quantitative research to analyse the key factors influencing automation adoption in last-mile delivery within Malaysia's industry. The research focuses on collecting and analyzing numerical data to accurately depict the current state of automation adoption and explore the relationships between variables. The descriptive component aims to present a clear picture of the current level of automation adoption in last-mile delivery (Boysen et al., 2020). This involves gathering quantitative data through structured questionnaires distributed to logistics companies in Penang. The data is then subjected to statistical analysis, using descriptive statistics to present the findings. The explanatory component identifies and explains the relationships between variables influencing automation adoption. The study uses quantitative methods to ensure objectivity, reliability, and generalizability. Structured questionnaires are developed based on the theoretical framework and distributed to a large sample of logistics companies. A stratified random sampling technique ensures that the sample represents various industry segments. The collected data is analyzed using statistical software the SPSS, with descriptive statistics, correlation analysis, and regression analysis performed to test hypotheses and identify significant relationships

3.3 Population of Study

This study focuses on employees working in the last-mile delivery sector of Penang’s industry. The participants include individuals employed by logistics companies and directly involved employees in last-mile delivery operations. Penang's status as a significant hub of commerce and industry offers a conducive environment for studying the adoption of automation technologies. Targeting these employees provides direct insights into their experiences and perceptions, which is vital for understanding the practical challenges and benefits of adopting automation technologies in last-mile delivery. Due to the absence of an official registry or database identifying the total number of professionals in Penang, the population is considered unknown.

3.4 Sample and Sample Size

The study's sample will comprise representatives from logistics based in Penang, Malaysia. These participants were selected due to their direct experience and insights into the adoption of automation technologies in last-mile delivery. Due to the total population is unknown, the study utilises a non-probability sampling technique and the sample size is determined based on practical constraints Cochran,W.G (1977) and statistical considerations. A total of 147 respondents participated in the study. By engaging a substantial number of participants, the study ensures the findings are representative of the broader population of stakeholders involved in last-mile delivery within Malaysia's landscape.

3.6 Sampling Technique

This study uses purposive sampling, a commonly used non-probability sampling method, considering the unknown population size. Purposive sampling is a deliberate selection of individuals who are most likely to provide relevant and thorough information in line with the goals of the study. This technique is especially suitable in cases when the researcher does not have a full sampling frame or when examining a particular subpopulation with different knowledge or responsibilities. Purposive sampling was used in this study to find and include logistics experts directly engaged in last-mile delivery operations and/or the implementation or assessment of automation technology in Penang. Random sampling was unattainable given the absence of a centralised registration of logistics experts in Penang.

3.7 Instrumentation and Measurement of variable

The study uses a structured questionnaire to evaluate various factors influencing the adoption of automation in last-mile delivery. The framework includes multiple items for each variable to ensure comprehensive coverage and reliability. In addition to the main variables, the questionnaire collects demographic information. The items for the constructs are adapted from existing validated scales in prior research on technology adoption and automation, providing a robust foundation for validity and reliability. Each variable is measured with 5-10 items, ensuring detailed and reliable data collection. The demographic information items capture the characteristics of the respondent.

Table 3.1 : Summary Table of Instrumentation

Variables	Items	Authors
Perceived Usefulness (PU) (IV1)	Using automation technologies will improve the efficiency of last-mile delivery operations in Penang. Automation technologies improve delivery times for my company. Implementing automation technologies will reduce operational costs in last-mile delivery. Automation technologies will provide my company with a competitive advantage.	Davis (1989)
Perceived Ease of Use (PEOU) (IV 2)	Learning to operate automation technologies will be easy for employees in my company. Integrating automation technologies into existing logistics operations will require minimal system modifications. The complexity of maintaining automation technologies will be manageable for my company. Implementing automation in our last-mile delivery operations will not disrupt existing workflows.	Davis (1989)

Regulatory Constraints (IV 3)	The current regulations in Penang regarding the use of automation in last-mile delivery are clear. The process of obtaining the necessary permits for automation technologies is efficient. Potential legal issues related to autonomous delivery systems are a significant concern for our organization. Existing regulations create significant barriers to adopting automation technologies in last-mile delivery.	Manyika et al. (2017
Workforce Readiness (IV 4)	Our workforce possesses the necessary digital literacy skills to operate automation technologies. Our employees are supportive of adopting automation technologies in last-mile delivery operations. We have a well-defined plan for training and upskilling employees to use automation technologies effectively. Automation technologies will lead to significant job displacement within our organization.	Nin & Yao (2023)

Adoption of Automation in Last-Mile Delivery	Our company is willing to invest in automation technologies to improve last-mile delivery efficiency.	Lahti et al. (2024)
(DV)	The benefits of adopting automation in last-mile delivery outweigh the costs and challenges.	
	The employees would be willing to adopt and use automation technologies if provided with adequate training.	
	Our company expects a significant return on investment (ROI) from automation adoption in last-mile delivery.	

This study utilized a Likert scale to capture respondents' perceptions, allowing for standardized measurement of agreement levels across various statements. The scale facilitated consistency and comparability in responses, supporting reliable data analysis.

3.8 Data Collection Procedure

To gather the data for this study, an online survey was used as it offered a convenient and flexible way for logistics professionals who often have tight schedules to participate. The structured questionnaire was created using Google Forms, which allowed respondents to access and complete it easily on their phones or computers, at a time and place that suited them. Survey links were shared directly with targeted participants through email and WhatsApp, reaching out to individuals working in logistics companies and last-mile delivery services in Penang. The data collection process ran for four weeks, giving participants ample time to respond. From an ethical standpoint, participation was completely voluntary, and every respondent was informed that their responses would remain confidential and anonymous. Right at the start of the questionnaire, a brief explanation was provided outlining the purpose of the study, what their participation involved, and assuring them that their identities would not be disclosed. By creating a comfortable and transparent environment, the study aimed to ensure that participants felt respected and safe in sharing their honest opinions.

3.9 Data Analysis Strategy

The data analysis strategy for this study involves a multi-step process to ensure the reliability and validity of the findings and to test the proposed hypotheses effectively. Initially, descriptive statistics will be used to summarize the demographic characteristics of the respondents, including their roles within their organizations and their experience with automation technologies. This step will also include summarizing the distribution of responses for each questionnaire item, providing a clear overview of the data. To assess the consistency of the measurement instruments, a reliability analysis will be conducted using Cronbach's alpha. This statistic measures the internal consistency of the scales used in the questionnaire, ensuring that the items within each construct reliably measure the same underlying concept. A Cronbach's alpha value of 0.70 or higher will be considered acceptable for this study.

Chapter 4

Data Analysis and Findings

4.1 Introduction

This chapter outlines the analysis of the data collected for the study on factors influencing the implementing automation in last-mile delivery services in Penang. A systematic questionnaire was shared to logistics professionals in Penang who works in different companies and 147 respond were received. Before proceeding to the primary data analysis, a pilot test was conducted to ensure the reliability of the research instruments. Using Cronbach's alpha, all key factors as in PU, PEOU, regulatory constraints, workforce readiness, and the adoption of automation were found to have acceptable internal consistency.

4.2 Pilot Test

The pilot test results in Table 4.1 present the reliability analysis for the variables in this study. The internal linearity of the measurement scales for each construct is indicated by the Cronbach's alpha (α) values. PU recorded a reliability coefficient of $\alpha = 0.782$, reflecting good internal consistency. This suggests that the items measuring PU are sufficiently reliable for capturing respondents' perspectives on the benefits of automation in last-mile delivery. Similarly, PEOU yielded a Cronbach's alpha of $\alpha = 0.727$, indicating acceptable reliability. This implies that the measurement of user-friendliness and technological barriers is consistent. Regulatory constraints exhibited a reliability value of $\alpha = 0.724$, which falls within an acceptable range. This suggests that the scale used to assess regulatory challenges in last-mile automation is fairly consistent. Workforce readiness attained the highest reliability among all constructs, with an alpha value of $\alpha = 0.861$. This strong internal consistency suggests that the items used effectively measure workforce preparedness for automation adoption.

Finally, the adoption of automation in last-mile delivery obtained a reliability coefficient of α = 0.786, indicating good consistency in measuring respondents' adoption levels. Overall, all constructs demonstrated acceptable to high reliability, with values above the generally accepted threshold of 0.70. This confirms that the scales used in the pilot study are reliable for further data collection and analysis.

Table 4.1
Pilot test of perceived usefulness, perceived ease of use, regulatory constraints, workforce readiness and adoption of automation in last-mile delivery

Variables	**Total Item**	**Reliability (α)**
Perceived usefulness	4	0.782
Perceived ease of use	4	0.727
Regulatory constraints	4	0.724
Workforce readiness	4	0.861
Adoption of automation in last-mile delivery	4	0.786

4.3 Demographic Analysis

The demographic profile of 147 respondents in this study at the last-mile delivery sector provides insights into their roles, experience, business nature and familiarity with automation technologies. This Among the respondents, logistics managers constituted the largest group (25.9%), followed by logistics coordinators (21.1%) and inventory analysts (18.4%). Procurement officers (13.6%) and warehouse managers (12.9%) had smaller representations, while 8.2% fell into the other category. Regarding industry experience, most respondents had between 2 to 5 years (25.9%) or 11 to 15 years (23.1%) of experience, suggesting a balanced mix of early-career and seasoned professionals. Those with 6 to 10 years of experience accounted for 22.4%, while 15.0% had less than two years and 13.6% had over 15 years in the field. The respondents came from different business sectors, with retail (23.1%) and food & beverage delivery (22.4%) being the most represented. Wholesale distribution (20.4%)

and courier & express delivery (18.4%) also had significant participation, while e-commerce (8.8%) and manufacturing & production (6.8%) had the lowest representation. When asked about automation use in last-mile delivery, 36.1% of companies had plans to adopt it, but had not yet implemented it, while 32.0% had integrated automation in certain areas. Only 16.3% reported extensive use, whereas 15.6% had no immediate plans for adoption. In terms of familiarity with automation technologies, the majority of respondents were at least somewhat familiar (29.9%) or very familiar (25.2%), while 18.4% were moderately familiar. However, 10.2% were not familiar at all and only 16.3% considered themselves experts. The main challenges to automation adoption included technological complexity and integration challenges (22.4%), followed by resistance to change (15.6%) and lack of a skilled workforce (15.6%). Regulatory and compliance issues (12.2%), security concerns (14.3%) and high implementation costs (11.6%) also posed barriers.

Table 4.2
Demographic information

Variables		**Frequency**	**%**
What is your role in last-mile delivery?	Inventory analyst	27	18.4
	Logistics coordinator	31	21.1
	Logistics manager	38	25.9
	Procurement officer	20	13.6
	Warehouse manager	19	12.9
	Other	12	8.2
How many years of experience do you have in the logistics or supply chain industry?	Less than 2 years	22	15.0
	2-5 years	38	25.9
	6-10 years	33	22.4
	11-15 years	34	23.1
	More than 15 years	20	13.6
What is the nature of your business?	Courier & Express Delivery	27	18.4
	E-commerce	13	8.8

Variables		Frequency	%
	Food & Beverage Delivery	33	22.4
	Manufacturing & Production	10	6.8
	Retail	34	23.1
	Wholesale Distribution	30	20.4
Does your company currently use automation in last-mile delivery?	No and we have no immediate plans to adopt it	23	15.6
	No, but we are planning to adopt it	53	36.1
	Yes, but only in some areas	47	32.0
	Yes, extensively	24	16.3
How familiar are you with automation technologies in last-mile delivery?	Not familiar at all	15	10.2
	Somewhat familiar	44	29.9
	Moderately familiar	27	18.4
	Very familiar	37	25.2
	Expert level	24	16.3
What are the main challenges your company faces in adopting automation for last-mile delivery?	High implementation costs	17	11.6
	Lack of skilled workforce	23	15.6
	Regulatory and compliance issues	18	12.2
	Resistance to change from employees	23	15.6
	Security and data privacy concerns	21	14.3
	Technological complexity and integration challenges	33	22.4
	Other	12	8.2

4.4 NORMALITY TEST

Based on skewness and kurtosis, the normality test results for the study’s key variable are shown in table 4.3. According to George and Mallery (2003), a normal univariate distribution is indicated by all skewness and kurtosis values falling within the permissible range of -2 to +2. For each parametric research, this suggests the data for these constructs are adequately frequently distributed. All variables have mean values between 3.08 and 3.23, nor the raw mean and the 5% trimmed mean differ very little indicating that extreme values have minimal impact on the distribution.The variance values, which measure data dispersion, range from 1.06 to 1.25, with standard deviations between 1.03 and 1.12, suggesting moderate variability in responses. In terms of skewness, all variables exhibit values close to zero, indicating a relatively symmetrical distribution. PEOU shows a slightly negative skew (-0.84), suggesting that responses lean slightly toward higher values. Similarly, workforce readiness (-0.05) and regulatory constraints (0.08) show negligible skewness, reinforcing the normality assumption. Adoption of automation in last-mile delivery (0.15) and PU (0.08) also display minimal skewness, indicating balanced distributions.

Regarding kurtosis, most variables have values below zero, indicating a slightly flatter distribution. PU (-1.07), regulatory constraints (-1.00), workforce readiness (-1.04) and adoption of automation in last-mile delivery (-0.99) all demonstrate slight platykurtic tendencies, meaning their distributions are slightly flatter than a normal curve. However, PEOU has a higher kurtosis value (3.19), suggesting a more peaked distribution with a concentration of responses around the mean. Overall, these results confirm that the data exhibit an approximately normal distribution, making them suitable for further statistical analysis using parametric methods such as correlation and regression.

Table 4.3
Normality test of perceived usefulness, perceived ease of use, regulatory constraints, workforce readiness and adoption of automation in last-mile delivery

Variables	**Mean**	**Standard Deviation**	**Skewness**	**Kurtosis**
Perceived usefulness	3.12	1.12	0.08	-1.07
Perceived ease of use	3.11	1.03	-0.84	3.19
Regulatory constraints	3.19	1.06	0.08	-1.00
Workforce readiness	3.23	1.07	-0.05	-1.04
Adoption of automation in last-mile delivery	3.08	1.09	0.15	-0.99

4.5 PEARSON CORRELATION ANALYSIS

Table 4.4 presents the Pearson correlation analysis examining the relationship between PU, PEOU, regulatory constraints and workforce readiness with the adoption of automation in last-mile delivery operations in Penang. The significance level (Sig).), Pearson correlation coefficients, and their interpretation are all covered in detail in the table below. Correlation coefficients between 0.10 and 0.29 are considered as weak, those between 0.30 and 0.49 as moderate and those between 0.50 and 1.0 as strong according to Pallant (2016). A perfect positive correlation coefficient of +1, an ideal negative correlation by a correlation value -1, and no correlation by a correlation coefficient of 0. All variables show significant correlations at the 0.00 significance level, indicating strong associations with automation adoption. Workforce readiness exhibits the highest correlation with the adoption of automation (r = 0.85, p = 0.00), suggesting that companies with a workforce prepared for automation are more likely to integrate such technologies into their last-mile delivery operations. This strong correlation highlights the critical role of employee readiness in facilitating automation adoption.

Regulatory constraints also show a strong positive correlation with automation adoption (r = 0.71, p = 0.00). This suggests that regulatory compliance and policy-related factors significantly influence automation implementation. Companies that navigate regulatory challenges effectively may have higher adoption rates, whereas restrictive policies could pose barriers. PEOU demonstrates a strong correlation with automation adoption (r = 0.63, p = 0.00). This indicates that automation technologies perceived as easy to use and less complex are more likely to be adopted, reinforcing the importance of user-friendly systems and seamless integration into existing operations. PU is also positively correlated with automation adoption (r = 0.59, p = 0.00), suggesting that organizations that recognize the benefits of automation are more inclined to implement it. This relationship highlights the role of perceived value in driving technological advancements in logistics operations. Overall, these findings emphasize that while workforce readiness is the most critical factor influencing automation adoption, regulatory compliance, ease of use and PU also play significant roles in shaping companies' decisions to integrate automation in last-mile delivery operations.

Table 4.4
Pearson correlation analysis to determine the relationship between key factors and automation adoption in last-mile delivery operations in Penang

Variables	**Adoption of Automation In Last-Mile Delivery**	
	Sig.	**Pearson Correlation**
Perceived usefulness	0.00	0.59
Perceived ease of use	0.00	0.63
Regulatory constraints	0.00	0.71
Workforce readiness	0.00	0.85

**Correlation is significant at the 0.01 level (2-tailed)*

4.6 MULTIPLE REGRESSION ANALYSIS

Table 4.5 outlines the metrics used to assess multicollinearity, as discussed by Pallant (2007). Tolerance indicates the extent to which the variance of a particular independent variable is not explained by other independent variables in the model (Pallant, 2007). In this study, the tolerance values range from 0.38 to 0.60, well above the minimum threshold of 0.20. This suggests that multicollinearity is not a concern. Further evidence supporting this conclusion comes from the Variance Inflation Factor (VIF) values, which range from 2.67 to 2.61, remaining comfortably below the critical threshold of 5. As noted by Hair et al. (2011), multicollinearity becomes problematic when VIF exceeds 5 and tolerance falls below 0.20. Therefore, based on these results, multicollinearity does not present a significant issue in this study.

Table 4.5
Multicollinearity test

Variables	Collinearity Statistics	
	Tolerance	**VIF**
Perceived usefulness	0.60	1.67
Perceived ease of use	0.55	1.80
Regulatory constraints	0.56	1.79
Workforce readiness	0.38	2.61

Table 4.6 provides an overview of multiple regression analyses involving impact of PU, PEOU, regulatory constraints and workforce readiness on adoption of automation in last-mile delivery operations in Penang. The findings reveal that these combined factors accounted for 77% of the variance in predicting adoption of automation in last-mile delivery operations in Penang (R^2 = 0.77).

Table 4.6
Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.88	0.77	0.76	0.53

Multiple linear regression analysis was used to forecast Penang's adoption of automation in last-mile delivery operations and the results are summarized in the ANNOVA table. The regression section demonstrates how well the model explains the observed variation in the dependent variable. The statistical significance of the complete model is shown by F-statistic of 118.65 and the corresponding p-value of 0.00. Overall, according to the ANNOVA results, the regression model is quite significant in identifying the factors that influence Penang's last-mile delivery operations use of automation.

Table 4.7
ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	133.00	4.00	33.25	118.65	0.00
	Residual	39.79	142.00	0.28		
		172.79	146.00			

Table 4.8 presents the results of a multiple regression analysis examining the impact of PU, PEOU, regulatory constraints and workforce readiness on the adoption of automation in last-mile delivery operations in Penang. The findings indicate that while some variables significantly predict automation adoption, others do not exhibit strong statistical significance.

PU has the lowest impact, with an unstandardized coefficient (B) of $B = 0.07$ and a standardized beta of $\beta = 0.08$, indicating that a one-unit increase in PU only results in a 0.07-unit increase in automation adoption. The t-value of $t = 1.46$ and a non-significant p-value of $p = 0.15$ suggest that PU does not have a statistically meaningful effect on automation adoption. This finding implies that while organizations may recognize the benefits of automation, other factors such as workforce preparedness and regulatory considerations play a more dominant role in influencing adoption decisions.

PEOU has an unstandardized coefficient (B) of $B = 0.11$ and a standardized beta of $\beta = 0.10$, meaning that a one-unit increase in PEOU and lower technological complexity results in a 0.11-unit increase in automation adoption. However, the t-value of $t = 1.84$ and a p-value of $p = 0.07$ indicate that this relationship is not statistically significant at the conventional 0.05 level. While ease of use and minimal technological complexity may influence automation adoption, their impact appears to be weaker compared to workforce readiness and regulatory factors.

Regulatory constraints have an unstandardized coefficient (B) of $B = 0.26$ and a standardized beta of $\beta = 0.25$, suggesting that a one-unit increase in regulatory constraints corresponds to a 0.26-unit increase in automation adoption. The t-value of $t = 4.70$ and a significant value of $p = 0.00$ confirm the strong influence of regulatory policies on the adoption process. This result indicates that companies that effectively address compliance and regulatory requirements are more likely to integrate automation into their last-mile delivery operations.

Workforce readiness has an unstandardized coefficient (B) of $B = 0.58$ and a standardized beta of $\beta = 0.57$, indicating that for every one-unit increase in workforce readiness, the adoption of automation in last-mile delivery increases by 0.58 units. The t-value of $t = 8.75$ and a significant value of $p = 0.00$ suggest that this relationship is highly significant. This finding highlights that a workforce that is adequately trained and prepared for automation plays a crucial role in facilitating its adoption within last-mile delivery operations. Overall, the regression analysis highlights that workforce readiness and regulatory constraints are the most significant factors influencing the adoption of automation in last-mile delivery. While PEOU show a marginal effect, PU does not significantly predict automation adoption. These findings underscore the importance of workforce preparation and regulatory navigation in successfully implementing automation in last-mile delivery operations.

Table 4.8
Summary of multiple regression analysis impact of key factors on automation adoption in last-mile delivery operations in Penang in last-mile delivery operations in Penang

Variable	**Unstandardized B**	**Standardized Beta**	***p***
Perceived usefulness	0.07	0.08	0.15
Perceived ease of use	0.11	0.10	0.07
Regulatory constraints	0.26	0.25	0.00
Workforce readiness	0.58	0.57	0.00

p <0 .05 (significant at the 0.01 level, 2-tailed)

Chapter 5
Discussion and Conclusion

5.1 Introduction

This chapter explores the influence of key variables on the adoption of automation in last-mile delivery operations in Penang. It also analyses the implications of this study, addresses its constraints, and makes recommendations for further research.

5.2 Summary Research

The research aimed to examine the factors affecting the implementation of automation in last-mile delivery companies in Penang. The study was based on the Technology Acceptance Model (TAM), emphasising PU and PEOU, and was enhanced by a discussion of regulatory constraints and workforce readiness. Data were obtained from 147 logistics professionals using a standardised questionnaire. The study uses descriptive statistics, Pearson correlation, and multiple regression analysis to analyse the correlations among the variables. Findings highlight that automation adoption in last-mile delivery is primarily influenced by workforce readiness and regulatory considerations rather than PU.

5.3 Discussion Analysis Result

The findings shows that workforce readiness and regulatory constraints play a crucial role in driving automation adoption in last-mile delivery with workforce readiness being the strongest influencing factor. This supports earlier studies suggesting that a well-prepared workforce can ease the transition to automation by reducing resistance and boosting efficiency. On the other hand, regulatory constraints such as unclear policies and complex compliance requirements discourage business from moving forward with automation investments. Although PU is positively linked to automation, it does not significantly influence adoption decisions. This indicates that businesses may acknowledge the value of automation but practical challenges like staffing and regulations take precedence. Similarly, while PEOU shows a weak impact, it alone isn't enough to drive the adoption when larger obstacles remain. These results highlight the importance of investing in workforce development and creating clearer, more supportive regulatory guidelines to encourage broader adoption of automation in the logistics sector.

5.4 Major Finding Study

The findings from the correlation and regression analysis reveal key insights into the factors influencing the adoption of automation in last-mile delivery. The correlation analysis indicates a significant positive relationship between PU and the adoption of automation ($r = 0.59$, $p < 0.01$). However, regression analysis shows that PU does not significantly predict automation adoption ($\beta = 0.08$, $p = 0.15$). This suggests that while businesses recognize the potential benefits of automation, other factors play a more dominant role in influencing adoption decisions.

Previous research supports the notion that PU influences technology adoption but may not always be the strongest predictor. Davis (1989) and Venkatesh and Davis (2000) emphasize that users are more likely to adopt a technology when they perceive it as useful, aligning with Siegfried and Zhang's (2021) findings that businesses integrate automation to enhance efficiency and reduce costs. Similarly, Yuen et al. (2022) found that retailers using autonomous robots reported increased efficiency, reinforcing the idea that PU encourages investment in automation. However, Ee et al. (2024) argue that in regions with low labor costs and underdeveloped technological infrastructure, businesses may not prioritize automation, even if they recognize its usefulness. This could explain why PU in this study does not emerge as a significant predictor in the regression model, as external barriers such as regulatory constraints and workforce readiness may outweigh its impact. PEOU and technological complexity exhibit a moderate positive correlation with automation adoption ($r = 0.63$, $p < 0.01$), yet in the regression model, this factor is only marginally significant ($\beta = 0.10$, $p = 0.07$). This implies that while businesses acknowledge the importance of ease of use, its direct influence on adoption is somewhat limited. The Technology Acceptance Model (TAM) highlights ease of use as a key determinant of technology adoption (Davis, 1989). Venkatesh and Davis (2000) suggest that when a system is perceived as easy to use, adoption likelihood increases. However, Siegfried and Zhang (2021) argue that automation solutions must integrate seamlessly into existing logistics operations to be widely accepted. If businesses perceive automation as overly complex or requiring significant training, they may resist implementation due to concerns over operational disruptions and costs (Heid et al., 2018). Rogers' (2003) Diffusion of Innovation (DOI) Theory also supports this view, emphasizing that technological complexity can hinder adoption.

Chau and Tam (1997) highlight that when automation technologies are intuitive and require minimal modifications, they gain higher acceptance. This is evident in studies where companies with simplified automation systems reported smoother transitions (Venkatesh & Bala, 2008). Therefore, while ease of use is an important consideration, the slight insignificance in this study suggests that other pressing factors such as regulatory constraints and workforce readiness may have a stronger influence on adoption decisions. Workforce readiness demonstrates the strongest correlation with automation adoption ($r = 0.85$, $p < 0.01$) and is also the most significant predictor in the regression model ($\beta = 0.57$, $p < 0.01$). This finding indicates that a workforce's preparedness, skills and willingness to adapt to technological advancements play a crucial role in automation adoption. Previous research aligns with this result, emphasizing that skilled and adaptable employees facilitate the integration of automation technologies (Schmidt et al., 2017). Chuang and Graham (2020) argue that when employees are trained to operate and collaborate with automation, efficiency improves and resistance decreases. On the contrary, Frey and Osborne (2017) found that when employees lack the necessary skills or fear job displacement, resistance increases, leading to slower adoption rates. Organizations that fail to invest in training may struggle with automation errors and system inefficiencies, negating the intended benefits (Wamba et al., 2021). As a result, businesses should prioritize workforce development, ensuring that employees receive adequate training and hands-on experience with automation. This aligns with Nabiha et al. (2020), who argue that effective training programs can significantly enhance automation adoption rates, especially in industries where workforce adaptation is a critical concern.

Regulatory constraints show a strong correlation with automation adoption ($r = 0.71$, $p < 0.01$) and emerge as a significant predictor in the regression model ($\beta = 0.25$, $p < 0.01$). This suggests that legal and regulatory barriers are key considerations when businesses decide whether to implement automation technologies. Taylor, Roberts and Green (2021) argue that strict regulations often discourage companies from investing in automation due to uncertainty and compliance complexities. Samouh et al. (2020) found that businesses facing difficulties in obtaining approvals for autonomous deliveries often delay automation projects or opt for traditional methods. In contrast, regions with well-defined regulatory frameworks, such as the United States and parts of Europe, have seen higher adoption rates (Siegfried & Zhang, 2021). This is because clear regulations reduce uncertainty and encourage businesses to invest in automation.

In Malaysia, Nabiha et al. (2020) found that the absence of standardized policies for autonomous deliveries has slowed automation adoption. Businesses hesitate to implement new technologies without clear legal guidelines, fearing penalties or operational disruptions. To address this issue, Venkatesh and Bala (2008) suggest that governments should establish standardized regulations, offer financial incentives and develop infrastructure to support automation. This would create a more favorable environment for businesses, ultimately accelerating automation adoption in last-mile delivery. The findings of this study align with existing literature in several key aspects. Workforce readiness is consistently identified as the strongest predictor of automation adoption, reinforcing the argument that a skilled and adaptable workforce is crucial for successful implementation. Regulatory constraints are also highlighted as a significant barrier, which is supported by previous studies emphasizing the role of government policies in shaping technological adoption.

However, the insignificance of PU in the regression model presents an interesting contrast to TAM-based studies. While previous research suggests that PU is a major driver of adoption (Davis, 1989; Venkatesh & Davis, 2000), the findings here indicate that external barriers such as regulations and workforce readiness play a more dominant role in last-mile delivery automation. This suggests that while businesses recognize the benefits of automation, they may be unable to act on these perceptions due to practical constraints. Similarly, while PEOU is positively correlated with automation adoption, it is only marginally significant in the regression model. This aligns with studies suggesting that while ease of use is important, it is often secondary to factors such as workforce readiness and regulatory support (Chau & Tam, 1997; Heid et al., 2018).

This study provides valuable insights into the factors influencing automation adoption in last-mile delivery. Workforce readiness and regulatory constraints emerge as the most critical determinants, emphasizing the need for skilled labor and supportive regulatory frameworks. While PU and ease of use are relevant, their influence is overshadowed by external barriers that restrict businesses from implementing automation. These findings highlight the importance of investing in employee training and advocating for clearer regulatory policies to foster a more conducive environment for automation adoption.

5.5 Contribution of the study

This study contributes to the understanding of automation adoption in last-mile delivery by identifying key factors that influence its implementation. One of the major contributions is highlighting the critical role of workforce readiness in adopting automation. The findings suggest that a well-trained and prepared workforce significantly facilitates automation adoption, emphasizing the need for organizations to invest in employee upskilling and technological training. Additionally, this study underscores the importance of regulatory constraints in shaping automation adoption. By demonstrating that compliance with legal and industry regulations is a significant factor, the study provides valuable insights for policymakers and logistics companies on the necessity of creating clear regulatory frameworks to support automation initiatives. The study also contributes to the Technology Acceptance Model (TAM) by assessing PU and PEOU in an automation context. The findings reveal that these factors are less influential compared to workforce readiness and regulatory constraints, suggesting that traditional TAM variables may not fully explain automation adoption in last-mile delivery. Practically, this study provides logistics firms with data-driven insights to develop effective automation strategies. By addressing workforce readiness and regulatory challenges, businesses can enhance operational efficiency, reduce costs and improve last-mile delivery processes. Future research can expand on these findings by incorporating cost and infrastructure considerations.

5.6 Limitation Of Study

This study has several limitations that should be acknowledged. First, the use of convenience sampling may limit the generalizability of the findings. The sample was drawn from last-mile delivery operations in Penang, which may not fully represent the broader logistics industry in other regions with different regulatory environments and technological infrastructures. Future research should consider a more diverse sample to enhance the applicability of the findings. Second, the study primarily relies on self-reported data, which may introduce response bias. Participants' perceptions of automation adoption could be influenced by personal experiences or organizational policies, leading to potential overestimation or underestimation of the factors examined. Incorporating objective performance data or observational studies could strengthen the validity of future research. Third, while the study focuses on PU, PEOU and technological complexity, regulatory constraints and workforce readiness, other factors such as cost considerations, infrastructure limitations and industry competition were not explored. These factors could also play a significant role in automation adoption and should be examined in future studies. Lastly, the cross-sectional nature of the study prevents an assessment of causal relationships. A longitudinal study could provide deeper insights into how these factors influence automation adoption over time.

5.7 Future Recommendation

This research should be broadened in in future research by taking into consideration other variables that might affect the adoption of automation in last-mile delivery. Additional significant variables including financial concerns, infrastructural readiness, and industry competition should be assessed, even though this study concentrated on workforce readiness, regulatory constraints, PU, PEOU, and technological complexity. Examining these components may yield a more thorough comprehension of the opportunities and difficulties associated with automation implementation.

Furthermore, a longitudinal research design should be used in future studies to observe the adoption of automation over time. A time-based method would be useful for evaluating how regulatory constraints and workforce readiness evolve over time and influence automation decision-making process. This would provide more thorough understanding of the long-term effects and sustainability of automation in the logistics industry. Increasing the study's scope to include additional industries and geographical areas would improve its applicability to other industries. Important contextual variations in the adoption of automation may be found through comparative studies conducted in different locations with different technology infrastructures and legal frameworks. Incorporating qualitative and quantitative approaches may also yield a more comprehensive viewpoint. Interviewing business executives and other key stakeholders would enhance the findings of surveys by providing more in-depth understanding of operational and strategic factors. Future studies and real-world logistics automation solutions would benefit from addressing these suggestions.

5.8 Conclusion

This chapter examines key factors influencing automation adoption in last-mile delivery in Penang, focusing on PU, PEOU, regulatory constraint and workforce readiness. Findings show workforce readiness is the strongest predictor, highlighting the need for skilled talent to support automation. Regulatory constraint also plays a significant role as compliance issue can hinder adoption. While PU and PEOU show positive correlations, they are not significant predictors suggesting external barriers outweigh user perceptions. The study extends the Technology Acceptance Model (TAM) by emphasizing regulatory and workforce factors. Limitations include convenience sampling and self-reported data, which may affect generalizability. Future research should explore cost, infrastructure and competition using longitudinal and mixed method approaches.

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Appendix A
Questionnaire

Research Questionnaire Survey

Dear Respondents,

My name is Kamalleswary and I am
a postgraduate student at University Utara Malaysia (UUM). Currently, I am in the final semester of my program, diligently working on my final year project (thesis) titled "Factors Determining the Adoption of Automation in Last-Mile Delivery in Penang. This study aims to explore the key factors influencing the adoption of automation technologies in last-mile delivery within Penang. It seeks to understand industry perceptions, challenges, and potential benefits associated with automation, contributing to the growing body of knowledge in supply chain and logistics automation. The findings from this study will provide insights that could help businesses and policymakers in making informed decisions regarding the implementation of automation in last-mile logistics.

Thank you in advance for
participating in my research study. Your valuable insights are crucial to my research. Please take a few minutes to complete the following questionnaire. Your feedback will significantly
contribute to the success of my research. All responses will be kept strictly confidential and used solely for academic purposes.

Kamalleswary

School of Technology Management and Logistics

Universiti Utara Malaysia (UUM), Kedah.

Section A - Demographics/Background

This section is about the respondent's industry role, experience, and exposure to automation in last-mile delivery. Please respond to all the questions that best describe you.

1. What is your role in last-mile delivery?

- ◯ Warehouse Manager
- ◯ Logistics Manager
- ◯ Logistics Coordinator
- ◯ Inventory Analyst
- ◯ Procurement Officer
- ◯ Other (please specify) :

2. How many years of experience do you have in the logistics or supply chain industry?

- ◯ Less than 2 years
- ◯ 2-5 years
- ◯ 6-10 years
- ◯ 11-15 years
- ◯ More than 15 years

3. What is the nature of your business?

- ◯ E-commerce
- ◯ Retail
- ◯ Wholesale Distribution
- ◯ Courier & Express Delivery
- ◯ Food & Beverage Delivery
- ◯ Manufacturing & Production

4. Does your company currently use automation in last-mile delivery?

- ◯ Yes, extensively
- ◯ Yes, but only in some areas
- ◯ No, but we are planning to adopt it
- ◯ No, and we have no immediate plans to adopt it

5. How familiar are you with automation technologies in last-mile delivery?

- ◯ Not familiar at all
- ◯ Somewhat familiar
- ◯ Moderately familiar
- ◯ Very familiar
- ◯ Expert level

6. What are the main challenges your company faces in adopting automation for last-mile delivery? (Select all that apply)

- ◯ High implementation costs
- ◯ Lack of skilled workforce
- ◯ Resistance to change from employees
- ◯ Regulatory and compliance issues
- ◯ Technological complexity and integration challenges
- ◯ Security and data privacy concerns
- ◯ Other (please specify):

Section B – Dependent Variable

This section assesses key factors influencing automation adoption, including perceived usefulness, ease of use, regulatory constraints, and workforce readiness.

Please indicate the extent to which your organizations strongly agree, agree, neither agree or disagree, and strongly disagree with the statement presented by choosing the likert scale.

A) Perceived Usefulness (PU)

7. Using automation technologies will improve the efficiency of last-mile delivery operations in Penang.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

8.Automation technologies improve delivery times for my company.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

9. Implementing automation technologies will reduce operational costs in last-mile delivery.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

10. Automation technologies will provide my company with a competitive advantage.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

B) **Perceived Ease of Use & Technological Complexity (PEOU)**

11. Learning to operate automation technologies will be easy for employees in my company.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

12.Integrating automation technologies into existing logistics operations will require minimal system modifications.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

13. The complexity of maintaining automation technologies will be manageable for my company.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

14. Implementing automation in our last-mile delivery operations will not disrupt existing workflows.

- Agree
- Strongly agree
- Neither agree or disagree
- Disagree
- Strongly disagree

C) Regulatory Constraints

15. The current regulations in Penang regarding the use of automation in last-mile delivery are clear.

- Agree
- Strongly agree
- Neither agree or disagree
- Disagree
- Strongly disagree

16. The process of obtaining the necessary permits for automation technologies is efficient.

- Agree
- Strongly agree
- Neither agree or disagree
- Disagree
- Strongly disagree

17. Potential legal issues related to autonomous delivery systems are a significant concern for our organization.

- Agree
- Strongly agree
- Neither agree or disagree
- Disagree
- Strongly disagree

18. Existing regulations create significant barriers to adopting automation technologies in last mile delivery.

- Agree
- Strongly agree
- Neither agree or disagree
- Disagree
- Strongly disagree

D) Workforce Readiness

19. Our workforce possesses the necessary digital literacy skills to operate automation technologies.

- Agree
- Strongly agree
- Neither agree or disagree
- Disagree
- Strongly disagree

20. Our employees are supportive of adopting automation technologies in last-mile delivery operations.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

21. We have a well-defined plan for training and upskilling employees to use automation technologies effectively.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

22. Automation technologies will lead to significant job displacement within our organization.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

E. Adoption of Automation in Last-Mile Delivery

23. Our company is willing to invest in automation technologies to improve last-mile delivery efficiency.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

24. The benefits of adopting automation in last-mile delivery outweigh the costs and challenges.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

25. The employees would be willing to adopt and use automation technologies if provided with adequate training.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

26. Our company expects a significant return on investment (ROI) from automation adoption in last-mile delivery.

- ◯ Agree
- ◯ Strongly agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

Submit | Clear form

Appendix B

All SPSS Results

Pilot Test

Reliability

Scale: PU

Case Processing Summary

		N	%
Cases	Valid	35	100.0
	Excluded[a]	0	.0
	Total	35	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.782	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
7. Using automation technologies will improve the efficiency of last-mile delivery operations in Penang.	9.34	10.114	.871	.585
8.Automation technologies improve delivery times for my company.	9.34	9.761	.845	.588
9. Implementing automation technologies will reduce operational costs in last-mile delivery.	9.23	9.829	.783	.619
10. Automation technologies will provide my company with a competitive advantage.	9.11	16.281	.055	.970

Reliability

Scale: Perceived Ease of Use & Technological Complexity

Case Processing Summary

		N	%
Cases	Valid	35	100.0
	Excluded[a]	0	.0
	Total	35	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.727	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
11. Learning to operate automation technologies will be easy for employees in my company.	9.29	8.328	.798	.475
12.Integrating automation technologies into existing logistics operations will require minimal system modifications.	9.09	17.022	-.146	.980
13. The complexity of maintaining automation technologies will be manageable for my company.	9.29	9.092	.848	.474
14. Implementing automation in our last-mile delivery operations will not disrupt existing workflows.	9.37	8.005	.880	.417

Reliability

Scale: Regulatory Constraints

Case Processing Summary

		N	%
Cases	Valid	35	100.0
	Excluded[a]	0	.0
	Total	35	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.724	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
15. The current regulations in Penang regarding the use of automation in last-mile delivery are clear.	9.80	18.282	-.224	.978
16. The process of obtaining the necessary permits for automation technologies is efficient.	10.06	7.644	.839	.423
17. Potential legal issues related to autonomous delivery systems are a significant concern for our organization.	10.06	8.879	.853	.454
18. Existing regulations create significant barriers to adopting automation technologies in last-mile delivery.	10.03	8.087	.885	.408

Reliability

Scale: Workforce Readiness

Case Processing Summary

		N	%
Cases	Valid	35	100.0
	Excluded[a]	0	.0
	Total	35	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.861	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
19. Our workforce possesses the necessary digital literacy skills to operate automation technologies.	10.31	10.398	.827	.776
20. Our employees are supportive of adopting automation technologies in last-mile delivery operations.	10.34	9.291	.921	.728
21. We have a well-defined plan for training and upskilling employees to use automation technologies effectively.	10.54	9.079	.885	.741
22. Automation technologies will lead to significant job displacement within our organization.	10.29	13.681	.292	.976

Reliability

Scale: Adoption of Automation in Last-Mile Delivery

Case Processing Summary

		N	%
Cases	Valid	35	100.0
	Excluded[a]	0	.0
	Total	35	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.786	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
23. Our company is willing to invest in automation technologies to improve last-mile delivery efficiency.	9.37	9.240	.853	.604
24. The benefits of adopting automation in last-mile delivery outweigh the costs and challenges.	9.43	9.017	.870	.591
25. The employees would be willing to adopt and use automation technologies if provided with adequate training.	9.17	15.264	.022	.974
26. Our company expects a significant return on investment (ROI) from automation adoption in last-mile delivery.	9.14	7.891	.838	.586

Results

Frequencies

Statistics

		1. What is your role in last-mile delivery?	2. How many years of experience do you have in the logistics or supply chain industry?	3. What is the nature of your business?	4. Does your company currently use automation in last-mile delivery?	5. How familiar are you with automation technologies in last-mile delivery?	6. What are the main challenges your company faces in adopting automation for last-mile delivery? (Select all that apply)
N	Valid	147	147	147	147	147	147
	Missing	0	0	0	0	0	0

Frequency Table

1. What is your role in last-mile delivery?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Inventory Analyst	27	18.4	18.4	18.4
	Logistics Coordinator	31	21.1	21.1	39.5
	Logistics Manager	38	25.9	25.9	65.3
	Other (please specify) :	12	8.2	8.2	73.5
	Procurement Officer	20	13.6	13.6	87.1
	Warehouse Manager	19	12.9	12.9	100.0
	Total	147	100.0	100.0	

2. How many years of experience do you have in the logistics or supply chain industry?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	11-15 years	34	23.1	23.1	23.1
	2-5 years	38	25.9	25.9	49.0
	6-10 years	33	22.4	22.4	71.4
	Less than 2 years	22	15.0	15.0	86.4
	More than 15 years	20	13.6	13.6	100.0
	Total	147	100.0	100.0	

3. What is the nature of your business?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Courier & Express Delivery	27	18.4	18.4	18.4
	E-commerce	13	8.8	8.8	27.2
	Food & Beverage Delivery	33	22.4	22.4	49.7
	Manufacturing & Production	10	6.8	6.8	56.5
	Retail	34	23.1	23.1	79.6
	Wholesale Distribution	30	20.4	20.4	100.0
	Total	147	100.0	100.0	

4. Does your company currently use automation in last-mile delivery?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No, and we have no immediate plans to adopt it	23	15.6	15.6	15.6
	No, but we are planning to adopt it	53	36.1	36.1	51.7
	Yes, but only in some areas	47	32.0	32.0	83.7
	Yes, extensively	24	16.3	16.3	100.0
	Total	147	100.0	100.0	

5. How familiar are you with automation technologies in last-mile delivery?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Expert level	24	16.3	16.3	16.3
	Moderately familiar	27	18.4	18.4	34.7
	Not familiar at all	15	10.2	10.2	44.9
	Somewhat familiar	44	29.9	29.9	74.8
	Very familiar	37	25.2	25.2	100.0
	Total	147	100.0	100.0	

6. What are the main challenges your company faces in adopting automation for last-mile delivery? (Select all that apply)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High implementation costs	17	11.6	11.6	11.6
	Lack of skilled workforce	23	15.6	15.6	27.2
	Other (please specify):	12	8.2	8.2	35.4
	Regulatory and compliance issues	18	12.2	12.2	47.6
	Resistance to change from employees	23	15.6	15.6	63.3
	Security and data privacy concerns	21	14.3	14.3	77.6
	Technological complexity and integration challenges	33	22.4	22.4	100.0
	Total	147	100.0	100.0	

Reliability

Scale: PU

Case Processing Summary

		N	%
Cases	Valid	147	100.0
	Excluded[a]	0	.0
	Total	147	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.813	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
7. Using automation technologies will improve the efficiency of last-mile delivery operations in Penang.	9.41	10.175	.860	.646
8.Automation technologies improve delivery times for my company.	9.44	10.426	.884	.640
9. Implementing automation technologies will reduce operational costs in last-mile delivery.	9.18	10.398	.857	.651
10. Automation technologies will provide my company with a competitive advantage.	9.44	16.988	.096	.982

Reliability

Scale: Perceived Ease of Use and Technological Complexity

Case Processing Summary

		N	%
Cases	Valid	147	100.0
	Excluded[a]	0	.0
	Total	147	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.783	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
11. Learning to operate automation technologies will be easy for employees in my company.	9.52	15.005	.011	.982
12.Integrating automation technologies into existing logistics operations will require minimal system modifications.	9.17	8.348	.834	.588
13. The complexity of maintaining automation technologies will be manageable for my company.	9.37	8.755	.875	.578
14. Implementing automation in our last-mile delivery operations will not disrupt existing workflows.	9.27	8.717	.857	.585

Reliability

Scale: Regulatory Constraints

Case Processing Summary

		N	%
Cases	Valid	147	100.0
	Excluded[a]	0	.0
	Total	147	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.791	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
15. The current regulations in Penang regarding the use of automation in last-mile delivery are clear.	9.45	8.934	.832	.609
16. The process of obtaining the necessary permits for automation technologies is efficient.	9.63	15.809	.032	.980
17. Potential legal issues related to autonomous delivery systems are a significant concern for our organization.	9.65	9.173	.883	.590
18. Existing regulations create significant barriers to adopting automation technologies in last-mile delivery.	9.51	9.361	.856	.606

Reliability

Scale: Workforce Readiness

Case Processing Summary

		N	%
Cases	Valid	147	100.0
	Excluded[a]	0	.0
	Total	147	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.804	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
19. Our workforce possesses the necessary digital literacy skills to operate automation technologies.	9.67	9.263	.886	.615
20. Our employees are supportive of adopting automation technologies in last-mile delivery operations.	9.74	9.111	.885	.612
21. We have a well-defined plan for training and upskilling employees to use automation technologies effectively.	9.73	16.306	.037	.988
22. Automation technologies will lead to significant job displacement within our organization.	9.67	9.553	.861	.631

Reliability

Scale: Adoption of Automation in Last-Mile Delivery

Case Processing Summary

		N	%
Cases	Valid	147	100.0
	Excluded[a]	0	.0
	Total	147	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.815	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
23. Our company is willing to invest in automation technologies to improve last-mile delivery efficiency.	9.31	9.447	.890	.636
24. The benefits of adopting automation in last-mile delivery outweigh the costs and challenges.	9.23	9.946	.878	.650
25. The employees would be willing to adopt and use automation technologies if provided with adequate training.	9.20	16.150	.084	.990
26. Our company expects a significant return on investment (ROI) from automation adoption in last-mile delivery.	9.26	9.686	.874	.647

Explore

Case Processing Summary

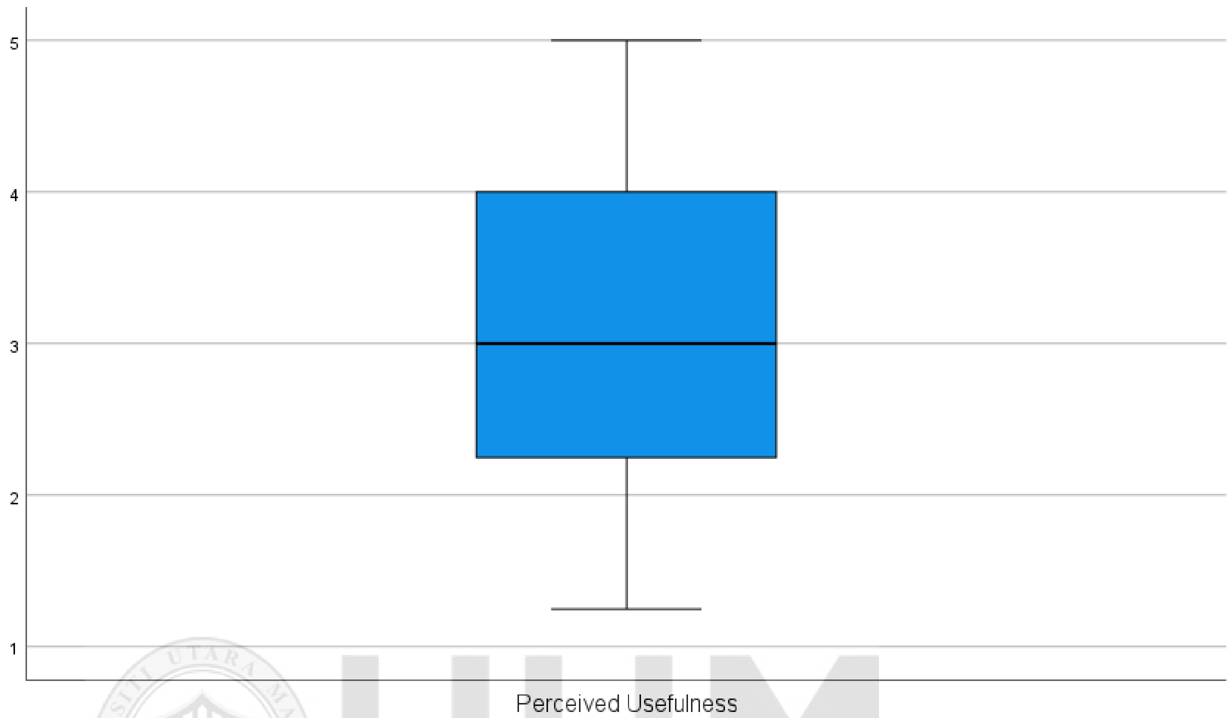
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Perceived Usefulness	147	100.0%	0	0.0%	147	100.0%
Perceived Ease of Use and Technological Complexity	147	100.0%	0	0.0%	147	100.0%
Regulatory Constraints	147	100.0%	0	0.0%	147	100.0%
Workforce Readiness	147	100.0%	0	0.0%	147	100.0%
Adoption of Automation in Last-Mile Delivery	147	100.0%	0	0.0%	147	100.0%

Descriptives

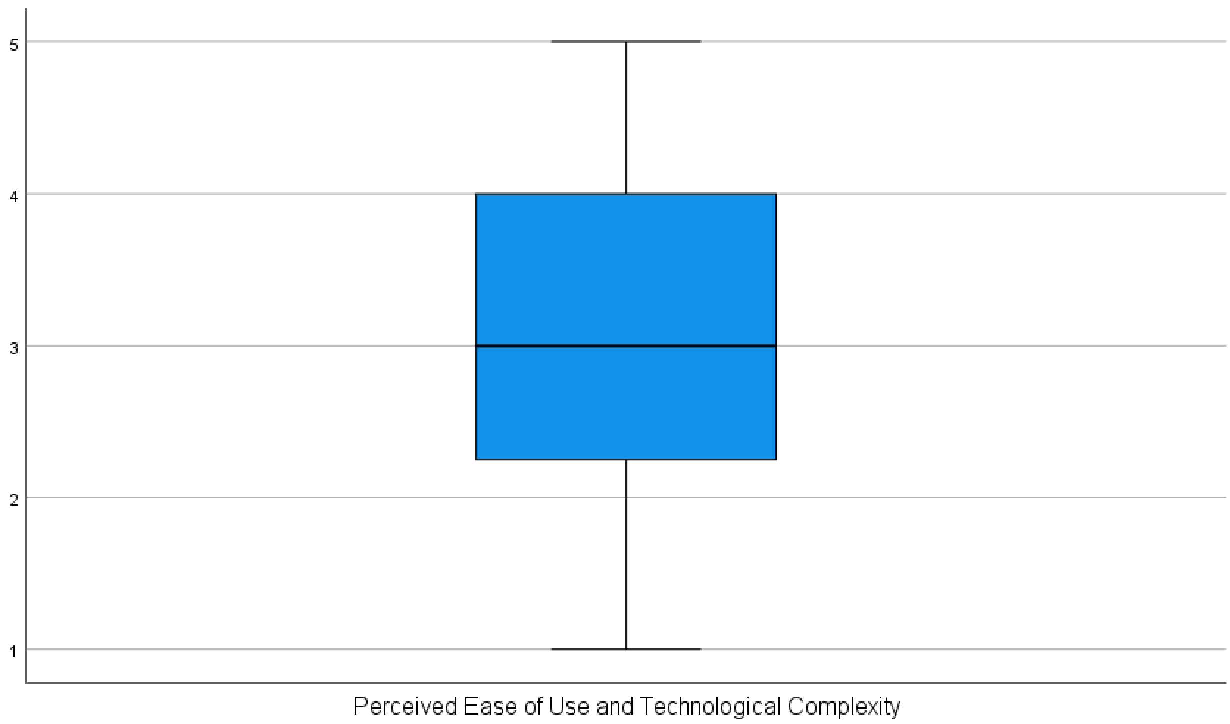
			Statistic	Std. Error
Perceived Usefulness	Mean		3.1224	.09238
	95% Confidence Interval for Mean	Lower Bound	2.9399	
		Upper Bound	3.3050	
	5% Trimmed Mean		3.1222	
	Median		3.0000	
	Variance		1.255	
	Std. Deviation		1.12009	
	Minimum		1.25	
	Maximum		5.00	
	Range		3.75	
	Interquartile Range		1.75	
	Skewness		.081	.200
	Kurtosis		-1.074	.397
Perceived Ease of Use and Technological Complexity	Mean		3.1105	.08482
	95% Confidence Interval for Mean	Lower Bound	2.9429	
		Upper Bound	3.2782	
	5% Trimmed Mean		3.1139	
	Median		3.0000	
	Variance		1.057	
	Std. Deviation		1.02834	
	Minimum		1.00	
	Maximum		5.00	
	Range		4.00	
	Interquartile Range		1.75	
	Skewness		.052	.200
	Kurtosis		-.836	.397
Regulatory Constraints	Mean		3.1871	.08744
	95% Confidence Interval for Mean	Lower Bound	3.0143	
		Upper Bound	3.3599	
	5% Trimmed Mean		3.1914	
	Median		3.0000	
	Variance		1.124	
	Std. Deviation		1.06019	
	Minimum		1.00	
	Maximum		5.00	
	Range		4.00	
	Interquartile Range		2.00	
	Skewness		.079	.200

	Kurtosis		-.998	.397
Workforce Readiness	Mean		3.2347	.08858
	95% Confidence Interval for Mean	Lower Bound	3.0596	
		Upper Bound	3.4098	
	5% Trimmed Mean		3.2462	
	Median		3.2500	
	Variance		1.153	
	Std. Deviation		1.07399	
	Minimum		1.00	
	Maximum		5.00	
	Range		4.00	
	Interquartile Range		1.75	
	Skewness		-.054	.200
	Kurtosis		-1.040	.397
Adoption of Automation in Last-Mile Delivery	Mean		3.0833	.08973
	95% Confidence Interval for Mean	Lower Bound	2.9060	
		Upper Bound	3.2607	
	5% Trimmed Mean		3.0806	
	Median		3.0000	
	Variance		1.184	
	Std. Deviation		1.08789	
	Minimum		1.00	
	Maximum		5.00	
	Range		4.00	
	Interquartile Range		1.75	
	Skewness		.148	.200
	Kurtosis		-.990	.397

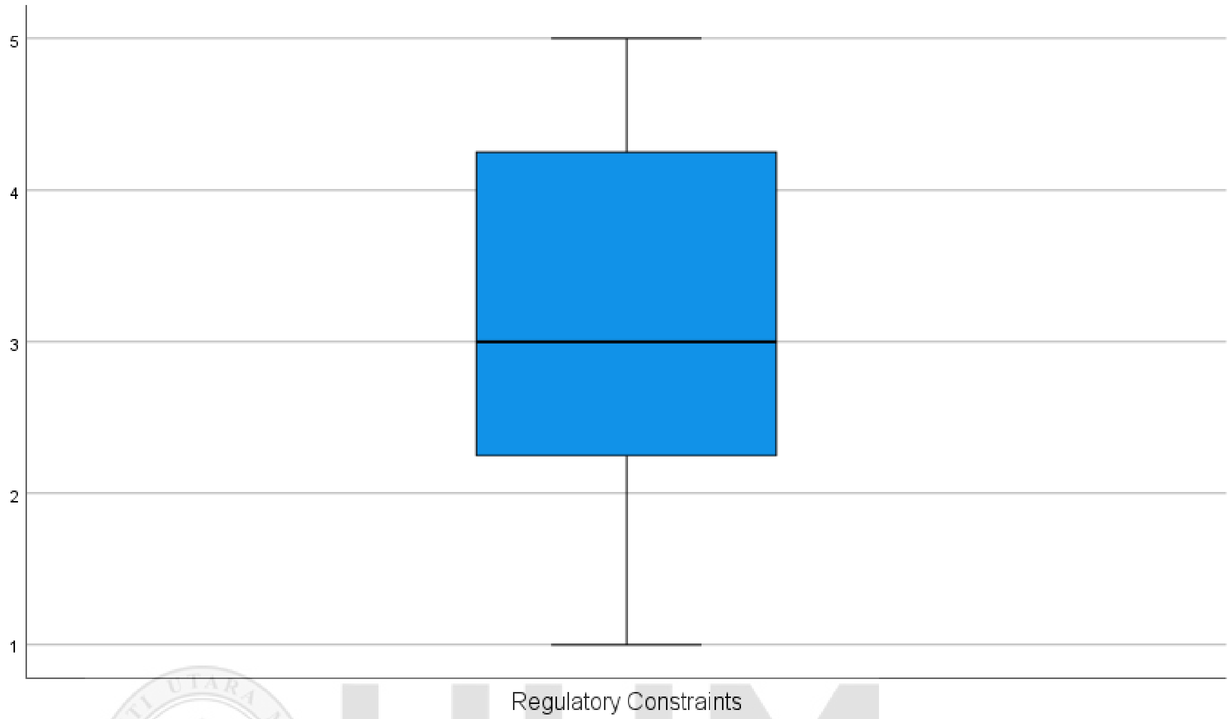
Perceived Usefulness



Perceived Ease of Use and Technological Complexity

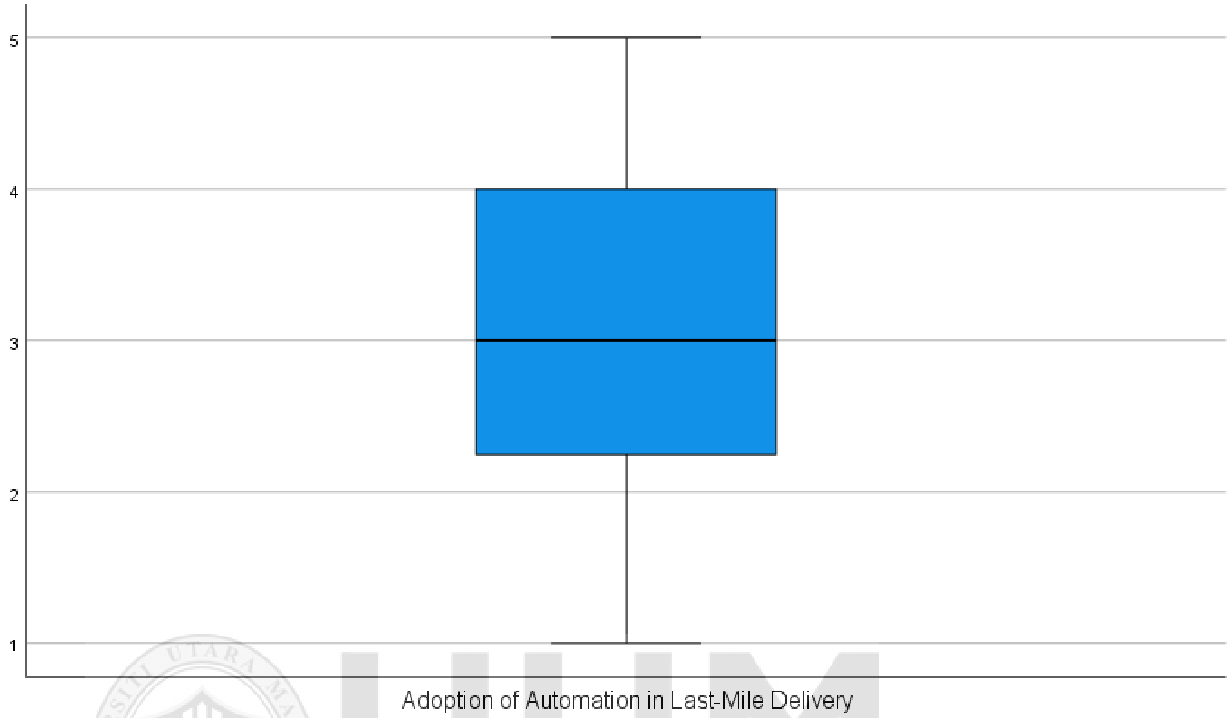


Regulatory Constraints



Workforce Readiness

Adoption of Automation in Last-Mile Delivery



Correlations

Correlations

		Perceived Usefulness	Perceived Ease of Use and Technological Complexity	Regulatory Constraints	Workforce Readiness	Adoption of Automation in Last-Mile Delivery
Perceived Usefulness	Pearson Correlation	1	.504**	.464**	.614**	.593**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	147	147	147	147	147
Perceived Ease of Use and Technological Complexity	Pearson Correlation	.504**	1	.507**	.646**	.634**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	147	147	147	147	147
Regulatory Constraints	Pearson Correlation	.464**	.507**	1	.653**	.711**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	147	147	147	147	147
Workforce Readiness	Pearson Correlation	.614**	.646**	.653**	1	.846**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	147	147	147	147	147
Adoption of Automation in Last-Mile Delivery	Pearson Correlation	.593**	.634**	.711**	.846**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	147	147	147	147	147

**. Correlation is significant at the 0.01 level (2-tailed).

Regression

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Workforce Readiness , Perceived Usefulness, Regulatory Constraints , Perceived Ease of Use and Technological Complexity[b]	.	Enter

a. Dependent Variable: Adoption of Automation in Last-Mile Delivery

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.877[a]	.770	.763	.52938

a. Predictors: (Constant), Workforce Readiness , Perceived Usefulness, Regulatory Constraints , Perceived Ease of Use and Technological Complexity

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	132.998	4	33.249	118.647	.000[b]
	Residual	39.794	142	.280		
	Total	172.792	146			

a. Dependent Variable: Adoption of Automation in Last-Mile Delivery

b. Predictors: (Constant), Workforce Readiness , Perceived Usefulness, Regulatory Constraints , Perceived Ease of Use and Technological Complexity

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-.169	.165		-1.022	.308		
	Perceived Usefulness	.074	.051	.076	1.460	.146	.599	1.670
	Perceived Ease of Use and Technological Complexity	.105	.057	.100	1.841	.068	.555	1.802
	Regulatory Constraints	.260	.055	.254	4.704	.000	.558	1.793
	Workforce Readiness	.576	.066	.569	8.750	.000	.383	2.608

a. Dependent Variable: Adoption of Automation in Last-Mile Delivery

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Variance Proportions Perceived Usefulness	Variance Proportions Perceived Ease of Use and Technological Complexity	Variance Proportions Regulatory Constraints	Variance Proportions Workforce Readiness
1	1	4.809	1.000	.00	.00	.00	.00	.00
	2	.061	8.894	.44	.59	.00	.06	.02
	3	.055	9.337	.50	.22	.03	.29	.07
	4	.048	10.033	.01	.07	.75	.33	.00
	5	.028	13.202	.05	.12	.22	.32	.91

a. Dependent Variable: Adoption of Automation in Last-Mile Delivery