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PORT DIGITALISATION: TECHNOLOGY READINESS ASSESSMENT AND SEGMENTATION PROFILE OF MALAYSIAN PORT OPERATORS

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Abstract: This study addresses the critical gap in understanding how digital technologies impact operational efficiency in international trade ports. With a specific focus on a major Malaysian port, the research examines the adoption of the E-Gate Pass system among 157 port terminal employees. Utilising the Technology Readiness Index (TRI) 16-item scale, the study evaluates employees' attitudes towards technology-based work processes and their readiness to integrate these technologies. Findings from K-Means Clustering reveal distinct technology readiness profiles among employees: Explorers, pioneers, laggards, sceptics, and paranoids. These profiles are pivotal in understanding the factors inhibiting or motivating digital technology adoption. The study's results indicate a moderate level of readiness among surveyed port operators, providing key insights into strategies to enhance digital technology adoption and improve port operational efficiency and competitiveness.

Keywords: Port digitalisation, Technology Readiness Index, segmentation profile.

Introduction

As logistics, cargo handling, and vessel operations hubs, ports are crucial in global supply chains. Technological advancements have significantly changed various sectors, particularly maritime transportation and logistics. In response to the increasing demands of international trade, ports adopted digital technologies to enhance operational efficiency and competitiveness (UNCTAD, 2018; UNCTAD, 2020). The digitalisation of ports has become a global trend due to its potential benefits in improving port operations (Inkinen *et al*., 2019; Brunila *et al*., 2021). This trend is evident in Malaysian ports. To date, the Malaysian port industry is experiencing many integrated initiatives as proposed by the industry players (MIMA, 2020). Some initiatives are prone to the enhancement of the operational excellence activity at the port terminal such as (i) reducing the congested traffic, (ii) integrated planning of warehouses and logistics systems, and (iii) the efforts in facilitating the Electronic Data Interchange (EDI) for the port communities ease of use. Port digitalisation refers to integrating and applying digital technologies and systems in various aspects of port operations, including but not limited to automation, data analytics, connectivity, and digital platforms. Digitalisation can enhance port operations' efficiency, productivity, sustainability, and competitiveness. It enables real-time data sharing, streamlined processes, improved decision-making, and enhanced stakeholder collaboration (Ng *et al*., 2017; Panayides *et al*., 2018).

Malaysia's maritime industry has experienced mixed development while dealing with technology, digitalisation, and human capital (Bernama, 2022). Despite the increasing interest and adoption of digital technologies in ports, there is a need for a systematic and comprehensive understanding of the extent of port digitalisation. Standardised frameworks or indices need to be used to measure the level of digitalisation in ports and assess their readiness to embrace and fully leverage digital technologies. In addressing the needs of a fast-changing business environment, adopting digitalisation and automation at the port shapes a new framework for employees (George & Leotta, 2019). Employees need to respond and adapt to new technologies. According to Lee (2020), a lack of skilled employees and insufficient focus on digital literacy and innovation would result in slower adaptability to fast-evolving technology. Many ports remain traditional and equipped with outdated technology and operating systems, making them less likely to be fully automated and digitised.

The rapid digital transformation of global industries has positioned digital technologies as a cornerstone for achieving competitive advantage and operational efficiency. In international trade, ports play a pivotal role as critical nodes within the global supply chain. However, integrating digital technologies in ports, particularly in emerging economies has been met with varied levels of acceptance and readiness among the workforce, which can significantly influence the success or failure of technological implementations. This study focuses on a major Malaysian port, where adopting the E-Gate Pass system represents a critical step toward enhancing throughput efficiency and security. Given the strategic importance of ports in national economies and the substantial investments in digital infrastructure, understanding the factors that influence technology adoption by port employees is crucial. This research aims to address this gap by exploring the attitudes of port employees towards digital work processes and their readiness to engage with these technologies, providing insights that could guide more effective strategies for digital transformation in ports globally.

For the study, one of the operational excellence activities selected for observation is the E-Gate Pass system also known as a Client-Server application software with a Model View Controller (MVC). This system aims to enhance and boost the existing system by elevating the efficiency and effectiveness of the manual work of business processes (Lengure *et al*., 2018). The E-Gate Pass was used mainly for security purposes and this can be explained by past articles that demonstrate the system is being deployed in the organisation's area, where it will monitor and facilitate the records of anyone who passes by the area (Sunico *et al*., 2020). It simplifies the task and reduces the conservative paperwork flow in the organisation to paperless activities. However, it was claimed that the tasks were done manually despite the aggressive installation of equipment and required facilities. Thus, the research objectives of this paper are to determine the readiness level of the terminal employees on the adoption of E-Gate Pass and to explore potential strategies for accelerating the rate of technology adoption by addressing concerns, leveraging positive attitudes, and ensuring a smooth transition to digital port operations. The research questions are: (1) Are the terminal employees ready to utilise the digital technology of E-Gate Passes? and (2) What are the strategies to enhance the E-Gate Pass adoption rate in supporting the transition to digital port operations?

This research aims to contribute to understanding port digitalisation by evaluating technology readiness, identifying strategies to enhance the adoption rate and providing evidence-based recommendations. The research findings will benefit port authorities, policymakers, and stakeholders, enabling them to make informed decisions and strategies to optimise port digitalisation and enhance technology readiness in the dynamic global trade landscape. The following sections provide the literature review, research methods, findings for discussion, and conclusions.

Literature Review

The literature review of existing studies and scholarly articles is related to port digitalisation and the measurement of technology readiness. This review focuses on the period from 2015 to 2023, exploring various concepts, frameworks, and models that contribute to our understanding of the relationship between port digitalisation and the Technology Readiness Index (TRI).

Port Digitalisation

Port digitalisation refers to integrating and utilising digital technologies and systems in port operations to enhance efficiency, productivity, and sustainability. Scholars have emphasised the multi-dimensional nature of port digitalisation, encompassing various aspects such as automation, data analytics, Internet of Things (IoT) integration, and advanced communication systems (Teixeira *et al*., 2019; Yang *et al*., 2021). For instance, Teixeira *et al*. (2019) highlight the importance of digital platforms facilitating information sharing and collaboration among stakeholders in port ecosystems.

Numerous studies have investigated the impact of port digitalisation on various performance indicators. Liu *et al*. (2020) find a positive relationship between port digitalisation and port performance in China, highlighting improvements in vessel turnaround time and cargo handling capacity. Wang *et al*. (2022) focus on the environmental sustainability aspect of port digitalisation, demonstrating how digital technologies contribute to reduced emissions and improved energy efficiency. Furthermore, Wang *et al*. (2022) suggest that digitalisation enables better monitoring and optimising port environmental practices, fostering sustainability.

The port's digitalisation offers numerous benefits that can improve operational efficiency, reduce costs, enhance transparency, and increase customer satisfaction (Ng *et al*., 2017; Panayides *et al*., 2018). For example, Panayides *et al*. (2018) highlight that digitalisation enables real-time data sharing, facilitating more accurate planning and resource allocation. However, challenges accompany the implementation of port digitalisation. These challenges include the need for significant infrastructure investments, concerns regarding cybersecurity, and addressing workforce skill gaps (Ng *et al*., 2017). Infrastructure requirements such as installing sensor networks and advanced communication systems are crucial for effective data collection and analysis (Yang *et al*., 2021). Additionally, cybersecurity measures must be in place to protect sensitive data and ensure the smooth functioning of digital systems. The correlation between port digitalisation and cybersecurity is evident in the increased efficiency and vulnerability that digital transformation brings. While digitalisation offers numerous benefits for port operations, it also necessitates robust cybersecurity measures to protect against evolving threats (Nguyen *et al*., 2019). Ports must adopt a holistic approach to cybersecurity, integrating advanced technologies, compliance with regulations, and proactive risk management strategies to ensure secure and resilient operations (Ben *et al*., 2022).

Diffusion of Innovation

The theory of Diffusion Of Innovation (DOI) developed by Everett Rogers explains how new ideas, practices, and technologies spread through cultures and social systems. This theory is particularly relevant to understanding the process of port digitalisation. The correlation between DOI and port digitalisation can be explored through several key aspects, including innovation attributes, adoption categories, communication channels, and social and cultural factors. Diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system". The diffusion of innovation theory suggests that diffusion of innovation focuses on four aspects: (1) Innovation, (2) communication through the social system, (3) time, and (4) the social networks.

In the context of this study, one of the factors that influence the time element of innovation adoption and diffusion is the "degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system"—innovativeness. According to the theory, the evaluation to adopt innovation by most individuals in a social system is based on the subjective assessment of near-peers, who have adopted the innovation and not on scientific research by experts. Rogers divided the individuals into five categories based on their level of innovativeness. The categories are: (1) Innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards.

The bell-shaped graph in Figure 1 illustrates how different adopter types are distributed within a social system. The innovators are the first to adopt innovation, making up only 2.5% of all adopters. They fit into this category because of their risk-taking tendencies, tight relationships with other innovators, and financial resource management. Since they are the ones who introduce innovation from outside the system's boundaries, they are crucial to the diffusion process.

As such, the innovator acts as a gatekeeper to allow new ideas to enter a system. Early adopters are the group of people who embrace new ideas the second fastest. They represent 13.5% of all adopters in the social system. Their level of opinion leadership is the highest. Prospective adopters typically look to early adopters as role models in a social system and ask them for guidance and information about the innovation. Within the social system, 34% of individuals are classified as early majority. They rarely have positions of opinion leadership in a system but they do engage with early adopters and their peers regularly.

The early majority may consider a new idea carefully before fully embracing it. The subsequent group known as the late majority, accounts for an additional 34% of the people within a given social system. They adopt an innovative approach only after most of society has done so and with much scepticism. Peer pressure through the growing network may lead to adoption. Before adopting an innovation, they must eliminate uncertainty due to limited resources. The remaining group of adopters, laggards, comprises 16% of the population within the social system. They usually emphasise the past and customs and are the last to embrace innovation. Before they adopt, they need to be sure that a novel idea will succeed.

In the context of port digitalisation, the theory provides an extended understanding of the size of the adopter categories in the innovation diffusion process, which is crucial and makes the temporal aspects of the theory significant to this research. Understanding adopter categories would help managers effectively manage diffusion in the context of adoption management. When it comes to innovation, early adopters serve as role models within a social system and possess the highest level of opinion leadership. Their influence is instrumental in helping to achieve the critical mass required for the adoption of an innovation.

Social system members seek information and guidance from early adopters, who significantly impact the decision-making of other adopters within the social system. Early adopters are generally characterised by empathy, open-mindedness, rationality, adaptability to change, and a higher tolerance for risk and uncertainty than other adopters. Furthermore, early adopters are generally thought to have higher goals and be more highly connected through interpersonal networks within their social system than others. Within the framework of this study, the rate and extent to which the early adopters among

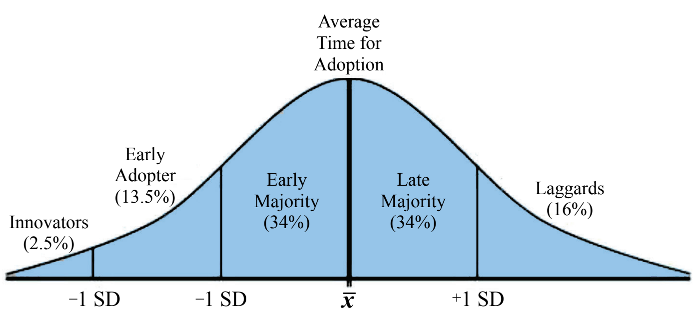

Figure 1: Roger's adopter categories
Source: Rogers (2003)

the port operators may dictate port digitisation initiatives spread.

Effective communication channels are critical for raising awareness of digital breakthroughs and supporting the adoption rate. Industry conferences, webinars, and trade magazines contribute significantly to disseminating information regarding successful digitisation initiatives in ports (Panayides *et al.*, 2018). Opinion leaders in the port industry such as renowned port authorities and industry experts can influence digital technology adoption by promoting its benefits and sharing best practices (Rogers, 2003). On the same note, an organisation's organisational culture impacts how prepared it is to embrace new technologies.

Digitalisation is more likely to be adopted by ports with a culture that values innovation and ongoing development (Heilig *et al.*, 2017). The regulatory environment also influences the uptake of digital technology. Ports that operate in areas where digitalisation is encouraged by policy and offered incentives are more likely to invest in new technology (Lam & Notteboom, 2014). The correlation between the theory of diffusion of innovation and port digitalisation is demonstrated by how digital technology attributes, adoption categories, communication routes, and social systems influence the adoption process. Understanding these characteristics will assist port authorities in developing effective digitalisation initiatives that will increase port competitiveness in the global maritime industry.

Technology Readiness Research

Technology Readiness (TR) as described by Parasuraman (2000) is an individual's propensity toward embracing and utilising new technologies for accomplishing goals in both home life and work settings. TR was put forward as an approach that explained the psychology of users. As stated differently, technological readiness gauges an individual's preparedness to utilise novel technologies. Thus, while rapidly evolving innovative technologies help people, they can make them angry and disappointed. People can see and feel positive and negative feelings about high-tech goods and services simultaneously (Nugroho & Fajar, 2017; Roy *et al.*, 2018; Chen & Lin, 2018).

The four subdimensions of technology readiness are insecurity, discomfort, inventiveness, and optimism. Although discomfort and insecurity are barriers to technological readiness, optimism and innovativeness play a role. It has been proved that these four factors are highly effective at predicting technology-related behaviours (Parasuraman, 2000; Parasuraman & Colby, 2014). From an optimistic perspective, optimism is a favourable outlook on emerging technologies that provide users enhanced control, flexibility, and efficiency. The propensity to be a thought leader and early user of new technologies is referred to as innovativeness.

On the other hand, discomfort is defined as a person's expectation of not having a sense of control over the new technologies and feeling overtaken by them. The term "insecurity" describes mistrust of emerging technology and doubts about its viability (Parasuraman, 2000; Parasuraman & Colby, 2014; Nugroho & Fajar, 2017; Roy *et al.*, 2018). People who score highly on technological readiness are typically knowledgeable, enthusiastic, and at ease using cutting-edge technologies; they rarely experience technical issues.

Conversely, those who score poorly on technological readiness are probably anxious and suspicious, and they might resist utilising new technologies (Wang *et al.*, 2022). These four factors co-exist when determining how someone views new technologies (Parasuraman, 2000; Chen & Lin, 2018). According to Parasuraman (2000), high scores for innovativeness and optimism lead to an increase in overall technological preparedness while high scores for discomfort and insecurity result in a decrease.

Parasuraman (2000) states that five characteristics of technology users can be further identified through K-Mean: Explorers, pioneers, sceptics, paranoids, and laggards. These categories are frequently linked to Everett Rogers' (1962) diffusion of innovation theory when discussing technology adoption.

This idea states that various groups adopt new technologies at varying speeds. Pioneers and innovators: These people are the first to use new technologies. They tend to be risk-takers, daring, and knowledgeable about technological developments. They enthusiastically accept innovations and fresh concepts. Early adopters or pioneers adopt new technology later than the innovators, who are known as early adopters. They take calculated risks to experiment with new technology and are respected community thought leaders. They can accept technologies earlier since they frequently have higher social standing and greater financial liquidity. Sceptics or early majority is a more cautious group. They are the first to accept new technology but only after most inventors and early adopters have tried it.

Before people accept a new technology, they want proof and advantages. Late majority or paranoids embrace new technology later than the rest of the population, so they are known as the late majority. They frequently accept new technology because they believe they have no other option and resist change. Both outside influences and peer pressure have an impact on them. Laggards accept new technology last among this group. They are staunch traditionalists who find it difficult to accept change. Laggards are the most resilient and frequently have the fewest social and financial resources. The summary of the characteristics by the technology readiness dimension is depicted in Table 1.

In this study, the TRI serves as a measurement tool to assess the technological preparedness of organisations or sectors for digitalisation (e.g., Brida *et al*., 2019; Oliveira *et al*., 2020). The TRI encompasses multiple dimensions, including physical and digital infrastructure, connectivity, data management and analytics capabilities, cybersecurity measures, technology adoption rates, and innovation culture (Brida *et al*., 2019). It provides a holistic view of technology readiness and helps identify strengths and weaknesses in adopting and integrating digital technologies. TRI is a valuable tool for studying port digitalisation as it helps measure the readiness and propensity of individuals and organisations to adopt and utilise new technologies (Lin *et al.,* 2007). It can identify barriers and facilitators to adoption (Tsourela & Roumeliotis, 2015) design effective training programs (Caison *et al*., 2008), enhance change management strategies and predict adoption success (Venkatesh *et al*., 2003) and align with strategic goals of the Port Digitalisation (Oliveira & Martins, 2011; Philip, 2020). By leveraging the TRI, port authorities can better navigate the complexities of digital transformation and ensure successful technology adoption.

This study addresses the critical gap in understanding the impact of digital technologies on operational efficiency in international trade ports, particularly through the lens of employee readiness for technology adoption. The primary hypothesis of this research posits that the level of technology readiness among port employees

Table 1: Characteristics of technology segments

Technology Segments	Optimism	Innovativeness	Discomfort	Insecurity
Explorers	High	High	Low	Low
Pioneers	High	High	High	High
Sceptics	Low	Low	Low	Low
Paranoids	High	High	Low	Low
Laggards	Low	Low	High	High

Source: Parasuraman (2000)

significantly influences the successful adoption of digital technologies such as the E-Gate Pass system in enhancing port operational efficiency. Specifically, it hypothesises that higher levels of technology readiness (as segmented into explorers and pioneers) correlate with more positive attitudes towards digital technology adoption, thereby facilitating greater operational improvements at ports. Conversely, lower readiness levels (laggards, sceptics, and paranoids) are hypothesised to correlate with resistance to technology adoption, posing challenges to digital transformation efforts.

Research Methodology

Sampling Method

The study employed a purposive sampling technique to select 157 employees from one of the major ports in Malaysia. This approach was chosen because it allows for the selection of individuals who are directly engaged with the E-Gate Pass system; thus, providing insights from those most affected by and familiar with the digital technology under investigation. Purposive sampling ensures that the sample reflects specific characteristics such as job role and experience with the system, which are critical to the study's aim of evaluating technology readiness and adoption. The choice of sampling method for this study on technology adoption at a major Malaysian port is crucial for ensuring the relevance and validity of the findings.

The purposive sampling method used in this study is well-justified based on several considerations: (1) Specificity of the research subject: Purposive sampling allows researchers to selectively choose individuals who are most knowledgeable about or experienced with the phenomenon being studied. In the context of this research, the method enables the selection of port employees who directly interact with or are affected by the E-Gate Pass system. This ensures that the data collected is pertinent and informed by the experiences of those most engaged with the digital technology under review. (2) Goal-oriented sampling: The study aims to assess the readiness and attitudes of employees towards digital technology in port operations. Purposive sampling is particularly suitable here as it allows for selecting a diverse range of participants across different roles, seniorities, and experiences with the technology. This diversity is crucial for understanding the factors influencing technology acceptance and readiness levels within the port. (3) Practicality and access: Given the operational constraints and security considerations at ports, gaining access to a broad random sample of employees might be challenging. Purposive sampling offers a practical solution by allowing researchers to work within these constraints to select participants who are accessible and willing to participate, thereby ensuring efficient use of resources while still collecting valuable data. (4) Theoretical saturation: In qualitative research and studies dealing with attitudes and perceptions, purposive sampling can achieve theoretical saturation more effectively. By focusing on participants who offer the most significant insights into the research questions, the study can gather in-depth data until no new information is observed; thus, ensuring comprehensive coverage of the attitudes towards technology adoption. This sampling method aligns well with the research goals, providing focused, relevant, and rich data that can inform strategies for digital transformation in port operations, catering specifically to the needs and challenges faced by the industry.

Research Procedures

Research procedures include data collection and data analysis. First, data was collected through a structured questionnaire based on the TRI 16-item scale. The questionnaire was administered electronically over three weeks, targeting employees across various shifts to ensure a comprehensive representation of attitudes and experiences.

The primary data for this study was collected from a population of 1,658 terminal employees with a sample size of 312 representing six job levels and seven departments directly involved in utilising the E-Gate Pass system. 400 questionnaires were distributed by the port management through WhatsApp using Google Forms. A response rate of 157 (39%) usable feedback was obtained. The input was measured using the TRI 16 scale developed by Parasuraman and Colby (2014). The statements were designed by using the Likert scale from 1 (strongly disagree) to 5 (strongly agree) for the positive TR dimensions, which are optimism and innovativeness and from 1 (strongly agree) to 5 (strongly disagree) for the negative TR dimensions which are discomfort and insecurity. Demographic information, including gender, age, education, computer literacy, department, and job levels were included in the questionnaires.

Subsequently, two commonly used techniques were applied. First, descriptive analysis involves summarising and presenting the TRI data using statistical measures such as mean, median, mode, standard deviation, and frequency distribution. Second, cluster analysis is used to identify groups or clusters of ports with similar technology readiness profiles. This analysis helps classify port operators based on technology readiness levels and identify common characteristics or patterns. Cluster analysis can assist in benchmarking and identifying best practices by comparing the performance of port operators within the same cluster.

Data Analysis

The study began with the design of a questionnaire based on the TRI 16-item scale, tailored to assess attitudes towards technology with each item measured on a five-point Likert scale. A pilot test was conducted with a small group of port employees to refine the questionnaire for clarity and relevance. Data was collected through an online platform accessible to employees across different shifts for three weeks, where participation was voluntary and anonymity assured. Following data collection, the preliminary analysis involved cleaning the dataset by removing incomplete responses and conducting descriptive statistics to identify initial trends. The core of the analysis used K-Means Clustering with variables selected from TRI responses. The optimal number of clusters was determined using the elbow method, which led to the segmentation of respondents into five groups: Explorers, pioneers, laggards, sceptics, and paranoids. Further inferential statistical tests, including Analysis of Variance (ANOVA), and correlation analyses were conducted to examine relationships between technology readiness levels and attitudes towards digital adoption. Findings were validated through focus group discussions with representatives from each cluster to understand the nuances behind their readiness levels and attitudes.

Results and Discussion

Results of descriptive and cluster analysis are presented in the following sections. The descriptive analysis provides an overview of the distribution of technology readiness scores across different dimensions and subdimensions. It helps identify the range and variation in technology readiness levels, enabling a deeper understanding of the current state of digitalisation within the port context. Cluster analysis assists in benchmarking and identifying best practices by comparing users' performance within the same cluster. It aids in understanding the heterogeneity in technology readiness across ports and provides insights into the factors contributing to high or low technology readiness.

Demographic Profile

The demographic profile is essential to validate the representation of the sample to the targeted population in this research. Demographic analysis is a crucial aspect of studying port digitalisation for several reasons. It helps in understanding the characteristics of the workforce, which directly influences the adoption and effectiveness of digital technologies. The demographic analysis provides a detailed justification for age distribution, gender distribution, educational background, and experience level. Demographic analysis is essential for tailoring training and support programs, enhancing change management strategies, and predicting technology adoption in port digitalisation. Descriptive statistics provide valuable insights into these demographic factors, enabling organisations to make informed decisions and implement effective digital transformation strategies. The correct sample selection assures the sources' reliability and the results' adequacy.

Reflecting the size and characteristics of the population as explained in the research methodology section, this study has appropriately addressed the targeted population: The technology user of the E-Gate Pass system. The total sample size is 157 terminal employees and the respondent's profile is shown in Table 2.

Table 2: Respondent's profile

Description	Frequency	Percentage (%)
Gender		
Male	146	93
Female	11	7
Age		
25 years old and below	2	1.3
26 - 35 years old	54	34.4
36 - 45 years old	73	46.5
46 - 55 years old	23	14.6
56 years old and above	5	3.2
Education level		
Lower secondary (PMR/SRP)	3	1.9
Upper secondary (SPM/STPM/SVM)	117	74.5
Sijil Kemahiran Malaysia (SKM)	7	4.5
Diploma	19	12.1
Bachelor's degree	11	7
Department		
Container services	3	1.9
Conventional cargo services	59	37.6
Facilities	1	0.6
Healthy, Safety, Security and Environment (HSSE)	54	34.4
Logistics services	22	14
Marine services	18	11.5
Job unit		
Senior Management	1	0.6
Operations Executive	13	8.3
Admin Executive	6	3.8
Non-executive Operations	97	61.8
Non-executive Admin	12	7.6
Other	28	17.8

Years of service		
Below than 1 year	1	0.6
1 - 3 years	3	1.9
4 - 6 years	17	10.8
7 - 10 years	49	31.2
More than 10 years	87	55.4
Computer literacy		
Never use computer/not having computer	4	2.5
Less than 1 year	4	2.5
1 - 3 years	18	11.5
3 - 5 years	30	19.1
More than 5 years	101	64.3

According to the demographic profile presented in Table 1, it is evident that the terminal employees of the port exhibit seven essential characteristics. The gender distribution indicates that 93% of the respondents are male while 7% are female. This finding suggests a predominant male representation within the population of terminal employees. Second, the leading group of respondents are 36 to 45 years old at 46.5%, 26 to 35 years old at 34.4%, and 25 years old and below at 1.3%. Approximately 81% of Generation Y are 26 to 45 years old and able to adapt to technology faster.

Most respondents indicated an upper secondary (SPM/STPM/SVM) education level at 74.5%, followed by 12.1% holding a diploma, and 7% holding a bachelor's degree. These figure suggest that most respondents have completed at least 12 years of required education, indicating a predominantly middle-level educational background among terminal employees. Furthermore, 55.4% of respondents have been employed for more than 10 years while 31.2% have seven to 10 years of service, and 10.8% have four to six years of experience. This data illustrates that the majority of respondents are long-term, experienced workers possessing a noteworthy level of expertise and skill.

Another interesting point is the level of computer literacy. 64.3% of the respondents have more than five years of computer literacy, followed by three to five years with 19.1%, and one to three years of computer literacy with 11.5%. This shows that more than 94% of the respondents have appropriate knowledge of computers and are competent in using the port system. Concerning department and management level, the conventional cargo services comprised 37.6%, followed by Healthy, Safety, Security and Environment (HSSE) with 34.4% and logistic services with 14%. For the respondents' job units, 61.8% of the non-executive operations were followed by others. The respondents' non-managerial positions are those of the primary users of the E-Gate Pass system. From the demographic profile, the respondents are relatively (i) middle-aged group, (ii) acquired 12 years and above of education level, (iii) long-term experienced workers, and (iv) possess adequate computer skills.

The descriptive analysis results of the 16-item scale question Technology Readiness Index by dimensions, optimism, innovativeness, discomfort, and insecurity are presented in the following section. Table 3 shows user perception of the E-Gate Pass system by the responses for each dimension and overall TRI.

Table 3 provides the detailed responses for the TR dimension: Optimism (OPT), innovativeness (INN), discomfort (DIS), and insecurity (INS). Based on Table 3, the overall TRI mean score is 3.30 with a standard deviation

Table 3: Overall Technology Readiness Index (TRI)

Technology Readiness Index (TRI)	Mean	Std. Dev.
Optimism	3.68	0.739
Innovativeness	3.31	0.721
Discomfort	3.14	0.735
Insecurity	3.06	0.784
Overall TRI	3.30	0.021

of 0.021, which indicates a moderate level of technology readiness among the respondents. This suggests that, on average, respondents are somewhat prepared and willing to engage with the new technology but there may be varying enthusiasm and apprehension.

Optimism's mean score is 3.68 and the standard deviation is 0.739. Optimism is relatively high. This indicates that respondents generally have positive expectations about the benefits and potential of the E-Gate Pass system. The moderate standard deviation of 0.739 suggests that while most respondents are optimistic, there is some variability in their levels of optimism. Meanwhile, innovativeness has a mean score of 3.31 with a standard deviation of 0.751. The mean score reflects a moderate tendency among respondents to be early adopters of new technologies. The standard deviation of 0.751 indicates a moderate spread in respondents' innovativeness, suggesting that while some are eager to embrace new technologies, others may be more cautious. Discomfort has a mean score of 3.14, indicating a moderate level of unease or apprehension about using the E-Gate Pass system. The standard deviation of 0.738 shows some variation in how uncomfortable respondents feel, possibly due to differences in their familiarity with the technology or their comfort with change. The mean score for insecurity is 3.06, which points to a moderate level of concern about the potential risks or unreliability of the new technology. The standard deviation of 0.784, the highest among the dimensions, suggests a broader range of responses, indicating that some respondents feel entirely secure while others have significant reservations.

At the same time, all dimensions indicated a moderate level of perceptions. Overall, the respondents view the E-Gate Pass system technology positively. The TRI scores reflect an overall positive perception of the E-Gate Pass system technology. Despite some levels of discomfort and insecurity, the higher scores in optimism and innovativeness indicate that respondents see the potential benefits and are willing to engage with the technology. All dimensions indicated moderate levels of perception, implying that while respondents are generally favourable towards the technology, there are still areas that need to be addressed to harness their readiness fully. This could involve providing more information, enhancing user support, and addressing specific concerns to improve comfort and security levels.

Based on Table 4, the optimism dimension is four and it can be concluded that the respondents preferred the E-Gate Pass system and agreed that the technology makes their work easier. The highest mean score for optimism is 3.73 for better quality of work life. The highest mean score for innovativeness is 3.62, which is the statement "the users are keeping up with the technology development that they are interested in". Innovativeness suggests the attitude of acquiring new technology independently and actively. From the two dimensions, the results indicate that users neither have a positive nor negative perspective towards the E-Gate Pass system technology but are open to technological applications. For discomfort and insecurity, the

Table 4: Descriptive for the TRI dimensions

TRI 2.0	Scale Item	Mean	Std.
Optimism			
OPT1	Better quality of life	3.73	0.754
OPT2	More freedom mobility	3.60	0.815
OPT3	Control over their daily lives	3.69	0.678
OPT4	More productivity in life	3.70	0.702
Innovativeness			
INN1	Advise on technologies	3.40	0.697
INN2	Acquire technology when it appears	3.09	0.719
INN3	Figure out new technology without the help	3.13	0.740
INN4	Keep up latest technology development	3.62	0.730
Discomfort			
DIS1	Being taken advantage	3.22	0.713
DIS2	Technical support not helpful	3.20	0.711
DIS3	Technology does not design to be used by ordinary user	3.13	0.766
DIS4	No such thing as easy manual	3.03	0.751
Insecurity			
INS1	Too many people are depending on technology	3.07	0.785
INS2	Too many technologies distract people to the point where it is harmful	3.12	0.737
INS3	Technology lowers the quality of the relationship	3.04	0.846
INS4	Do not confident in doing business online	3.03	0.768

analysis recorded the lowest mean score due to reverse coding analysis. The lowest mean score for discomfort is 3.03, which implies the statement, "there is no such thing as an easy manual". The users have expressed that they are neutral towards the statements from this dimension. Therefore, it can be concluded that the users are neither positive nor negative towards the E-Gate Pass system technology. Lastly, Insecurity's lowest mean score for this segment is 3.03, which is the statement, "the users are not confident in doing business online". The mode of the dimension is three, which is neutral. This shows that the users are neither positive nor negative towards the insecurity statement. The standard deviation is below one, which is considered low variance.

Technology Segments

An analysis of the identification of five clusters was conducted through K-Mean by Parasuraman's (2000) user segmentation. The findings of this analysis are presented in Table 5. Table 5 shows that explorer is the biggest group with 86 respondents (74%). The users of this segment have a high mean score for optimism and innovativeness while a low mean score for discomfort and insecurity. The second highest user segment is the pioneers with 18% of the users. Pioneer segment has a high mean score for all dimensions. The third segment is the laggards with 5% of the users. This segment has a low mean score of optimism and innovativeness and a high score of discomfort and insecurity. The sceptics segment recorded 1.7% of users. This segment has a low mean score for all

Table 5: User segmentation using TRI mean

Technology Segments	Percentage (%)	Optimism	Innovativeness	Discomfort	Insecurity
Explorers (86)	74	3.93	3.71	2.33	2.2
Pioneers (21)	18	3.98	3.48	3.40	3.37
Sceptics (2)	1.7	3.20	2.93	2.92	2.73
Paranoids (1)	0.9	4.38	3.63	2.13	3.25
Laggards (6)	5	1.82	2.00	4.03	3.78

dimensions. The minor user is the paranoids segment with only 0.9% of the users. This segment has a high mean score for the positive dimensions (optimism and innovativeness) and a low mean score for the negative dimensions (discomfort and insecurity).

Discussion

One notable discovery pertains to the demographic analysis of terminal employees. The sample effectively reflects the population of 1,658 terminal employees, representing the workforce at the port. Out of the surveyed individuals, 157 are directly involved in the implementation of the E-Gate Pass. Based on the demographic profile, the respondents primarily fall within the (i) middle-aged demographic, (ii) male-dominated workforce, (iii) possess 12 years or more of education, (iv) have extensive work experience, and (v) possess proficient computer skills. Several exciting characteristics of the workforce can be drawn from the profile. First, different age groups may have varying levels of comfort and familiarity with digital technologies. Younger employees might be more adaptable and enthusiastic about adopting new technologies than older employees, who might require more training and support (Paulaskas *et al.*, 2023). The result suggests that 37% of the terminal employees below 35 years old indicate a relatively young workforce and possess some level of comfort and familiarity with digital technologies. However, the challenges remain as there might be some discomfort and unfamiliarity among the remaining (63%) terminal employees, who are 36 years old and above.

Second, gender dynamics can influence the adoption and usage of technology. Understanding gender distribution helps ensure that training and support programs are inclusive and cater to the specific needs of all employees (Tsourela & Roumeliotis, 2015). Reflecting the domination of males (97%) in the terminal community shows a high degree of influence of only one gender. Gender equality may not be the case in this type of workplace. The gender ratio (male) can highlight gender imbalances in the workforce. A ratio of 4:1 indicates that males significantly outnumber females, which could be important for developing gender-inclusive training programs.

Third, the educational qualification of the workforce can affect their ability to understand and utilise new technologies. Analysing the distribution of educational qualifications helps in understanding educational diversity. Employees with higher educational backgrounds find it easier to adapt to digital tools while others might need additional support and training (Leidner & Kayworth, 2006; Vaggelas, 2020). Studies show that many employees with bachelor's degrees are part of a well-educated workforce. However, this study found that a significant percentage (93%) of the workforce has yet to obtain a bachelor's degree, indicating a moderately low educated workforce. Thus, the port needs to look into firm-specific training to enhance its ability to understand and utilise new technologies. It refers to training programs designed to address the diverse needs of a varied workforce. This approach is essential when employees have different backgrounds, capabilities, skill levels, learning, preferences, and cultural experiences. The goal is to create an inclusive training environment that maximises learning effectiveness for all participants (Gasparotti *et al*., 2023). The importance of training and support is aligned with sustaining effective communication channels as conceptualised in the diffusion of innovation by Rogers (2003).

Fourth, employees with different experience levels might have varying attitudes towards digitalisation. Those with more experience might be set in their ways and resistant to change, whereas newer employees might be more open to adopting new technologies (Oliveira & Martins, 2011). The distribution of experience levels helps identify the balance between experienced and less experienced employees. A workforce with a high percentage of employees with over than 10 years of experience might indicate potential resistance to change. On the same note, the findings of this study highlight that more than 50% of the workforce has worked for more than 10 years, suggesting potential resistance to change. It depends on how the remaining 50% of the workforce predicts that technology adoption will be rare in the port. In sum, the characteristics of the terminal employees suggest that the port operators are less likely to conform to the criteria of highly adaptive and ready to change. Further discussion on the results of the TRI is needed to verify and provide insights into the terminal employee's readiness at the port.

The TRI is a valuable tool for assessing the technological preparedness and readiness of organisations, sectors, or industries for digitalisation. It encompasses various dimensions and indicators that provide insights into technological adoption and integration. The study identifies a moderate TRI level among employees using the E-Gate Pass system for port digitalisation with 157 respondents' feedback being evaluated. The overall TRI mean score of 3.30 with a standard deviation of 0.021 suggests the respondents were optimistic towards TRI's dimensions. While Cronbach's alpha value of 0.70 is considered acceptable, all TRI dimension is a good coefficient scale for internal consistency reliability for having a value of 0.8, lower than one. All dimensions indicated a moderate level of technology-related behaviour with an overall mean between 3.06 and 3.68. The port operators will likely have a fair perception of the innovativeness and optimism of the technology used. The respondents are fairly educated and can learn, accept, and adapt to the technology. At the same time, they feel uncomfortable and insecure about the technology.

The five-technology user segmentation using TRI means shows that the explorers are 74%, the pioneers are 18%, laggards are 18%, sceptics are 1.7%, and paranoids are 0.9%. The explorer (74%) are early adopters, who tend to have a high degree of motivation and a low degree of resistance. While 18% of the pioneers hold strong positive and negative views about technology, the sceptics tend to have a detached view of technology with less extreme positive and negative beliefs. The paranoids (0.9%) and laggards (5%) are less likely to be concerned about this as the percentage is tiny; though, they may tend to have a high degree of resistance, low-motivation, and a low-degree of innovativeness.

The Chi-square test was done for each of the demographic profiles of the segments. The results show that the demographic features with significant value ($p < 0.05$) are age group, level of education, department, job unit, and computer literacy. In contrast, other features (gender and years of services) are not significant ($p > 0.05$). With the integration of digital technology into the port system, the port management can directly identify the group of employees and customise training, retraining, and upskilling treatment to accelerate digitalisation. In determining the readiness level for port digitalisation, it is essential to draw upon previous studies that have used the TRI and other relevant frameworks to assess technological adoption in similar contexts.

Conclusions

The contribution of the paper is twofold: (1) Specifying the level of technology readiness among the terminal employees to utilise the digital technology of E-Gate Pass and (2) understanding strategies taken to enhance the rate of adoption of E-Gate Pass in supporting the transition to digital port operations.

The critical finding that could be drawn is that port digitalisation using the E-Gate Pass system has a moderate level of technology readiness, which can be supported by understanding the employees' perceptions and behaviours as users. The respondents have a favourable view of the E-Gate Pass system technology. The port can adopt a new digitalised system due to the composition of the users, who are mainly middle-aged, have adequately acquired 12 years and above of education level, have long-term experience at the organisation, and possess adequate computer skills. In contrast to the available studies on demographic profile, the paper proposes that demographic profile is not likely to explain the level of readiness and predicts the attitude towards technology readiness as referred by Venkatesh *et al*. (2003) for age distribution, Tsureila and Roumeliotis (2015) for gender distribution, Leidner and Kayworth (2006) for high education background, and Perović *et al*. (2020) for human resources management.

The distribution of technology readiness scores across different dimensions and subdimensions provides insight into digitalisation within the port context. TRI shows a relatively moderate level of optimism, innovativeness, discomfort, and insecurity. High scores in optimism and innovativeness indicate a positive attitude towards new technologies among employees. It is essential to capitalise on this readiness by introducing pilot projects and advanced training programs to build on this enthusiasm. On the same note, moderate scores in discomfort and insecurity highlight potential resistance areas. Employees might have concerns about job security and the complexity of new technologies. While the group is considerably small compared to optimism and innovativeness, the port may address these concerns through comprehensive training, clear communication about the benefits of digitalisation, and assurances regarding job security. This suggests a general readiness to embrace digitalisation and concurs with Othman *et al*. (2022), suggesting that technology employment is a crucial driver of port digitalisation and D'Amico *et al*. (2021) on the importance of increasing involvement and awareness among port and terminal personnel to support smart port initiatives.

The cluster analysis assists in benchmarking and identifying best practices by comparing user performance within the five segments. It aids in understanding the heterogeneity in technology readiness across port systems and provides insights into the factors contributing to high or low technology readiness. The results of the segmentation analysis provide insight into the characteristics of the users who have positive behaviour towards technology (Parasuraman & Colby, 2014). This reflects the mixed development into complete digital transformation, whereby the port may need to find appropriate measures to promote strong optimism and innovativeness while accelerating digital literacy and advancement of technology to implement the E-Gate Pass system fully.

This study provides an extension to our understanding of the application of diffusion of innovation theory and TRI in explaining an individual's propensity toward embracing and utilising new technologies to accomplish goals in the work setting. In the case of port digitalisation, port operators do not have a choice to adopt or not to adopt technologies. From a different perspective, managers may support the determination and commitment of port operators to fully embrace and transform work processes by addressing the issue of adoption at varying degrees. The study provides detailed information to guide the management in steering the full adoption of new digital systems and eventually, achieving better port performance due to successful port digitalisation. The study results suggest that employee readiness either inhibits or motivates the management's efforts in port digitalisation. Adopting the E-Gate Pass system impacted port operations regarding the new technology foundation of intelligent ports. It has successfully unlocked opportunities to increase value for the benefit of overall port communities. The findings help to understand the port measures in leveraging the positive attitudes among the different adopters.

The research provides evidence-based findings and recommendations that will benefit port authorities, policymakers, and stakeholders, enabling them to make informed decisions and strategies to optimise port digitalisation and enhance technology readiness in the dynamic global trade landscape. Strategic implications for port management can be drawn from customised training and support. One of the considerations regarding the potential measures to ensure a smooth transition towards full port digital operations is providing continuous support in communication and training such as firm-specific and gender-inclusive training. The port management may also look into effectively communicating the benefits and addressing each segment's concerns to mitigate resistance. For instance, emphasising the reliability and security of new technologies can alleviate the fears of paranoids. Engaging explorers and pioneers in pilot programs can help gather valuable feedback and build internal support for digital initiatives. Their positive experiences can be showcased to encourage wider adoption. Some other measures include implementing continuous feedback loops to monitor the effectiveness of training and support programs to ensure that the needs of different segments are being met and adjustments can be made as necessary, as highlighted in the study by Yang and Hsieh (2024).

Some implications for academic knowledge can be drawn from advancing the theoretical frameworks related to technology adoption. The TRI can be integrated with other theoretical frameworks such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) to enhance the understanding of technology adoption behaviours (Venkatesh *et al*., 2003). TRI's focus on individual attitudes towards technology provides new insights into the psychological and emotional factors influencing technology adoption, enriching academics related to technology adoption and digital transformation and providing evidence-based recommendations discourse and theory development (Leidner & Kayworth, 2006). TRI can inform policy decisions for enhancing technology readiness at the organisational and societal levels (OECD, 2023).

The study contributed to the related studies on port digitalisation, smart port development, and port assessment worldwide, as mentioned in various studies (Hartel, 2017; Brunila, 2021; Hirata, 2022; Othman *et al*., 2022; Nguyen, 2023; Almeida, 2023; Utama *et al*., 2024). The findings of this study are less likely to be generalised as they are driven by a single case of digital system adoption at one of the Malaysian ports. However, they provide significant input into understanding similar practices in other settings as the setting is one of Malaysia's most important ports for the logistics and maritime industry. Future studies may look into digital transformation issues concerning employees' technology readiness and foster a more effective adoption of technology study at the firm level by understanding behaviour.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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