

Evaluating the social acceptance of autonomous ferries: An observation from passengers' boarding willingness

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Abstract

Ferries are crucial for the transportation of passengers in coastal areas, offering multi-route, high-frequency, and point-to-point services at a lower cost than bridges or tunnels. Recently, many countries have been advocating for autonomous ferries due to their eco-friendliness and potential to mitigate accidents that often occur on traditional manned ferries due to human error. However, the public's acceptance of autonomous transport systems is frequently influenced by scientific evidence that supports their practical applications. This study endeavours to scrutinise the social acceptance of autonomous ferries from the passenger's perspective, employing the perceived value theory. A total of 151 responses have been collated from our questionnaire, aiming to investigate the public's acceptance of autonomous ferries, and to obtain the users' opinions on key influential dimensions such as the perceived price, quality, value, risk, and willingness to use an autonomous ferry. Structural equation modelling (SEM) has been employed to examine the relationship among these dimensions. The findings reveal that the perceived price and quality have a positive effect on the perceived value, which, in turn, has an indirect effect on the willingness to use autonomous ferries. The conjecture that the perceived risk influences the perceived value and willingness to use autonomous ferries is fully supported by our findings. Building on the findings of this research, this study offers specific recommendations to industry operators and government authorities to guide policy formulation and operational decision-making in the development of autonomous ferry.

Keywords: Autonomous Ferries, Perceived Value Model, Perceived Risk, Passenger, Willingness

1. Introduction

Numerous studies have demonstrated that over 80% of maritime accidents are either directly or indirectly caused by human error (Chang et al., 2021). There is no exception for causing accidents when operating ferry service manually. Ferry accidents can be attributed to a variety of factors. Among this, human error is a significant contributing factor in ferry accidents, accounting for 70% to 80% of incidents, including errors in navigation, communication, judgment, and decision-making. Other contributing factors include mechanical failures (10-15%), weather conditions (5-10%), and design flaws or security issues account for 5-10 percent of the casualties (Maintenance and Cure Law Firm, 2023). This breakdown highlights the predominance of human error in ferry accidents, underscoring the need for enhanced training, improved safety protocols, and advanced technology to mitigate these risks and ensure safer maritime operations.

In order to reduce human error, unmanned ships or Maritime Autonomous Surface Ships (MASS), as they are referred to by the International Maritime Organization (IMO), are presented as an emerging solution and the concept attracts increasing attention in the maritime industry. MASS is defined as “*ships which, to a varying degree, can operate independently of human interaction*” (IMO, 2018). MASS have a number of benefits compared to conventional vessels such as enhanced safety and security, improved human resource management, and reduced operational costs (Komianos, 2018; Chang et al., 2024). Additionally, MASS can aid in achieving decarbonisation goals and be more environmentally friendly since they can be all-electric in many cases, emitting less pollution. Furthermore, they can assist in shifting cargo from road to sea, which is a more environmentally efficient mode of transportation in terms of reducing emissions (Burmeister et al., 2014).

Autonomous ferries, similar to MASS, present several advantages over traditional alternatives, including enhanced safety, cost-effectiveness, and environmental sustainability (Chang et al., 2021; Calderón-Rivera et al., 2024). Specifically, autonomous ferry services offer considerable potential in reducing labour costs, which is essential for sustaining low-intensity connections within urban transport networks. By reducing reliance on manual operation, autonomous ferries can contribute to more efficient and economical transportation solutions, thereby improving connectivity and promoting sustainability in urban areas. Additionally, since they are a new technology that people would like to experience, they may attract more passengers than traditional vessels. Furthermore, because autonomous ferries are more eco-friendly, governments may be more inclined to subsidise their construction and operations, resulting in lower fares for users.

Due to the complexity of autonomous marine navigation, the current technology for autonomous ferries is arguably not fully mature; some unsolved issues include (a) that current technologies still cannot fully support autonomous operations, especially for ferries and, thus, there are some safety concerns, and (b) the fact that ferries carry passengers who might need some additional services or have special requirements; the latter is what differentiates autonomous ferries from autonomous cargo vessels. These uncertainties and risks might affect passengers' willingness to use autonomous ferries, as well as their perception of the value and service quality. Despite the above, autonomous shipping and research on MASS attract increasing attention. Although there are no lacking studies on autonomous ferries in general, through a quick search using the Web of Science database, one could only identify 28 papers that include the keywords {Autonomous ferries AND passenger}, and interestingly enough there is no result when searching for {Autonomous ferries AND willingness}. The development of autonomous ferries has been recognised as an unavoidable trend due to the

benefits they offer. Within this context, it is necessary and urgent to better understand passengers' willingness to use autonomous ferries against a few key influential attributes such as safety and cost. To this extent, this paper aims to examine the interrelationship among the key factors that affect passengers' willingness to use autonomous ferries using Taiwan as a case study.

The rest of the paper is structured as follows. Section 2 reviews the development of MASS and autonomous ferries, as well as the factors affecting the willingness to use autonomous ferries. Section 3 describes the development of the methodology, and Section 4 presents the research results. Discussions and conclusion are drawn in Section 5.

2. Literature review

2.1. The development of MASS

IMO has defined four 'degrees of autonomy' (DoA) as follows (IMO, 2018):

***Degree 1. Ship with automated processes and decision support:** Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.*

***Degree 2. Remotely controlled ship with seafarers on board:** The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.*

***Degree 3. Remotely controlled ship without seafarers on board:** The ship is controlled and operated from another location. There are no seafarers on board.*

***Degree 4. Fully autonomous ship:** The operating system of the ship is able to make decisions and determine actions by itself."*

A number of projects have examined the various aspects related to MASS design and development; 'Maritime Unmanned Navigation through Intelligence in Networks' (MUNIN) from 2012 to 2015 is perhaps the most widely known, which aimed to develop an autonomous ship concept by combining automated decision systems with remote control through a shore-based station. In fact, several countries have committed themselves to the development of MASS, with 'Yara Birkeland' being the most well-known industry project in Norway and the first autonomous containership in the world that has commercially operated in Degree 2 of DoA in 2022 (Yara, 2022). DB Schenker has also planned to operate an autonomous container feeder in Norway (DB Schenker, 2022). In Japan, a trial project, the so-called 'DFFAS project' (Designing the Future of Full Autonomous Ship) was conducted by 30 companies from 2020 to 2022. A trial sailing between Port of Tokyo and Port of Tsu-Matsusaka of the fully autonomous container ship 'Suzaku' was demonstrated (Ando, 2022). In Korea, the Ministry of Oceans and Fisheries & Ministry of Trade launched a \$133 million autonomous ship project from 2020 to 2025 to develop core technology for autonomous ships (Kim and Yeo, 2022). Additionally, Hyundai Heavy Industries led a project named HiNAS 2.0, and they aim to commercialise a Degree 2 DoA system by July 2023 (Maritime Executive, 2022). China is also undertaking many industry projects. For instance, the first commercially operated autonomous container feeder in China, Zhi Fei, started its operations in Qingdao Port in 2022 (Safety4Sea, 2022). Furthermore, more industry initiatives and projects can be found in Zhang et al. (2021).

2.2. The development of autonomous ferries

The area of autonomous ferries has received some academic attention. Figure 1 depicts the proliferation of papers (indexed in the Web of Science, with the keyword: Autonomous ferry) dealing with autonomous ferry research, indicating a marked uptick in interest in this subject

matter over the previous decade. An analysis of this literature reveals that most of them focus on system design; for example, Velasco et al. (2012) and Ellefsen et al. (2020). Guo et al. (2021) employed Bayesian networks to examine an autonomous ferry's safety and risk of collision. Tarkowski and Puzdrakiewicz (2021) discussed the benefits of autonomous ferries in Poland as a zero-emissions transportation means. Goerlandt and Pulsifer (2022) utilised survey and interview methodologies to investigate public attitudes towards autonomous ferries in Canada, revealing that respondents considered the primary advantage of autonomous ferries to be their positive environmental impact, but their foremost concern was on safety, including concerns over the proficiency of their operators. Yuen et al. (2020) addressed the determinants of public acceptance of autonomous vehicles (AVs) based on innovation diffusion and value theories. The study develops and tests a theoretical model to identify the latent factors influencing public acceptance of AVs. It draws on innovation diffusion, perceived value, and trust theories and examines their interrelationships. The research results suggest that addressing innovation diffusion attributes, perceived value and trust are critical in promoting public acceptance of AVs.

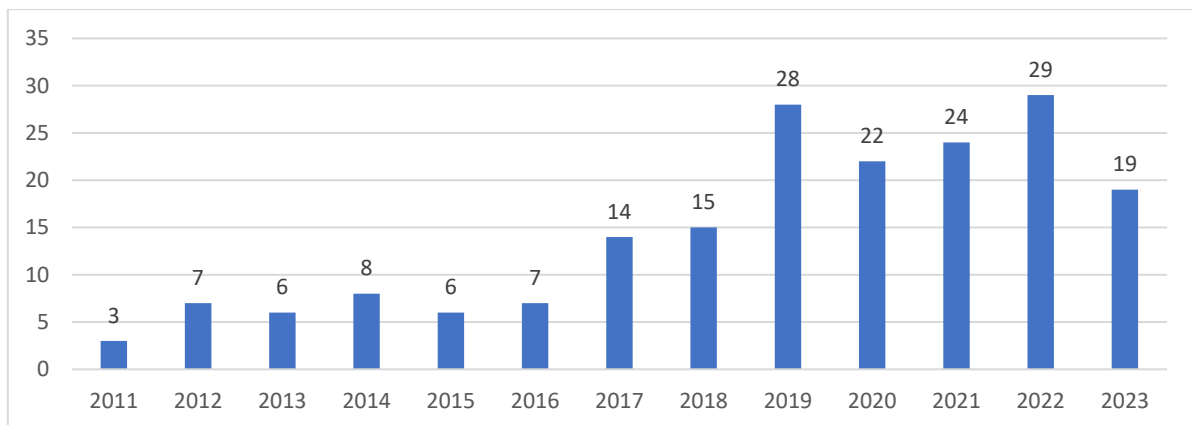


Figure 1: Number of papers related to autonomous ferries – Data source: WoS (08 Jan 2024)

Several cities are advancing the development of autonomous ferry services, each demonstrating unique approaches and objectives. In 2021, Norway's Norwegian University of Science and Technology (NTNU) Digital Transformation Initiative introduced the concept of small autonomous passenger ferries for urban areas (NTNU, 2021). This innovative approach, known as Autoferry, aims to provide a more flexible and environmentally friendly alternative to traditional bridges and manned ferries. Further in 2022, NTNU completed operational trials of the world's first urban autonomous passenger ferry, MilliAmpere 2. This marks the first urban trial of a self-propelled electric passenger ferry (Briard Maritime, 2024). In Finland, Helsinki is pioneering autonomous ferries in its harbours and lakes to enhance public transit efficiency, as part of its Autonomous Ferry Projects (Forum Virium Helsinki, 2024). In Amsterdam, testing is underway to integrate these ferries into the existing transport network and alleviate congestion (City of Amsterdam, 2024). Paris is deploying autonomous ferries on the Seine River to improve traffic flow and sustainability (Paris.fr., 2020). Singapore is conducting trials to incorporate autonomous ferries into its smart transport initiatives, including a private commuter service that shuttles over 3,000 passengers daily at speeds up to 21 knots between Pasir Panjang Ferry Terminal and Shell's Energy and Chemical Park on Pulau Bukom (Workboat 365, 2024).

Ferry services are prevalent in Taiwan's main cities due to several key factors. Taiwan's geography and numerous harbours make ferries essential for connecting urban areas with offshore islands and rivers. High population density and urbanisation in cities like Taipei,

Taichung, Kaohsiung, and Tainan necessitate ferries to alleviate road congestion and improve mobility. Ferries also support economic activities by facilitating the movement of goods and people. Additionally, ferry services enhance tourism by linking popular destinations. Environmental concerns drive the use of clean-energy ferries, aligning with Taiwan's sustainability goals. Government investments in ferry infrastructure support their widespread adoption, integrating them into the urban transportation network in Taiwan.

Kaohsiung, the largest industrial city in Taiwan, serves as an illustrative example with its comprehensive transportation network, encompassing the MRT, bus systems, and essential ferry services that connect the harbour to Cijin Island. According to the Transportation Bureau of Kaohsiung City Government (2023), the ferry service in Kaohsiung City experienced a decline following its peak of 7,613,847 passengers in 2014. Although the passenger volume saw a slight decrease during the COVID-19 pandemic from 2019 to 2021, it began to show annual growth starting in 2019 (as shown in Figure 2). A similar trend is observed in terms of operational nautical miles, which also declined during the pandemic but have since recovered, reaching a total of 90,612 nautical miles in 2023. The ferry services in Kaohsiung City, primarily operated by the Kaohsiung Shipping Company, provide four key routes—Gushan to Cijin, Cijin to Hongmaogang, Linhai 2nd Road to Qijin, and Kaohsiung Harbor tour ferries—which form an integral part of the city's public transportation network. These routes play a significant role in enhancing mobility and accessibility for both daily commuters and tourists. According to the Transportation Bureau of Kaohsiung City Government (2023), ferry usage has steadily increased by 20% in recent years, following the introduction of more frequent services. This has led to improved integration with major transportation hubs, such as metro stations, benefiting the 1.5 million daily commuters. Additionally, the ferry services have successfully alleviated traffic congestion, particularly along the Gushan to Cijin route, which transports approximately 6,000 passengers daily, reducing an estimated 2,000 vehicles from congested streets, especially during peak times. The shift to ferry services has attracted 35% more passengers who would otherwise travel by car or motorcycle, further contributing to a 10% improvement in traffic flow on major arterial roads. Moreover, the efficiency of travel to popular destinations such as Cijin Island has improved, with a 25% reduction in average travel time compared to driving. These developments underscore the crucial role of ferry services in reducing congestion, enhancing public transportation use, and improving overall traffic flow in Kaohsiung.

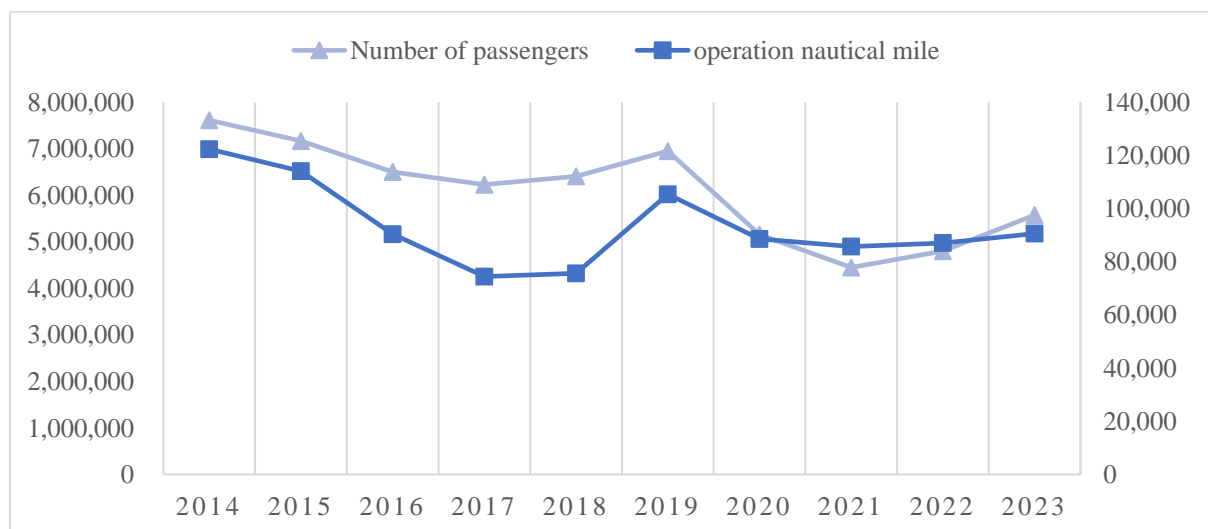


Figure 2 Ferry operation overview in Kaohsiung City-Data source: Transportation Bureau of Kaohsiung City Government (2023)

Despite ongoing improvements, the city still faces traffic congestion challenges, underscoring the need for advanced solutions like autonomous ferries. These ferries are essential for enhancing urban mobility, sustainability, and economic development. Social factors such as passenger perceptions, environmental considerations, and government support play pivotal roles in the success of autonomous ferry initiatives. Consequently, Kaohsiung has emerged as Taiwan's first city to pioneer the development of autonomous ferries.

Meanwhile, the development of an autonomous ferry (with Degree 2 of DOA) led by four organisations (Kaohsiung City Shipping Co. Ltd., Ship and Ocean Industries R&D Center, Academia Sinica, and Industrial Technology Research Institute) had been trialled in 2020 (Kaohsiung City Shipping Co., Ltd., 2020). This initiative involved cross-disciplinary collaboration to develop essential technologies for the autonomous navigation of intelligent vessels. These technologies include core vessel control systems, long-range wireless communication systems, advanced image recognition technologies, and intelligent collision avoidance systems. Based on the aforementioned reference, it is evident that the operation of the majority of autonomous ships require supplemental operations or supervision by onboard seafarers, which fits the definition of Degree 2 of DOA. Therefore, the autonomous ferry service discussed in this study will be under the above degree.

2.3. The dimensions concerning the use of autonomous ferries

Perceived value theory

The perceived value theory, situated within consumer behaviour, investigates how individuals evaluate the worth of products or services based on subjective perceptions. The definition of 'perceived value' has evolved over time, with Zeithaml (1988, p.14) describing it as "the consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given". Dodds and Monroe (1985) introduced a model exploring the causal relationship among perceived quality, price, sacrifice, perceived value, and willingness to purchase. Shaped by personal preferences and extending beyond intrinsic qualities, perceived value involves assessing benefits against costs, encompassing expenses and time (Petrick et al., 1999). Influenced by contextual factors, marketing, and brand image, perceived value spans multidimensional, emotional (Castellanos-Verdugo et al., 2016), and experiential aspects. Additionally, it is dynamic and responsive to market trends, correlating with customer satisfaction and loyalty, affecting repurchase likelihood and recommendations. Researchers apply this theory for consumer behaviour analysis (Xia et al., 2024), effective marketing strategy design, and enhancing the overall customer experience. Identifying factors contributing to perceived value allows businesses to tailor offerings and communication strategies to align with target audience expectations. Multiple factors, including quality, price, and service, contribute to the multidimensional nature of perceived value within different functional and emotional dimensions.

Previous studies have examined the topic of perceived value; customer perceived value is indeed a widely used concept in marketing literature, see for example Aulia et al. (2016) and El-Adly (2019). There is also a limited number of studies related to transport. Table 1 displays research papers on perceived value in the transportation industry that have been published after 2020 and utilised SEM. Most of the papers address land-based public transport, with only one paper focusing on water-based public transport. For example, Hapsari et al. (2016) utilised Structural Equation Modelling (SEM) to analyse the correlation among service quality, perceived value, and customer satisfaction with airline passengers. Baker and Fulford (2016) used regression analysis to examine the relationship among perceived value (multidimensional), satisfaction, and willingness to recommend from the viewpoint of cruise passengers. Kim and

Park (2019) also adopted a multidimensional concept of perceived value in the context of airport passengers, employing SEM. Wang et al. (2019) studied the roles of perceived value (multidimensional) and perceived risk in the context of ride-sharing services, using SEM.

Table 1: Selected papers on perceived value in the transportation industry

Source	Industry	Framework factors
Ni et al. (2020)	Public transport	Safety; convenience; reliability; comfort; economy; rapidity
Suhartanto et al. (2020)	Motorcycle taxi	Mobile App quality; service quality; satisfaction; loyalty
Yuen et al. (2020)	Autonomous vehicles (AV)	Relative advantage; compatibility; complexity; trialability; observability; trust
Lin et al. (2021)	Short sea shipping	Service preference; purchase intentions
Yuen et al. (2021)	Cruise	Perceived benefit; perceived health threat; self-efficacy; cues to action; perceived trust
Ibrahim et al. (2021)	Light rail	Passenger expectation, perceived quality; perceived satisfaction
Yilmaz et al. (2021)	Light rail	customer expectation, perceived quality; satisfaction; loyalty; customer complaints
Yuen et al. (2022)	Autonomous public transport	Performance expectancy; effort expectancy; social influence; facilitating conditions; hedonic motivation; trust
Zou et al. (2022)	Autonomous vehicles (AV)	Perceived value of time; perceived risk; perceived AV sickness; willingness to use time more efficiently in an AV
Kenesei et al. (2022)	Autonomous vehicles (AV)	perceived risk; trust
Xiao and Goulias (2022)	Autonomous vehicles (AV)	Incorporate demographic variables and travel behaviours attributes to the understanding of AV; perceived usefulness; intention to adopt AVs.
Chen and Lee (2023)	shared e-scooter	App platform service quality; mobility service quality; perceived hedonic value; customer participation behaviour; customer citizenship behaviour
Xia et al. (2024)	Airline	Perceived ease of use of platform; perceived usefulness of information; market strategies; purchase intention

According to our review of the relevant literature, there is limited research on autonomous transport, particularly with respect to autonomous ferries. This highlights a significant research gap and indicates that the perceived value, in the context of the emerging and crucial domain of autonomous waterborne transportation of passengers, has been understudied. In line with the aforementioned literature, our study also employs a multidimensional approach to perceived value in the context of autonomous ferries, which encompasses not just price, but also quality, experience, and other aspects. Table 1 presents the key influential dimensions of perceived value (as presented in the relevant literature), including perceived cost and time saving, perceived quality, risk, and willingness to use the transport mode. These dimensions are further elaborated below.

Perceived cost and time saving

Ding et al. (2007) addressed self-service technology and suggested that ‘perceived cost saving’ refers to the degree to which an individual believes that the use of a particular system will curtail their expenditure during the service process. Additionally, they defined ‘perceived time saving’ as the degree to which an individual believes that the use of a particular system would lessen the time spent on the service process. Kamdjoug et al. (2022) also addressed perceived cost and time saving in the use of e-banking. In the transport industry, Subramanian et al. (2014) found that perceived cost saving would positively affect the application of cloud computing in the logistics industry. Mola et al. (2020) highlighted the perceived cost saving as an essential element affecting the public's willingness to adopt a more efficient and eco-friendly transportation system. Zhang et al. (2022) proposed an equation for perceived cost that can better explain the behaviour of mode choice between autonomous vehicles and manually driven vehicles. In line with the above, in our study, perceived cost saving denotes the perceived reduction in ticket fares and waiting time.

Perceived quality

Zeithaml (1988, p.3) defined ‘perceived quality’ as “*the consumer’s opinion about the product overall excellence and superiority*”. Dwivedi and Merrilees (2013) distinguished between ‘production quality’, which is derived from objective measures of a product's features and manufacturing processes, and ‘perceived quality’, which is based on consumers' subjective evaluations of a product. In the present study, perceived quality, following the approach of Pan and Chen (2019), captures the perceived service quality of autonomous ferry transportation, encompassing factors related to the equipment, facilities, timetable, technology, and overall service quality.

Perceived risk

‘Perceived risk’, proposed by Bauer (1960), refers to the possible negative consequences of buying a new product or service. He also stated that it is a combination of uncertainty when making decisions and serious consequences when making wrong decisions. Consumer perception of risk is an important hindrance to consumer decision-making in consumer behaviour research (Chang and Tseng, 2013). In the transport sector, passengers’ perceived risk could directly and indirectly affect their transport mode selection. Nguyen-Phuoc et al. (2021) analysed passengers’ perceived risk when using ride-sourcing services. Kenesei et al. (2022) revealed that users’ perceived risk and trust are two of the most influential factors for adopting autonomous vehicles. They found that performance trust has a direct effect on intention to use autonomous vehicles, while trust in manufacturers has an indirect effect with the mediation of privacy risk. In this study, perceived risk refers to the fear of taking autonomous ferries due to the new technology that might cause economic risk and time risk issues.

Willingness to use autonomous ferries

The concept of ‘willingness to use autonomous ferries’ is rooted in the concept of ‘willingness to purchase’, which is a well-studied concept in consumer behaviour. Willingness to purchase refers to consumers’ intention to buy certain products or services, and it is used to predict purchase behaviour (Poushneh and Vasquez-Parraga, 2017). Liu et al. (2019) addressed the willingness to pay for self-driving vehicles (SDV) in China by using SEM. They found that several factors such as familiarity, age, education, and income affect users’ willingness to pay for SDVs. In their recent study, Xiao and Goulias (2022) explored the interconnections between observed and latent variables concerning the acceptance of autonomous vehicles using Structural Equation Modelling (SEM). Their findings revealed that the perceived usefulness of

the technology was a vital determinant of behavioural intention. In line with the above, in this study, the act of opting for an autonomous ferry trip can be perceived as a demonstration of a willingness to pay for the corresponding service.

3. Methodology

3.1. Research structure

Drawing upon the 'Perceived Value' theory, this study incorporates various dimensions related to perception, specifically perceived cost and time savings, perceived quality, perceived value, perceived risk, and willingness to use autonomous ferries, into the proposed model. This model will be employed to examine the relevant hypotheses using various statistical methodologies. The research model of this study, as depicted in Figure 3, is established based on the existing literature (refer to Sections 2.2 and 2.3 for more details on the selected dimensions).

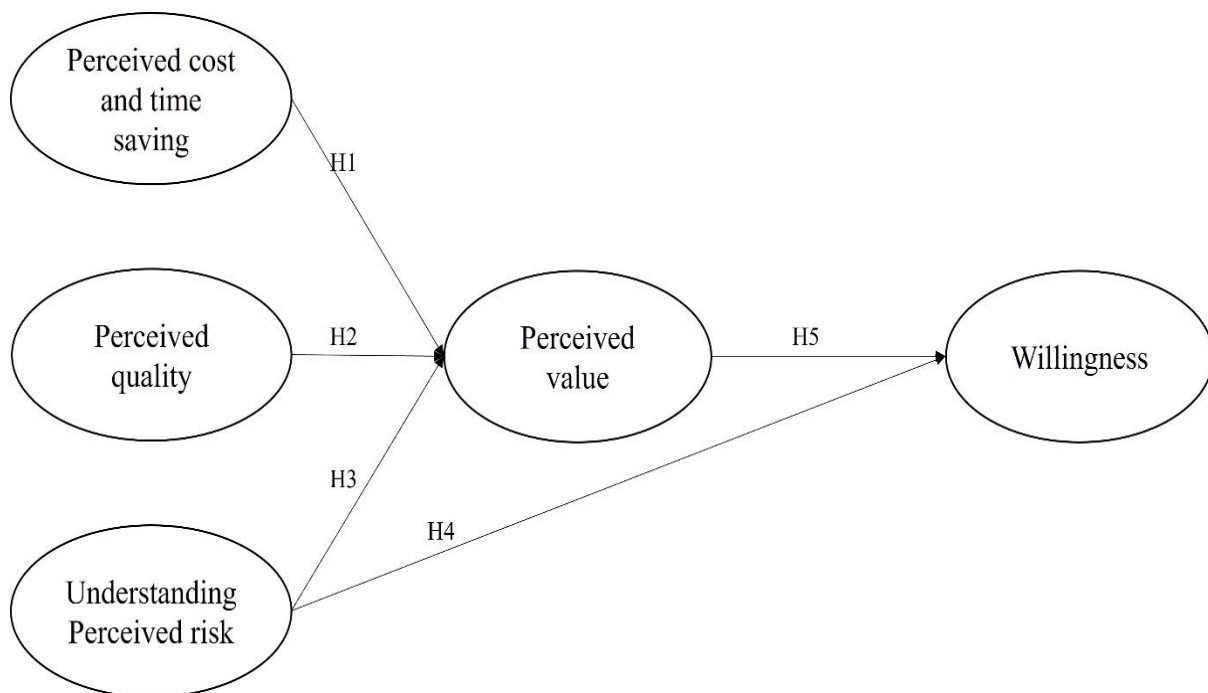


Figure 3: Proposed research model

3.2. Research hypotheses

Although the Perceived Value theory and the hypotheses have been utilised in other industries, there is no research that applied the theory in the autonomous ferry industry. Thus, examining the relationship between variables such as perceived cost and time savings, perceived quality, understanding of perceived risk, perceived value, and willingness to use autonomous ferries provides critical insights into user adoption and acceptance of this technology. Understanding how these factors interrelate helps identify key drivers and barriers to adopting autonomous ferries. For instance, perceived cost and time savings might directly influence perceived value and willingness to use, while perceived quality and risk understanding shape overall acceptance. This analysis informs targeted strategies to enhance user experience, address concerns, and improve the implementation of autonomous ferries, contributing to more effective adoption and integration into urban transportation systems. As depicted in Figure 2, five hypotheses are proposed based on the relevant literature as follows.

(1) The relationship between perceived cost and time saving, and perceived value

The concept of perceived value involves assessing the benefits perceived by customers, including the overall evaluation of the cost of the ticket, waiting time, and the quality of transportation services received (Wirtz and Bateson, 1995). When the perceived value (i.e. after the purchase) is consistent with the passenger's expectations, the two can be considered equivalent; if the perceived value falls short of expectations, it leads to dissatisfaction, and if the perceived value exceeds the passenger's expectations, it results in positive satisfaction. (Dodds and Monroe, 1985; Konuk, 2019). Hence, H1 is proposed as:

H1: Perceived cost and time saving has a positive impact on the perceived value

(2) The relationship between perceived quality and perceived value

The value of the customer experience can be evaluated based on four aspects, including the value created by products and services: (a) investment returns: consumers make financial investments using their own affordable finance; (b) service excellence: excellent market service, the praise of marketing ability, the superiority of service comes from the promise of the provider to communicate the product to improve the quality; (c) aesthetics: it refers to the visual attraction of the product to the individual's psychology, and improves the perceptual quality; (d) enjoyment: consumers of products can arouse their inner happiness, and it will increase the interest in consumption, and achieve the utility of identifying its value (Castellanos-Verdugo et al., 2016). Jeong and Lambert's (2001) pointed out on the perceived quality and perceived value of products and services that indicated when the perceived quality of a product/service is high, its perceived value is also high from their clients (Konuk, 2019). Therefore, H2 is proposed as:

H2: Perceived quality has a positive impact on perceived value

(3) The relationship between understanding perceived risk and perceived value

The impact of perceived risk on consumer purchasing behaviour is evident, stemming from the uncertainty inherent in decision-making outcomes and the potential consequences of erroneous choices. Whitfield et. al., (2009) proposed that increased trust and understanding in the nuclear governance institutions reduce perceived risk of nuclear power and together higher trust and lower risk perceptions predict positive attitudes toward nuclear power. Wang et al. (2019) delved into the willingness of prospective ride-sharing users, considering perceived value and perceived risk dimensions. Their study revealed that both perceived value and risk significantly influence consumers' willingness to engage in ride-sharing. Furthermore, their research highlighted a moderate effect of perceived risk on both perceived value and consumers' willingness to participate in ride-sharing. Based on the above, we propose H3 as follows:

H3: The understanding of perceived risk has a positive impact on perceived value

(4) The relationship between understanding perceived risk and willingness to use autonomous ferries

A substantial body of research on consumer behaviour consistently indicates that elevated subjective perceived risk significantly influences consumers' purchase intention (Forsythe and Shi, 2003). The results from Whitfield et. al., (2009) focused on how understanding the influence of decreasing perceived risk creates customer value in service projects. In investigating the online information environment and its influence on online consumer behaviour, Xiong (2011) investigated the cognitive processes involved in consumer information comprehension. The study scrutinises factors such as perceived risk, value, and

trust that shape decision-making behaviour in the context of e-business. The findings indicated a positive correlation between a heightened understanding of perceived risk and a greater inclination towards adapting to the online information environment. A study conducted by Liu et al. (2019), specifically investigating the willingness to adopt self-driving services, provides additional evidence supporting the influential role of perceived risk. Their research revealed a conspicuous effect of perceived risk on the willingness to pay for such services. Based on the above inferences, H4 is proposed as follows:

H4: The understanding of perceived risk has a positive impact on the willingness of taking autonomous ferries

(5) The relationship between perceived value and willingness to use autonomous ferries

Previous research revealed that passengers' intentions to use vehicles are significantly influenced by perceptions of the perceived value (Zeithaml, 1988). Perceived value affects customers' willingness to consume. When consumers purchase goods, they evaluate the perceived advantages and disadvantages; their perception of advantages increases the perceived value, otherwise the disadvantages increase instead. It is likely for passengers to produce the same perceived value when taking an autonomous ferry. When the perceived value is higher, the willingness to use autonomous ferries will be higher; when the perceived value is lower, the willingness to use autonomous ferries will be lower (Chang et al., 2016; Wang et al., 2019; Zhang et al., 2020). Liu et al. (2019) also found that perceived benefit positively affects the willingness to pay for self-drive service. A hypothesis is, therefore, proposed as follows:

H5: Perceived value has a positive impact on the willingness of taking autonomous ferries

3.3. Research design

Based on the literature review, a questionnaire on the five dimensions is designed, validated through expert interviews, and administered using a five-point Likert scale (1: strongly disagree to 5: strongly agree) online survey platform to obtain respondents' views on the willingness to use autonomous ferries. As the study focuses on perceptions of new transportation types, respondents were required to confirm their experience with traditional ferries before proceeding. This ensures that only relevant and valuable responses are collected. Table 2 provides details on the dimensions, question items and the literature that supports their selection.

In multivariate analysis, sample size plays a critical role. A common guideline is to have at least ten samples per observed variable to ensure robust results. However, excessively large sample sizes may adversely affect chi-square fit and lead to model rejection due to the increased likelihood of discrepancies between actual data and the hypothesised model. Schumacker and Lomax (1996) recommended a sample size of between 200 and 500, though some scholars suggested that acceptable sample sizes can be fewer than 200 or more than 500. Bentler and Chou (1987) proposed that five samples per observed variable are sufficient (Lin and Chang, 2021), while other researchers advocated for a sample-to-variable ratio of between 10:1 and 15:1. Loehlin (1992) and Mueller (1997) suggested a minimum sample size of 100 for structural equation modelling (SEM) analysis. This study collected 151 valid samples to analyse 17 observed variables within the SEM model. While this sample size is slightly below the recommended threshold, it meets the criterion of having more than five samples per variable.

Additionally, further statistical tests will be conducted to ensure the validity and reliability of the analysis results derived from these samples.

Additionally, we addressed the potential issue of non-response bias by following the method proposed by Armstrong and Overton (1977). They recommend comparing the responses of the last quartile or second wave of survey participants with those of non-respondents to detect any bias. In this study, the 151 respondents were categorised into two groups based on their response timing: the first wave (n=101, 66.9%) and the second wave (n=51, 33.1%). T-tests were conducted to compare perceptions of perceived value, perceived cost and time savings, perceived quality, understanding of perceived risk, and willingness to use autonomous ferries between the two groups at a 5% significance level. The results indicated no significant non-response bias, as the responses of the second wave participants were comparable to those of the first wave.

Descriptive statistics, reliability and validity tests, confirmatory factor analysis (CFA), and SEM are used to analyse the data collected. To avoid errors generated by various factors while filling out the questionnaire, it is essential to carry out the evaluation of reliability/validity before subsequent analyses (Hair et al., 2019).

Table 2: Dimensions and items related of willingness to use autonomous ferries

Dimension	Code	Items	Relevant literature
Perceived value	PV1	The experience between using autonomous ferries and conventional ones is different	Velasco et al. (2012); Wang et al. (2019); Ellefsen et al. (2020)
	PV2	Opting for autonomous ferries guarantees a superior level of service.	
	PV3	Using autonomous ferries is a valued and special experience	
	PV4	The trip using autonomous ferries is more enjoyable	
Perceived cost and time saving	PC1	I think that ticket prices for autonomous ferries should be comparatively lower than those for conventional ones.	Wirtz and Bateson (1995); Dodds and Monroe (1985); Konuk (2019)
	PC2	An affordable ticket price for trips using autonomous ferries is an important consideration for me	
	PC3	I think the trip duration (time) using autonomous ferries is shorter compared to using conventional ones	
Perceived quality	PQ1	I think that autonomous ferry services should offer real time information (e.g., position, expected arrival times)	Jeong and Lambert (2001); Ansari and Riasi (2016); Pan and Chen (2019)
	PQ2	I think that autonomous ferries provide a better passenger experience (i.e., vessels are fitted with Wi-Fi and USB/wireless phone charges)	
	PQ3	Autonomous ferries are manned by teams of highly trained professionals	

Understanding perceived risk	PR1	I understand there might be a risk that autonomous ferry services may be disrupted due to malfunctions	Whitfield et. al. (2009); Chang and Tseng (2013);
	PR2	I understand the impact of cybersecurity issues when considering autonomous ferry services	
	PR3	I understand there might be a possibility that autonomous ferries may stall on the water due to insufficient battery levels	
	PR4	I understand that autonomous ferries might take more time compared to conventional ones (due to, for example, more time-consuming purchasing processes)	
Willingness to use autonomous ferries	W1	I would contemplate selecting autonomous ferries if their ticket prices were equivalent to those of conventional ones	Chang et al. (2016); Wang et al. (2019); Zhang et al. (2020)
	W2	I would prefer autonomous ferries over conventional ones if the trip time was the same	
	W3	I am willing to use an autonomous ferry for future trips	

The reliability and validity of the questionnaire are evaluated using Cronbach's coefficient alpha, composite reliability (CR), average variance extracted (AVE), and CFA. The Cronbach's coefficient alpha value is commonly adopted to measure internal consistency reliability among items selected into the formation of a single scale. Coefficients at a value of 0.7 or more are considered a satisfactory level of reliability based on the suggestion of Iacobucci and Churchill (2018). Further, a convergent validity analysis technique, including composite reliability (CR) and average variance extracted (AVE), is used for evaluating whether each selected item qualified in the identified construct. Confirmatory factor analysis (CFA) is then used to test the reliability and validity for ensuring the homogeneity of the selected items in each dimension.

Finally, an SEM is employed to investigate the relationships among the five constructed dimensions, allowing all dimensions to be analysed simultaneously. Although linear regression can also be utilised for examining the relationship between dimensions, SEM allows all dimensions to be analysed simultaneously (Liu et al., 2019; Lin et al., 2022; Kanwal et al., 2024) dealing with the relationship between multiple sets of variables, hence showing superiority in our research. Several common indices proposed in SEM are applied to test the goodness of fit of the research model (see Table 6 in Section 4.4).

4. Results

4.1 Respondents Background

Table 3 presents information about the demographic characteristics of the survey respondents (n=151), such as their age, gender, occupation, education level, income, and other relevant factors. All responses have been included in the final sample. Approximately 65% of the respondents are female, while over 60% of the total sample are under the age of 27. Furthermore, over three-quarters of the participants possess a higher level of education, having completed at least a Bachelor's degree.

However, their disposable income seems to be on the low side; around 55% of the respondents have a disposable monthly income of less than 20,000 Taiwan Dollars (TWD). To put this in

perspective, according to official statistics the average annual disposable income per household in 2021 was 1,090,554 TWD; this corresponds to 31,446 TWD per month assuming an average household of 2.89 persons, see RoC (Taiwan) National Statistics (2022) household income and expenditure survey. Note that 1 US Dollar (USD) equals to around 28-32 TWD (based on the last 5 years exchange rates).

This is not surprising though, as 56.3% of the respondents are students or young people and 60% are under the age of 27. It, therefore, is probably expected that their disposable income is way below the national average. These characteristics are important as one might expect that students or young people, in general, might be more willing to experience a novel transport system but, at the same time, they have budget constraints.

Table 3: Demographic characteristics

Demographic variable	Frequency	Percentage (%)
Gender		
Male	52	34.4
Female	99	65.6
Age		
Under 27	93	61.6
27-58	53	35.1
Over 58	5	3.3
Education level		
High school or below	34	22.7
Bachelor	112	74.0
Master or above	5	3.3
Occupation		
Students	85	56.3
Employed individuals	47	31.1
Non-working group	19	12.6
Monthly disposable income (TWD)		
10,000 or less	55	36.4
10,001-20,000	28	18.5
20,001-30,000	14	9.3
30,001-40,000	14	9.3

40,001-50,000	8	5.3
50,000 or above	14	9.3
prefer not to say	18	11.9

4.2 Descriptive analysis

Respondents were asked to provide the level of perceived agreement with the items presented; note again the scale used i.e., from 1 (strongly disagree) to 5 (strongly agree).

Results shown in Table 4 indicate that all mean scores of measures ranged between 3.576 and 4.489. Regarding the perceived value factor, the top item is ‘The trip using autonomous ferries is more enjoyable’ (PV4, mean: 4.352). In the perceived cost and time saving aspect, the top item is ‘I think the trip duration (time) using autonomous ferries is shorter compared to using conventional ones’ (PC3, mean: 4.159). The results indicate that when the respondents think about using an autonomous ferry, the most important consideration is the duration of the journey. Further, for the perceived quality, the top item is ‘I think that autonomous ferries provide a better passenger experience’ (PQ2, mean: 4.591). This implies that the respondents have a high degree of agreement on their belief that autonomous vessels provide a superior passenger experience.

Regarding the perceived risk, the top one is ‘There is a possibility that autonomous ferries may stall on the water due to insufficient battery levels’ (PR3, mean: 3.962). This shows that respondents are most concerned about the endurance power of autonomous ferries. For the willingness to use autonomous ferries, the top item is ‘I am willing to use an autonomous ferry for future trips’ (W3, mean: 4.489), which actually shows that the public is indeed ready for autonomous ferry services.

Table 4: Results of descriptive analysis

Construct	Item	Mean	Standard Deviation
Perceived value (PV)	PV1	4.068	0.961
	PV2	3.913	0.949
	PV3	3.883	0.989
	PV4	4.352	0.851
Perceived cost and time saving (PC)	PC1	3.955	0.817
	PC2	4.049	0.991
	PC3	4.159	0.978
Perceived quality (PQ)	PQ1	4.523	0.724
	PQ2	4.591	0.669
	PQ3	4.496	0.750
Perceived risk (PR)	PR1	3.701	1.027

	PR2	3.580	0.923
	PR3	3.962	1.067
	PR4	3.576	0.960
Willingness to use autonomous ferries (W)	W1	4.212	0.998
	W2	4.083	1.075
	W3	4.489	0.780

This study employs a self-report questionnaire to collect data, which may result in a common method variance (CMV) problem, leading to evaluation bias while measuring multiple factors based on identical responding samples (Podsakoff et al., 2003). To address this potential bias, an ex-ante approach is employed. First, the dependent variables (perceived cost, price saving, quality, value, and risk) are measured based on respondents' perceptions of their public transportation experience, while the independent variable (willingness to use autonomous ferries) is based on respondents' perceptions of existing unmanned ships. Respondents' anonymity is assured to encourage them to answer as honestly as possible. By doing so, the CMV problem is alleviated in this study.

To ensure the accuracy and content validity of the proposed model, a reliability test is conducted to examine the internal consistency of items in each factor. The results indicate that Cronbach's α values of all factors range from 0.77 to 0.86, all above the benchmark value of 0.7, confirming the reliability of the proposed model (see Table 5).

This study employs several validity tests, with convergent validity being the most commonly used method, which refers to how closely the new scale is related to other variables and other measures of the same construct. Our results show that each item contained in each construct has a factor loading greater than 0.5, which satisfies the criterion suggested by Iacobucci and Churchill (2018). In addition, we utilise the Average Variance Extracted (AVE) and Composite Reliability (CR) to confirm the existence of convergent validity between each factor. Discriminant validity is also achieved by ensuring that the AVE is higher than the squared correlation between any two factors (Iacobucci and Churchill, 2018). In this study, the results indicate that each construct's CR values exceed 0.6, and AVE values exceed 0.7, which fully meets the requirements. Therefore, we can conclude that the proposed model has satisfactory convergent and discriminant validity.

Table 5: Assessment of reliability and validity of the willingness to use autonomous ferries

Construct	Item	Loading	α value	CR	AVE
Perceived value	PV2	0.882	0.855	0.904	0.703
	PV3	0.862			
	PV4	0.825			
	PV1	0.781			
Perceived cost and time saving	PC2	0.883	0.704	0.886	0.723

	PC3	0.879			
	PC1	0.785			
Perceived quality	PQ3	0.886	0.865	0.909	0.770
	PQ1	0.874			
	PQ2	0.872			
Understanding perceived risk	PR4	0.852	0.719	0.904	0.702
	PR1	0.847			
	PR2	0.828			
	PR3	0.825			
Willingness to use autonomous ferries	W3	0.894	0.827	0.883	0.716
	W2	0.824			
	W1	0.818			

Abbreviation: *a* value: Cronbach's *a*; CR: composite reliability; AVE: average variance extracted

4.4 Confirmatory factor analysis (CFA)

In order to confirm that the five dimensions previously established for each aspect can accurately represent the core meaning of the aspect, this research utilises CFA to examine whether each aspect has sufficient measurement quality. The fitness indicators such as GFI, AGFI, TLI, NFI, RMR, and RMSEA, which collectively help assess the overall fit of a CFA model, guiding researchers in model refinement, are employed to evaluate whether this factor is suitable as a representative. The GFI and AGFI indicate how well the model explains variance, with values closer to 1 preferred. The TLI and NFI compare the model to a null model, with values above 0.80 being ideal. The RMR (Root Mean Square Residual) measures average residuals, with lower values indicating better fit, while RMSEA evaluates fit per degree of freedom, with values below 0.08 suggesting acceptable fit (Hair et al., 2019). Table 6 shows that all the fitness indicators meet the corresponding thresholds.

Table 6: Goodness of fit indicators for CFA

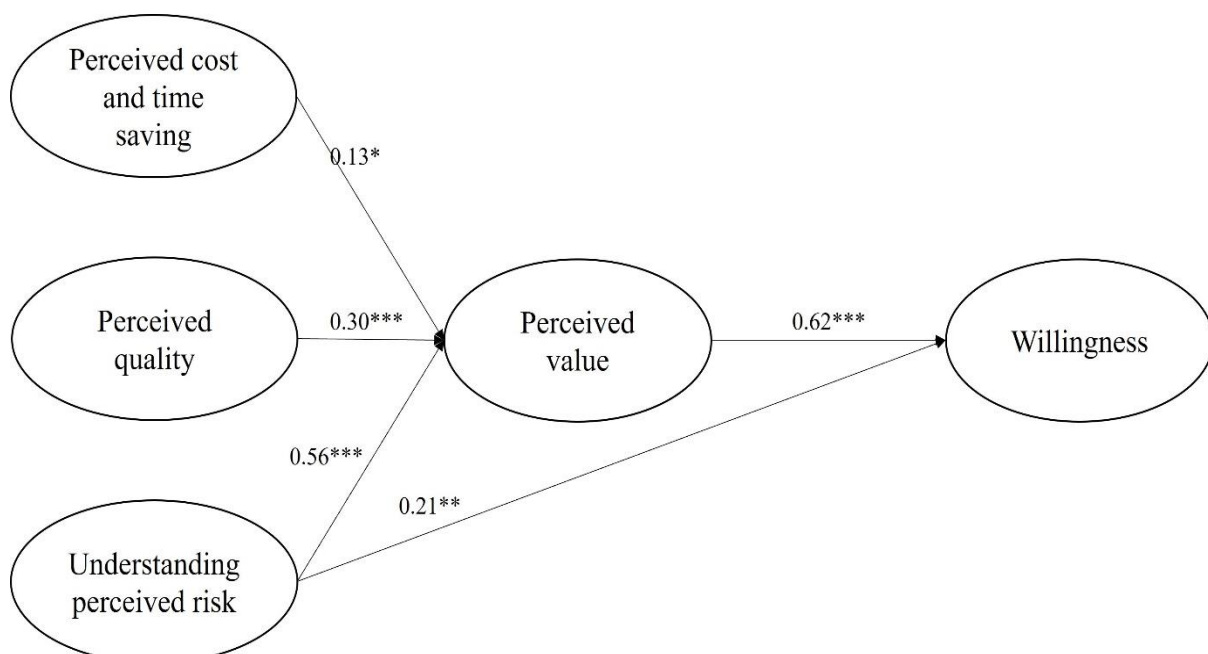
Fit Indices	Results	Criterion	References
GFI	0.88	> 0.80	Kanwal et al. (2022)
AGFI	0.83	> 0.80	Chang et al. (2021); Kanwal et al. (2022)
TLI	0.83	> 0.80	Hair et al., 2019; Lin et al. (2022)
NFI	0.86	> 0.80	Kanwal et al. (2022)
RMR	0.07	< 0.08	Chang et al. (2021); Lin et al. (2022); Kanwal et al. (2022)
RMSEA	0.07	< 0.08	Chang et al. (2021); Lin et al. (2022); Kanwal et al. (2022)

Abbreviations: GFI: goodness of fit index; AGFI: adjusted goodness-of-fit index.
TLI: Tucker-Lewis index; NFI: normed fit index; RMR: root mean square residual;
RMSEA: root mean square error of approximation

4.5. Structural equation modelling (SEM)

After confirming the fitness of the integrated measuring items, this research continues with evaluating the proposed structural model and probing into the hypothesised relationships using SEM. Numerous goodness-of-fit indices have been performed, including a chi-square divided by the degrees of freedom (χ^2/df) at 2.19, GFI of 0.91, AGFI of 0.87, TLI of 0.93, and NFI of 0.91 (all above the acceptable thresholds of 0.8), as well as both RMR of 0.06 and RMSEA of 0.07 – this is the minimum acceptable level. These indicate that the data adequately support the estimated model.

After confirming the fitness of the integrated measuring items, this research continues with evaluating the proposed structural model and probing into the hypothesised relationships using SEM. For the cause-and-effect relationship among the five dimensions, this study uses the β (beta) values to examine the research hypotheses, whereas utilises the t-value and p-value to test whether there are significant correlations between each pair of factors or not. The results of the final model are shown in Figure 4.



Note: *:p<0.1; **:p<0.05; ***:p<0.01

(χ^2/df): 2.19; GFI: 0.91; AGFI: 0.87; TLI: 0.93; NFI: 0.91; RMR: 0.06; RMSEA: 0.07

Figure 4: SEM results

Table 7 illustrates the Structural Equation Modelling (SEM) results, which unveil the significance of the interrelationships between the five dimensions. The results indicated that perceived quality, perceived cost and time savings have a positive impact on perceived value, subsequently influencing the willingness to use autonomous ferries. On the other hand, understanding perceived risk has a discernible impact on both perceived value and willingness to use. Consequently, the investigation confirms H1, H2, H3, H4 and H5, which suggest that the public's willingness to use autonomous ferries can be influenced by their perceived value as well as understanding perceived risk.

Table 7: Results of SEM

Path	Estimates		S.E.	C.R.	p
	Standardised	Non-standardised			
Perceived cost and time saving → Perceived value (H1)	0.130	0.150	0.092	1.625	*
Perceived quality → Perceived value (H2)	0.304	0.352	0.092	3.825	***
Understanding perceived risk → Perceived value (H3)	0.562	0.809	0.156	5.187	***
Understanding perceived risk → Willingness to use (H4)	0.213	0.434	0.180	2.408	**
Perceived value → Willingness to use (H5)	0.617	0.873	0.133	6.586	***

Note: *: $p < 0.1$; **: $p < 0.05$; ***: $p < 0.01$

Table 8 shows the path analysis results. In the relationship between perceived cost and time saving, and perceived value, the total effect is 0.130 (0.130 direct effect and no indirect effect). The results also show only an indirect effect (0.080) on the link to willingness to use autonomous ferries, suggesting that perceived cost and time saving has no direct influence on willingness to use autonomous ferries. In terms of perceived quality, there is a direct impact of 0.304 on perceived value, with no indirect impact (resulting in a total impact effect of 0.304). Regarding the relationship between perceived quality and the willingness to use autonomous ferries, the direct effect on willingness is 0, while the indirect effect is 0.187, yielding a total effect of 0.187. Additionally, perceived risk directly affects perceived value with an impact of 0.562, without any identified indirect effects, resulting in a total effect of 0.562. Confirming the total effect of perceived risk on the willingness to use autonomous ferries, the analysis indicates a value of 0.560 (comprising a direct effect of 0.231 and an indirect effect of 0.347). Lastly, perceived value directly influences the willingness to use autonomous ferries (0.617), with no identified indirect effects.

Table 8: Path analysis results

	Direct effect	Indirect effect	Total effect
Perceived cost and time saving → Perceived value	0.130	---	0.130
Perceived cost and time saving → Willingness to use autonomous ferries	---	0.080	0.080
Perceived quality → Perceived value	0.304	---	0.304
Perceived quality → Willingness to use autonomous ferries	---	0.187	0.187
Understanding perceived risk → Perceived value	0.562	---	0.562
Understanding perceived risk → Willingness to use autonomous ferries	0.213	0.347	0.560
Perceived value → Willingness to use autonomous ferries	0.617	---	0.617

5. Conclusions and discussion

5.1. Conclusions

With the development of autonomous ships, autonomous ferries are also getting increasing attraction from both industry and academia. The current state of autonomous ferry technology faces challenges, particularly in addressing safety concerns and accommodating passenger needs. The complexity of marine navigation poses hurdles, distinguishing autonomous ferries from cargo vessels. Despite these uncertainties, the field of autonomous shipping, including Maritime Autonomous Surface Ships (MASS), garners increasing attention. Notably, limited research focuses specifically on passengers' attitudes towards autonomous ferries, with a scarcity of studies on willingness, which indicates most of the research addressed their technologies and feasibility but did not much focus on the user perspective.

This research aims to investigate the passenger's acceptance to use autonomous ferries by applying the 'Perceived Value' theory. The results show that the perceived cost and time saving, perceived quality, and understanding perceived risk all have a direct and positive impact on the perceived value (H1, H2 and H3 support). Understanding perceived risk also revealed a direct effect on willingness to use autonomous ferries (H4 support). Perceived value, in turn, has a direct and positive impact on the willingness to use them (H5 support). In addition, perceived cost and time saving, perceived quality, and understanding perceived risk all revealed significant mediating effects to willingness to use autonomous ferries through perceived value. This can be inferred that when the perceived value is higher than expected, the public has a higher willingness to use autonomous ferries. The reason may be that autonomous ferries are a kind of novel service for carrying passengers, and the service quality that people are expecting is perceived as higher than the actual one it brings, which results in the public being willing to pay a higher price.

Notably, from the examining results of hypotheses 3 and 4, the research robustly validates the assumption that understanding perceived risk significantly impacts both perceived value and the willingness to use autonomous ferries. This finding underscores the notion that public transportation users seek a safe and expedient means of reaching their destination. If this requirement can be fulfilled through an autonomous ferry, despite its inherent risks, individuals may derive a sense of accomplishment, thereby elevating the perceived value. The adoption of autonomous ferry services represents a novel and uncertain transportation mode for the public. In contrast to traditional public transportation, individuals exhibit heightened curiosity and interest in exploring these innovative vehicles, driven by the allure of novel experiences and the intrigue surrounding the uncertainties associated with autonomous ferry travel.

5.2. Discussion and recommendations

The successful operation of autonomous ferries requires not only advancements in technology and regulatory frameworks but also a deep understanding of public perception and acceptance of this emerging service model. A comprehensive approach is essential, involving the formulation of appropriate policies, strategic resource allocation, and the construction of a viable operational framework. Based on the research findings, several recommendations are put forward for both the industry and governmental authorities to enhance the adoption and acceptance of autonomous ferries.

(1) Addressing perceived risk: Understanding perceived risk is crucial as it significantly impacts both the perceived value of autonomous ferries and the public's willingness to use them. To mitigate these concerns, the industry should prioritise the development of robust safety

protocols. This includes the implementation of advanced navigation systems, collision avoidance technologies, and real-time monitoring systems that can reassure passengers of the technology's reliability. Transparent communication regarding these safety features is also essential to build public trust and reduce apprehension.

(2) Enhancing perceived value: Efforts should be made to increase the perceived value of autonomous ferries by ensuring that the service meets or exceeds public expectations. This can be achieved by optimising key aspects of service quality, such as punctuality, comfort, and accessibility. Moreover, providing additional amenities or personalised services could enhance the overall travel experience, making the service more attractive to potential users. Ensuring a smooth and enjoyable journey will play a crucial role in shaping positive user experiences and fostering repeat usage.

(3) Passenger-centric design: The design and operation of autonomous ferries should prioritise passenger needs and preferences. This involves conducting thorough user research and incorporating feedback into the iterative development process. By aligning the service design with passenger expectations, the industry can ensure that the technology is not only innovative but also practical and user-friendly. Features such as easy boarding procedures, real-time updates, and accessible facilities will contribute to a more favourable perception of the service.

(4) Targeted communication strategies: Effective communication is key to increasing public awareness and acceptance of autonomous ferries. Public awareness campaigns should highlight the tangible benefits of using autonomous ferries, such as cost savings, time efficiency, environmental sustainability, and the novelty of the experience. Additionally, educating the public about how autonomous ferries operate, the safety measures in place, and the potential for enhanced urban mobility will help foster a more positive attitude towards this new mode of transportation.

5.3. Research contributions

Our study contributes significantly from a policy perspective. Firstly, it identifies a crucial gap in research concerning the public's willingness to use autonomous ferries and introduces a new model that comprehensively considers various dimensions influencing the public's acceptance of this emerging mode of transportation. This model can serve as a valuable tool for the ferry industry, enabling them to grasp the factors impacting the public's willingness to embrace autonomous ferries and pinpoint the primary concerns affecting their decision-making process.

Secondly, the findings highlight that passengers' top three concerns revolve around perceived value, specifically focusing on diversified service, navigational information, and the professionalism of the ferry teams. This research provides companies and government authorities with guidelines to enhance these aspects, thereby improving the overall passenger experience and increasing willingness to use autonomous ferries.

Thirdly, this study explores the relationships among perceived cost savings, service quality, value, risk, and willingness to use autonomous ferries. This research is valuable for ferry companies seeking to enhance their services and boost passengers' intention to adopt this new technology. The government can play a supportive role by facilitating initiatives.

Finally, this study offers comprehensive recommendations for both the ferry industry and the government across various domains, including safety and security, service quality, and policy implementation. Implementation of these recommendations can enable ferry companies to

provide sustainable autonomous ferry services, fostering public acceptance. Simultaneously, the government can play a crucial role in overseeing service quality.

5.4. Limitations and future research

In the preceding sections, we have detailed several limitations inherent to our research. We believe there are several areas that warrant further investigation to enhance the depth and applicability of the findings. Firstly, future research could benefit from examining the various motives behind the use of autonomous ferries, such as commuting versus tourism. Understanding whether different user groups hold divergent perceptions can provide nuanced insights into how these services might cater to varied needs and preferences. Additionally, extending the research over a longer time frame could offer insights into the stability and consistency of the results. Longitudinal studies could reveal whether perceptions and willingness to use autonomous ferries evolve as more information and experience become available.

In our study, the sample predominantly consisted of young individuals. The results suggest that younger demographics favour ferry services due to several factors: their preference for convenient and innovative transportation options, a higher acceptance of new technologies and digital solutions, and a strong awareness of environmental sustainability, making eco-friendly ferries particularly appealing. Economic considerations also contribute, as ferries offer a cost-effective means of short-distance travel. However, these findings may not be generalisable across different age groups or socio-economic backgrounds. Future research should aim for a more balanced demographic representation to enhance the generalisability of the results. Additionally, collecting data at multiple points over time will help analyse changes in attitudes and behaviours towards autonomous ferries, providing a comprehensive understanding of public willingness and influencing factors

Continuous research is necessary to monitor public attitudes towards autonomous ferries and to identify any emerging concerns or barriers to adoption. Longitudinal studies that track changes in user perception over time will provide valuable insights into how these attitudes evolve as the technology matures and becomes more integrated into daily life. This ongoing research will be crucial for making data-driven adjustments to the service and ensuring its long-term success. The adoption of autonomous ferries remains a pertinent and challenging issue. Given that our research is a preliminary study, future investigations should account for the maturity of technology in relation to the adoption of autonomous ferries. As technology evolves, its maturity can significantly influence user acceptance and operational feasibility. Future research should examine how advancements in autonomous ferry technology such as improvements in navigation systems, safety features, and environmental sustainability affect public perceptions and willingness to use these services. Additionally, studies should explore the impact of technological maturity on the effectiveness and efficiency of autonomous ferries in real-world settings. By addressing these aspects, subsequent research can provide clearer recommendations for the integration of autonomous ferries into urban transportation networks, ensuring that technological developments align with user expectations and regulatory standards.

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