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Analyzing the Factors Influencing the Intention to Adopt Autonomous Ships Using the TOE Framework and DOI Theory

You-Jin Park · Yu-Jin Jeong** · Young-Su An*** · † Jong-Kap Ahn*

**Ph.Doctor, Department of Business Administration, Yonsei University, Seoul, 03722, Korea*
***Lecturer, Department of Business Administration, Yonsei University, Wonju, Gangwon-do, 26493, Korea*
****Professor, Institute of Marine Industry, Gyeongsang National University, Tongyeong 53064, Korea*
† Professor, Institute of Marine Industry, Gyeongsang National University, Tongyeong 53064, Korea

Abstract : *The development and operation of autonomous ships are spotlighted as a next-generation technology that will provide new benefits for the maritime business during the fourth industrial revolution. To expand the adoption of autonomous ships, the much more interest of the nation and the industries will have to be changed to actual adoption in shipping companies. For this, it is judged that research to identify the factors impacting the adoption intention of autonomous ships should be preceded. However, most studies on autonomous ships have focused on developing the technology, revising the law, establishing policies, and managing human resources, with few studies on influencing factors in the adoption of autonomous ships. A model, to identify the factors that impact the intention to the adoption of autonomous ships, based on the theory of diffusion of innovation and the TOE framework was developed. The suggested model was verified through empirical analysis targeting the shipping companies and the marine industries in Korea. As the result of this study, it was found that top management support, financial slack, and competitive intensity significantly impacted the intention to adopt autonomous ships. Additionally, it was revealed that the overall awareness of autonomous ships among Korean shipping companies is poor.*

Key words: *the forth industrial revolution, autonomous ship, TOE framework, DOI theory, intention to adopt autonomous ships*

1. Introduction

Since the 4th Industrial Revolution emerged as a global topic at the World Economic Forum in Switzerland in January 2016, core technologies such as IoT, big data, AI, and cloud systems have been applied to medical, welfare, education, and social safety. Furthermore, transportation technologies, including automobiles, aircraft, and marine vehicles, are becoming important areas of application.

The shipping industry is perceived to be more conservative when investing in new technologies than the aircraft and automobile industries. Nevertheless, recognition of the needs for automation of shipping vessels is increasing, and it is progressing systematically toward autonomy through satellite communication systems and e-Navigation which optimizes data exchange between land and ships (Yoo et al., 2019).

According to the report published from the Boston Consulting Group in 2018, seven digital technologies will contribute to the container shipping industry(Egloff et al., 2018): E-platforms, Advanced analytics, the Internet of Things (IoT), Artificial Intelligence(AI), Autonomous vessels and robotics, Blockchain, and Cyber security.

Therefore, the development and operation of autonomous ships are highlighted as next-generation technologies that will create new added value in the maritime business. The technological development of autonomous ships is progressing rapidly, mainly in Europe. To direct the technical development and international standardization of autonomous ships, EU countries are concentrating their capabilities on R&D investment, the development of laws and policies, and the assessment of technical impact. In particular, Norway and Finland, where shipbuilding equipment and shipping industries are highly developed, formed an industry-academia-research consortium and carried out several autonomous ship development projects such as MUNIN, ReVolt, and AAWA. In addition, Rolls-Royce is accelerating technological development with the goal of unmanned inland and offshore vessels by 2025 and complete unmanned ocean vessels by 2030 (Korea

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† Corresponding author, JongKap.Ahn@gnu.ac.kr 055)772-9042
* parkyoujin@yonei.ac.kr
** eaujin@yonei.ac.kr
*** yosuan@gnu.ac.kr
Note) "Review of the factors influencing the intention to adopt autonomous ships", Speech at the Korean Society of Marine Engineering, youtube(online), 24~25 June 2021

Maritime Institute, 2018).

Asian countries are actively developing technologies under government leadership. Japan has established a plan to build 250 cargo ships using AI autonomous technology by 2025. China reflected on the development of smart ships in its 'Made in China 2025' policy. South Korea is developing technology for the commercialization of autonomous ships and promoting the preemptive revision of the law and support of policy within the Ministry of Trade, Industry and Energy, the Ministry of Science and ICT, and the Ministry of Oceans and Fisheries. The Ministry of Oceans and Fisheries established a smart maritime logistics system including MASS, Maritime Communication Networks, and Smart Ports to innovate the national logistics system according to the 2018 strategy plan. In addition, industrial companies are investing in developing related technologies and applying them for patents.

According to the Acute Market Report (2017), the global autonomous ship market is expected to grow rapidly from approximately \$5.7 billion in 2016 to about \$15.5 billion in 2025, and fully autonomous ships will lead to growth. The largest autonomous ship market in the Asia-Pacific region is expected to account for approximately 68.66% of the market by 2025, an increase from the 29.4% in 2016.

If interest in autonomous ships and the efforts of related organizations are directly connected to the adoption of autonomous ships, the adoption of autonomous ships can be further expanded to the maritime business. Consequently, further studies should be conducted to examine the factors affecting adoption intention of autonomous ships from various perspectives. However, most studies on autonomous ships have concentrated on developing technology, revising laws, establishing policies, and managing human resources, with few studies focusing on the factors influencing the adoption of autonomous ships.

This study aims to identify the factors that affect the intention to adopt autonomous ships. In this study, a model was developed based on the TOE framework and the DOI theory to measure the intention to adopt autonomous ships. An empirical analysis was conducted for Korean shipping companies. We also investigate the overall degree of awareness of autonomous ships by domestic shipping companies and finally based on the findings of this study, a method to improve the intention to adopt autonomous ships is presented.

The remainder of this paper is organized as follows. The literature review will be presented in the second section. The research model and hypotheses will be introduced in the third section. Research methodology and data analysis and results will be described in the fourth and the fifth section respectively. Finally, the discussion and conclusions will be provided in the last section.

2. Literature review

2.1 Autonomous Ship

At the 98th Maritime Safety Committee(MSC) conference, the IMO defined a Maritime Autonomous Surface Ship(MASS) as “a ship that can operate independently of human interaction to varying degrees”. The IMO was categorized into four phases of autonomy to assess the scope of different levels of autonomous ships. Level 1 is defined as a ship with automated processes and decision support. Level 2 is defined as a remotely controlled ship with seafarers on board it. Level 3 is defined as a remotely controlled ship without seafarers on board it. Finally, level 4 is defined as a fully autonomous ship (IMO, 2018). In this study, the term autonomous ship is used instead of MASS.

With growing interest in autonomous ships, several studies have been conducted on this topic. However, most studies have focused on technical(Im et al., 2018; Jung et al., 2019; Wright, 2019; Chen et al., 2020), legal(Choi et al., 2018; Karlis, 2018; Kim, 2020; Klein et al., 2020), and human resources(Ahvenjärvi, 2016; Mallam et al, 2020; Shahbakhsh et al, 2022), with few studies on influencing factors in the adoption of autonomous ships. In addition, there have net been many studies have comprehensively reviewed the factors that influence the adoption of autonomous ships. Recently, Wiśnicki et al. (2021) conducted a study to identify the key factors underlying the successful adoption of technological innovations in sea shipping, divided into three critical research areas: technology readiness, social acceptance, and technology implementation. This study suggests that the key success factors include compliance of the innovation with future legal requirements and the involvement of maritime carriers or sea transport operators in the implementation process. This study is meaningful because it identifies the successful adoption factors for autonomous ships. However, there is a limitation in that it did not reflect the opinions of the actual industry because the survey was conducted with navigation students rather than seamen.

Fonseca et al. (2021) pointed out that most discussions on autonomous ships have focused solely on technical developments, thus overlooking the complex array of socio-economic and policy factors. They developed and applied a novel model of technology adoption (TechAdo) to assess autonomous ships holistically as an innovation. They showed that MASS is in development but still in its infancy through triangulating data from elite interviews, with work at the IMO and a systematic literature search. In addition, they showed that factors in the enabling environment (social acceptance, regulation, and governance), along with human capital need to be carefully considered in future research and policy. This study is meaningful because it develops and applies a novel model of technology adoption (TechAdo) to holistically assess autonomous ships as an innovation. However, because the conclusions of this study were based on the literature and interviews, it has a flaw in that it did not conduct empirical research.

Li and Yuen(2022) proposed a theory-driven model that identifies and ranks the critical success factors(CSFs) of autonomous ship adoption by combining four theories: innovation diffusion, resource-based perspective, stakeholder theory, and accidental theory. This study is meaningful in that it suggested a comprehensive model for the adoption of autonomous ships, and used Fuzzy AHP to identify and rank the CSFs of autonomous ship adoption. However, the relationship between the derived CSFs and the adoption of autonomous ships has not been statistically verified.

As previously said, some researchers have examined the factors that influene the adoption of autonomous ships. However, no empirical study has been conducted on these factors. Therefore, this study differs from previous studies in that it investigates and empirically evaluates the factors influencing the adoption of autonomous ships.

2.2 DOI theory and TOE framwork

DOI(Diffusion of Innovations) theory is an individual and firm-level theory of how, why, and at what rate new ideas and technology move through cultures(Oliveira & Martins, 2011).

Rogers'(1995) model is the most extensively used theoretical foundation in IT adoption research(Pervan et al., 2005). He suggested relative advantage, compatibility, complexity, observability, and trialability as innovation attributes and stated that these five attributes account for 49%-87% of the variation in adoption rates. In addition, He proposed that organizational structure variables related to organizational innovativeness be subdivided into six dimensions: centralization, complexity, formalization, interconnectedness, organizational slack, and size. Of these six factors, complexity, interconnectedness, organizational slack, and size are positively associated with innovativeness. Conversely, centralization and formalization are negatively associated with innovativeness.

Since DOI theory was first applied in IS research, it has been applied to various systems in the IS field, including MRP, CAD/CAM, EDI, Intranets, Websites, ERP, e-Procurement, and e-Business(Oliveira and Martins, 2011).

Tornatzky and Fleischer(1990) proposed a technology – organization – environment(TOE) framework to study the adoption of technological innovations. The framework identifies three aspects of an enterprise's context that influence its adoption and implementation of technological innovation: technology, organizational, and environment.

The technology context refers to the organization's internal and external technologies that are available for possible adoption. The organizational context refers to the descriptive characteristics of the firm(i.e., organizational structure, firm size, managerial structure, and degree of centralization), resources(human and slack resources), and the process of communication(formal and informal) among employees. The environment context comprises market elements, competitors, and a regulatory environment (Oliveira et al., 2014).

Currently, the TOE framework is used by EDI and open systems(Kuan and Chau, 2001), KMS(Lee et al, 2009), E-commerce(Liu, 2008), Internet websites(Oliveira and Martins, 2008), E-business(Oliveira and Martins, 2010; Zhu & Kraemer, 2005), ERP(Pan and Jang, 2008), and B2B(Teo et al., 2006) to adopt various IT innovations within organizations.

If one theoretical perspective does not provide a sufficient explanation of a phenomenon, it should be combined with one or more theories or added independent or control variables. Many scholars have advocated methodologies that combine diverse theoretical views(Oliveira et al., 2014).

The TOE framework and DOI theory have a complementary relationship and have been used in research on the adoption of technological innovation. Hsu et al.(2006) stated that the TOE framework can help the innovation diffusion theory better explain the diffusion of innovation within a firm. Zhu et al.(2006) and Low et al.(2011) conducted studies that combined the TOE framework and DOI theory to explain the adoption of innovative technologies within an organization. Lee and Chang(2018) empirically examined the factors affecting the intention to use big data technology for maritime port organizations based on the TOE framework and DOI theory.

3. Research model and hypotheses

Decisions to adopt autonomous ships are made at the organizational level. To decide whether to adopt autonomous ships, the various environments surrounding the company should be considered, which is why we combined the TOE framework and the DOI theory in this study.

The research model used in this study is illustrated in Fig. 1 This research model integrates technology, organizational, and environment contexts as major factors in the intention to adopt autonomous ships.

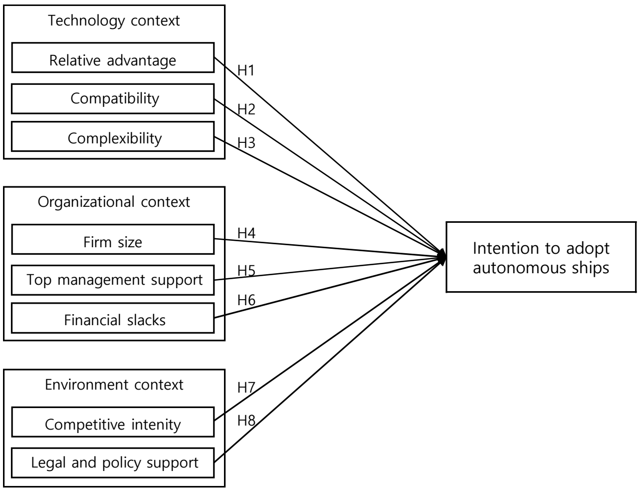

Fig. 1 A conceptual model for the intention to adopt autonomous ships

3.1 Technology context

TOE's technology context is implicitly the same as Rogers' innovation attributes(Oliveira, et all, 2014). In this study, we use innovation attributes instead of technical variables in the TOE framework(Lee and Chang, 2018).

The advantages generally derived from the use of autonomous ships in shipping companies include a reduction in human error, operational and maintenance costs, and environmental pollution. Thus, if autonomous ship adoption provides relative advantages over conventional ships, its adoption will increase. Hence,

[H1] Relative advantage positively influences the intention to adopt autonomous ships.

The more a new technological innovation is regarded as consistent with the potential adopter's current value systems and procedures, the more likely it is to be adopted(Ettlie, 1986; Lee and Kim, 2007). Thus, if autonomous ships are highly compatible with the management and operation of conventional ships, their adoption will increase. Hence,

[H2] Compatibility positively influences the intention to adopt autonomous ships.

The challenges and complexities associated with comprehending, managing, and running novel technologies have detrimental effects on innovation the adoption. Thus, if the adoption and operation of autonomous ships is complicated and difficult, their adoption will decline. Hence,

[H3] Complexity negatively influences the intention to adopt autonomous ships.

3.2. Organizational context

Autonomous ship adoption at the organizational level requires great skill and capital. Larger companies are generally better equipped and more likely to have resources to drive innovation. This makes innovation easier for the firms. Hence,

[H4] Firm size positively influences the intention to adopt autonomous ships.

Top management support is critical for determining whether a company can successfully adopt innovation. Hence,

[H5] Top management support positively influences intention to adopt autonomous ships.

Companies that maintain financial slack can benefit from good investment opportunities and expand the scale and scope of their operations by deploying slack to build technological resources. Hence,

[H6] Financial slack positively influences the intention to adopt autonomous ships.

3.3 Environment context

Competition may drive firms to initiate and adopt innovation to preserve their competitive advantage(Zhu et al. 2006). Hence,

[H7] Competitive intensity positively influences the intention to adopt autonomous ships.

Government legal and policy support are crucial when introducing a new system or innovation. Hence,

[H8] Legal and policy support positively influence the intention to adopt autonomous ships.

4. Research methodology

4.1 Sampling and Data Collection

To evaluate the proposed theoretical relationships, a survey was conducted among shipping companies listed on the Korea Marine Officers Association and Korea Shipowner's Association.

In this study, the CEO, who can influence the decision to adopt autonomous ships; executives, who are judged to have a high level of understanding about autonomous ships; and individuals who are in charge of departments related to autonomous ships were selected, with the number of those surveyed being about to 1-3 people, depending on the volume of the company.

The data were gathered through an e-mail survey of 160 respondents. A total of 41 responses were received, and all the collected questionnaires were deemed valid. The frequency analysis was performed using SPSS version 22. Reliability, validity, and hypothesis testing were performed using SmartPLS 3.3.3. Several criteria regarding the minimum number of samples for analysis exist in PLS analysis. According to Chin(1998) and Gefen and Straub(2000), the minimum sample size must be at least ten times the number of items in the most complex construct. As four measurement items were employed for each variable in this study, a minimum of 40 samples was required. Consequently, 41 samples met the inclusion criterion.

4.2 Measurement

In this study, 32 measurement items for the eight constructs of the questionnaire were obtained from a comprehensive literature review and were modified to fit the context of autonomous ships.

The technology context consists of relative advantage(RA), compatibility(COP), and complexity(COX). We define relative advantage as the degree to which autonomous ship adoption is perceived to be better than the use of conventional ships. Compatibility is defined as the degree to which autonomous ships are compatible with the management and operation processes of conventional ships. Finally, we defined complexity as the degree to which autonomous ships are relatively difficult to understand, manage, and operate compared with conventional ships.

The organizational context comprises firm size(FS), top management support(TMS), and financial slack(FIS). We define firm size as the overall size of an organization, including assets, sales, and number of employees. Top management support is defined as the degree of CEO awareness and support for adopting autonomous ships. Finally, financial slack is the financial resources required to adopt autonomous ships.

The environment context includes competitive intensity(CI) and legal and policy support(LPS). Competitive intensity refers to the degree of competition among shipping companies regarding adoption of autonomous ships. Legal and policy support is defined as the degree of support from the government and related organizations in terms of legal and policy aspects related to autonomous ships.

The dependent variable, autonomous ship adoption intention(ADO), was measured using six items.

All items were measured using a 7-point Likert-type scale(1=strongly disagree to 7=strongly agree). In addition, the general level of awareness of autonomous ships and overall status of the companies were measured using 18 items.

5. Data analysis and results

5.1. Sample characteristics

A total of 41 respondents were included in this study. The statements that they were in charge of all tasks, including ship owners, sales, operations, and ship management, and that they were in charge of ship management obtained the most votes, with 17(41.5%).

The number of years of employment was highest, with 19 people(46.35%) having 16 or more years of employment. Furthermore, 25 participants(61%) indicated that they had three - ten years of onboard experience.

Table 1 shows the characteristics of the autonomous ships. As a result of examining the IMO's degrees of autonomy, eight responses were level 1, in other words, it was the stage in which seafarers were on board to operate and control shipboard systems and functions. Six responses were level 2, in other words, it was the stage in which seafarers are available on board to take control and operate the shipboard systems and functions. Among the operating fleets, 36 responses (87.8%) answered “There is no proportion of autonomous ships at all” and 5 responses (12.2%) answered that “There is some (partial) proportion of autonomous ships”. As for the degree of readiness for the adoption of autonomous vessels, 18 responses (43.9%) responded they were “monitoring without a plan,” which was the most frequent response, followed by “not interested at all” with 17 (41.5%) responses. We allowed multiple responses on the method of adopting autonomous ships in the future, 15 responses were “building or chartering new ships,” and 4 responses were “purchasing or chartering used ships”. “No plan to adopt” was selected by 26 responses.

The respondents’ level of awareness of autonomously operated ships is shown in Table 2. The average interest in autonomous ships was 4.83. The average awareness that autonomous ships were divided into partially and fully autonomous ships was 4.70. The average awareness that autonomously operated ships are ships operate autonomously regardless of human presence was 4.49. However, the average recognition of the types and contents of autonomous navigation technology was 3.10. The average recognition of research and policies related to the autonomous ships of companies and countries was 3.22. The average awareness of the differences between the smart and autonomous ships was 3.78. The average level of recognition of the degree of autonomy was 3.83.

Table 1 The characteristics related to autonomous ships

Characteristics		N(%)	N
IMO autonomy level	level 1	8	multiple response
	level 2	6	
	level 3	0	
	level 4	0	
Proportion of autonomous ships	not at all	36(87.8)	41
	partial	5(12.2)	
Degree of readiness	already in progress	4(9.8)	41
	plan to ready by 1-2 years	2(4.9)	
	monitoring without a plan	18(43.9)	
	not interested at all	17(41.5)	
Method of adoption	building or chartering new ships	15	multiple response
	purchasing or chartering used vessels	4	
	no plan to adopt	26	

Several statistical functions require the distribution to be either normal or nearly normal. This study tested the normality using skewness and kurtosis. In general, data are considered normal if the skewness is between 2 and +2 and kurtosis is between 7 and +7. Except for the general question, the test results showed that both normality values were within an acceptable range. Therefore, no items were removed from the original questionnaire and used for subsequent analyses.

Table 2 The The level of awareness of the respondents about autonomous ships

Items	N	Mean	SD
Interest in autonomous ship	41	4.83	1.76
The awareness of the difference between smart ship and autonomous ship	41	3.78	1.89
The awareness that an autonomous ship is a vessel that operates autonomously regardless of human presence	41	4.49	1.96
The awareness that autonomous ship is divided into partially autonomous and fully autonomous	40	4.70	2.11
The level of autonomy	41	3.83	1.99
Research and policies related to an autonomous ship of companies and countries	41	3.22	1.68
The types and contents of autonomous navigation technology	40	3.10	1.61

5.2. Analysis of the measurement model

As all constructs were modeled using reflective indicators, internal consistency reliability, convergent validity, and discriminant validity were used to evaluate the proposed model.

The internal consistency of the constructs was assessed using composite reliability(CR). Outer loadings and AVE(average variance extracted) were used to examine convergent validity, and HTMT was used to assess discriminant validity.

According to the guidelines when using the PLS-SEM proposed by Hair et al.(2014; 2019), CR ranges from 0.70 to 0.95, AVE is greater than 0.5, outer loading is greater than 0.7, and HTMT is less than 0.9.

Table 3 summarizes the evaluation results of the reflective measurement model.

We removed RA1, RA4, COP1, COP2, COX2, SLACK1, SLACK2, CI1, CI2, and LPS1 with outer loadings less than

0.7 to ensure convergence validity.

Table 4 shows HTMT results for discriminant validity.

The values of CR, outer loading, AVE, and HTMT for the construct were satisfactory, as shown in Tables 3 and 4. As a result, we conclude that reliability and validity of the proposed conceptual framework were established.

Table 3 Summarizes the evaluation results of the reflective measurement model

Variable	Items	M	SD	CR	AVE	Outer Loadings
RA	RA2	4.415	1.884	0.866	0.765	0.809
	RA3	3.450	1.616			0.936
COP	COP3	4.610	1.730	0.803	0.672	0.782
	COP4	4.400	1.630			0.856
COX	COX1	4.342	1.905	0.809	0.586	0.713
	COX3	4.425	1.824			0.754
	COX4	4.439	1.690			0.824
FS	FS1	3.854	1.740	0.941	0.800	0.834
	FS2	2.400	1.614			0.896
	FS3	2.390	1.563			0.909
	FS4	2.830	1.745			0.936
TMS	TMS1	4.268	1.450	0.932	0.773	0.858
	TMS2	4.512	1.583			0.897
	TMS3	3.634	1.624			0.866
	TMS4	2.366	1.428			0.894
FIS	FIS3	4.317	2.091	0.902	0.821	0.948
	FIS4	2.659	1.460			0.863
CI	CI3	2.725	1.679	0.950	0.911	0.948
	CI4	2.122	1.453			0.960
LPS	LPS2	2.829	1.787	0.901	0.753	0.868
	LPS3	4.667	1.137			0.817
	LPS4	3.768	1.223			0.915

Table 4 HTMT results

	ADO	RA	COP	COX	FS	TMS	FIS	CI	LPS
ADO									
RA	0.295								
COP	0.548	0.409							
COX	0.627	0.729	0.711						
FS	0.308	0.082	0.439	0.219					
TMS	0.724	0.400	0.574	0.587	0.361				
FIS	0.834	0.137	0.609	0.607	0.319	0.714			
CI	0.813	0.071	0.609	0.340	0.375	0.514	0.737		
LPS	0.724	0.471	0.782	0.749	0.216	0.707	0.873	0.649	

5.3. Analysis of the structural model

Once the reliability and validity of the reflective measurement model are established, the next step is to assess the structural model.

Before assessing structural relationships, multicollinearity using the variance inflation factor(VIF) must be examined to ensure the results(Hair et al., 2019). As shown in Table 5, all VIF values in this study were less than five(Hair et al., 2017), and no multicollinearity problem was found.

To evaluate the structural model, we employed the coefficient of determination R^2, effect size f^2, predictive fit Q^2, and statistical significance and relevance of the path coefficients. The results of the structural model evaluation are presented in Table 5.

In general, if R^2 for an endogenous latent variable is 0.25, it indicates a weak value; if it is 0.50, it indicates a medium value; and if it is 0.75, it indicates a large value (Hair et al., 2017). The R^2 value in this study was 0.81, indicating a large explanatory power.

We used f^2 and Q^2 as another criterion for measuring predictive suitability.

According to Cohen(1988), when f^2 is less than 0.02, the effect size is small; when it is 0.15, it is medium; and when it is 0.35 or more, it is large. As a result of the evaluation of f^2, CI was found to contribute significantly to ADO. RA(0.023), COP(0.025), COX(0.072), TMS(0.147) and FIS(0.146) made moderate contributions. In contrast, FS (0.001) and LPS (0.003) appeared to contribute only slightly.

The Q^2 value was 0.680, which was greater than 0 (Sarstedt et al., 2014), confirming that the structural model has a predictive fit for ADO.

Table 5 Structural model assessment

	ADO		R^2	R^2 Adjusted	Q^2
	VIF	f^2			
RA	1.467	0.023	0.814	0.767	0.680
COP	1.588	0.025			
COX	2.103	0.072			
FS	1.431	0.001			
TMS	2.159	0.147			
FIS	2.949	0.146			
CI	2.003	0.608			
LPS	2.884	0.003			

Path coefficients signify hypothesized associations among the constructs. To measure the level of consequence or the statistical significance of the path coefficients for all paths, we ran a bootstrapping function.

As shown in Table 6 and Fig. 2, the CI(β = 0.476, t = 4.532, $p<0.001$), TMS(β = 0.243, t = 1.981, $p<0.05$), and FIS (β = 0.283, t = 2.258, $p<0.05$) were significantly related to the intention to adopt autonomous ships. However, RA, COP, COX, FS, and LPS were not found to have any significant relationships with the intention to adopt autonomous ships. Therefore, H5, H6, and H7 are supported, whereas H1, H2, H3, H4, and H8 are not.

Table 6 Summary of hypothesis testing

Hypothesis	R/ship	Path coefficient	T value	Decision
ADO				
H1	RA→ADO	0.079	0.515	Not Supported
H2	COP→ADO	−0.086	0.848	Not Supported
H3	COX→ADO	0.168	1.143	Not Supported
H4	FS→ADO	0.012	0.135	Not Supported
H5	TMS→ADO	0.243	1.981^{*}	Supported
H6	FIS→ADO	0.283	2.258^{*}	Supported
H7	CI→ADO	0.476	4.532^{***}	Supported
H8	LPS→ADO	−0.040	0.291	Not Supported

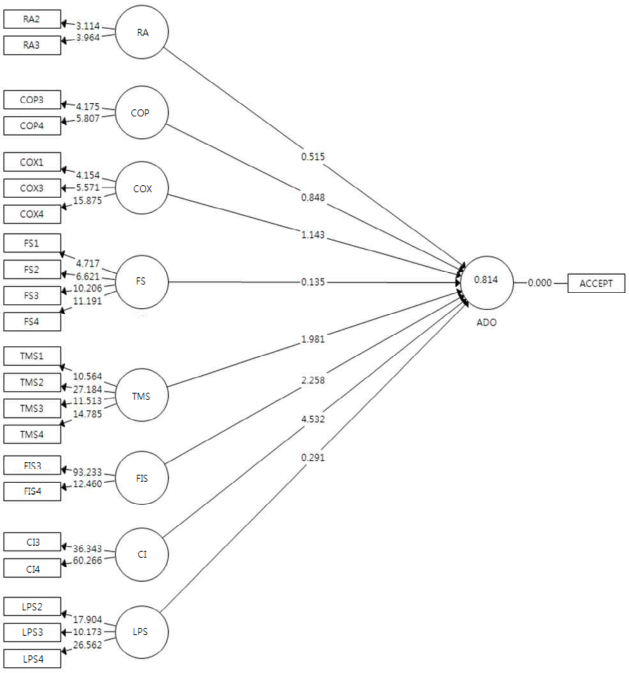

Fig. 2 The result of PLS-SEM

6. Discussion and Conclusion

The main purpose of this study was to identify the factors that affect the intention to adopt autonomous ships. In this study, we propose a model for measuring autonomous ship adoption intention by combining the TOE framework and DOI theory. In addition, we investigate the overall degree of awareness of autonomous ships among Korean shipping companies.

As suggested in this study, the model for measuring the intention to adopt autonomous ships was found to have considerable reliability and validity.

The main findings of the empirical study using the proposed model are summarized as follows.

First, relative advantage, compatibility, and complexity in technology context are not significant discriminators. This finding is inconsistent with those of Wu and Chiu(2015). However, some studies investigating innovation adoption have found that not all variables in the technology context of innovation significantly affect adoption(Grover, 1993; Li, 2008; Wang, et al, 2010; Low et al, 2011). One probable explanation is that autonomous ship technology is still in its infancy. While autonomous ships are regarded as one of the digital trends in the Fourth Industrial Revolution, significant implementation rates of autonomous ships are yet to be observed. Nevertheless, this insignificance does not imply that shipping companies believe that autonomous ship adoption does not have a relative technological advantage, compatibility, and complexity. This is because, as shown in Table 4, the average technical context was not low, between 3.450 and 4.610.

Second, in the organizational context, top management support and financial slack are significant discriminators, whereas the firm size is not. The chances of adopting an autonomous ship increase when the organization has the support of top management and has both financial and technical resources available. This finding is consistent with the results of earlier studies on the adoption and use of innovative technologies(Li, 2008; Low et al., 2011; Oliveira et al., 2014). Unexpectedly, firm size was not a significant predictor. This finding is inconsistent with those of previous studies(Wang et al., 2010; Low et al., 2011; Oliveira, et al., 2014). However, financial slack significantly affected the adoption of autonomous ships. This means that financial slack has a greater effect on the intention to adopt autonomous ships than company size does, as measured by the number of employees, sales, and assets. Therefore, the intention to adopt autonomous ships is expected to increase if top management support and financial slack for adoption are secured.

Third, in the environment context, even if competitive intensity turns out to be insignificant in innovation (Premkumar and Roberts, 1999; Lin and Lin, 2008), it is found to be a significant discriminator in this study. As the shipping industry becomes more competitive, companies may feel the need to adopt autonomous ships to obtain or sustain a competitive advantage. Shipping companies may also respond to mimetic pressure to keep up with competitors based on the extent of adoption and the perceived success of their competitors' autonomous ship adoption(Li, 2008). Additionally, trading partner power has a positive effect on the adoption of autonomous ships. This power can be either convincing or compulsory(Low et al., 2011). This result implies that, when shipping companies face continued pressure from competitors and trading partners, they adopt autonomous ships. However, legal and policy support was not significant discriminatory factors. These results are consistent with the findings of Li(2008) and Oliveira et al. (2014) that government promotion and regulatory support do not significantly affect innovation adoption.

Additionally, the overall degree of awareness of autonomous ships by Korean shipping companies was investigated. Currently, technology development and research are being conducted on various aspects of the commercialization of autonomous ships. However, overall awareness and interest in autonomous ships among Korean shipping companies was low. In addition, they do not plan to adopt autonomous ships in the future.

Autonomous ships are an innovative technology that will provide new value to the shipping industry during the 4th industrial revolution. However, the adoption of autonomous ships cannot be achieved through corporate effort. Because the adoption of autonomous ships incurs huge costs, it must not conflict with current complex and entangled maritime concepts. Therefore, it is necessary to develop new concepts for autonomous ships.

This study is significant in that it identifies the factors affecting the intention to adopt autonomous ships and empirically analyzes shipping companies. It is also meaningful in that it investigates the current status and awareness of autonomous ships by domestic shipping companies.

There are several limitations in this study. First, we reviewed only two theories to suggest adopting model autonomous ships. Future studies could extend this model by identifying theories rooted in management, and innovation. Second, we gathered only 41samples. Future research could pursue more generalizable surveys by collectiing more information.

In addition, as a future study following this study, if economic effects on the industrial side are realized through autonomous ships, it is necessary to conduct additional research on the perception of autonomous ships.

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