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Article

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The Impact of Industry 4.0 Adoption Barriers on Supply Chain Capacity and Operational Efficiency: Empirical Evidence in Vietnamese Transport Logistics Industry

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ABSTRACT

Purpose: This study evaluates the impact of Industry 4.0 adoption on supply chain capacity and operational performance under the mediating effect of barriers at Vietnamese transport logistics companies.

Design/methodology/approach: Based on the perspective of Contingency theory and Resource-based theory, the research model is proposed and data is surveyed from 768 managers at Vietnamese transport logistics companies. Data were processed using SPSS and AMOS software.

Findings: The results show that internal and external barriers have a negative impact on Industry 4.0 adoption, supply chain capacity, and operational performance. Applying Industry 4.0 also increases the operational efficiency and capacity of the supply chain.

Research limitations/implications: The study proposes some implications to help businesses in the industry apply Industry 4.0 more successfully. However, the research is limited in the scope of data samples. Specifically, the data sample in the study mainly focuses on transport and logistics businesses in Vietnam, reducing the representativeness and generalizability of the results. In addition, limitations in assessment methods need to be improved. Although using a linear structural model, the study still has limitations in accurately assessing the relationship between variables.

Originality/value: The research has important implications for managers in successfully applying Industry 4.0 to increase supply chain capabilities and achieve operational efficiency.

Keywords: Barriers, industry 4.0, Operational efficiency, Supply chain capacity, Transport logistics

I. Introduction

The development of Industry 4.0 has brought many benefits and challenges to businesses (Chauhan et al., 2021; Chunga and Hyun, 2019). By enabling the connections between processes, Industry 4.0 will

enable businesses to expand in an environmentally responsible manner (Kiel et al., 2017; Jang and Lee, 2022). According to previous research, new technologies can boost operational effectiveness, responsiveness, traceability, capacity utilization, and cost-effectiveness (Barreto et al., 2017; Chauhan et al., 2021). Thereby improving the sustainable performance of the business. Furthermore, data transparency can reduce unnecessary errors and eliminate losses throughout the value chain, helping to decrease waste and improve operational

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efficiency (Büchi et al., 2020).

Over the past decade, the use and development of information and communications technology in businesses has become inevitable, mainly due to its importance in improving organizational efficiency and competition (Barreto et al., 2017). This has promoted the adoption of information technology in most industry activities, especially in the operations of transport logistics companies. This technological development is demonstrated by well-known applications that are widely used by most organizations such as Enterprise Resource Planning (ERP), Warehouse Management System (WMS), Transportation Management System (TMS), and Intelligent Transportation System (Sun et al., 2022). The connection between a number of the technologies underpinning Industry 4.0 and the transport logistics companies' supply chain capabilities and operational performance, however, is not clear (Büchi et al., 2020).

The adoption of Industry 4.0 was slower in developing nations than in developed nations. Developing nations primarily prioritize financial objectives for digitalization, while developed nations emphasize marketing-related goals (Chauhan et al., 2021). Due to a lack of funding, Vietnam and other developing nations are vulnerable to cost-related obstacles. Moreover, institutional barriers like a dearth of government policies that encourage it will hinder businesses' efforts to implement Industry 4.0 (Bonilla et al., 2018). Many other challenges, including insufficient facilities and a labor force lacking the necessary skills, have also been found by researchers to be major obstacles to the implementation of Industry 4.0 (Sun et al., 2022). Nevertheless, not enough research has been done on how these barriers affect the connection between Industry 4.0, supply chain capabilities, and operational efficiency.

While the logistics sector is experiencing growth globally, Vietnam's logistics industry is still in its early stages, despite the country's recent emphasis on expanding this service industry (Nguyen, 2020). Logistics is still a relatively new field in Vietnam, encompassing both theoretical systems and real-world operations. The needs of the local market can only be partially met by businesses that specialize in

logistics services; they have not yet expanded to the regional or global markets. Vietnam still has very little hard and soft infrastructure to support the development of this service (Nguyen et al., 2021). Therefore, more research is needed to help Vietnamese Transport Logistics companies have a clearer orientation and achieve operational efficiency in their industry 4.0 adoption strategy. This study intends to close this gap by integrating the capabilities of the supply chain, operational efficiency, and Industry 4.0 structure in the transport logistics sector, one of the key industries supporting Vietnam's economic growth.

This study contributes empirical evidence on the impact of Industry 4.0 adoption barriers on supply chain capacity and operational efficiency in the context of the transport logistics industry. The research findings also contribute to the advancement of resource-based view theory and contingency theory. Enterprises operating in the service sector, particularly those in the transportation and logistics domain, are likely to encounter both internal and external obstacles that result in disparate resource capacities. This implies that having a proper Industry 4.0 adoption strategy is essential. There are four parts left in the research paper's structure: The literature review is in part two, the methodology is in part three, the research results is in part four, the discussion is in part five, and the conclusion and management implications is in part six.

II. Literature Review

A. Contingency Theory

Contingency theory highlights that there is no one organizational structure that is thought to be optimal for organizations, and it describes the diversity of organizational behaviors and structures researchers (Makkonen et al., 2014). According to this theory, organizations are open systems whose effectiveness depends on how well they adapt to external factors that affect their performance at different levels and how their organizational structure is designed.

Organizations should modify their structures to enhance efficiency (Omoluabi, 2016). The study employs contingency theory to explain the reasons behind the different features that influence the supply chain capacity and performance of enterprises in the transport logistics sector. Barriers from the outside make up these characteristics.

B. Resource-based View Theory

The resource-based view (RBV) theory was initiated by Penrose in 1959, arguing that a company's unique resources are one of its primary sources of competitive advantage (Utami and Alamanos, 2022). Many scholars later developed and maintained this viewpoint, especially Barney (1991). According to the theory, a business's competitive advantage and performance are primarily determined by its resources, as every business possesses unique resources. If a business makes good use of the special resources it has, it can improve its operating efficiency (Prasad et al., 2023). However, the only resources that can help businesses gain an edge and stay competitive are those that satisfy the four requirements of valuable, rare, unique, and non-substitutable (Utami and Alamanos, 2022).

The performance of a business depends on the performance of other member businesses participating in the supply chain (Ellinger et al., 2012). An organization's supply chain can gain a competitive edge and boost operational efficiency when a member of the chain possesses one or more unique resources (Ganesan et al., 2016). This theory is used to explain the internal barriers that also lead to different businesses' adoption of Industry 4.0, which in turn affects supply chain capabilities and operational efficiency.

C. Research Hypotheses

Industry 4.0 marks the emergence of a series of new technologies, based on the fusion of all scientific

and engineering disciplines, blurring the lines between physical, digital, and biological. It affects all industries and sectors of the economy (Büchi et al., 2020). Industry 4.0 not only focuses on developing new technology and tools to improve production efficiency but also revolutionizes entire businesses (Huang et al., 2019;). Putting Industry 4.0 into practice has become essential to achieving business objectives through manufacturing operations reform (Ghobakhloo, 2018).

In a fiercely competitive market, businesses increasingly focus on providing highly personalized services. This requires domestic and foreign transport logistics companies to adapt to this changing environment (Lai and Cheng, 2003). The operations of companies in the industry are quite complex and due to the increasing complexity, companies cannot have their entire operational process handled by conventional planning and control measures (Lai et al., 2004). As a condition of accepting Industry 4.0, they must offer "smart logistics," or intelligent services and goods. These are human-performed services with integrated automated workflows (Barreto et al., 2017). By providing these services, the business will become more responsive to the needs of its clients and be more flexible and adaptable to changes in the market. Resource planning, warehouse management systems, transportation management systems, and intelligent transportation systems are some of the variables that affect how successfully these companies implement Industry 4.0 (Barreto et al., 2017; Kim et al., 2023).

According to Jabbour et al. (2016), internal and external barriers are the two primary categories of barriers that exist in the supply chain. External barriers show how the external environment affects how a business or industry operates (Walker et al., 2008). Various external barriers can impact the operations of transport logistics companies, including incomplete government regulations that result in a lack of reference standards and structures, as well as a shortage of skilled labor (Gellman, 1986), lack of cyber security and privacy policies, ineffective information technology applications (Walker et al., 2008). According to Post and Altman (2017), external barriers limit an organization's capabilities, leading to a decline in

the business's ability to become a smart service provider. Internal barriers are organizational barriers that include things like leaders who are not prepared to embrace Industry 4.0, employees who lack the necessary knowledge and skills, businesses that are unable to apply new business models, and high implementation costs (Karam et al., 2021).

According to Flynn and Saladin (2006), empirical verification in various real-world scenarios supports the existence of environmental influences on the application of Industry 4.0. Businesses face obstacles from the external environment that prevent them from adopting digital technology and related problems. Businesses adopting Industry 4.0 must be flexible enough to meet the demands of shifting external environments (Ortt and Van Der Duin, 2008). Studies additionally demonstrate that the existence of multiple obstacles adversely affects the implementation of Industry 4.0 in enterprises, particularly in the transportation logistics sector (Cichosz et al., 2020; Karam et al., 2021).

Research indicates that the adoption of Industry 4.0 may face obstacles due to an absence of skilled labor and opposition to workplace modifications (Ilin et al., 2019; Cichosz et al., 2020). Companies must adapt their operations, financial commitment, and organizational structure to adopt Industry 4.0 (Kiel et al., 2017). Nwaiwu et al. (2020) examined the importance of strategy, organizational structure, human resources, and competitiveness as barriers to adoption. Researchers are also focusing on the absence of a communication and information technology infrastructure, the improper establishment of applicable standards and laws, and other obstacles (Karam et al., 2021). Thus, the author proposes the following hypotheses:

Hypothesis H1: Industry 4.0 adoption and internal barriers have a negative relationship.

Hypothesis H2: Industry 4.0 adoption and external barriers have a negative relationship.

Supply chain capabilities are considered critical to achieving competitive advantage and are defined as the diffuse result of physical and technological

factors (Bagchi, 2001). Businesses gain a competitive edge by optimizing their resource utilization rather than simply possessing them. RBV theory emphasizes the effective use of financial, human, and material resources to create value for businesses. Industry 4.0 helps transport logistics firms allocate resources more effectively by using data that is gathered in real-time from multiple sources, enabling companies to improve their supply chain capabilities (Bonilla et al., 2018). By providing the supply chain with a wide range of technologies, digitalization makes these companies more competitive in satisfying the growing demands of the market (Torn and Vaneker, 2019). Service providers can also reduce provisioning time and information changes by integrating their information with suppliers and buyers through Industry 4.0. Providers can concentrate on their core competencies in product innovation by having access to integrated information (Frank et al., 2019).

The introduction of new technologies and the accompanying modifications affect the performance of businesses (Ghobakhloo, 2018; Sitorus et al., 2022). Through cost savings, quality improvement, on-time delivery, and the creation of new services, Industry 4.0 adoption may encourage transport logistics businesses to run more profitably (Moeuf et al., 2018). Porter and Heppelmann (2015) propose four distinct capabilities that will be enhanced by the implementation of Industry 4.0. These distinctive capabilities are the foundation of digitalization such as modularity, decentralization, virtualization, mass personalization, and interoperability (Ghobakhloo, 2018). Applying these capabilities will help businesses excel in their field in terms of responsiveness, reducing costs, and time to deliver product innovation. These technologies also enable businesses to mass service and personalize their products to give customers better value (Frank et al., 2019). From there, the author proposes the following hypotheses:

Hypothesis H3: Industry 4.0 adoption and supply chain capacity have a positive relationship.

Hypothesis H4: Industry 4.0 adoption and operational efficiency have a positive relationship.

Supply chains are a competitive tool for businesses, so they use technological innovation to increase the supply chain's overall capabilities (Wisner, 2003). Internal and external barriers negatively impact supply chain capabilities as businesses adopt digital technologies (Shaiful Fitri Abdul Rahman et al., 2022). To lessen the detrimental effects of the barriers connected with them, business models must be adjusted, making barrier management crucial (Kiel et al., 2017). Businesses that are careful in managing barriers will have higher supply chain capabilities, thereby meeting customer expectations with better product quality, service, and lower costs (Bagchi, 2001). Therefore, the author proposed the following hypotheses:

Hypothesis H5: Internal barriers and supply chain capacity have a negative relationship.

Hypothesis H6: External barriers and supply chain capacity have a negative relationship.

Contingency theory state that outside pressure on a company will affect its overall performance and strategy (Donaldson, 2006). A company's performance is based on how well its structure and surroundings match (Sousa and Voss, 2008). Previous research has acknowledged that business performance depends on factors beyond its control, such as government laws and competitors' actions (Yalabik and Fairchild, 2011). According to RBV theory, a business's resources are an important factor in determining its strategy and success. Business decisions are the result of analysis based on available resources (Coates and McDermott, 2002). Human, financial, and material resources will help businesses gain a competitive advantage. The lack of these resources hinders Industry 4.0 implementation and lowers business performance (Somsuk and Laosirihongthong, 2014). Therefore, the author proposes the following research hypothesis:

Hypothesis H7: External barriers and performance have a negative relationship.

Hypothesis H8: Internal barriers and performance have a negative relationship.

Supply chain capacity is the ability of the supply

chain to meet customer needs with low cost and high service quality (Kouvelis and Milner, 2002). Transport logistics companies with superior supply chain capabilities demonstrate higher levels of customer satisfaction and shareholder value than the industry average (Ellinger et al., 2012). Therefore, supply chain capacity is considered a reflection of business performance. When supply chain capacity is increased, production efficiency will be significantly improved because products will be shipped promptly to their destination (Cichosz et al., 2020).

However, efforts to maximize corporate efficiency as a whole may have an adverse impact on supply chain efficiency, undermining the chain's ability to compete (Patrucco et al., 2023). Supply chain efficiency in the transport logistics industry is only optimized when a 'cross-organisation, cross-functional' strategic approach is adopted by all partners in the chain (Gabdullina et al., 2020). The supply chain's competitive position is strengthened by the organizational strategy supporting it, which raises the business's overall operational efficiency and that of each supply chain partner. Based on that, the hypothesis is stated as follows:

Hypothesis H9: Supply chain capacity and operational efficiency have a positive relationship.

From hypotheses H1 to H9 mentioned above, the author proposes the research model in Figure 1.

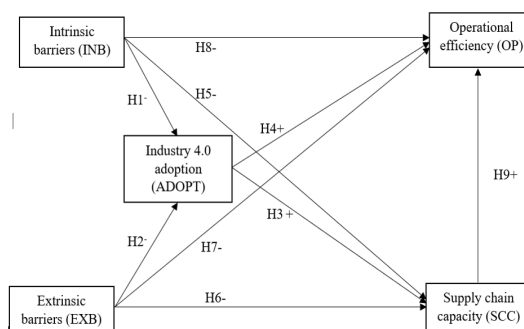


Figure 1. Proposed research model

III. Research Methodology

A. Measurement Scale

The observed variables were built and inherited with adjustments from previously published studies, applying a 5-point Likert scale to measure all observed variables, from completely disagree to agree (Table 1).

B. Research Data

To identify the impact relationship between barriers to Industry 4.0 adoption, supply chain capacity, and business performance, this study uses a quantitative method. After conducting a preliminary evaluation of the scale through 50 samples, the scale was assessed to ensure reliability. Research data is from a large-scale survey of middle and senior managers working at transport logistics companies. The survey sample

Table 1. Scale of measurement

Variable name	Variable symbols	Construct	Source
Extrinsic barriers (EXB)	EXB1	Absence of framework and standards of reference	Chauhan et al. (2021)
	EXB2	Absence of laws and rules from the government	
	EXB3	Absence of privacy and cybersecurity guidelines	
	EXB4	Inadequate IT programs	
	EXB5	Lack of skills in the labor market	
Intrinsic barriers (INB)	INB1	Inadequate communication between the units	Chauhan et al. (2021)
	INB2	There is not enough readiness for leadership.	
	INB3	Unable to implement new business models	
	INB4	High implementation expenses	
	INB5	Employees lack expertise and skills	
Industry 4.0 adoption (ADOPT)	ADOPT1	Control over production remotely.	Chauhan et al. (2021)
	ADOPT2	Adaptable operating conditions for production	
	ADOPT3	Integrating engineering systems for development and production	
	ADOPT4	Utilizing virtual models, create and perform	
	ADOPT5	Gather and evaluate big data	
	ADOPT7	Combine online services with physical goods	
Supply chain capacity (SCC)	SCC1	Customer satisfaction	Green et al. (2014)
	SCC2	Capabilities to customize products	
	SCC3	Quick delivery	
	SCC4	Low logistics costs	
	SCC5	Adaptable delivery and ordering	
	SCC6	Large inventory turnover	
	SCC7	Ability to carry out orders.	
Operational efficiency (OP)	OP1	Reduce operating costs	Kumar et al. (2020)
	OP2	Cut down on the time it takes to develop and release new products	
	OP3	Effectively introduced new goods	
	OP4	Improve product quality	
	OP5	Boost the innovation of products.	

Abbreviation: ADOPT, Industry 4.0 adoption; SCC, Supply chain capacity; EXB, Extrinsic barriers; OP, Operational efficiency; INB, Intrinsic barriers

has a variety of demographic characteristics over the period from January 1, 2024, to April 30, 2024.

The study was surveyed using a questionnaire including 36 observed variables. The sample includes managers at Vietnamese transport logistic companies. Surveys are sent in person and online via the Google Form platform. This study uses the convenience sampling method, applying the "10 times rule" principle to calculate the number of samples needed for the study (Hair et al., 2019). However, to ensure reliability and increase the representativeness of the sample, the author chose a ratio of approximately 20:1, meaning the sample size must be 400 samples or more. The number of questionnaires collected from the survey was 820 and 791 were returned. After filtering and eliminating invalid ones, the number of qualified answers was 768.

C. Data Processing Method

The author uses statistics to describe the characteristics of the research sample. At the same time, use the SPSS 26.0 to test the reliability and convergent validity of the scale through Cronbach's Alpha coefficient. Exploratory Factor Analysis (EFA) was then employed to reduce a set of k observed variables

into a set F of more significant factors (where $F < k$). Confirmatory factor analysis (CFA) also was used to test the appropriateness of the measurement model. The research model has two intermediate variables, so the CB-SEM approach is used to test the hypothesis and quantify the impact of the variables. Subsidiary relationships between variables are tested, assessing the fit of the overall model and path coefficients in the structural model through parameters similar to CFA analysis.

IV. Research Results

A. Descriptive Statistics

Table 2 provides a statistical description of all 768 qualified observations. There are 169 female respondents to the survey or 22% of the total. As a result, men made up the majority of survey respondents. 72% of survey respondents are college graduates in terms of education. The majority of the survey sample (60%) was found in the Southern region; 32% was found in the Northern region, and 8% was found in the Central region. Road transport companies employ 52% of the workforce, followed

Table 2. Descriptive statistics results

		Number of responses	Percentage of
		Demographics content	responses (%)
Gender	Male	599	78%
	Female	169	22%
Education	Bachelor	553	72%
	Master and PhD	215	28%
Area	North	246	32%
	Central Region	61	8%
	Southern	461	60%
Nature of business	Sea transport	169	22%
	Road transport	399	52%
	Air transport	15	2%
	Third-party logistics services	185	24%
	Total	768	100%

by sea transport companies (22%), third-party logistics services (24%), and air transport companies (2%).

B. Scale Reliability Analysis

Cronbach's Alpha coefficient is a test to measure the internal consistency reliability of the scale. The larger the Cronbach's Alpha coefficient, the more reliable the scale is (Hair et al., 2019). When the concept being studied is new or new to respondents in the research context, a Cronbach's Alpha coefficient of 0.6 or higher is appropriate (Nunnally, 1975). Nevertheless, the Cronbach's Alpha coefficient does not suggest which variables should be kept or removed. Consequently, the total variable correlation coefficient is used in addition to Cronbach's Alpha coefficient, and variables with a total variable correlation less than 0.3 will be removed. According to the results of the Cronbach's Alpha evaluation, some components (EXB6, EXB7, INB6, INB7, ADOPT6, SCC8, OP6) were removed because the total variable correlation was less than 0.3. All other scales meet the required threshold so they are retained to continue analyzing for the next step. The calculation results of the remaining scales are presented in Table 3.

C. Exploratory Factor Analysis (EFA)

The two exploratory factor analyses resulted in the elimination of INB5 and SCC2. INB5 loaded on both factors, violating discrimination, and SCC2 had a loading factor of less than 0.5. The analysis results show that the KMO index is $0.904 > 0.5$, proving that the data used for factor analysis is completely appropriate. Barlett's test with significance level $\text{Sig} = 0.000 < 0.05$, so the variables are correlated with each other and meet the conditions for factor analysis. Based on the criterion Eigenvalue $1.13 > 1$ from the 26 observed variables that were used in the EFA, five factors were extracted, and these factors offer the most thorough summary of the data. The five extracted factors account for 53.71% of

Table 3. Internal consistency reliability results

Variable symbols	Cronbach's Alpha	Corrected Item - Total Correlation
EXB1	$\alpha = 0.84$	0.64
EXB2		0.53
EXB3		0.69
EXB4		0.73
EXB5		0.66
INB1	$\alpha = 0.85$	0.63
INB2		0.63
INB3		0.66
INB4		0.69
INB5		0.69
ADOPT1	$\alpha = 0.86$	0.69
ADOPT2		0.68
ADOPT3		0.62
ADOPT4		0.69
ADOPT5		0.63
ADOPT7		0.57
SCC1	$\alpha = 0.89$	0.73
SCC2		0.64
SCC3		0.67
SCC4		0.71
SCC5		0.71
SCC6		0.72
SCC7		0.67
OP1	$\alpha = 0.84$	0.69
OP2		0.66
OP3		0.63
OP4		0.59
OP5		0.59

Abbreviation: ADOPT, Industry 4.0 adoption; SCC, Supply chain capacity; EXB, Extrinsic barriers; OP, Operational efficiency; INB, Intrinsic barriers

the data variation of the 26 observed variables that are part of the EFA research model, as their total variance is $53.71\% > 50\%$ (Table 4).

D. Confirmatory Factor Analysis (CFA)

This study uses the CFA method to test the theoretical structure of the scales among research

variables without measurement error. Furthermore, it is also possible to test the convergent validity and discriminant validity of the scale.

The results of CFA analysis show that the total variance extracted coefficient and the composite reliability of the scales all reach values higher than 0.5 and $CMIN/df \leq 5$; $GFI \geq 0.8$, $TLI, CFI \geq 0.9$; $RMSEA \leq 0.08$; $PCLOSE \geq 0.01$ is statistically significant. The results of the CFA analysis also showed that the scale achieved reliability ($CR > 0.7$) and convergence ($AVE > 0.5$). AVE value $> MSV$

so the scale is discriminatory (Table 5).

E. Structural Models (SEM) Analysis

Structural model analysis is used to test the model and research hypotheses. The results show that the indicators measuring the model's suitability include Chi-square/df value < 5 , $GFI = 0.896 > 0.8$, $CFI = 0.945 > 0.9$; $TLI = 0.938 > 0.9$; $RMSEA = 0.048 < 0.08$; $PCLOSE = 0.713 > 0.001$, so the model is consistent

Table 4. Rotation matrix of variables in the research model

	Factor				
	1	2	3	4	5
ADOPT2	0.78				
ADOPT1	0.77				
ADOPT3	0.70				
ADOPT4	0.69				
ADOPT5	0.67				
ADOPT7	0.62				
SCC5		0.87			
SCC6		0.84			
SCC7		0.76			
SCC1		0.71			
SCC4		0.55			
SCC3		0.51			
EXB4			0.83		
EXB3			0.75		
EXB5			0.73		
EXB1			0.72		
EXB2			0.60		
OP2				0.77	
OP4				0.73	
OP1				0.69	
OP3				0.62	
OP5				0.59	
INB1					-0.78
INB2					-0.70
INB3					-0.69
INB4					-0.67

Abbreviation: ADOPT, Industry 4.0 adoption; SCC, Supply chain capacity; EXB, Extrinsic barriers; OP, Operational efficiency; INB, Intrinsic barriers

Table 5. Tests of convergence, discriminability, and reliability

	CR	AVE	MSV	ADOPT	OP	EXB	INB	SCC
ADOPT	0.86	0.51	0.45	0.71				
OP	0.84	0.50	0.45	0.67	0.71			
EXB	0.85	0.53	0.15	-0.25	-0.29	0.73		
INB	0.81	0.52	0.45	-0.48	-0.67	0.03	0.72	
SCC	0.88	0.56	0.35	0.54	0.59	-0.39	-0.47	0.75

Abbreviation: ADOPT, Industry 4.0 adoption; SCC, Supply chain capacity; EXB, Extrinsic barriers; OP, Operational efficiency; INB, Intrinsic barriers

Table 6. Results of testing research hypotheses

Hypotheses	Relationships	Path coefficient	S.E.	C.R.	P-value	Conclusion
H1	ADOPT←INB	-0.40	0.06	-6.55	0.000	Accept
H2	ADOPT←EXB	-0.14	0.03	-3.93	0.000	Accept
H3	SCC←ADOPT	0.33	0.08	4.37	0.000	Accept
H4	OP←ADOPT	0.35	0.07	4.97	0.000	Accept
H5	SCC←INB	-0.29	0.06	-4.61	0.000	Accept
H6	SCC←EXB	-0.19	0.04	-5.23	0.000	Accept
H7	OP←EXB	-0.08	0.03	-2.38	0.017	Accept
H8	OP←INB	-0.36	0.06	-5.78	0.000	Accept
H9	OP←SCC	0.14	0.06	2.27	0.023	Accept

Abbreviation: ADOPT, Industry 4.0 adoption; SCC, Supply chain capacity; EXB, Extrinsic barriers; OP, Operational efficiency; INB, Intrinsic barriers

with reality. The conclusions of the initially proposed research hypotheses are shown in Table 6.

The analysis results in Table 6 show that Intrinsic barriers and Extrinsic barriers have a negative impact on Industry 4.0 adoption with path coefficients of -0.40 and -0.14, respectively, and both factors are statistically significant. Thus, the results confirm hypotheses H1 and H2. In particular, Intrinsic barriers have a stronger impact than Extrinsic barriers. The results also show that both internal and external barriers have a negative and significant impact on Supply chain capacity with impact coefficients of -0.29 and -0.19 respectively. The results are compatible with hypotheses H5 and H6. Thus, Intrinsic barriers have a stronger influence than Extrinsic barriers. In addition, Intrinsic barriers and Extrinsic barriers also show a negative and significant impact on Operational efficiency with impact coefficients of -0.36 and -0.08, respectively. The results are consistent with hypotheses H8 and H7, the influence of Intrinsic

barriers on Operational efficiency is more prominent than Extrinsic barriers.

Industry 4.0 adoption also shows a positive relationship between Supply chain capacity and Operational efficiency with impact coefficients of 0.33 and 0.35, respectively, at a significant level of significance. This supported hypotheses H3 and H4. Hypothesis H9 is also confirmed, supply chain capacity has a positive impact with an impact coefficient of 0.14 and is statistically significant.

V. Discussion

The relationship between Industry 4.0, supply chain capacity, and operational efficiency has been confirmed by many studies. Based on RBV theory and contingency theory, the study's findings support

several conclusions. Internal and external barriers have a negative relationship with Industry 4.0 adoption. The obtained results are opposite to the findings of Chauhan et al. (2021), compared to external barriers, internal barriers have more impact on Industry 4.0 adoption. The reason could be that, although Industry 4.0 has attracted a lot of attention thus far in Vietnam, it is still in its early stages, and corporate internal resources are primarily responsible for the lack of completed macro policies and infrastructure.

The results also confirm the positive impact of Industry 4.0 adoption on supply chain capacity and operational efficiency. Enterprises adopting Industry 4.0 are becoming better in terms of operational efficiency, a result also consistent with Huang et al. (2019) said that applying Industry 4.0 is beneficial for businesses. This study also evaluates the direct impact of internal and external barriers on supply chain capacity and performance. Research results show that barriers negatively affect supply chain capacity and operational efficiency. Therefore, in moving towards Industry 4.0 at the enterprise level, internal and external barriers must be addressed as they negatively affect supply chain capacity as well as operational efficiency.

The study's findings offer crucial knowledge and understanding to managers who have concerns about what will happen when their companies adopt Industry 4.0 (Frank et al., 2019). Business leaders must decide on the best course of action and allocate resources to overcome obstacles (Karam et al., 2021). According to research, implementing Industry 4.0 will increase operational efficiency. As a result, managers need to consider developing a vision, strategy, and implementation roadmap. The results of this study should also be noted by companies that are implementing adoption, as both internal and external barriers can have a detrimental impact on performance. Furthermore, this research incorporates empirical data from the transport logistics industry, which presents both opportunities and challenges for implementing Industry 4.0.

VI. Conclusion and Management Implications

Research has been done on how barriers to the adoption of Industry 4.0 affect the capacity of supply chains and the operational effectiveness of companies involved in transportation logistics. To successfully implement Industry 4.0 and promote sustainable business development through efficient resource use across the whole operation and supply chain, it is critical to comprehend and reduce these obstacles. The author suggests the following policy implications to fulfill the aforementioned goal:

First and foremost, company executives must alter their perspective on implementing Industry 4.0, as it involves more than just implementing technology; rather, it begins with the business plan and leadership philosophy. Educate business executives on Industry 4.0 so they can make choices that suit their company's needs and resources.

Second, to implement Industry 4.0, businesses must strategically mobilize their internal resources. For businesses to create a sustainable competitive advantage, they must use both tangible and intangible resources (Barney, 2001). Transport logistics companies must work toward digital development and a digitalization vision, define a clear Industry 4.0 vision, implement the plan, and conduct human resource training to improve employees' skills to overcome and lessen the impact of internal barriers.

Third, reduce the adverse effects of outside obstacles by intervening through policy. Building the required infrastructure for Industry 4.0 is one action the government can take to promote and facilitate its adoption. To lessen the detrimental effects of external barriers, policy intervention focuses on institutionalizing adoption and boosting support. When implementing Industry 4.0, policies supporting logistics and transportation companies must be developed with a clear and workable plan that is grounded in real-world data. Technology investment must be given top priority to develop infrastructure, which stands in the way of adoption. The government

needs to establish comprehensive policies aimed at digitalization to support the transport logistics sector's performance in the current unstable global economic environment. To encourage the implementation of Industry 4.0 in the nation, policies involving technology providers, all levels of government, and transport logistics firms must be coordinated.

VII. Limitations of the Study

This study is limited in the scope of data samples. Specifically, the data sample in the study mainly focuses on transport logistics businesses in Vietnam, reducing the representativeness and generalizability of the results. Therefore, to overcome this limitation in the future, the authors could expand the data sample by including more occupations and multinational studies. In addition, limitations in assessment methods need to be improved. Although using a linear structural model, the study still has limitations in accurately assessing the relationship between variables. To overcome this, in the future, researchers can consider using many different statistical methods and reliability tests, as well as test the model on independent data samples and consider adding control variables for further research.

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