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The Mediating Role of Industry 4.0 Implementation on Performance Achievement of Vietnam Automotive Parts Manufacturing Firms

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Abstract. Vietnam automotive industry, which contributes to economic growth, faces challenges in global competitiveness, highlighting the crucial need for Industry 4.0 adoption to improve performance. The purpose of this study was to investigate the relationships among organizational factors, and performance achievement in Vietnam automotive parts manufacturing firms. Another aim was to examine the mediating role of Industry 4.0 implementation in this relationship. The study uses Smart-PLS analysis with a sample of 265 respondents. The findings indicate that organizational factors such as industry forward, smart manufacturing and Block-chain leadership have a significant influence on performance achievement. Furthermore, the study reveals that Industry 4.0 implementation mediates the relationship between organizational factors and performance achievement. These results suggest that firms in the automotive parts manufacturing industry should focus on developing a vision of the industry forward, investing in smart manufacturing, and developing a supportive leadership style to facilitate the successful implementation of Industry 4.0 technologies. Additionally, firms should prioritize the integration of these technologies to achieve improved performance outcomes. Overall, this study provides valuable insights into the factors that contribute to successful Industry 4.0 implementation and performance achievement in Vietnam automotive parts manufacturing industry.

Keywords: Automotive Parts Manufacturing; Industry 4.0 Implementation; Organizational Factors; Performance achievement; Smart-PLS Analysis.

1. Introduction

The automotive industry is a key sector of the manufacturing industry and plays a critical role in the economic development of many countries, including Vietnam In recent years, the automotive industry in Vietnam has experienced rapid growth, with increasing investments from both local and foreign firms. However, as the industry becomes more competitive, firms are facing increasing pressure to improve their performance to maintain their market share and profitability.

The automotive parts manufacturing industry in Vietnam is experiencing rapid growth, with increasing investments from both local and foreign firms (Long, Huy, et al., 2022). However, as the industry becomes more competitive, firms are facing increasing pressure to improve their performance to maintain their market share and profitability. Industry 4.0, with its emphasis on automation, big data analytics, and artificial intelligence, is rapidly transforming the global manufacturing landscape. The implementation of Industry 4.0 technologies has been found to have a positive impact on firm performance in several studies (Anh et al., 2022). However, the literature suggests that the relationship between organizational factors and firm performance may be mediated by Industry 4.0 implementation.

The lack of research on the impact of organizational factors and Industry 4.0 implementation on firm performance in the automotive parts manufacturing industry in Vietnam creates a gap in the literature. This gap poses a problem for firms seeking to improve their performance as they may lack the necessary information and guidance on the factors that contribute to success. Furthermore, policymakers may lack the necessary information to design effective policies to support the growth and development of the automotive parts manufacturing industry in Vietnam.

Therefore, this research aims to address this problem by investigating the impact of organizational factors on the performance achievement of Vietnam automotive parts manufacturing firms. Additionally, this study seeks to examine the mediating role of Industry 4.0 implementation in this relationship. By doing so, this study can provide valuable insights into the factors that contribute to firm performance and the mechanisms that drive this relationship. Furthermore, the findings of this research can offer practical implications for firms seeking to improve their performance and policymakers seeking to support the growth and development of the automotive parts manufacturing industry in Vietnam.

2. Literature Review

The automotive industry is crucial for Vietnam's economic growth. As competition rises, firms must improve performance (Long et al., 2015). Factors like industry forward, 6S smart manufacturing, and leadership impact performance. Industry 4.0 adoption is essential for performance improvement.

2.1. The Current Industry 4.0 Readiness of Vietnam in the Global Context

Vietnam has made strides in adopting Industry 4.0 technologies, but its global readiness remains relatively low. According to the World Economic Forum's Global Competitiveness Index 2019, Vietnam ranked 67th out of 141 countries in overall competitiveness and 84th in technological readiness (Schwab, 2019). To address this, Vietnam established the "Vietnam 4.0" initiative, focusing on digital infrastructure, innovation, and skilled workforce development (WorldBank, 2018). The government has implemented supportive policies, such as tax incentives and funding for R&D and technology startups. Challenges persist, including digital infrastructure and skilled worker availability. With continued investment and government support, Vietnam can enhance its competitiveness in Industry 4.0.

2.2. Performance Achievement in Vietnam Automotive Part Manufacturing Firms

Vietnam automotive industry has grown and attracted foreign investors, aided by supportive government policies. Despite the impact of Covid-19, the industry is expanding, with Vinfast gaining global recognition. Korean companies are interested in Vietnam automobile parts sector, offering collaboration opportunities (Cekindo, 2022). To compete globally, Vietnam needs to develop its

assembly and supporting industries, reduce taxes, support suppliers, and improve management standards and capacity building (MOIT, 2022).

2.3. Industry Forward

Industry forward is a strategic approach that is increasingly being adopted by firms to achieve competitive advantage through innovation, integration, and optimization of their operations. Top management commitment, supply chain integration, and IT infrastructure are key factors that facilitate the adoption and implementation of industry forward practices (Jayashree et al., 2021). Top management commitment involves leadership support for industry forward initiatives, which can be achieved through a clear vision, effective communication, and allocation of resources. Supply chain integration involves the alignment of processes, systems, and strategies across the supply chain, which can lead to improved coordination, efficiency, and responsiveness (Ghadge et al., 2022). IT infrastructure involves the use of technology to support industry forward practices, such as data analytics, simulation, and automation.

H1: Industry forward, including top management commitment, supply chain integration, and IT infrastructure, have a positive impact on performance achievement of Vietnam automotive parts manufacturing firms.

2.4. Smart Manufacturing

Smart manufacturing is another approach that is gaining prominence in the manufacturing industry. It involves the integration of advanced technologies, such as artificial intelligence, Internet of Things, and cloud computing, to create self-aware, self-predictive, self-comparing, self-configuring, self-maintaining, and self-organized manufacturing systems (Valero et al., 2022). These systems can improve the accuracy, speed, and flexibility of manufacturing processes, as well as reduce waste, downtime, and costs (Ntamo et al., 2022).

H2: Smart manufacturing, including self-awareness, self-prediction, self-comparison, self-configuration, self-maintenance, and self-organization have a positive impact on performance achievement of Vietnam automotive parts manufacturing firms.

2.5. Block-chain Leadership

Block-chain Leadership has the highest significant and positive relationship with Vietnam automotive industry (Long, Ooi, et al., 2022). Leadership is a critical factor that influences the success of industry forward and smart manufacturing initiatives. In particular, blockchain leadership can facilitate the adoption and implementation of these practices by promoting agility, flexibility thinking, innovation and creativity, inspirational motivation, technology-oriented thinking, and human values and ethics (Long et al., 2023). Agility involves the ability to respond quickly to changing circumstances and to experiment with new ideas (Long, Duong, et al., 2022). Flexibility thinking involves the ability to adapt to different perspectives and to find creative solutions to problems. Innovation and creativity involve the ability to generate new ideas and to think outside the box. Inspirational motivation involves the ability to inspire and motivate others to achieve common goals (T. V. Le et al., 2022). Technology-oriented thinking involves the ability to understand and leverage technology for strategic advantage (Trang et al., 2022). Human values and ethics involve the ability to uphold ethical and moral principles in decision-making and behaviour (T. Le et al., 2023).

H3: Blockchain leadership, including agility, flexibility thinking, innovation and creativity, inspirational motivation, technology-oriented thinking, and human values and ethics have a positive impact on performance achievement of Vietnam automotive parts manufacturing firms.

2.6. Industry 4.0 Implementation

Industry 4.0 implementation is a key enabler of industry forward and smart manufacturing practices. It involves the integration of cyber-physical systems, data analytics, and advanced communication

technologies to create a more transparent, flexible, and adaptive manufacturing environment. Assessment of Industry 4.0 maturity by incorporating the following dimensions: physical and virtual worlds, humans, strategy and culture, products and services, value chain, and the broader environment (Nick et al., 2021). Industry 4.0 implementation can improve visibility, transparency, predictiveness, capacity, and adaptability in manufacturing processes, leading to improved efficiency, productivity, and quality (Dacal-Nieto et al., 2022).

H4: Industry 4.0 implementation, including visibility, transparency, predictive capabilities, capacity, and adaptability mediates the relationship with performance achievement of Vietnamese automotive parts manufacturing firms.

2.7. Performance Achievement

Performance achievement is a critical outcome of industry forward, smart manufacturing, and Industry 4.0 implementation. It encompasses several dimensions, including safety, workload, quality, productivity, and efficiency. Automated manufacturing in the automotive industry with a specialization in technologies related to Industry 4.0 up to a level of implementation such as advanced robotic devices, 3D printing, Internet of Things provides efficiency and fluidity (Papulová et al., 2022). Safety involves the prevention of accidents and injuries in the workplace. Workload involves the balance of work demands and resources to reduce stress and fatigue. Quality involves the conformity of products to customer requirements and specifications (Valentina et al., 2021). Productivity involves the output of goods or services per unit of input. Efficiency involves the ratio of output to input, reflecting the optimal use of resources (Somohano-Rodríguez & Madrid-Guijarro, 2022).

Industry forward, smart manufacturing, Block-chain leadership, Industry 4.0 implementation, and performance achievement are interrelated concepts that can facilitate the competitiveness and sustainability of automotive parts manufacturing firms. By adopting these practices and developing the necessary vision, manufacturing, and leadership, firms can achieve better performance outcomes and respond more effectively to the challenges and opportunities of the modern manufacturing landscape.

2.8. Literature Gap

The literature review reveals several gaps in the existing research related to the impact of organizational factors and Industry 4.0 implementation on the performance achievement of Vietnam automotive parts manufacturing firms. These gaps include a lack of research on the relationship between industry forward practices and performance achievement, limited understanding of the role of smart manufacturing in this relationship, a need to identify the specific leadership characteristics necessary for effective Block-chain leadership in the Vietnamese context, insufficient understanding of the barriers and challenges to Industry 4.0 implementation, and a lack of research on the specific performance outcomes most relevant and important for the Vietnam automotive parts manufacturing industry. Addressing these gaps will contribute to a more comprehensive understanding of the factors that influence performance achievement in this industry and facilitate the development of more effective strategies for improving organizational performance.

3. Methodology and Research Model

This study utilized a quantitative approach and involved a population of 1200 individuals from various sectors related to the automotive industry, including upstream and downstream economic sectors, adjacent sectors, and influencing sectors. Quantitative data was collected through a Likert-scale survey of 265 individuals. The responses were then coded and analyzed using Smart-PLS 3.0, which measured construct quality and discriminant validity through correlation analysis. The study also tested variance explanation, effect size, level of collinearity, and predictive relevance. Path coefficient analysis was employed to evaluate the relationship and mediation between predictors and the dependent variable within the proposed research framework. The conceptual framework below illustrates the relationship between variable factors and Vietnam automotive parts manufacturing firms.

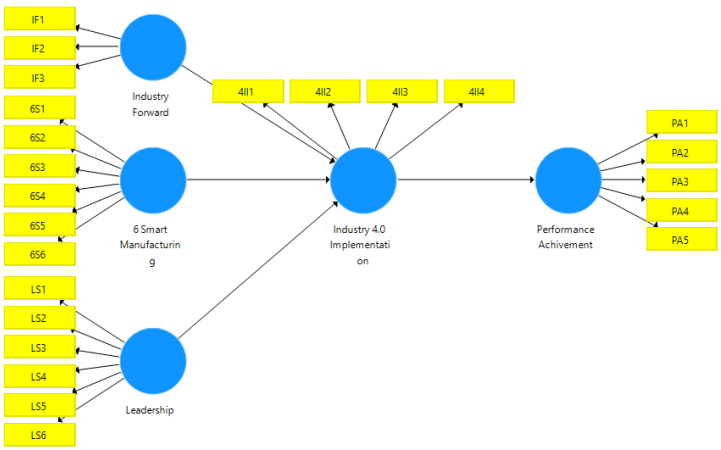

Fig. 1: Theoretical Framework

4. Results and Discussion

4.1. Demographic Profile

Table 1: Demographic Profile

No.	Category		Frequency (N=265)	Percent (%)
1	Organization Type	Local	56	21.1
		State-owned	32	12.1
		Foreign	77	29.1
		Joint venture	100	37.7
2	Organization Size	less than 50 employee	164	61.9
		from 50 to 200 employee	53	20.0
		from 201 to 500 employee	16	6.0
		above 501 employee	32	12.1
3	Industry	Manufacturing	202	76.2
		Service	21	7.9
		Government	11	4.2
		Education & Training	31	11.7
4	Position	State officer	27	10.2
		Enterprise manager	207	78.1
		Researcher	31	11.7
5	Organization Characteristic	Lean Production Applied	135	50.9
		4.0 Industry Applied	45	17.0
		Both	85	32.1
		None	0	0.0

The demographic profile of the sample population in this study consisted of 265 respondents from various organization types, sizes, and industries. The majority of organizations were joint ventures (37.7%) and local firms (21.1%), while state-owned and foreign organizations accounted for 12.1% and 29.1% of the sample, respectively. In terms of organization size, the majority of respondents represented small organizations with less than 50 employees (61.9%), followed by organizations with 50 to 200 employees (20.0%), and organizations with 201 to 500 employees (6.0%). Only 12.1% of respondents were from large organizations with over 501 employees. The manufacturing industry was the most represented industry in the sample (76.2%), followed by education and training (11.7%), services (7.9%), and government (4.2%). The majority of respondents held positions as enterprise managers (78.1%), followed by researchers (11.7%) and state officers (10.2%). Finally, half of the organizations reported implementing lean production practices (50.9%), while 17% reported implementing Industry 4.0 practices, and 32.1% reported implementing both. None of the organizations reported implementing

neither lean production nor Industry 4.0 practices.

4.2. Construct Quality Measurement

The table presents the outer loadings, Cronbach's Alpha (CA), and composite reliability (CR) for the constructs used in the research. The first three independent variables (IV1, IV2, IV3) are Industry Forward, 6S Smart Manufacturing, and Block-Chain Leadership, respectively. The mediating variable (MeV) is Industry 4.0 Implementation, and the dependent variable (DV) is Performance Achievement. The outer loadings for each construct range from 0.752 to 0.887, indicating good convergent validity. The Cronbach's Alpha (CA) values for each construct range from 0.806 to 0.899, indicating good internal consistency. The composite reliability (CR) values for each construct range from 0.885 to 0.925, indicating good reliability.

Table 2: Construct Quality Measurement

No.	Construct	Item	Mean	Outer loadings	CA	CR
IV1	Industry Forward	Top Management Commitment	5.1	0.875	0.806	0.885
		Supply Chain Integration	5.0	0.856		
		IT Infrastructure	5.2	0.814		
IV2	6S Smart Manufacturing	Self-aware	4.8	0.797	0.910	0.930
		Self-predict	5.3	0.816		
		Self-compare	5.3	0.821		
		Self-configure	4.6	0.799		
		Self-maintain	5.0	0.857		
		Self-organized	5.1	0.887		
IV3	Block-chain Leadership	Agility	5.3	0.825	0.892	0.918
		Flexibility Thinking	5.4	0.788		
		Innovation and Creativity	5.2	0.793		
		Inspirational Motivation	5.8	0.752		
		Technology Oriented Thinking	5.4	0.823		
		Human Values and Ethics	5.5	0.854		
MeV	Industry 4.0 Implementation	Visibility	5.0	0.797	0.833	0.889
		Transparency	4.5	0.831		
		Predictive Capacity	4.7	0.775		
		Adaptability	4.8	0.861		
DV	Performance Achievement	Safety	4.0	0.844	0.899	0.925
		Workload	4.1	0.837		
		Quality	4.0	0.824		
		Productivity	4.1	0.859		
		Efficiency	4.0	0.852		

4.3. Construct Convergent and Discriminant Validity

Table 3: Construct Convergent and Discriminant Validity

Construct	AVE	1	2	3	4	5
6S Smart Manufacturing (1)	0.689	0.830				
Block-chain Leadership (2)	0.650	0.334	0.807			
Industry 4.0 Implementation (3)	0.667	0.497	0.547	0.817		
Industry Forward (4)	0.720	0.378	0.410	0.575	0.849	
Performance Achievement (5)	0.711	0.344	0.475	0.741	0.489	0.843

The Fornell-Larcker criterion was used to assess the discriminant validity of the research variables. The average variance extracted (AVE) values were calculated for each variable and compared with the squared correlations between the variables. The results indicate that the variables met the discriminant

validity requirements. All variables had AVE values above the recommended threshold of 0.5 and the squared correlations between the variables were all lower than the AVE values, demonstrating that each variable measures a distinct construct. Therefore, the research variables can be considered to have discriminant validity.

4.4. Effect Size, Collinearity Statistics, Predictive Accuracy and Predictive Relevance

This table shows the values of the construct's f2 and VIF. The f2 value represents the construct's effect size, while the VIF value indicates the level of multicollinearity between the constructs. The results indicate that the construct of Industry 4.0 implementation has a high effect size (f2=1.216), while the constructs of 6S Smart Manufacturing, Block-Chain Leadership, and Industry Forward have lower effect sizes (f2=0.111, f2=0.163, and f2=0.185, respectively). Additionally, all constructs have VIF values below the threshold of 5, indicating that multicollinearity is not a concern.

The R-squared adjusted values for Industry 4.0 Implementation and Performance are 0.497 and 0.547, respectively. The Q^2 values for Industry 4.0 Implementation and Performance are 0.313 and 0.363, respectively, indicating that the predictors in the model have a moderate to strong effect on the outcomes.

Table 4: Effect Size (f2), Collinearity Statistics (VIF), Predictive Accuracy (R2) and Predictive Relevance (Q2)

Construct	f2	VIF	R Square Adjusted	Q^2 (=1-SSE/SSO)
6S Smart Manufacturing	0.111	1.222		
Block-chain Leadership	0.163	1.258		
Industry 4.0 Implementation	1.216	1.000	0.497	0.313
Industry Forward	0.185	1.304		
Performance Achievement			0.547	0.363

4.5. Hypothesis Testing Results

The table presents the path coefficients, original sample values, p-values, and results of hypothesis testing for the proposed hypotheses.

- Hypothesis H1a, which proposes a positive relationship between Industry Forward and Industry 4.0 Implementation, is mostly supported ($O = 0.346$, $p < 0.001$).
- Hypothesis H1c, which proposes a positive relationship between Block-Chain Leadership and Industry 4.0 Implementation, is secondly supported ($O = 0.319$, $p < 0.001$).
- Hypothesis H1b, which proposes a positive relationship between 6S Smart Manufacturing and Industry 4.0 Implementation, is also supported ($O = 0.259$, $p < 0.001$).
- Furthermore, Hypothesis H2, which proposes a mediating role of Industry 4.0 Implementation and Achievement, is supported ($O = 0.788$, $p < 0.001$).

Table 5: Path Coefficients and Hypothesis Testing Results

No.	Path Coefficients	Original Sample (O)	P Values	Result
H1a	Industry Forward ⇒ Industry 4.0 Implementation	0.346	0.000	Supported
H1c	Block-chain Leadership ⇒ Industry 4.0 Implementation	0.319	0.000	Supported
H1b	6s Smart Manufacturing ⇒ Industry 4.0 Implementation	0.259	0.000	Supported
H2	Mediating Role of Industry 4.0 Implementation ➞ Performance Achievement ⇒ Performance Achievement	0.788	0.000	Supported

4.6. Discussion

The study aimed to investigate the relationship between Industry 4.0 implementation and performance achievement in the context of the automotive manufacturing sector in Vietnam.

Industry 4.0 Implementation serves as a mediator in enhancing Performance Achievement (O =

0.788). To improve overall performance, it is crucial to prioritize the implementation of Industry 4.0 technologies and practices. Specifically, focusing on improving visibility (Mean = 5.0), enhancing adaptability (Mean = 4.8), predictive capacity (Mean = 4.7), and ensuring transparency (Mean = 4.5) are key factors that contribute to achieving better performance outcomes. By emphasizing these aspects, organizations can optimize their operations and leverage the benefits offered by Industry 4.0 to enhance their overall performance achievement.

The findings indicate a significant positive relationship between Industry Forward and Industry 4.0 Implementation (O = 0.346). This implies that automotive firms that prioritize Industry Forward practices are more inclined to adopt and implement Industry 4.0 technologies and practices. To enhance their Industry 4.0 Implementation, these firms should focus on improving key factors such as IT Infrastructure (Mean = 5.2), Top Management Commitment (Mean = 5.1), and Supply Chain Integration (Mean = 5.0). By strengthening these areas, automotive firms can effectively embrace Industry 4.0 and leverage its potential benefits in their operations and overall performance.

The results demonstrate a significant positive relationship between Block-Chain Leadership and Industry 4.0 Implementation (O = 0.319). This suggests that automotive manufacturing firms with strong Block-chain Leadership skills are more likely to embrace Industry 4.0 technologies and practices. To optimize their performance in this regard, these firms should prioritize areas such as Inspirational Motivation (Mean = 5.8), Human Values and Ethics (Mean = 5.5), Technology-Oriented Thinking, and Flexibility Thinking (Mean = 5.4), as well as Agility, Innovation, and Creativity (Mean = 5.3 and 5.2). By focusing on these aspects, automotive firms can enhance their Block-Chain Leadership and effectively drive the adoption and implementation of Industry 4.0 strategies, ultimately leading to improved performance outcomes.

The findings reveal a significant positive relationship between 6S Smart Manufacturing and Industry 4.0 Implementation (O = 0.259). This suggests that companies that adopt 6S Smart Manufacturing practices are more likely to embrace Industry 4.0 technologies and practices. To enhance their performance in this context, automotive firms should prioritize areas such as Self-predict and Self-compare (Mean = 5.3), Self-organized and Self-maintain (Mean = 5.1 and 5.0), as well as Self-aware and Self-configure (Mean = 4.8 and 4.6). By focusing on these aspects, automotive firms can effectively implement 6S Smart Manufacturing principles, leading to improved adoption of Industry 4.0 strategies and better performance outcomes.

The study provides valuable insights into the relationship between Industry 4.0 implementation and performance achievement in the manufacturing industry. Further research can build upon these findings by investigating the specific mechanisms through which Industry 4.0 implementation leads to improved performance outcomes and exploring potential moderating factors that may influence this relationship.

4.7. Recommendations

Based on the findings of this study, the following recommendations are suggested for practitioners and researchers.

For practitioners, it is recommended to focus on the implementation of Industry 4.0 technologies, such as smart manufacturing, as well as the development of Industry Forward strategies to enhance Industry 4.0 implementation. Furthermore, improving Block-chain leadership practices that promote smart manufacturing can lead to successful Industry 4.0 implementation and improved performance outcomes. For researchers, it is recommended to conduct further studies on Industry 4.0 implementation and its effects on various industries and sectors. Future research can also explore the potential moderating effects of contextual factors on the relationship between Industry 4.0 implementation and performance outcomes. Additionally, investigating the role of other Industry 4.0 technologies, such as artificial intelligence, big data, and the Internet of Things, on performance outcomes can provide valuable insights for practitioners and researchers alike.

5. Conclusions

This study examined the relationship between Industry 4.0 implementation, 6S smart manufacturing, Block-chain leadership, and industry forward, and their impact on performance achievement in the manufacturing industry. The results supported a positive impact of Industry 4.0 implementation on performance achievement. Additionally, 6S smart manufacturing, Block-chain leadership, and industry forward were found to positively influence Industry 4.0 implementation.

The findings suggest that manufacturing firms should prioritize Industry 4.0 technologies, develop strong Block-chain leadership skills, and adopt 6S smart manufacturing practices to enhance their performance. This study contributes to the understanding of Industry 4.0 implementation and its impact on performance achievement in manufacturing. Future research can further investigate this relationship using longitudinal data and objective performance measures. Embracing Industry 4.0 technologies is crucial for improving performance in the manufacturing industry.

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