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Linkage mapping of organizational DNA and sustainable performance through industry 4.0-enabled digital transformation: A cutting–edge PLS-SEM model analysis

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ABSTRACT

This study was conducted to close the knowledge gap in previous research examining the effects of organizational DNA (ODNA) on sustainable performance (SP) through the mediating role of Industry 4.0 – Enabled Digital Transformation (I4.0-DT). The current study methodology is based on a mixed approach combining a systematic literature review with a self-reported questionnaire administered to the study sample. The study used data gathered from senior and middle-level managers working in pharmaceutical manufacturing companies in Jordan. A random sample consisted of 300 managers. SEM-PLS was used for analysis. The results show that ODNA enhances SP across economic, environmental, and social dimensions. The study identifies that I4.0–DT partially mediates the relationship between ODNA and SP interpreted as around 31.74% of the total effect. These findings highlight that while ODNA is critical; its effectiveness is multiplied by integrating advanced technologies. The implications of this study provide practical guidance for managers in the pharmaceutical sector. Pharmaceutical companies can leverage these findings to justify investments in I4.0-DT to enhance the impact of ODNA on SP. This can be achieved by cultivating a culture of continuous learning, innovation, and adaptability, improving the effectiveness of their digital transformation initiatives and thus achieving SP.

Contribution/Originality: This paper provides new insights into studying various management topics and diagnosing the interaction of their variables and relationships which contributes to deducing new data for these effects and anticipating their future feasibility as it examines the impact of the inherent features of the ODNA on the SP of Jordanian pharmaceutical companies in addition to shedding light on the mediating role of I4.0-DT.

1. INTRODUCTION

Nowadays, we live in an interconnected digital world characterized by increased mobility and timely access to information. At the same time, we must address a range of global issues such as environmental protection, improved health and the fight against poverty (Fonseca, 2018). Organizations in developing economies such as Jordan struggle to balance social, economic, and environmental concerns. Furthermore, achieving SP has become increasingly important in the pharmaceutical sector (Sharabati, 2018).

Since organizations are subject to the same natural law as all living organisms in terms of genetic and hereditary composition represented in the life cycle, many researchers have studied these unique characteristics that distinguish the organization from other organizations and help explain its behaviors (Nafei, 2015). Despite the importance of ODNA in the functioning of organizations, it has not received sufficient research attention to date (Qabaja, 2018).

In the digital transformation era, sustainable development takes on new dimensions, requiring organizations to adapt to emerging technologies and keep up with and adjust to changing customer demands (Yang, Wu, & Yang, 2023). Industry 4.0 technologies have heralded a new era of digital transformation which has led to a radical change in how organizations operate and compete (Yaqub & Alsabban, 2023).

Surprisingly, manufacturing companies are at a disadvantage compared to other industrial communities regarding the transition to Industry 4.0 (Kane, Palmer, Phillips, Kiron, & Buckley, 2017). However, there remains a major hurdle that organizations may overlook how these technologies are integrated with the structural and cultural characteristics of the organization known as ODNA. However, changes often come with multiple risks and challenges, and the obstacles to digital transformation should not be underestimated. Some studies have indicated that the inherited cultural norms entrenched in organizations have played a major role in this rejection (Almatrodi & Skoumpopoulou, 2023). This exposes any manufacturing company that lags to a high risk of losing its competitive position (Calabrese, Levialdi Ghiron, & Tiburzi, 2020).

Previous research has focused on investigating the separate effects of digital transformation on different organizational domains, including performance, innovation and culture (Yang et al., 2023). Researchers have proposed several factors that may contribute to SP such as organizations, technology, intellectual property, human resource management, knowledge sharing, lean processes, organizational culture, and others (Asif, Yang, & Hashim, 2024). The current study seeks to conduct a deeper analysis of the study variables from a theoretical and applied perspective, especially in the pharmaceutical manufacturing companies' sector in Jordan compared to previous research.

The objectives of the study are as follows: first, studying the impact of ODNA on SP to consider how the inherent features of ODNA affect the SP of Jordanian pharmaceutical companies. Second, it highlights the mediating role of I4.0-DT in the relationship between ODNA and SP. Finally, the implications for pharmaceutical companies in Jordan will be identified and practical suggestions and recommendations will be provided on how to enhance their long-term success and improve their competitiveness.

2. LITERATURE REVIEW

2.1. Organizational DNA (ODNA)

ODNA is defined as the genetic nature of the organization, including methods of analysis, thinking, ideology, and work within the organization and administrative and leadership methods (Soroush, Mohammadpouri, Poorfarahmand, & Esfahani, 2014). It determines the organization's features, characteristics, and internal human and material environment in a way that distinguishes it from competitors (Mohamed & Al-Rumaidi, 2019). According to Neilson, Pasternack, and Mendes (2004) at Booz Allen Hamilton, who promoted this concept, there are four chromosomes or basic building blocks of ODNA which may be called nucleotides: decision-making rights (DM), motivators (MV), information (INF), and structure (S) which determine the effectiveness of the organization's response to internal and external challenges (Rashid & Chalab, 2007).

2.2. Sustainable Performance (SP)

Sustainable development goals (SDGs) and SP concepts have become increasingly important in organizations. An effective assessment of SP passes through the evaluation of three dimensions: economic performance (EP), social performance (SCP), and environmental performance (EVP) (Alshawabkeh, Abu Rumman, & Al-Abbadi, 2024; Mansour, Al-Ma'aitah, Deek, Alshaketheep, & Shajrawi, 2024). It became clear that the organization must simultaneously achieve these dimensions to be truly sustainable (e.g., (Abdul-Rashid, Sakundarini, Raja Ghazilla, & Thurasamy, 2017; Souto, 2022)).

2.3. Industry 4.0 - Enabled Digital Transformation (I4.0-DT)

The I4.0-DT integrates biological, physical, and digital systems in the Fourth Industrial Revolution or Industry 4.0 (Schwab, 2016) through modern digital technologies (Aldhafar, 2020). The measurement process must first include verifying the formulation and implementation of a digital transformation strategy (DTS) represented by a plan adopted by the organization that involves the systematic use of digital technologies to develop business processes and innovate new methods to measure the I4.0-DT of any organization comprehensively. Second, digital transformation applications (DTA) use digital tools, programs, and systems to improve operations, quality, innovation, efficiency, and performance (Ma, Zhang, & Dong, 2023). At the same time, according to Lueth (2024), the five applications expected to be the most popular in the coming years will be adopted to measure the DTA dimension which are cybersecurity, process automation, IT programs (e.g., enterprise resource planning (ERP) and customer relationship management (CRM)), artificial intelligence, and the Internet of Things.

3. HYPOTHESIS DEVELOPMENT

3.1. The Relationship between ODNA and SP

Literature suggests that organizations with a unique set of organizational elements that shape their identity and performance behavior (i.e., strong DNA) are expected to have more SP because their internal elements allow them to adapt and respond effectively to environmental and competitive pressures and maintain higher performance over time (Elsakaan, Ragab, El-Gharbawy, & Ghanem, 2021). This comes from the idea that these basic features of the organization's DNA play a crucial role in achieving the organization's long-term sustainability goals by creating a work environment conducive to innovation and sustainable practices (Elsanhawy & Badway, 2023).

The study by Elsanhawy and Badway (2023) found a strong impact of the ODNA on organizational flexibility and sustainability. In the same context, the study conducted by Pakdelan, Azarberahman, Saremi, and Ghaderi (2021) found that the distinctive elements of culture and structure of the ODNA affect the achievement of sustainable results. Accordingly, Gugenishvili, Francu, and Koporcic (2023) emphasize that aligning the organization's strategies with social and environmental goals requires integrating sustainability practices into the ODNA which means that the approach directed towards sustainability practices is integrated into the ODNA so that these practices are deeply rooted in the organization's processes, culture, structure and decisions to be the basis of the organization's distinctive identity and not an additional element and this is related to the organization's success in the long-term and enhancing its flexibility. This requires the organization to adopt a strong and well-defined ODNA that integrates the idea of sustainability into the organization's values, beliefs, and strategic practices which enhances its SP in the long-term (Alkhodary, 2023). Therefore, the organization's genes may be a motive or incentive to move towards achieving its goals and may be a preventive to it if the composition of its cells and dimensions deteriorates (Nafei, 2015). By reviewing the findings of previous literature, organizations should integrate sustainability goals into their ODNA as it will serve as a driver and incentive for them to achieve sustainable performance. Based on this, the current study proposes the following hypothesis:

H_1: ODNA has a significant and positive effect on SP.

A set of hypotheses developed from this main hypothesis:

$H_{1.1}$: ODNA significantly and positively affects economic performance (EP).

$H_{1.2}$: ODNA significantly and positively affects social performance (SCP).

$H_{1.3}$: ODNA significantly and positively affects environmental performance (EVP).

3.2. The Mediating Role of Industry 4.0-Enabled Digital Transformation between Organizational DNA and Sustainable Performance

To ensure the effectiveness of digital transformation, organizations need to start the journey by changing the mindset of employees regarding the adoption of digital technology (Gupta, Modgil, Bhushan, Kamble, & Mishra,

2024) and they require a major change in the behavior of employees inside and outside the organization. Employees must have positive attitudes to integrate new digital tools and procedures into the organization's practices, activities and routines (Fahmi, Tjakraatmadja, & Ginting, 2023). This requires organizations to find a way to integrate the new technological system into their culture (Martínez-Caro, Cegarra-Navarro, & Alfonso-Ruiz, 2020). The results of a study conducted by Almatrodi and Skoumpopoulou (2023) indicate that the transition to digital transformation depends largely on organizational practices.

As shown by a review of previous research, the success of the digital transformation process requires the organization to have a high capacity for innovation and adaptation, which can be enhanced by good coordination of its ODNA (Gökçe & Pelit, 2023). In addition, Martinelli, Farioli, and Tunisini (2021) emphasized that industrial companies should use organizational memory/heritage and important lessons learnt from previous industrial revolutions to ensure a successful digital transformation process. Therefore, the success of an organization's transition phase depends on leveraging the digital transformation strategy to ensure that information is easily shared and flows throughout the organization as well as assessing the structure, decision-making processes, and motivations (Alshawabkeh et al., 2024; Pakdelan et al., 2021).

However, the successful implementation of these technologies requires more than just adopting technology. It requires alignment with the organization's infrastructure and culture referred to as ODNA (Nawahda, Mohammed, Al, & Abdul, 2022). ODNA plays a pivotal role in determining how effectively an organization can leverage digital transformation to achieve sustainable performance (Elsakaan et al., 2021). Based on this discussion, the following hypothesis was formulated:

H_2: ODNA has a significant and positive effect on I4.0-DT.

Organizational performance is improved through the use of cutting-edge digital technologies to improve operations and provide internal growth prospects (Ying & Jin, 2023). The critical role of digital transformation in ensuring sustainability has been the subject of numerous studies (e.g., (Chen, Li, & Shahid, 2024; Su & Wu, 2024; Yang et al., 2023)). According to Kopeinig, Woschank, and Olipp (2024), several I4.0-DT can help manufacturing become more environmentally sustainable. However, others have drawn attention to the scarcity of comprehensive research on the significant impacts of digital transformation on sustainability (Bocean & Vărzaru, 2023). Companies may achieve a better balance between productivity and environmental benefits by leveraging technologies such as artificial intelligence, the Internet of Things, and information technology systems (Yang et al., 2023). Therefore, achieving the goal of reducing environmental pollution and emissions is crucial to the organization's green development. Moreover, digital transformation provides a means to increase operational flexibility and efficiency by using digital technologies to automate processes, improve workflow and enable rapid responses to market fluctuations (Bocean & Vărzaru, 2023).

Due to digital transformation, organizations may be forced to shift to a business model that includes high-value goods and services, enhance the quality of those goods and services, and strengthen their position in the market. In addition, digital transformation reduces the marginal cost of innovation and research & development (R&D) which encourages companies to take on more social responsibility (Su & Wu, 2024). Digitization has a proven impact on reducing unemployment, improving the quality of life, and enhancing citizens' access to public services. It allows governments to operate with greater transparency and efficiency (Kapotas, 2023). The organization can obtain customer feedback promptly which enables it to continuously improve its products and services by developing a new set of capabilities to be flexible and responsive to rapidly changing customer requirements, thus enhancing their satisfaction (Su & Wu, 2024).

Moreover, the pharmaceutical industry has recognized the disruptive role of I4.0-DT as a transformative force. Artificial intelligence, big data analytics, and the Internet of Things offer unprecedented opportunities to enhance responsiveness, innovation, and operational efficiency (Kagermann, Wahlster, & Helbig, 2013). It is worth exploring whether digital transformation in Industry 4.0 will improve sustainable performance, organizations can develop comprehensive strategies that consider both the prior challenges and subsequent benefits of digital transformation, ensuring sustainable development in a more balanced environment (Yang et al., 2023). In this context, digital transformation can be crucial in promoting sustainable economic growth for organizations. Improving operational efficiency and reducing costs is a means for digital transformation to promote sustainable economic growth for organizations (Alojail & Khan, 2023; Martínez-Peláez et al., 2023). Therefore, the following hypothesis was formulated:

H_3: I4.0-DT has a significant and positive effect on SP.

Industry 4.0 has sparked the digital transformation with the emergence of Industry 4.0 technologies leading to a major shift in the way organizations operate and their business models, especially in their approach to digital transformation (Bocean & Vărzaru, 2023). Digital transformation is no longer just about adding technology to the production line but rather about changing all aspects of the business from processes to culture, starting with the mindset of individuals and as a collective organization. For this reason, new strategic initiatives are needed to accomplish such transformations (Jones, Hutcheson, & Camba, 2021).

Studies indicate that organizations that have been able to achieve a successful and strong alignment and integration between digital transformation strategies and ODNA are more likely to achieve SP (Alojail & Khan, 2023; Chen et al., 2024). Such alignment ensures that there is cultural and structural compatibility that supports technological changes in the right way (AlMkaneen, 2021). Digital technologies combined with a change in mindset can provide new opportunities for planning, management, and sustainable development (Alojail & Khan, 2023). In the same context, Ghobakhloo and Iranmanesh (2021) confirmed that the integration of advanced technologies into organizational processes through digital transformation supported by Industry 4.0 acts as a powerful facilitator in the relationship between ODNA and SP. Yaqub and Alsabban (2023) also confirmed that the successful integration of these technologies into the organization's DNA will enable it to achieve SP because it will be better responsive to its changing markets. Thus, digital transformation contributes to achieving sustainability goals related to the environment, society, and governance and plays a mediating role in achieving sustainable results for the organization (Su & Wu, 2024).

This means that there is an intersection between the ODNA, I4.0-DT, and SP as organizations become faster responsive to market changes and more compatible with their organizational elements (Martínez-Peláez et al., 2023). By improving process efficiency, enabling more flexible responses to environmental and regulatory changes, and supporting real-time, data-driven decision-making, these digital tools can significantly affect how ODNA influences SP (Schwab, 2016).

There is a significant knowledge gap about the interactive relationships between these variables to successfully achieve sustainable performance by meeting various economic, social, and environmental responsibilities in the long-term, especially when the issue is digital transformation enabled by Industry 4.0 although there is a lot of research on Industry 4.0, digital transformation, and sustainable performance. Previous research has focused on this area which investigates the effects of digital transformation on different organizational domains, including performance, innovation, and culture (Almatrodi & Skoumpopoulou, 2023; Yang et al., 2023). Despite the importance of organizational DNA in the functioning of organizations, it has not received sufficient research attention to date (Qabaja, 2018). Accordingly, the current study proposes the following hypothesis:

H_4: I4.0-DT mediates the relationship between ODNA and SP.

4. RESEARCH MODEL

By reviewing the findings of previous literature, organizations should integrate sustainability goals into their ODNA as it will serve as a driver and incentive for them to achieve SP through the mediating role of I4.0-DT. Based on this, the current study proposes the following conceptual model (see Figure 1):

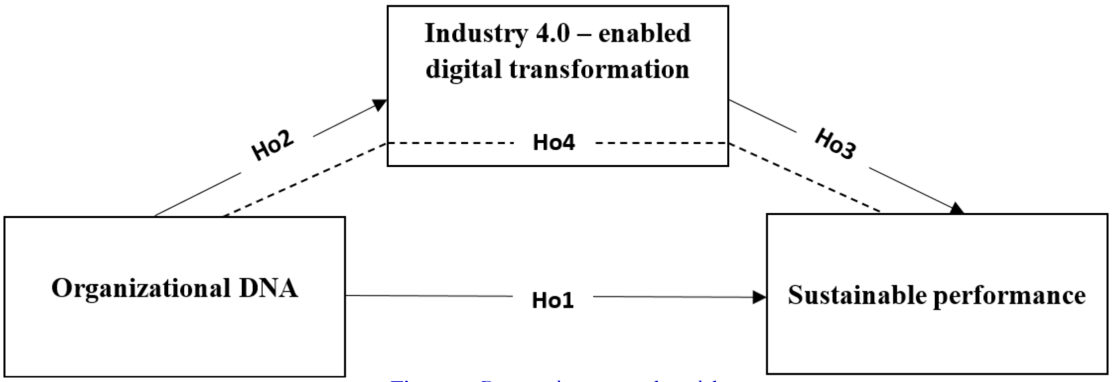

Figure 1. Proposed conceptual model.

5. METHODOLOGY

The current study methodology is based on a mixed approach combining a systematic literature review theoretically through developing a conceptual framework and summarizing and reviewing the results of previous literature to deduce hypotheses on the one hand and an experimental analysis based on a questionnaire that is used to collect data from the pharmaceutical manufacturing companies that have applied the technologies enabled by Industry 4.0 and analyzing them statistically to reach results that prove the proposed hypotheses.

The study population consisted of 1019 senior and middle-level managers working in pharmaceutical manufacturing companies in Jordan. A random sample was applied to the current study and a questionnaire was used to collect data from the target sample. The study relied on the sampling strategy by applying the relative random sampling method and based on Sekaran and Bougie (2016). The sample size for the study population of 1019 is 300 employees. A total of 350 questionnaires were distributed while the returned questionnaires were 316 and 34 were not returned. Only 287 questionnaires were useable indicating an 82% response rate. The sample period was selected to capture data during significant digital transformation in the pharmaceutical sector in Jordan characterized by increased adoption of digital technologies and organizational restructurings.

The variables were selected based on their theoretical relevance and practical importance in assessing the relationship between ODNA, I4.0-DT, and SP. In the current study, data was collected through a questionnaire using a five-point Likert scale which was adopted from previous literature. Specifically, the items related to the ODNA were adapted from the studies (Alshawabkeh, 2021; Qabaja, 2018) while the items for the SP were drawn (Al-Abbadi & Abu Rumman, 2023; Ma et al., 2023). Additionally, the items addressing the mediating variable (I4.0-DT) were developed based on the works of Ma et al. (2023) and Masoud and Basahel (2023). Table 1 presents the final version of the questionnaire.

Table 1. Questionnaire items

Independent variable: Organizational DNA	
Decision-making rights (DM)	
DM1	Our company provides data and information to decision-makers quickly and accurately.
DM2	The necessary powers are delegated to decision-makers and clearly defined.
DM3	Our company follows a participatory approach in decision-making.
DM4	The decisions taken are clear and transparent.
Motivators (MV)	
MV1	The applied incentive policy is fair and equitable.
MV2	Our company provides material and moral incentives.
MV3	The performance evaluation system is characterized by objectivity and fairness.
MV4	Our company provides opportunities for promotion and career development for employees.
Information (INF)	
INF1	Our company relies on modern methods in collecting and processing data.
INF2	Information is shared and exchanged between departments and employees.
INF3	Our company has its own database and information systems.
INF4	Our company is keen on the accuracy and reliability of its information and its continuous updating.

Structure (ST)	
ST1	The organizational structure is clear and consistent with the nature of the company's work.
ST2	The organizational structure is flexible and adaptable to changes.
ST3	Communication channels are defined and clear.
ST4	Roles and responsibilities are distributed fairly and according to efficiency.
Dependent variable: Sustainable performance (SP)	
Economic performance (EP)	
EP1	Our company achieves continuous increases in revenues and profits.
EP2	Our company achieves a continuous decrease in costs.
EP3	Our company has achieved an increase in market share compared to previous years.
Social performance (SP)	
SP1	Our company develops voluntary community programs to support needy parties.
SP2	Our company supports many social, health, sports, and cultural activities.
SP3	Our company considers the interests of the local community when making decisions.
Environmental performance (EVP)	
EVP1	Our company follows strict programs and policies to limit negative impacts on the environment.
EVP2	Our company is keen to rationalize the consumption of resources and prevent waste.
EVP3	Our company has reduced its use of chemicals and relied on recycling and clean technology.
Mediating variable: Industry 4.0- enabled digital transformation (I4.0-DT)	
Digital transformation strategy (DTS)	
DTS 1	Our company's management believes in the importance of digital transformation to support its performance.
DTS 2	Our company's management has a clear vision to benefit from digital transformation in the future.
DTS 3	Our company's management provides all support for digital transformation (e.g. human, physical, and technological infrastructure).
DTS 4	The company's management strategies include objectives to adopt digital transformation in all its operations and activities.
Digital technologies application (DTA)	
DTA1	Our company uses cyber-physical systems (CPS) to facilitate intelligent control of production lines effectively.
DTA2	Our company uses smart technologies and systems to automate processes such as advanced robotics and industrial automation systems to improve, monitor, and streamline operations.
DTA3	Our company uses IT Software/ Applications such as Cloud computing, big data analytics and ERP to inform decision-making and increase the efficiency and effectiveness of its operations.
DTA4	Our company uses artificial intelligence and machine learning (ML/AI) to support the efficiency of its operations, improve design and manufacturing processes, increase innovation, and discover drugs.
DTA5	Our company uses the Internet of Things through smart sensors and Internet-connected machines to improve quality control, analyze real-time data, and track shipments.

6. RESULTS

This section presents the major findings obtained from the secondary date of the current study. The results are organized systematically to provide a clear understanding of the data collected and analyzed.

6.1. Utilizing PLS-SEM and Bootstrapping Analysis for Robust Model Assessment

Structural Equation Modeling (SEM) is a versatile statistical technique used for testing and estimating complex relationships among variables. The two main approaches in SEM are Covariance-Based SEM (CB-SEM) and Partial Least Squares SEM (PLS-SEM) (Hair, Hult, Ringle, & Sarstedt, 2017). The primary use of CB-SEM is to confirm or reject the theory whereas PLS-SEM is to develop the theory in exploratory research. In addition, smart PLS also allows researchers to perform advanced mediation analysis in terms of theory development in different research fields (Hair Jr, Sarstedt, Hopkins, & Kuppelwieser, 2014).

This study utilized the SEM-PLS approach for analyzing the model. Table 2 demonstrates the mean and standard deviations of the study variables, discusses the results of statistical analysis, average variance extracted, and composite reliability.

Table 2. Descriptive Analysis, CA, CR, and AVE of study variables

Variables	items	Mean	Standard deviation	Cronbach's alpha (CA)	Composite reliability (CR)≥ 0.6	Average variance extracted (AVE)≥0.50
Decision- Making (DM)	DM1	4.15	0.681	0.864	0.908	0.713
	DM2	3.82	0.855			
	DM3	3.85	1.024			
	DM4	3.75	1.047			
	Total	3.8929	0.76675			
Motivators (MV)	MV1	3.77	0.954	0.890	0.924	0.753
	MV2	3.80	1.017			
	MV3	3.82	0.995			
	MV4	3.90	0.859			
	Total	3.8232	0.83040			
Information (INF)	INF1	3.53	1.170	0.924	0.946	0.815
	INF2	3.53	1.176			
	INF3	3.42	1.220			
	INF4	3.52	1.197			
	Total	3.5000	1.07519			
Structure (ST)	ST1	3.38	1.208	0.856	0.912	0.775
	ST2	3.44	1.172			
	ST3	3.87	1.318			
	ST4	3.93	0.882			
	Total	3.6542	0.88300			
Organizational DNA (ODNA)		3.7176	0.88883	0.806		
Economic Performance (EP)	EP1	4.42	0.625	0.862	0.916	0.784
	EP2	4.31	0.683			
	EP3	4.35	0.687			
	Total	4.3589	0.58944			
Social Performance (SCP)	SCP1	4.39	0.649	0.723	0.846	0.648
	SCP2	4.23	0.690			
	SCP3	4.24	0.725			
	Total	4.2869	0.55345			
Environmental Performance (EVP)	EVP1	4.11	0.769	0.815	0.890	0.730
	EVP2	4.13	0.769			
	EVP3	4.13	0.842			
	Total	4.1266	0.67696			
Sustainable Performance (SP)		4.2575	0.60662	0.792		
Digital Transformation strategy (DTS)	DTS1	4.26	0.694	0.893	0.921	0.701
	DTS2	4.05	0.801			
	DTS3	3.79	0.863			
	DTS4	3.83	1.021			
	Total	3.9852	0.64640			
Digital Technologies Application (DTA)	DTA1	3.87	0.983	0.811	0.889	0.727
	DTA2	3.93	0.974			
	DTA3	3.89	0.992			
	DTA4	3.92	0.968			
	DTA5	4.05	0.841			
	Total	3.9303	0.79677			
Industry 4.0 – enabled digital transformation (I4.0-DT)		3.9578	0.72158	0.767		

Table 2 shows that the level of ODNA dimensions is high with an arithmetic mean (3.7176). It indicates that the level of SP dimensions is high with an arithmetic mean (4.2575). Moreover, it suggests that the level of I4.0-DT dimensions is high among pharmaceutical manufacturing companies in Jordan by achieving an arithmetic mean (3.9578).

6.2. Internal Consistency Reliability

The reliability of the study tool means its ability to achieve consistent results when reapplied to the same individuals whether under the same or similar conditions. The stability level is considered good if the stability coefficient exceeds 0.70 (Sekaran & Bougie, 2016) which indicates the reliability of the tool and its effectiveness in accurately and continuously measuring the targeted phenomenon. As shown in Table 2, the results of measuring the stability of the various axes of the questionnaire show that the value of Cronbach's alpha coefficient for all indicates an acceptable degree of reliability for each of the fields. According to Hair Jr et al. (2014), some paragraphs did not achieve sufficient saturation, they were deleted because the average coefficient of variation was low. Accordingly, the final form of the study model is shown in Figure 2.

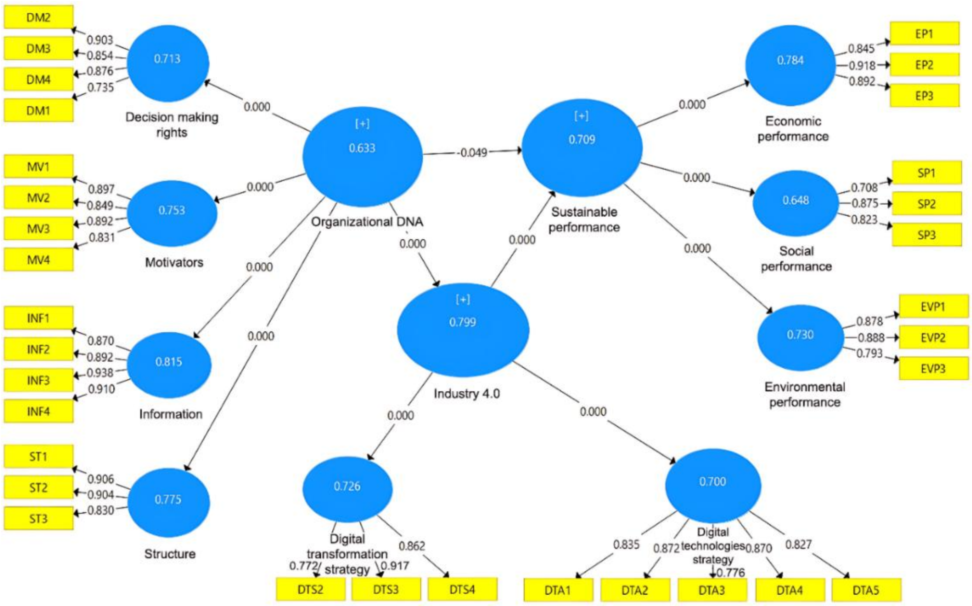

Figure 2. Factors loadings model after deleting the weak indicators.

6.3. Discriminant Validity

The Fornell-Larcker criterion was used to assess discriminant validity, according to the results presented in Table 3, discriminant validity was achieved because all the average variance extracted (AVE) values confirmed the discernment validity for the measurement instruments.

Table 3. Discriminant validity (Fornell-Larcker criterion)

Variables	DM	DTA	DTS	EP	EVP	INF	MV	SCP	ST
DM	0.845								
DTA	0.694	0.837							
DTS	0.927	0.561	0.853						
EP	0.210	0.193	0.241	0.885					
EVP	0.330	0.150	0.397	0.398	0.854				
INF	0.384	0.286	0.428	0.286	0.277	0.903			
MV	0.737	0.797	0.759	0.268	0.424	0.818	0.868		
SCP	0.302	0.041	0.460	0.621	0.683	0.315	0.389	0.805	
ST	0.284	0.079	0.333	0.262	0.247	0.859	0.264	0.720	0.880

6.4. Hypothesis Testing

This section presents the major findings that have been obtained from the secondary date of the current study. The results are organized systematically to provide a clear understanding of the data collected and analyzed. The hypotheses were tested by testing the path analysis using the Smart PLS software. Table 4 shows the test of the first hypothesis by examining the effect of ODNA on SP.

Table 4. Coefficient: ODNA on SP

Elements	B values	Mean	S. D	T-values	P- values	Result
ODNA -> SP	0.459	0.454	0.050	9.169	0.000	Accept
ODNA -> EP	0.343	0.348	0.046	7.405	0.000	Accept
ODNA -> EVP	0.406	0.406	0.054	7.543	0.000	Accept
ODNA -> SCP	0.430	0.432	0.049	8.846	0.000	Accept

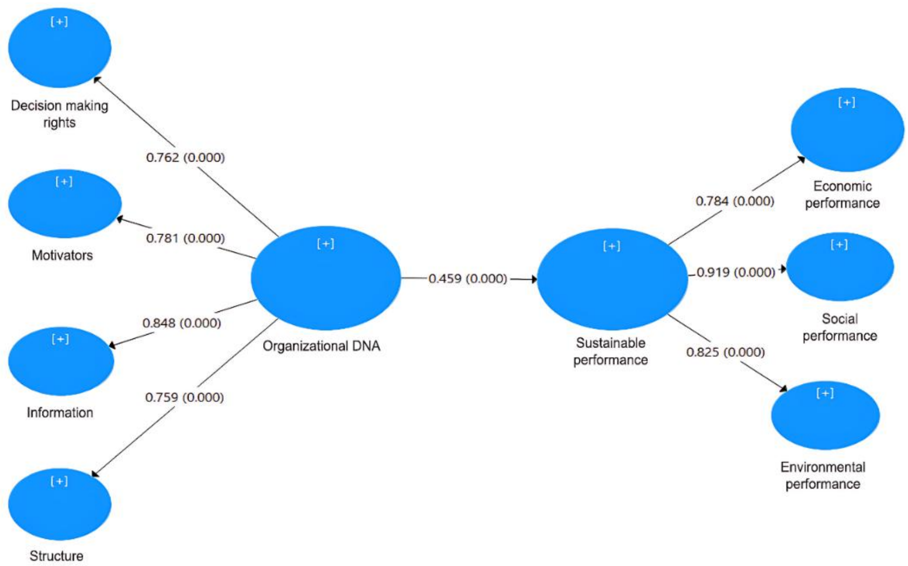

Figure 3. Path analysis test (t) for ODNA on SP.

As shown in Table 4 and Figure 3, for all the relationships tested, the p-values were less than 0.05. It turns out that ODNA has a positive and direct impact on SP. ODNA has a positive and direct effect on economic performance, social performance, and environmental performance.

The second hypothesis was tested which suggests a positive and significant effect of ODNA on I4.0-DT. The results were in Table 5 and Figure 4. ODNA has a direct and positive effect on I4.0-DT.

Table 5. Coefficient: ODNA on I4.0-DT

Elements	B value	Mean	S. D	T- value	P- value	Result
ODNA -> I4.0-DT	0.497	0.500	0.053	9.318	0.000	Accept

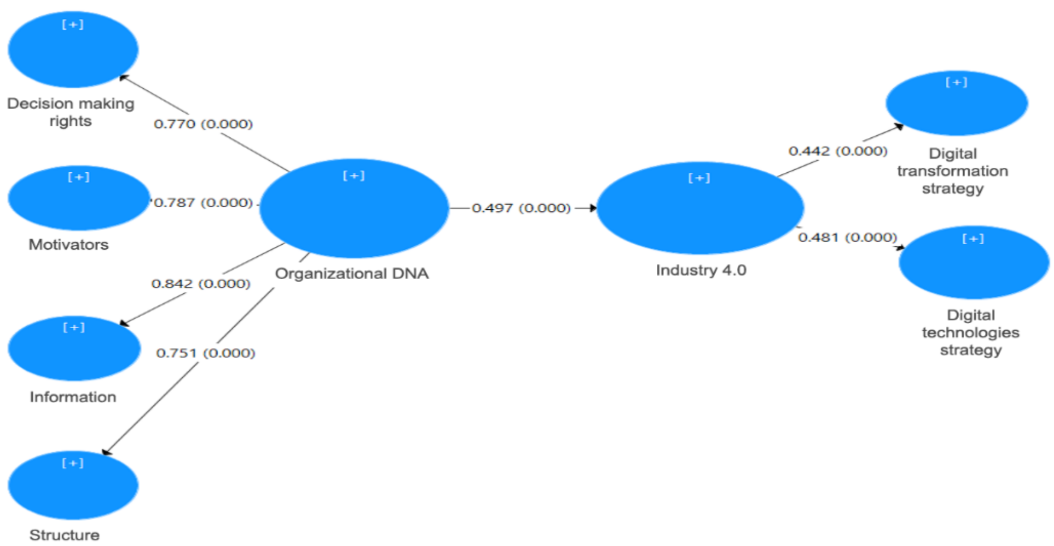

Figure 4. Path analysis test (t) for ODNA on I4.0-DT

The p-values appear to be less than 0.05 as shown in Table 5 and Figure 4. ODNA has a direct and positive effect on I4.0-DT.

The third hypothesis was tested which suggests a positive and significant effect of I4.0-DT on SP. As shown in Table 6 and Figure 5, it appears that the p-values were less than 0.05. It turns out that there is a positive and direct impact of I4.0-DT on SP. This means that the I4.0-DT such as AI, big data, and IoT help pharmaceutical manufacturing companies optimize SP by its dimensions (EP, SCP, and EVP).

Table 6. Coefficient: I4.0-DT on SP.

Elements	B value	Mean	S. D	T- value	P- value	Result
I4.0-DT -> SP	0.155	0.151	0.067	2.311	0.021	Accept

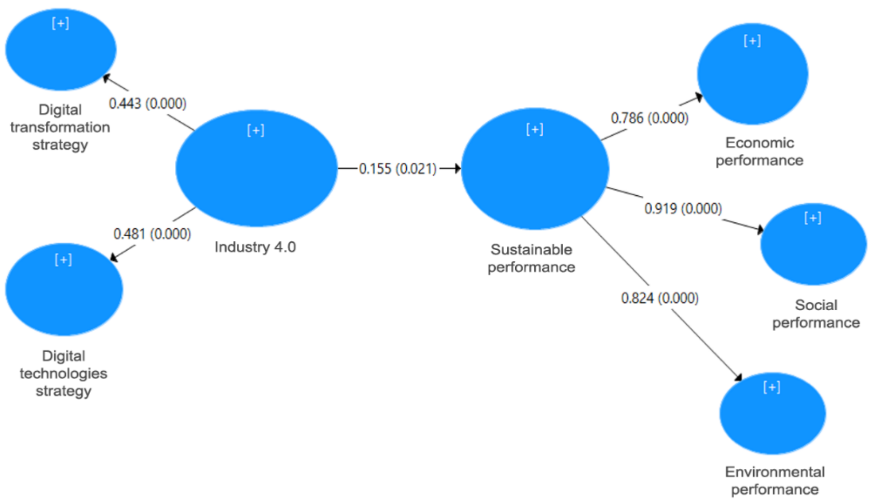

Figure 5. Path analysis test (t) for I4.0-DT on SP.

To test the fourth hypothesis, the study also used the critical path analysis in which ODNA affects SP through the mediating role of I4.0-DT. The results were as shown in Table 7 and Figure 6.

Table 7. Coefficient of the ODNA effect SP through the mediating role of I4.0-DT

Elements	B values	Mean	S. D	T- values	P- values	Result
ODNA -> SP	-0.210	-0.206	0.107	1.967	0.050	Accept
ODNA -> I4.0-DT	0.871	0.873	0.011	77.632	0.000	Accept
I4.0-DT-> SP	0.748	0.745	0.105	7.132	0.000	Accept
ODNA -> I4.0-DT-> SP	0.652	0.651	0.094	6.924	0.000	Accept

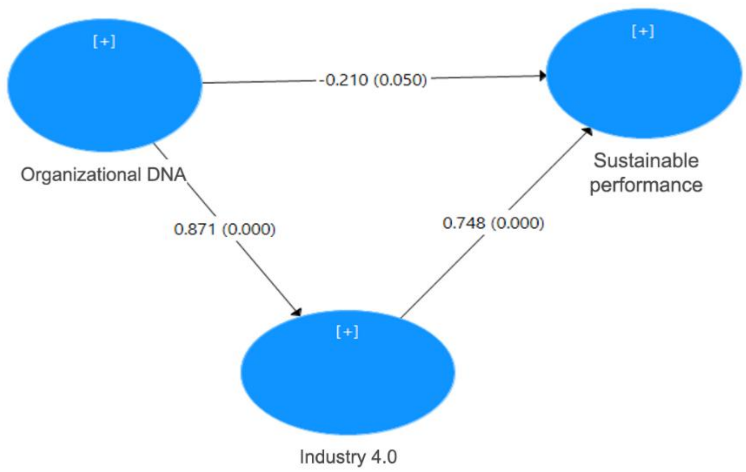

Figure 6. Path analysis test (t) for ODNA on SP through the mediating role of I4.0-DT

Table 8. Mediation analysis.

Relationship	Path A		Path B		Indirect effect			VAF	Confidence interval		Type of mediation P&H	Decision
	Path coeff.	t-value	Path coeff.	t-value	Path coeff.	SE	t-value		95% LL	95% UL		
ODNA -> I4.0-DT-> SP	-0.210	1.967	0.748	7.132	0.652	0.094	6.924	31.74%	0.471	0.823	Partial	Supported

In this case, it appears that for all the relationships tested, the p-values were less than 0.05. It turns out that I4.0-DT mediates a positive effect between ODNA and SP.

Table 8 shows the value of VAF which was greater than 20% and less than 80% which indicates the presence of partial mediation of I4.0-DT through the following equation (Hair Jr et al., 2014):

$$\text{Value Added Fraction (VAF)} = \frac{(PartialPressureofA) * (PartialPressureofB)}{(\text{PartialPressureofA}) * (\text{PartialPressureofB}) + (PartialpressureofC)}$$

VAF= (pa * Pb)/ (pa * Pb+ Pc).

VAF= (-0.210* 0.748)/ (-0.210* 0.748+ 0.652).

VAF= -0.15708/-0.49492.

VAF= 31.74%.

This study employed the bootstrapping method with 2,000 bootstrap samples to test the significance level of each mediating effect to confirm the findings regarding mediation type in Table 8. This section indicates the variance between two signals with the calculated Variance Accounted For (VAF). In other words, I4.0-DT plays a partial mediator effect in the relationship between ODNA and SP, interpreted as around 31.74% of the total effect.

7. DISCUSSION

The results showed a positive and significant relationship between ODNA and SP. This result is in line with previous research findings. Several research has shown that a well-organized ODNA, which includes knowledge, structures, motivations, and decision-making, produces a strong framework that drives SP in the social, economic, and environmental domains. According to several studies (e.g., (Alkhodary, 2023; Elsanhawy & Badway, 2023)), a line with the current findings, a study by Pakdelan et al. (2021) found that the unique cultural and structural components of ODNA impact achieving long-term outcomes. According to research by Elsakaan et al. (2021), the four dimensions of ODNA impact organizational excellence and performance. According to Nawahda et al. (2022) ODNA affects the achievement of pioneering performance in its aspects (planning, efficiency, risk-taking, creativity, innovation, and modernization). ODNA and innovation performance were found to be positively related by Rashid and Chalab (2007). These findings demonstrate that ODNA sustains the performance of organizations and helps them develop economically.

This relationship is of particular importance to Jordanian pharmaceutical companies due to the push from regulations and the market to implement sustainable practices which ODNA helps enable by aligning regulatory goals with sustainability. Companies with environmentally focused ODNA are more likely to implement green technologies, promote resource efficiency, and foster a culture of environmental stewardship aligning with the study's findings.

According to the results of the current study, having a strong ODNA is essential for companies to properly use Industry 4.0 technology and enjoy its benefits. This conclusion is supported by previous research which shows that employee readiness, organizational culture, structure, procedures, and routines are all important elements in adopting new technologies. According to studies (e.g., (Almatrodi & Skoumpopoulou, 2023; Gökçe & Pelit, 2023; Gupta et al., 2024)), ODNA places a high value on learning, adaptability, and innovation which helps explain the high employee engagement rates in digital transformation programs. Fahmi et al. (2023) argue that employee attitudes toward digital transformation are a critical concern in this process. Since digital transformation often requires a cultural shift toward data-driven decision-making and continuous process improvement, this component of ODNA is crucial. According to a study by Shah, Chen, and Woydt (2021), companies with strong organizational identities and flexible structures are better equipped to integrate digital technologies such as automation, IoT, and AI into their operations. According to Plekhanov, Franke, and Netland (2023), the success of DTS initiatives often depends on cultural and structural adjustments.

The study results also showed a positive relationship between I4.0-DT and SP. This means that the various technologies generated by Industry 4.0 such as physical cyber systems, smart technologies and systems such as advanced robotics and industrial automation systems, IT software and applications such as cloud computing and big data, artificial intelligence systems and the Internet of Things help pharmaceutical companies improve resource utilization, increase internal growth, increase efficiency and reduce production costs, all of which contribute to SP in its dimensions (EP, SCP and EVP). Many studies have concluded the pivotal role of adopting I4.0-DT in ensuring sustainability (e.g., (Bocean & Vărzaru, 2023; Chen & Hao, 2022; Grover, Tseng, & Pu, 2022; Ying & Jin, 2023)). This agrees with Su and Wu (2024) who concluded the positive impact of digital transformation on improving environmental, social, and governance performance.

Castro, Fernandez, and Colsa (2021) support this by highlighting the importance of digital technologies to achieving economic and sustainable development goals (SDGs). Su and Wu (2024) found that digital transformation reduces the marginal cost of research, development, and innovation which provides an incentive for organizations to take greater social responsibility. A study by Kopeinig et al. (2024) demonstrated that companies with Industry 4.0 technologies for environmental monitoring achieved significant reductions in energy use and waste generation that can contribute to environmental sustainability in the manufacturing sector.

Based on the results, it was found that ODNA is a major facilitator of SP through the mediating function of I4.0-DT. This is consistent with the findings of several studies that found that companies that successfully embed sustainability goals and initiatives into their DNA, operations and strategies had a significant impact on their sustainability performance such as the study of Fonseca (2018), Jones et al. (2021), Alojail and Khan (2023) and Chen et al. (2024). According to the results, I4.0-DT mediates the relationship between ODNA and SP which means that the successful and effective integration of ODNA with sustainability initiatives and goals to achieve sustainable performance requires moving towards digital transformation supported by Industry 4.0 by employing a wide range of advanced digital technologies in the organization's activities and processes which is in line with research findings (e.g., (Alojail & Khan, 2023; Chen et al., 2024; Fonseca, 2018; Jones et al., 2021)). This means that I4.0-DT is a critical tool that contributes to making the goals a reality. Studies highlight that without the alignment between ODNA and advanced technologies supported by Industry 4.0, increased adaptability, data-driven decision-making, and continuous learning, digital transformation alone may not be sufficient to achieve SP. This is consistent with recent studies by Ghobakhloo and Iranmanesh (2021), Yaqub and Alsabban (2023) and Su and Wu (2024).

8. CONCLUSION

This study provides significant insights into the complicated relationships between organizational DNA, Industry 4.0-enabled digital transformation, and sustainable performance within Jordan's pharmaceutical manufacturing sector.

8.1. Study Contributions

The study shows how ODNA directly affects different dimensions of SP, including economic, environmental, and social aspects. This study enriches the theoretical understanding of the strategic importance of ODNA for sustainability in manufacturing by detailing how distinctive ODNA dimensions (decision-making rights, motivators, information, and structure) boost the ability to adapt to sustainability goals. In addition, this research emphasizes I4.0-DT as a partial mediator between ODNA and SP demonstrating that while ODNA is important, the use of digital transformation tools significantly increases its impact on sustainability.

This perspective provides a useful framework for scholars and researchers studying the links between distinctive organizational characteristics and technology in sustainability. This work advances theoretical understanding of the strategic importance of ODNA for sustainability. The report provides a useful starting point for pharmaceutical companies seeking to enhance their strategic operations through well-defined ODNA. Companies can better integrate sustainable practices into their strategic objectives by emphasizing values and activities that improve economic, social, and environmental performance. ODNA is viewed as a key driver of sustainability in this work, expanding theoretical knowledge on how organizational attributes can improve sustainability, especially in complex and regulated industries such as the pharmaceutical sector.

8.2. Practical Implications

Companies can use these findings to justify investments in I4.0-DT (such as DTS and DTA) to strengthen ODNA's impact on SP. This can be achieved by cultivating a culture of continuous learning, innovation, and adaptability, which will enhance the effectiveness of their digital transformation initiatives. This approach can improve efficiency, reduce resource waste, and meet regulatory requirements which is important in a resource-concentrated industry such as pharmaceutical companies.

Based on the results, decision-makers in pharmaceutical companies should adopt clear cultural values and norms from the chromosomes that will be a way of their companies' lifestyle which contributes to achieving SP, and commit to incorporating modern technologies stemming from Industry 4.0 into their strategies and activities, and take the lead in the digital transformation journey to become smart companies with a sustainable technical and knowledge workplace that supports creativity and innovation. By making their culture and ODNA based on integrating modern digital technologies into the ideas, values and norms of their company members, and aligning them with sustainability goals, by making decisions based on data and digital tools, promoting continuous learning, integrating digital systems and technologies into all activities of their companies, setting regulatory instructions for the use of artificial intelligence and expert systems, restructuring their companies in line with advanced technologies, making the necessary changes and preparing the training and awareness programs to enable employees to use advanced digital technologies, motivating employees and involving them in decision-making, which allows them to remain in the markets and achieve sustainable competitive advantages.

Hence, focusing on the alignment between SP and ODNA with leveraging I4.0-DT tools offers pharmaceutical companies a way to transform sustainability from a compliance issue to a competitive differentiator that can enhance public perception and customer loyalty.

8.3. Study Limitations

Several limitations must be acknowledged while this study contributes valuable insights into the relationships between ODNA, I4.0-DT, and SP in the Jordanian pharmaceutical manufacturing sector. The sample was drawn exclusively from the Jordanian pharmaceutical sector although the study achieved an 82% response rate with 287 usable questionnaires. This limits the generalizability of the findings to other industries or regions, where the dynamics of the relationships may vary significantly across different contexts. The study used a cross-sectional design where data were depicted at a single point in time. This approach limits the ability to conclude causal relationships and understand the dynamics of relationships over time. Longitudinal analyses could provide deeper insights into how these variables relate to each other. Using data provided by managers themselves may introduce biases including overestimation of measures. Future research may include third-party assessments or more objective performance measures.

There are some limitations and delimitations to this study. To focus more on such pivotal variables as ODNA and I4.0-DT, the research ignores other important factors that affect SP such as innovation, governance, environmental changes, total quality management, and some organizational aspects. A broader focus could lead to a more comprehensive understanding of how companies operating in the pharmaceutical manufacturing sector sustain their performance. Similarly, the approach adopted by the current study ignored the complementary components of ODNA and I4.0-DT such as the leadership style, workplace diversity, work climate, the extent of the supportive work environment, the extent of employee empowerment, involvement and engagement, and decision-making mechanisms.

8.4. Study Recommendations for Future Research

For future studies, we recommend applying the examination of how ODNA and I4.0-DT affect SP to a range of different cultural contexts, sectors, and diverse companies whether private or governmental, to understand the causal and correlational relationships between these variables. Using a mixed approach that combines quantitative and qualitative data could provide greater depth to the current findings. A deeper look could also be taken at other variables that influence the dynamics of the relationship between ODNA and SP, including leadership type, employee engagement and involvement, leadership style, diversity, environmental changes and technological innovation. Research should also identify the challenges and barriers that pharmaceutical companies face when implementing I4.0-DT to provide practical recommendations and solutions for companies hoping to sustain their long-term success. The failure rates of digital transformations are often high while longitudinal studies may be successful in achieving this as well.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
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