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Industry 4.0 Framework for Sustainable Manufacturing Sector in Jordanian Rural Areas

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ABSTRACT

Developing countries are facing increasing pressure to remain competitive in the global economy and markets. Industry 4.0 provides improved concepts to enhance manufacturing companies' productivity, efficiency, and sustainability. This study investigates how the Industry 4.0 factors influence the sustainability strategies of manufacturing companies in rural areas in Jordan taking into consideration the adoption and barriers of entry to Industry 4.0. Our study modifies the current model factors of technological, organizational, and environmental context by introducing Industry 4.0 adoption as a moderator, and barriers to adopting Industry 4.0 as a mediator to the sustainability outcomes. The results confirm that the three factors, the technological factor, the organizational factor, and the environmental factor, had a positive impact on the sustainability of rural manufactories in Jordan. Results show a negative moderating effect of Industry 4.0 adoption on the relationship between the TOE framework factors and sustainability, it also shows a partial mediating role of barriers for using Industry 4.0 on the relationship between the TOE framework factors and sustainability. This study fills the gap in the scientific literature to better understand how developing countries can take advantage of Industry 4.0 concepts and increase their competitiveness in the domestic and international economies.

1. INTRODUCTION

The world is currently under the influence of a wave of the most cutting-edge technology transformation known as the Fourth Industrial Revolution, or Industry 4.0 [1]. Industry 4.0 opens the door to a technical and social revolution that would drastically alter the world. During the past decade, the academic and manufacturing world debated Industry 4.0 systems and numerous projects to characterize and develop such systems [2]. Additionally, the Industry 4.0 strategy, if fully incorporated, will make it possible to build a world where everything is seamlessly and continuously interconnected [3]. The acquisitions of Industry 4.0 achieved a high of 132 in 2021 [4].

Meanwhile, shifting consumer preferences, unstable market conditions, sustainability concerns, and poor economic returns have forced several industries to reexamine their current organizational structures. Consequently, various industries are currently searching for ways to implement new technology that can meet sustainability standards [5]. Also, the spread of industrialization into urban areas, negative economic profits, and increasing consumer demands for environmentally friendly products have combined to force companies to reconsider their organizational structures and practices to create sustainable approaches in their operations [5]. There are expectations that the encroachment of industry into rural areas to significantly increase in the next few decades, which means there is a need for roadmaps of sustainable development strategies, powered by effective management decision processes and implementations. Worldwide, the cost of living and housing in urban areas has been increasing steadily and this trend and expectation is for these costs to continue [6]. In recent times, rural areas in Jordan have shown a growing interest in sustainability, and local authorities are doing their best to manage and protect the environment in the knowledge that, for countries to have sustainable industries [7], it is crucial to direct resources toward developing the necessary infrastructure, including energy and environment, ecological planning, and water resource management, that supports sustainable development initiatives [8]. In addition, Industry 4.0 can potentially increase production and effectiveness significantly and might increase the sustainability of the present industrial structure [9].

At this time, there is no existing research on the factors influencing sustainable manufacturing and how Industry 4.0 adoption would affect the relationship based on the technology-organization-environment (TOE) context of Jordanian rural areas. The current study uses the TOE framework to investigate the crucial factors affecting sustainable manufacturing in rural areas of Jordan. The elements of TOE include technological, organizational, and environmental contexts [10-17]. Thus, the current study aims to examine the factors that affect sustainable manufacturing, in addition to investigating the role of Industry 4.0 as a moderator and how it would impact the relationships between the TOE framework and sustainable manufacturing in

Jordanian rural areas, by answering the following questions:

RQ.1: Which factors influence sustainable manufacturing projects in Jordanian rural areas?

RQ.2: To what extent does Industry 4.0 adoption moderate the relationship between technological-organizational-environmental factors and sustainable manufacturing in Jordanian rural areas?

RQ.3: To what extent do barriers to using Industry 4.0 mediate the relationship between Industry 4.0 adoption and sustainable manufacturing in Jordanian rural areas?

RQ.4: To what extent does Industry 4.0 adoption impact sustainable manufacturing in Jordanian rural areas?

2. SIGNIFICANCE OF THE STUDY

To the best of the researchers' knowledge, there is no research pertaining to Jordan on this subject. Prior research on TOE and sustainable manufacturing was carried out in nations like Malaysia, which has significant success in implementing Industry 4.0, suggest conducting the same research in other nations and cultures [10-12]. As a result, the present study performed this first-time research on Jordan. In addition, past studies investigated the relationship between the TOE and sustainable manufacturing mediated by Industry 4.0 adoption [10-12, 17]. The current study investigated the relationship between TOE and sustainability manufacturing, examining Industry 4.0 adoption as a moderator for the first time in that context. Moreover, the current study aims to educate the general population on the value of developing sustainable initiatives to build contemporary communities and make rural areas more livable and conducive to employment. Furthermore, this study calls for additional research on the significance of creating sustainable instruments to address rural area concerns. Rural areas face several difficulties, especially in terms of infrastructure [18]. Therefore, this study explores the benefits of integrating sustainable initiatives with Industry 4.0 and how to take advantage of these benefits to address issues including resource consumption, improving energy efficiency, and organizing rural production [19-21].

3. OBJECTIVES AND AIM OF THE STUDY

The current study aims to examine the factors that affect sustainable manufacturing and to investigate the role of Industry 4.0 as a moderator and how it would impact the relationships between the TOE framework and sustainable manufacturing in Jordanian rural areas. The primary objective of the current study is to define and investigate the most significant factors influencing sustainable manufacturing in Jordanian rural areas. The sub objectives are:

(1) To examine the influence of technological-organizational-environmental factors on sustainable manufacturing in Jordanian rural areas.

(2) To examine the influence of Industry 4.0 adoption as a moderator between technological-organizational-environmental factors and sustainable manufacturing in Jordanian rural areas.

(3) To examine the influence of Industry 4.0 adoption on sustainable manufacturing in Jordanian rural areas.

(4) To examine the influence of Industry 4.0 adoption on sustainable manufacturing mediated by barriers to using Industry 4.0 in Jordanian rural areas.

4. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

4.1 TOE framework

In 1990, Tornatzky and Fleischer [22] introduced the technological-organizational-environmental (TOE) framework in 1990, and initially used to describe technical development, which is the process of implementing new technologies. The TOE framework has a solid academic foundation and strong empirical basis several studies applied the diffusion of technological advancements [10-12, 19]. In addition, Oliveira and Martins [20] supports that the TOE framework has strong conceptual and practical facts. Mahakittikun et al. [21] indicate that previous research support that the TOE framework employs the approach to specify and forecast variables affecting the adoption of different technologies at the corporate level. The TOE model outlines three crucial factors that have an impact on the adoption and implementation of technology, namely technological, organizational, and environmental factors. The research uses all three factors since they are suitable and were heavily weighted in the literature when determining an organization's readiness. Also, a significant number of previous studies in the wider literature have studied the TOE framework [10-17]. Likewise, several prior studies used TOE to understand sustainable manufacturing [10-12, 17]. Thus, the present study adopted the conceptual model of TOE, demonstrated in Figure 1.

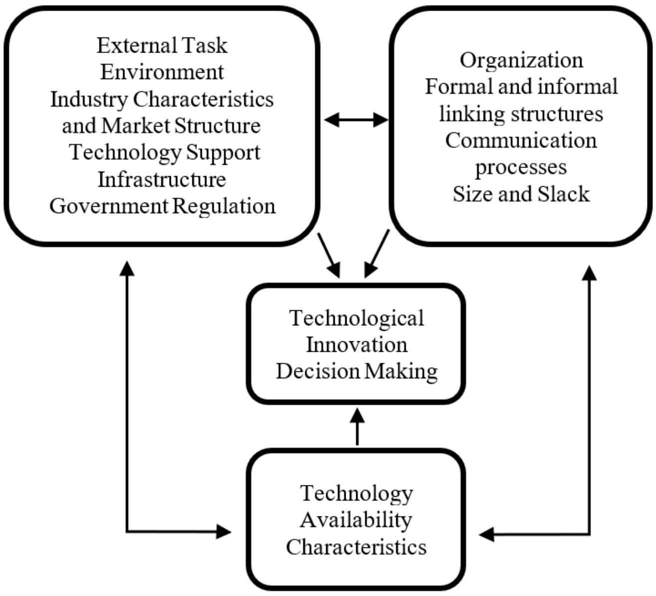

Figure 1. The conceptual model of TOE [22]

Past studies investigated the relationship between TOE and sustainable manufacturing mediated by Industry 4.0 adoption [10-12, 17]. The current study investigated the relationship between TOE and sustainable manufacturing, and they examined the Industry 4.0 adoption as a moderator for the first time in that context. Also, the present study examined the relationship between Industry 4.0 adoption and sustainable manufacturing mediated by barriers to using Industry 4.0. Therefore, the current study confirms the research model seen in Figure 2 [10-13, 15-17, 23].

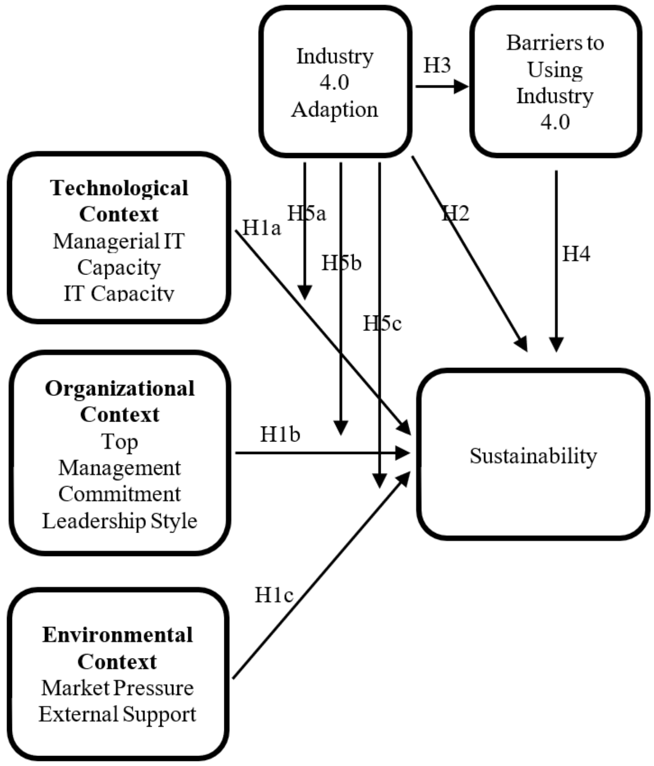

Figure 2. The research model. Industry 4.0 Framework for sustainable manufacturing sector in Jordanian Rural Areas

4.2 Technological context

Technological context refers to both external and internal innovations that the company finds valuable [24]. Technological context definition is the factors that affect how individuals, organizations, and industries accept innovations on the external and internal levels [25]. Additionally, technological factors focus on the technology's features, interoperability, and compatibility with the existing infrastructure [14]. Technological context described as being the primary determinant of how new technological advancements are adopted [21]. Furthermore, most of the related prior studies show that management IT capability and IT capability are the most critical factors that influence sustainable manufacturing [10, 12, 17]. Thus, to test the influence of the technological context on sustainable manufacturing, in this study, management IT capability and IT capability availability were used as indicators of the success of Industry 4.0 deployment in achieving sustainability goals. Thus, the first hypothesis is that:

H1a: The technological context has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.

4.2.1 Managerial IT capabilities

Managerial IT capabilities are intangible resources that serve as the foundation for a company's IT capabilities, which encapsulate training, practice, and employee perception about the improvement of one's technological and managerial experiences and skills [26]. Moreover, IT infrastructure is a crucial factor in adopting Industry 4.0 [17]. In addition, a study found that there is a positive relationship between managerial IT and sustainability [27]. Most of the related studies have confirmed that there is a significant positive relationship between IT infrastructure and sustainability manufacturing [12, 17]. Thus, the sub hypothesis of technological context would be that:

H1a1: Managerial IT capabilities have a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.

4.2.2 IT capabilities

Capabilities describe a company's ability to use organizational procedures to employ a group of resources to carry out tasks or activities. IT capabilities idea was established in 1996 and it were defined as a firm's capacity to use IT to achieve strategic goals [28]. IT capabilities can be summed up as the ability to administer a company's electronic information system to plan, direct, and carry out inter-firm operations [26]. A study on the impact of adopting Industry 4.0 on sustainability, found that there is a positive relationship between IT capabilities and sustainability [10]. Thus, the sub hypothesis of technological context would be that:

H1a2: IT capabilities *have a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.*

4.3 Organizational context

Organizational context definition is the characteristics and assets that a firm possesses, such as the organization's infrastructure for employing the structures, top-level management support, and business size [13]. Organizational context concentrates on descriptive metrics, such as the accessibility and skill with which resources are used, company scope, company age, sociological factors, cultural norms, functional configurations, sources of information and methods of communication, centralization of authority, and top management opinions [25]. Moreover, implementing sustainable approaches in organizations requires strong management backing. To analyze the influence of the organizational context on sustainable manufacturing, the existing study adopted top management commitment and leadership style as indicators of the effective execution of Industry 4.0 to achieve sustainability goals [29]. Thus, it is hypothesized that:

H1b: The organizational context has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.

4.3.1 Top management commitment

Top management commitment is a critical aspect of sustainability [17] since top managers have a significant impact on how corporate operations are planned and play a leading role in creating sustainable business models, strategies, and policies. In addition, top management commitment has a favorable impact on green administrative ideas and processes [30]. Top management commitment is one of the essential qualities for sustainable operations [31]. Senior management's capabilities and accountability are highly influential on environmentally friendly practices in the manufacturing sector [12]. Moreover, a study about green adoption revealed that there is a positive relationship between top management commitment and the adoption of green business practices [32]. Additionally, previous studies have demonstrated that there is a significant positive relationship between top management commitment and sustainable manufacturing [17, 12]. So, the sub hypothesis of organizational context is that:

H1b1: Top management commitment has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.

4.3.2 Leadership style

Leadership style refers to the type of behavior displayed by those in charge of a company. That style varies depending on the perceptions, expertise, and talents of the leaders. One of the most critical factors for achieving sustainability is leadership style [33]. A study mentioned that a positive, strong leadership style is a necessity for turning a business concept into a viable business model, which generates sustained goods and services [34]. Additionally, the same study highlighted how transformational leadership, which addresses ecological and socioeconomic challenges, is essential for sustainable productivity [34]. Furthermore, leadership style and the knowledge possessed by leaders have a significant impact on green performance [35]. Similarly, prior studies have shown that there is a significant positive relationship between leadership style and sustainability [36]. Hence, the sub hypothesis of organizational context is that:

H1b2: Leadership style has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.

4.4 Environmental context

Environmental context as discussed by earlier scholars refers to the features of the environment in which an organization does its business, including market variables, rivals, government rules, and other factors that may have an impact on whatever decisions an organization makes regarding the use of technology [37]. The environmental context has been found to be a significant force behind sustainable practices in various contexts [38]. Likewise, most of the previous studies show that there is a relationship between environmental context and sustainability [10, 39]. Besides, previous research show that external support and market pressure are the most critical factors that influence sustainability manufacturing [10, 11]. Additionally, to examine the effect of the environmental context on sustainable manufacturing, the current study adopted external support and market pressure as indicators for the evaluation of the effective execution of Industry 4.0 to achieve sustainability goals. Thus, it is hypothesized that:

H1c: The environmental context has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.

4.4.1 Market pressure

Pressure to adopt sustainability is increased when the stakeholders, including consumers, competitors, and suppliers, are included in a business strategy [11]. The adoption of new technologies was closely tied to market pressure as organizations use Industry 4.0 technologies to meet sustainable criteria [40]. One of the primary forces influencing the supply chain's decision to integrate sustainability is competition [41]. Furthermore, a study show that market pressure is the primary factor influencing the sustainability of business practices [42]. Additionally, another research found that there is a relationship between market pressure and sustainability [43]. Thus, the present research sub hypothesis for environmental context was formulated:

H1c1: Market pressure has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.

4.4.2 External support

External support is assistance provided during the innovation diffusion process, which positively affects the rate of technology acceptance [44]. Moreover, according to the literature currently available, external support may be essential for achieving sustainability. Also, prior studies support that companies might achieve sustainable measures with the help of proper support from external backers [11, 45]. A previous study about Industry 4.0 and sustainability, found that external support positively impacts sustainability [11], a view that was shared by numerous previous studies [10]. Based on the above explanation, the current study hypothesis was formulated:

H1c2: External support has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.

4.5 Industry 4.0 adoption

Initially, Industry 4.0 was envisioned as the fourth revolution to hit the manufacturing sector. However, over recent years, this idea has changed [46]. Also, in the modern era, Industry 4.0 refers to the complete digitalization of the consumer and industrial sectors, from the adoption of smart manufacturing to the digitization of all distribution channels [47]. Furthermore, the literature show that technological context positively affects Industry 4.0 adoption [10, 12-14, 17]. Industry 4.0 adoption is explained technologically by the availability of IT resources and IT info structure [12]. Previous research found that IT resources and IT infostructure positively affect Industry 4.0 adoption [10, 12, 17]. Another research stated that prior to integrating new technology, an organization must be ready in terms of its human, financial, and technological skills [48]. Numerous past studies show that there is a relationship between organizational context and Industry 4.0 adoption [13]. Since top management has a hefty impact on the company's financial and strategic direction, the adoption of Industry 4.0 needs the participation and backing of top-level management [49]. Top management commitment and leadership management are critical factors for a manufacturer to adopt Industry 4.0, and they recommend future studies to evaluate their effect on sustainable manufacturing [50]. Past studies support that there is a relationship between leadership style and Industry 4.0 adoption [51], and that top management commitment has a significant impact on Industry 4.0 adoption [12, 17]. Furthermore, past research has emphasized the role of environmental context in the adoption of Industry 4.0 because these studies have emphasized the value of the environmental element [13, 52]. Also, past studies found that the environmental context has a positive impact on Industry 4.0 adoption [10, 13, 39]. Another study show that the market pursues increased radiance for companies to adopt Industry 4.0 [53]. The literature review also demonstrated that there is a relationship between market pursuits and Industry 4.0 adoption [10] and that external support positively affects Industry 4.0 adoption [10, 11]. Therefore, the hypothesis and sub hypothesis are:

H2: Industry 4.0 adoption has a significant positive influence on sustainability in manufacturing in Jordanian rural areas.

H5a: Technological context has a significant positive *influence on sustainability moderated by Industry 4.0 adoption in manufacturing in Jordanian rural areas.*

H5b: Organizational context has a significant positive influence on sustainability moderated by Industry 4.0 adoption in manufacturing in Jordanian rural areas.

H5c: Environmental context has a significant positive influence on sustainability moderated by Industry 4.0 adoption in manufacturing in Jordanian rural areas.

4.6 Barriers to Industry 4.0 adoption

There are numerous obstacles to concentrating on Industry 4.0. Perceived obstacles can directly influence decisions to not invest in innovative technologies. For example, a company may decide not to move on opportunities associated with brand-new types of order needs owing to a lack of expertise and knowledge [54]. Also, organizations may face obstacles when they attempt to adopt Industry 4.0, such as an unclear understanding of the benefits of IoT, job interruptions, and change request processes [55]. Moreover, many decision-makers find it difficult to visualize and comprehend Industry 4.0, how their company would evolve, and how Industry 4.0 will benefit them. The adoption of information systems is limited by these knowledge gaps [56]. Hence, it is hypothesized that:

H4: Barriers to Industry 4.0 negatively influence Industry 4.0 adoption in manufacturing in Jordanian rural areas.

4.7 Barriers to using Industry 4.0 for sustainability

All sustainability elements can be supported by Industry 4.0, and in this regard, they identify prospects for industrial growth. In addition, Industry 4.0 is anticipated to have positive effects on sustainability in the following areas: increased efficiency, flexibility, waste minimization, power utilization, excess supply, automation, stakeholders' interaction, and improving the quality of the workplace while minimizing routine jobs [57]. On the other hand, all types of businesses have a global challenge in implementing Industry 4.0 innovations, techniques, and sustainability manufacturing in both supply chain and operations management [58]. Similarly, to create a sustainable corporate, Industry 4.0 involves many features and barriers [55]. Consequently, it is hypothesized that:

H3: Barriers to Industry 4.0 negatively mediate the relationship between the adoption of Industry 4.0 and sustainability of manufacturing in Jordanian rural areas.

After examining the previous studies and taking their recommendations into consideration, the current study hypotheses are summarized in Table 1 [10-17, 58].

Table 1. Research hypotheses

H1a	The technological context has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H1a1	Managerial IT capabilities have a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H1a2	IT capabilities have a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H1b	The organizational context has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H1b1	Top management commitment has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H1b2	Leadership style has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H1c	The environmental context has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H1c1	Market pressure has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H1c2	External support has a significant positive influence on the sustainability of manufacturing in Jordanian rural areas.
H2	Industry 4.0 adoption has a significant positive influence on sustainability in manufacturing in Jordanian rural areas.
H3	Barriers to Industry 4.0 negatively mediate the relationship between the adoption of Industry 4.0 and sustainability of manufacturing in Jordanian rural areas.
H4	Barriers to Industry 4.0 negatively influence Industry 4.0 adoption in manufacturing in Jordanian rural areas.
H5a	Technological context has a significant positive influence on sustainability moderated by Industry 4.0 adoption in manufacturing in Jordanian rural areas.
H5b	Organizational context has a significant positive influence on sustainability moderated by Industry 4.0 adoption in manufacturing in Jordanian rural areas.
H5c	Environmental context has a significant positive influence on sustainability moderated by Industry 4.0 adoption in manufacturing in Jordanian rural areas.

5. METHODOLOGY

5.1 Participants

The research was based on the technology-organization-environment (TOE) framework, which is used to identify the critical factors for the adoption of technological models within organizations [11]. The main objective of the current research was to investigate the factors impacting the Industry 4.0 framework application in the sustainable manufacturing sector in Jordanian rural areas, besides proposing optimal strategies, according to the target context, in applying this framework for building a sustainable manufacturing structure in rural areas in Jordan.

Employees in Jordanian manufactories located in rural areas represented the current research population. Bryman [59] indicated the possibility of applying the sampling method when dealing with large or unlimited populations to mitigate the temporal and spatial constraints of administrative research procedures [59]. He also clarified that the appropriate sample size for analysis is at least 385 responses with a response rate exceeding 50% to fulfil the sampling adequacy [59]. Therefore, the research instrument was distributed to a purposive sample consisting of 650 managers at the senior and middle managerial levels of Jordanian manufactories in rural areas. Of the 467 responses retrieved, 65 responses contained answers that did not fit the requirements of the model used in data analysis. Hence, the data used in the statistical analysis of the research was extracted from 402 responses, which in turn represented a response rate of 61.8%.

The analytical profile of the sample depicted that 44.0% of the respondents fell within the age group "41-50", followed by 38.3% who belonged to the group "31-40", then 10.7%

belonged to the group ">50", and finally 7.0% of the respondents belong to the age group "18-30". Most of the respondents were males (77.9%) versus 22.1% females. Moreover, it was found that respondents who held a bachelor's degree ranked first at 60.4%, followed by 29.4% of those who held degrees lower than a bachelor's, then 8.7% of those who held a master's degree, and 1.5% of those who held a PhD degree. In terms of governorates, Jerash had the highest response rate (12.2%) among the targeted rural areas, while Zarqa had the lowest response rate (4.7%).

5.2 Measures

The survey was applied for data collection related to the research based on a developed questionnaire. This questionnaire was formed electorally by Google Forms and was approved by the Institutional Review Board (IRB) of Princess Sumaya University for Technology (PSUT) with Protocol No. 2022-0008 after being supported to have an acceptable level of content validity. The questionnaire items were originally in English; thus, they were translated into Arabic to achieve the appropriate level of respondents' comprehension. After completing the data collection, the items were back translated to the English language by language specialists. This questionnaire included a cover letter to clarify its goals and obligations regarding privacy criteria. It included five sections, the first of which was devoted to control variables which reported the sample demographic information (age, gender, education, and governorate). The remaining sections were devoted to the major research variables and these items were measured by a five-point Likert scale.

TOE framework factors: The exogenous variables in this research that occupied the second section of the questionnaire included 28 items. The three main factors of TOE framework contained first-order variables. The technological factor was measured through managerial IT capability, e.g., “I understand the organization’s policies and procedures toward Industry 4.0”, and technical IT capability, e.g., “I engage in developing excellent IT applications”. The organizational factor was measured using leadership style, e.g., “We formulate a comprehensive vision for the future of Industry 4.0”, and top management commitment, e.g., “Our organization deploys Industry 4.0-related initiatives to whole employees”. As for the environmental factor, it was measured by market pressure, e.g., “Our customers are obliging us to adopt Industry 4.0”, and external support, e.g., “Adopting Industry 4.0 would help us to improve competitive capabilities to cope with rivals”.

Industrial 4.0 adoption: This is the moderated variable in the research, and the third section was allocated to its items. The questions for this section were developed through recommendations of (Masood and Egger [14] and Reza et al. [17]). Industry 4.0 adoption represented a first-order construct measured with seven items, e.g., “We have advanced algorithms to deal with problems and rapid changes in the business environment”.

Barriers for using Industry 4.0: This is the mediated variable in the hypothetical relationships of the research variables, and the fourth section was devoted to it. The items of this section were developed with the help of previous studies [58]. This variable was a first-order research construct measured using seven items, e.g., “Understanding the interplay gap between technology and humans is a restriction for applying Industry 4.0”.

Sustainability: It was the endogenous variable of the research, and the fifth and final section was devoted to its dimensions. This variable was a second-order construct fragmented into three first-order constructs. Economic sustainability was measured through four items, e.g., “We achieve economic sustainability by reducing the cost of purchasing materials”. Environmental sustainability was measured with four items, e.g., “We achieve environmental sustainability by reducing harmful air emissions”. Social sustainability was measured using four items, e.g., “We achieve social sustainability by emphasizing a fair wage policy”.

5.3 Analytical strategy

This research was a quantitative cross-sectional study targeting manufactories in rural areas in Jordan. The descriptive-analytical approach is the most appropriate in such studies, as the descriptive approach provides information about the respondents’ attitudes about the variables, while the analytical approach facilitates the determination of the cause-effect relationship among the research variables [60]. Therefore, means and standard deviations were used as statistical methods to achieve the objectives of the descriptive approach. Moreover, the research hypotheses were tested using several statistical methods, where the direct effect between TOE framework factors and sustainability was tested through multiple linear regression analysis using SPSS software. The moderated effect of Industry 4.0 adoption on the relationship between TOE framework factors and sustainability was examined by hierarchical regression analysis. As for the mediated role of barriers for using Industry 4.0 in the relationship between Industry 4.0 adoption and sustainability, it was estimated using path analysis through AMOS software.

6. FINDINGS

6.1 Measurement models assessment

Examining the research hypotheses required a series of pre-tests to verify the compatibility between the measurement model and the collected data. The confirmatory factor analysis (CFA) was recently considered one of the major advanced techniques used for determining the validity and reliability of the research instrument [61]. This technique was used in the current research to verify the convergent validity and the composite reliability of the measurement model, where Table 2 reports the results achieved from these tests.

Table 2. Convergent validity and reliability

Variable	Items	Loadings	AVE	C.R
Managerial IT Capability	MITC1	0.816	0.656	0.884
	MITC2	0.815		
	MITC3	0.821		
	MITC4	0.788		
Technical IT Capability	TITC1	0.784	0.622	0.868
	TITC2	0.755		
	TITC3	0.790		
	TITC4	0.824		
Leadership Style	LEST1	0.842	0.728	0.949
	LEST2	0.839		
	LEST3	0.851		
	LEST4	0.869		

	LEST5	0.855		
	LEST6	0.835		
	LEST7	0.883		
Top Management Commitment	TMCO1	0.854	0.731	0.942
	TMCO2	0.843		
	TMCO3	0.851		
	TMCO4	0.857		
	TMCO5	0.851		
	TMCO6	0.873		
Market Pressure	MAPR1	0.837	0.690	0.899
	MAPR2	0.832		
	MAPR3	0.805		
	MAPR4	0.848		
External Support	EXSU1	0.820	0.673	0.860
	EXSU2	0.812		
	EXSU3	0.828		
Industry 4.0 Adoption	INAD1	0.785	0.657	0.930
	INAD2	0.809		
	INAD3	0.812		
	INAD4	0.834		
	INAD5	0.806		
	INAD6	0.825		
	INAD7	0.801		
Barriers for Using Industry 4.0	BUIN1	0.750	0.577	0.905
	BUIN2	0.745		
	BUIN3	0.752		
	BUIN4	0.760		
	BUIN5	0.764		
	BUIN6	0.755		
	BUIN7	0.789		
Economic Sustainability	ECSU1	0.791	0.589	0.851
	ECSU2	0.767		
	ECSU3	0.760		
	ECSU4	0.751		
Environmental Sustainability	ENSU1	0.763	0.573	0.843
	ENSU2	0.753		
	ENSU3	0.728		
	ENSU4	0.782		
Social Sustainability	SOSU1	0.747	0.594	0.854
	SOSU2	0.779		
	SOSU3	0.771		
	SOSU4	0.785		

Factor loading coefficient and average variance extracted (AVE) were used to judge the convergent validity of the research measurement model. The results listed in Table 2 indicated that the factors' loading coefficients on their latent constructs were within the range (0.728-0.883). When loading coefficients are greater than 0.50, it indicates that the items should be kept and used in the research model [62]. Moreover, the results show that AVE for the latent constructs were higher than 0.50, which is the minimum value adopted for this indicator [63]. Accordingly, the research measurement model was considered to have convergent validity. For the composite reliability (C.R), the measurement model used was evaluated by McDonald's Omega coefficients. The results illustrated that all latent constructs had coefficients within the range (0.843-0.949). The minimum acceptable value for C.R, when using the McDonald's Omega coefficient, is 0.70 [64]. Therefore, all the achieved values exceed this threshold, which was evidence that the research measurement model was characterized by composite reliability.

CFA was also used to identify alternatives to measurement models to choose the most suitable one according to the collected data. Therefore, the discriminate validity was evaluated through the goodness of fit indicators. The results of these indicators are presented in Table 3.

Table 3. Discriminant validity

Variable	$\chi 2/df$	TLI	CFI	RMSE
One factor (FRFA+INAD+BUIN+SUST)	8.368	0.222	0.252	0.136
Two factors (FRFA+INAD, BUIN+SUST)	7.459	0.318	0.345	0.127
Three factors (FRFA+INAD, BUIN, SUST)	7.046	0.362	0.387	0.123
Three factors (FRFA, INAD+BUIN, SUST)	6.395	0.431	0.453	0.116
Four factors (FRFA, INAD, BUIN, SUST)	1.100	0.989	0.990	0.016

The results in Table 3 make it clear that the chi-squared to the degrees of freedom was greater than the upper threshold 3, except for the four factors model assumed in the current research, where its ratio was 1.100. Semenova and Khalin [65] identify the acceptable upper value of the chi-squared to the degrees of freedom by three [65]. The CFI and TLI indices for the alternative models were less than 0.90, while the assumed model acquired values higher than 0.90, the lowest permissible value [66]. Regarding the Root Mean Square Error of Approximation (RMSEA) indicator, the results pointed out that the most suitable was obtained by the assumed model in the research, where its value was less than 0.08, which is the upper threshold [67]. Therefore, the assumed research model was chosen as it was the most appropriate for the data and it will enable the researcher to reach the best possible results related to relationships between the research variables.

6.2 Descriptive analysis

Table 4 presents respondents' perceptions of the main research variables. Besides, it demonstrates the results of the multicollinearity test for variables taken as independent variables in the research model.

Table 4. Means, standard deviation, and multicollinearity tests

Variable	M	SD	VIF	Tol.
Managerial IT Capability	3.64	0.795	1.111	0.900
Technical IT Capability	3.69	0.753	1.083	0.924
Leadership Style	3.58	0.880	1.112	0.902
Top Management Commitment	3.49	0.897	1.120	0.893
Market Pressure	3.70	0.859	1.076	0.929
External Support	3.56	0.889	1.085	0.926
Industry 4.0 Adoption	3.54	0.741	1.056	0.947
Barriers for Using Industry 4.0	3.45	0.639	1.196	0.836
Economic Sustainability	3.60	0.706	---	---
Environmental Sustainability	3.71	0.687	---	---
Social Sustainability	3.69	0.711	---	---

The results in Table 4 indicated that the three factors that constituted the TOE framework were of moderate level. Market pressure (M= 3.70, SD= 0.859), as a sub-dimension of environmental factor, was ranked at high and first rank, while top management commitment (M= 3.49, SD= 0.897), as a sub-dimension of organizational factor, was at a moderate and last rank. Both Industry 4.0 adoption (M= 3.54, SD= 0.741) and barriers for using Industry 4.0 (M= 3.45, SD= 0.639) were at a moderate level. However, the sustainability dimensions ranged between high and moderate levels. Environmental sustainability (M= 3.71, SD= 0.687) was ranked first with a high level, then social sustainability (M= 3.69, SD= 0.711) was ranked second with a high level, and economic sustainability (M= 3.60, SD= 0.706) was ranked in last place at a moderate level. The result also listed the result of variance inflation factor (VIF) and tolerance (Tol.) that were utilized for measuring the multicollinearity between independent variables. It was clear that all VI values were less than 5 which is the highest threshold [68]. Moreover, tolerance values were in the range (0.836-0.947), thus they were higher than the lowest accepted value of 0.2 [69]. Accordingly, the research variables were autonomous and correlated between themselves at the admitted limits.

6.3 Hypotheses testing

For testing the research hypothesis, a variety of appropriate statistical methods were used through SPSS and AMOS programs. First, the hypotheses of the impact of TOE framework factors on sustainability that were expressed by the hypotheses H1a, H1b, and H1c were verified using multiple linear regression analysis. The model shown in Table 5 expresses the results of testing these hypotheses, which constituted the first stage of the research hypothesis tests.

Table 5. Hierarchical regression analysis for testing moderation effect

Independent variable (a)	Model 1		Model 2		Mode1 3	
	β	t	β	t	β	t
TEFA	0.250***	5.553	0.248***	6.187	0.239***	6.171
ORFA	0.200***	4.399	0.178***	4.402	0.152***	3.874
ENFA	0.294***	6.603	0.214***	5.335	0.156***	3.828
INAD			0.394***	10.157	0.327***	8.409
TEFA × INAD					-0.144**	-2.584
ORFA × INAD					-0.109*	-1.994
ENFA × INAD					-0.173***	-4.098
R2	0.288		0.435		0.483	
Δ R2			0.147		0.048	
Δ F	53.627		103.173		12.283	

Note: TEFA: Technological factors, ORFA: Organizational factors, ENFA: Environmental factors, INAD: Industry 4.0 Adoption, (a) dependent variable is sustainability.
* P< 0.05, ** P ≤ 0.01, *** P ≤ 0.001.

The results presented in Table 5 indicated that all TOE framework factors had a statistically significant impact on sustainability of rural area manufactories in Jordan, where their probability values were less than 0.05. In addition, the environmental factor had the highest impact (β=0.294, t=6.603, p<0.001), followed by the technological factor (β=0.250, t=5.553, p<0.001) in the second rank, then the organizational factor (β=0.200, t=4.399, p<0.001) in the last rank.

Moreover, Table 5 presented the results of testing the moderation role of Industry 4.0 adoption in the relationship between TOE framework factors and sustainability referred to by the research hypotheses H5a, H5b, and H5c. These hypotheses were tested by multiple hierarchical regression analysis using Z standard coefficients. The results determined that model 2, through which the Industry 4.0 adoption was introduced into the linear regression between the TOE framework factors and sustainability produced an improvement in the interpretation coefficient R2 at a rate 0.147 and an increase in the F value of 103.173. Also, these coefficients had probability values less than 0.05. In Model 3, the interaction between TOE framework factors and Industry 4.0 adoption on the sustainability of rural manufactories in Jordan were tested. The results expressed a negative-statistically significant interaction of all factors with the Industry 4.0 adoption. The interaction between the environmental factor and Industry 4.0 adoption (β=-0.173, t=-4.098, p<0.001) had the highest impact on sustainability, followed by the interaction between the technological factor and Industry 4.0 adoption (β=-0.144, t=-2.584, p<0.01), and finally the interaction between the organizational factor and Industry 4.0 adoption (β=-0.109, t=-1.994, p<0.05). Regarding the characteristics of this model, the results indicated that it achieved an improvement of 0.048 in the interpretation coefficient R2 and led to an increase in F value of 12.283. The following figures show the results of the interaction between each factor of the TOE framework and the Industry 4.0 adoption and how they affected the sustainability of rural factories in Jordan.

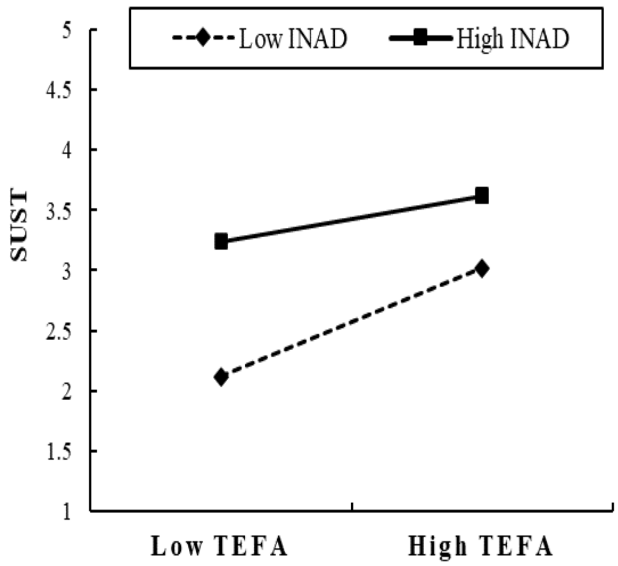

Figure 3. The interaction effect between TEFA and INAD for SUST

Figure 3 illustrates that although the interaction between the technology factor and Industry 4.0 adoption was statistically significant, this interaction led to better results on sustainability at low interaction levels, where the low interaction curve was sloped greater than the high level of interaction curve.

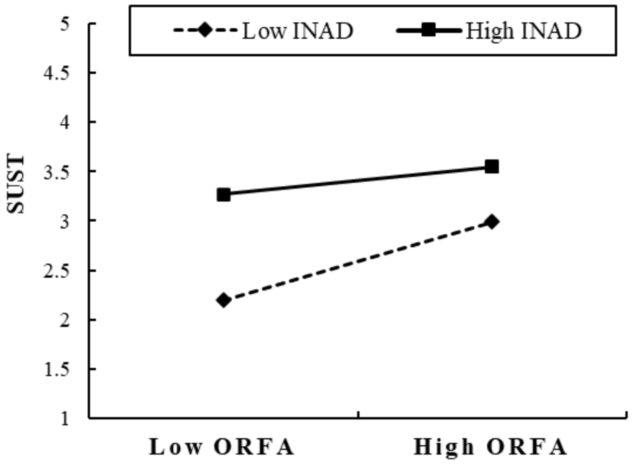

Figure 4. The interaction effect between ORFA and INAD for SUST

Figure 4 illustrates that although the interaction between the organizational factor and Industry 4.0 adoption was statistically significant, this interaction led to better results on sustainability at low interaction levels, where the low interaction curve was sloped greater than the high level of interaction curve.

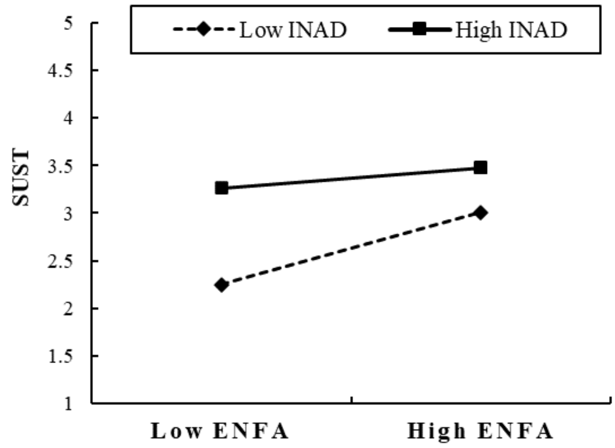

Figure 5. The interaction effect between ENFA and INAD for SUST

On the other hand, Figure 5 illustrates that the interaction between the environmental factor and Industry 4.0 adoption was almost worthless at the high level of interaction. However, this interaction led to an appropriate result on sustainability at low interaction levels, where the low interaction curve was sloped greater than the high level of interaction curve.

Table 6. Path analysis for testing mediation effect

		Paths			Direct effect	Indirect effect	Total effect	t	P
INAD	→	SUST			0.368***	---	0.368***	8.044	0.000
INAD	→	BUIN			0.405***	---	0.405***	8.866	0.000
BUIN	→	SUST			0.281***	---	0.281***	6.153	0.000
INAD	→	BUIN	→	SUST	0.368***	0.114***	0.482***	9.746	0.000

Note: INAD: Industry 4.0 Adoption, BUIN: Barriers for Using Industry 4.0, SUST: Sustainability.
* $P< 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

The remaining research hypotheses indicated the mediating effect of barriers for using Industry 4.0 between the Industry 4.0 adoption and sustainability in rural manufactories in Jordan. Path analysis was used as a statistical technique using the AMOS program to test these hypotheses, the results of which are listed in Table 6.

The results in Table 6 show that the Industry 4.0 adoption in the assumed model had a direct impact on sustainability (β= 0.368, t=8.044, p=0.000) as well as on the barriers for using Industry 4.0 (β=0.405, t=8.866, p=0.000). Furthermore, barriers for using Industry 4.0 had a direct impact on sustainability (β=0.281, t=6.153, p=0.000). The total impact of Industry 4.0 adoption on sustainability through barriers for using Industry 4.0 was (β=0.482, t=9.746, p=0.000), with an indirect impact of (β=0.114, p<0.001). Accordingly, the barriers for using Industry 4.0 partially mediate the relationship between the Industry 4.0 adoption and the sustainability of rural manufactories in Jordan.

7. CONCLUSIONS

The current research sought to determine the impact of a set of variables on the sustainability of rural manufactories in Jordan. The direct impact of TOE framework factors on sustainability was tested. The results support that the technological factor, the organizational factor, and the environmental factor, had a positive impact on the sustainability of rural manufactories in Jordan. Therefore, the awareness of the management of these factories of the need to change business strategies and innovate advanced management patterns that depend on the extensive use of technology and consider the ecological requirements enhance the ability to achieve long-term sustainability. The research aimed to test the extent of the role played by Industry 4.0 adoption in moderating the relationship between the TOE framework factors and sustainability. The results show that the interaction between the TOE framework factors, and Industry 4.0 adoption had a negative impact on sustainability. Accordingly, within the current context, on adopting business methods in line with Industry 4.0 requirements could lead to an increase in the impact of negative TOE framework factors on the sustainability of rural manufactories in Jordan.

One of the main research objectives was to examine the mediating role of barriers for using Industry 4.0 in the impact between Industry 4.0 adoption and sustainability. The results supported this assumption, as it was shown that barriers for using Industry 4.0 contributed a partial mediating role. Therefore, it is necessary for the management of rural manufactories in Jordan to increase their efforts to reduce the impact of cultural factors on the implementation of its strategic plans. They need to seek to develop business models that are more suitable for both customers and suppliers alike, especially with their increased interest and tendencies on dealing with manufactories with environmental and sustainable orientations.

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