

The Impact of Human-Centric Technology Adoption on the Success of JIT 4.0 Implementation: A Case Study Conducted on Moroccan Industrial Companies

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Abstract

This article's primary objective is to demonstrate the influence of the human-centric technology adoption factor on JIT4.0 implementation by displaying the best practices used in Moroccan JIT4.0 organizations and the benefits obtained. By analyzing the critical success factors (CSFs) or activities that manufacturing organizations perform when implementing Just-In-Time (JIT) and Industry 4.0, three latent variables are identified: production strategy (PS), relation with suppliers (RS), and human-centric technology (HCT). Based on the benefits obtained from JIT4.0 implementation, three latent variables are identified and analyzed: the benefits of the production process (BPP), the benefits of inventory management (BIM), and economic benefits (EB). The study also proposes a structural equation model that considers the human-centric technology adoption factor as the leading factor in the implementation of JIT4.0. Additionally, it demonstrates that this factor interacts with other CSFs and benefits as the primary independent latent variable.

Keywords

JIT4.0, JIT, human-centric technology, Industry 4.0, SEM, latent variable.

Introduction

JIT is one of the most popular management strategies aimed at increasing efficiency and reducing costs. The emergence of Industry 4.0 and its integration with the JIT concept have led to the introduction of the hybrid term 'JIT4.0' (Peron et al., 2020). Thus, the advantages of JIT4.0 have attracted more attention during the last decade. Nevertheless, obtaining these advantages is challenging. JIT and Industry 4.0 concepts are difficult to implement separately, and the challenges are even greater when they are combined. Academic institutions and industry players are working hard to understand the factors that influence the success of both integrated and separate implementations of Just-in-time (JIT) and Industry 4.0. The goal is to increase the chances of successful implementation

of JIT and Industry 4.0 in the future and to facilitate the efficient use of resources. Also, a number of studies have underlined that all initiatives of implementation have little chance of success if success factors are not well defined (Laureani & Antony, 2012). likewise, benefits provide a significant motivation for firms to support JIT4.0, which enhance the success of the implementation (Dora et al., 2016). As a result, identifying benefits and success factors is crucial for project success, as it enables companies to develop the appropriate strategy for implementation.

Several studies have been undertaken to explore JIT and Industry 4.0 separately in order to analyze the determinants of the application ((Jadhav et al., 2014; Netland, 2016; Koh et al., 2019). Nevertheless, only a few studies were carried out regarding the practical integration of JIT with Industry 4.0. The existing case studies on integrated applications are limited and are mainly focused on economic variables rather than the human factor and social dimension (Lopes de Sousa Jabbour, 2018).

The main objective of this research is to study the effects that exist between human-centric technology adoption as a JIT4.0 independent latent variable and other JIT4.0 critical success factors (CSFs) and benefits, using the structural equations modeling (SEM).

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Literature review

Critical success factors of JIT4.0

Different authors have tried to define the most important activities in JIT4.0 implementation called Critical Success Factors (CSFs), and several CSF are presented in this study. Table 1 shows a list of the main CSFs of JIT4.0 implementation which were addressed by authors.

The CSF “Human-centric technology” is ranked in the first place in Table 1, cited by 14 authors. “Production strategy” holds the second place, cited by 8 authors, while “suppliers relationships” holds the third place by 7 citations. Thus, it can be concluded that the most important CSFs for JIT4.0 implementation are particularly related to human-centric technology, production strategy, and the relation with suppliers.

Benefits obtained from JIT4.0

Numerous papers have reported the various kinds of advantages and benefits that companies in different sectors can obtain from a successful JIT4.0 implementation. This study present 19 main benefits of JIT4.0 practices, which were identified from different papers and industrial contexts. The list of reported benefits is hierarchically classified in Table 2 according to the

number of times that they were cited by authors.

The first benefit reported by authors is “Enhance productivity”, is ranked in the first place according to Table 2, cited by 15 authors. “Reduce inventories” is ranked in the second place, with 12 works, while “Enhance product quality” holds the third place since it was addressed by 11 works. Similarly, “Reduce wastes”, “Reduce costs”, and “enhance process quality” hold the fourth place, since they all reported 10 citations. On the other hand, benefits such as “increase profitability”, “Increase inventory turnover”, and “reduce inventories disparity” were cited merely once. Nonetheless, a low quotation does not denote their lack of significance or influence. It might be more appropriate to explain these advantages as the results of others.

Materials & Methods

A questionnaire was created as part of the research methodology, taking into account the benefits and critical success factors (CSF) discussed in the literature review. After that, managers from different enterprises were questioned in order to collect data for structural equation modeling analysis (SEM). Thus, the four steps that make up this research’s methodology are covered in the following sections.

Table 1
The main critical success factors of JIT 4.0 implementation reported in literature

CSF	References	Total
Human-centric technology	Rüttimann & Stöckli, 2016; Sanders et al., 2016; Wagner & Herrmann, 2017; Fettermann et al., 2018; Mayr et al., 2018; Lai et al., 2019; Pereira et al., 2019; Moeuf et al., 2020; Ramadan et al., 2020; Rosin et al., 2020; Taghavi & Beauregard, 2020; Tissir et al., 2020; Valamede & Akkari, 2020; Guo et al., 2021	14
Production strategy	Sanders et al., 2016; Wagner & Herrmann, 2017; Mayr et al., 2018; Pereira et al., 2019; Rosin et al., 2020; Valamede & Akkari, 2020; Ciano et al., 2021; Guo et al., 2021	8
Suppliers relationship	Sanders et al., 2016; Wagner & Herrmann, 2017; Rosin et al., 2020; Shahin et al., 2020; Taghavi & Beauregard, 2020; Valamede & Akkari, 2020; Ciano et al., 2021	7
Employee involvement	Sanders et al., 2016; Mayr et al., 2018	2
Layout	Lai et al., 2019; Valamede & Akkari, 2020	2
Organizational aspects	Wagner & Herrmann, 2017; Lai et al., 2019	2
Inventories	Valamede & Akkari, 2020	1
Distribution management	Wagner & Herrmann, 2017	1
IT systems	Wagner & Herrmann, 2017	1
Demand forecasting system	Wagner & Herrmann, 2017	1

Table 2
The benefits of JIT 4.0 reported in literature

JIT benefits	References	Total
Enhance productivity	Prinz et al., 2018; Juhász & Bányai, 2018; Şenkayas & Gürsoy, 2018; Tortorella et al., 2019; Ejsmont et al., 2020; Grassi et al., 2020; Tissir et al., 2020; Valamede & Akkari, 2021; Guo et al., 2022; Javaid et al., 2022; Mofolasayo et al., 2022; Nedjwa et al., 2022; Sartal et al., 2022; Ooi et al., 2023; Kassem et al., 2024	15
Reduce inventories	Prinz et al., 2018; Ejsmont et al., 2020; Valamede & Akkari, 2021; Guo et al., 2022; Javaid et al., 2022; Mofolasayo et al., 2022; Naciri et al., 2022; Nedjwa et al., 2022; Sartal et al., 2022; Ooi et al., 2023; Kassem et al., 2024; Reyes et al., 2024	12
Enhance product quality	Prinz et al., 2018; Şenkayas & Gürsoy, 2018; Tortorella et al., 2019; Ejsmont et al., 2020; Valamede & Akkari, 2021; Javaid et al., 2022; Mofolasayo et al., 2022; Rossi et al., 2022; Ooi et al., 2023; Kassem et al., 2024; Reyes et al., 2024	11
Reduce wastes	Juhász & Bányai, 2018; Ejsmont et al., 2020; Grassi et al., 2020; Tissir et al., 2020; Valamede & Akkari, 2021; Javaid et al., 2022; Mofolasayo et al., 2022; Sartal et al., 2022; Ooi et al., 2023; Kassem et al., 2024	10
Reduce costs	Juhász & Bányai, 2018; Ejsmont et al., 2020; Grassi et al., 2020; Sartal et al., 2022; Tissir et al., 2020; Valamede & Akkari, 2021; Mofolasayo et al., 2022; Javaid et al., 2022; Ooi et al., 2023; Kassem et al., 2024	10
Enhance process quality	Juhász & Bányai, 2018; Şenkayas & Gürsoy, 2018; Tortorella et al., 2019; Ejsmont et al., 2020; Grassi et al., 2020; Valamede & Akkari, 2021; Javaid et al., 2022; Mofolasayo et al., 2022; Ooi et al., 2023; Reyes et al., 2024	10
Reduce cycle time	Grassi et al., 2020; Guo et al., 2022; Javaid et al., 2022; Nedjwa et al., 2022; Rossi et al., 2022; Sartal et al., 2022; Ooi et al., 2023; Kassem et al., 2024;	8
Enhance process efficiency	Prinz et al., 2018; Şenkayas & Gürsoy, 2018; Ejsmont et al., 2020; Javaid et al., 2022; Mofolasayo et al., 2022; Sartal et al., 2022; Ooi et al., 2023; Reyes et al., 2024	8
Reduce space requirements	Prinz et al., 2018; Şenkayas & Gürsoy, 2018; Ejsmont et al., 2020; Valamede & Akkari, 2021; Guo et al., 2022; Javaid et al., 2022; Mofolasayo et al., 2022; Ooi et al., 2023	8
Reduce work in process	Tortorella et al., 2019; Tissir et al., 2020; Mofolasayo et al., 2022; Nedjwa et al., 2022; Rossi et al., 2022; Kassem et al., 2024	6
Increase process flexibility	Prinz et al., 2018; Tortorella et al., 2019; Ejsmont et al., 2020; Nedjwa et al., 2022; Kassem et al., 2024; Reyes et al., 2024	6
Reduce manpower costs	Ejsmont et al., 2020; Guo et al., 2022; Naciri et al., 2022; Ooi et al., 2023; Reyes et al., 2024	5
Improve resources utilization	Ejsmont et al., 2020; Valamede & Akkari, 2021; Rossi et al., 2022; Reyes et al., 2024	4
Reduce number of activities	Şenkayas & Gürsoy, 2018; Florescu & Barabas, 2022; Naciri et al., 2022	3
Reduce material handling	Grassi et al., 2020; Javaid et al., 2022; Rossi et al., 2022	3
Established cost reduction	Şenkayas & Gürsoy, 2018; Ooi et al., 2023	2
Increase profitability	Kassem et al., 2024	1
Increase inventory turnover	Ejsmont et al., 2020	1
Reduce inventory disparity	Ejsmont et al., 2020	1

Development of the survey

The creation of the questionnaire is predicated on a review of the literature with the goal of determining the critical elements and advantages of a successful JIT4.0 implementation. There are three primary sections to the questionnaire: The first is intended to gather demographic information about companies. The crucial success factors or actions that need to be taken to guarantee the successful implementation of JIT4.0 are covered in the second section. The measurement of the benefits obtained from carrying out these actions is covered in the final section.

This stage's objective is to generate a valid questionnaire based on the benefits and Critical Success Factors (CSFs) that authors have presented in previous studies. Three latent variables were identified for CSFs and were extracted from Table 1, Those variables are presented in Table 3 with the items that are used to measure them. Additionally, Table 2 revealed three latent variables for benefits, which are listed in Table 4 along with their corresponding items. This literature review serves as a logical validation of the data collection instrument (Li et al., 2005). A five-point Likert-based scale is intended to be used for responding to the questionnaire (Likert, 1932).

For data gathering, the following inclusion criteria are used to define the sample for this research:

- Only enterprises importing raw materials and exporting finished products are included.
- Enterprises should have a supply chain or a materials department.
- Only enterprises with an established JIT system are taken into consideration. In other words, the sampled enterprises have been applying the JIT for more than 5 years.
- Only companies that work on developing an integrated production system (e.g., advanced automation, IoT, cybersecurity)

Conducting the survey

The final questionnaire is administered to 251 Moroccan manufacturing firms between January 05 to August 30, 2021. The questionnaire is delivered using a variety of approaches. The first one consists in face to face interviews with responders after pre-established appointments. The second approach consists of e-mails sent to some enterprise managers to answer within 2 weeks, and responders are called at different times to collaborate every day from the moment they received the questionnaire the first time.

Table 3
Latent variables for critical success factors (CSFs) and their items

Latent variables	Items
Production strategy (PS)	• The company adopt pull manufacturing production system (PS1) • The company works on developing an integrated production system (e.g., advanced automation, IoT, cybersecurity) (PS2) • There is a synchronization of men, machines and materials as well as data-driven decision-making, using cyber-physical visibility and traceability in operations management (PS3) • The company uses predictive maintenance (PS4)
Human-centric technology (HCT)	• The company uses automation and industrial robotics that collaborate with workers (HCT1) • The company uses augmented reality (HCT2) • The company uses Artificial Intelligence and Big Data Analytics to help workers in decision making (HCT3) • The company uses Adaptive Automation Control Systems Strategies (HCT4)
Relation with suppliers (RS)	• Long-term contracts are made with suppliers. (RS1) • Suppliers deliver small quantities on regular schedules. (RS2) • Production expectations are constantly exchanged with suppliers. (RS3) • Suppliers consistently provide conforming products, therefore reception does not require quality control. (RS4) • Information systems that suppliers use are either integrated with your company's system or operate in collaboration. (RS5)

Table 4
Latent variables for benefits and their items

Latent variables	Items
Benefits associated with inventory management (BIM)	• Reduce inventories (BIM1) • Reduce work in process (BIM2) • Increase inventory turnover (BIM3) • Reduce inventory disparity (BIM4)
Benefits associated with production process (BPP)	• Enhance productivity (BPP1) • Enhance product quality (BPP2) • Reduce wastes (BPP3) • Enhance process quality (BPP4) • Reduce cycle time (BPP5) • Enhance process efficiency (BPP6) • Reduce space requirements (BPP7) • Increase process flexibility (BPP8) • Reduce number of activities (BPP9) • Reduce material handling (BPP10)
Economic benefits (BE)	• Reduce costs (BE1) • Reduce established costs (BE2) • Reduce manpower costs (BE3) • Improve resources utilization (BE4) • Increase profitability (BE5)

Data gathering and validation of the instrument

The main purpose of this stage is to validate the internal consistency or reliability of the questionnaire. Descriptive analysis of collected data is carried out using a database in SPSS22.0* software. The first step in the validation process is rational validity, which is performed as part of the literature review (Lévy & Varela, 2003) and implemented during the questionnaire development process.

A series of tests are performed to detect missing values before using the data. These values are replaced by the median value as a measure of central tendency because the data are represented in an ordinal Likert scale (Hair et al., 2013).

In order to determine internal consistency, a statistical validation process is carried out by calculating the Cronbach's alpha index (CAI) (Cronbach, 1951; Nunnally & Bernstein, 2005) with a minimum acceptable value of 0.8. In addition, some tests were performed to identify items that may be rejected to improve the CAI, because some items are closely correlated with others, or that they have very little variance. Thus, removing them will improve the reliability and internal consistency of the questionnaire (Kock, 2012).

Reliability and internal consistency of the questionnaire were determined using the Cronbach alpha in-

dex (CAI) for each latent variable. In addition, the loadings values and the Average Variance Extracted (AVE) were used to assess convergent validity, with a minimum acceptable value of 0.5 (Berghman, 2012). Also, the average variance extracted (AVE) was used to evaluate discriminant validity (Kesti, 2012). And, the Q-squared coefficient was calculated for each endogenous latent variable to evaluate the predictive validity. According to (Berghman et al., 2012), the calculated Q-squared values must be greater than zero and preferably extremely close to the estimated R-squared values.

Structural equations model

In order to establish relations between the CSFs of JIT4.0 and the benefits gained, a structural model is developed. The author's personal experience forms the basis for the relationships shown in Figure 1, but the PLS method is used to assess them.

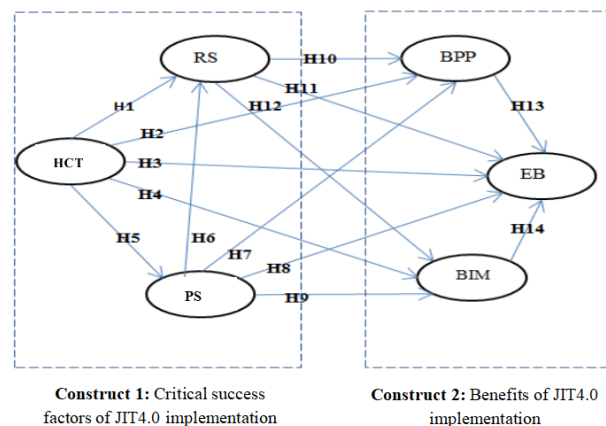


Fig. 1. Initial model with hypotheses

Structural Equations Modeling (SEM) method was used to test the hypotheses shown in Figure 1. The model's assessment is based on Partial Least Squared (PLS), with a bootstrapping resampling strategy for improved convergence, and, it was assessed using the SmartPLS 3 program.

Additionally, the model looked at three types of effects: (1) direct effects, (2) indirect effects, and (3) total effects.

Results

The survey's findings are divided into three main sections, and the results are thoroughly explained in the following paragraphs.

Sample description

A total of 251 valid questionnaires coming from Moroccan companies were used for the survey. Their sectors and headcounts are shown in Table 5. Notably, there were 100 enterprises in the automotive sector, 89 in the electronic sector, and 62 in the aeronautic sector.

Table 5
Sectors and headcounts

Number of employees	Industrial sector			Total
	Automotive	Electronic	Aeronautic	
> 500	21	18	22	61
500-1000	53	45	7	105
> 1000	26	26	33	85
Total	100	89	62	251

According to the job descriptions of the respondents, the engineering and supervision departments were the first two most examined in the sample, as shown in Table 6. The largest group of respondents – 106 – clearly consists of employees who have held their positions for more than ten years. They are followed by a group of 76 workers who have held their positions between five and ten years.

Table 6
Job position of the respondents and seniority

Job category	Work experience (year)				Total
	Less than 2	Between 2 and 5	Between 5 and 10	Over 10	
Technique	2	2	3	2	9
Supervisor	3	8	24	35	70
Engineer	12	24	36	69	141
Manager	4	14	13	0	31
Total	21	48	76	106	251

Survey validation

Before being used, data collected was subject to a validation process. All Cronbach's alpha and composite reliability values are over 0.7, which is regarded as the lowest cutoff value. Thus, the questionnaire could be considered as a reliable data collection tool.

The survey also exhibits discriminant and convergent validity, and the values for AVE were higher than 0.5 for every dimension (Table 7). Moreover, Table 7 presents the R-squared for each dependent latent variable, making it simple to observe the similarity between R-squared and Q-squared. Also, Q-squared

values for dependent latent variables exceeded zero. Thus, it is possible to confirm that independent variables are explaining the dependent variables as a result of the nonparametric predictive validation.

Table 7
Validation for latent variables

	HCT	PS	RS	BPP	BIM	EB
Cronbach's alpha	0.912	0.932	0.923	0.932	0.905	0.929
Composite reliability	0.938	0.944	0.942	0.943	0.934	0.946
AVE	0.790	0.678	0.764	0.623	0.778	0.778
R-squared	–	0.133	0.166	0.349	0.230	0.661
Q-squared	–	0.08	0.101	0.196	0.188	0.458

In order to further illustrate the convergent validity, Table 8 also displays the combined loadings and cross loadings. And, as it was expected, the factors have high loading values but low cross-loadings.

Table 8
Combined loading and cross loading for convergent validity

	HCT	PS	RS	BPP	BIM	EB
HCT1	0.898	0.330	0.265	0.299	0.271	0.343
HCT2	0.884	0.365	0.247	0.361	0.275	0.370
HCT3	0.869	0.305	0.330	0.362	0.183	0.350
HCT4	0.904	0.293	0.310	0.375	0.195	0.324
PS1	0.332	0.837	0.364	0.433	0.354	0.554
PS2	0.235	0.777	0.228	0.411	0.211	0.529
PS3	0.307	0.758	0.222	0.320	0.187	0.380
PS4	0.293	0.811	0.261	0.315	0.172	0.388
RS1	0.268	0.317	0.897	0.417	0.378	0.572
RS2	0.313	0.301	0.859	0.428	0.348	0.515
RS3	0.307	0.278	0.870	0.347	0.384	0.481
RS4	0.269	0.329	0.871	0.392	0.366	0.529
RS5	0.257	0.297	0.871	0.379	0.407	0.513
BPP1	0.320	0.355	0.362	0.802	0.007	0.467
BPP2	0.141	0.331	0.348	0.740	0.047	0.503
BPP3	0.365	0.308	0.304	0.724	–0.022	0.483
BPP4	0.273	0.338	0.304	0.751	0.009	0.452
BPP5	0.347	0.443	0.393	0.831	0.101	0.528
BPP6	0.358	0.423	0.294	0.761	0.107	0.558
BPP7	0.308	0.433	0.400	0.829	0.044	0.534
BPP8	0.320	0.421	0.381	0.839	0.050	0.458
BPP9	0.345	0.324	0.422	0.838	0.024	0.528
BPP10	0.298	0.367	0.333	0.770	–0.002	0.420

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	HCT	PS	RS	BPP	BIM	EB
BIM1	0.224	0.300	0.386	0.069	0.908	0.439
BIM2	0.198	0.317	0.387	0.073	0.866	0.413
BIM3	0.220	0.253	0.349	-0.015	0.857	0.321
BIM4	0.274	0.304	0.395	0.037	0.896	0.432
EB1	0.334	0.570	0.517	0.553	0.412	0.872
EB2	0.291	0.549	0.509	0.565	0.360	0.889
EB3	0.386	0.540	0.552	0.593	0.380	0.873
EB4	0.366	0.552	0.507	0.510	0.435	0.885
EB5	0.343	0.544	0.552	0.541	0.434	0.893

Structural equation model

Direct effects (hypothesis test)

The findings of the parameters obtained are shown in Figure 2 after evaluating the structural model presented in Figure 1. The model allows us to conclude that, with the exception of the relationships between HCT and EB ($P = 0.957 > 0.05$) and HCT and BIM ($P = 0.179 > 0.05$), all effects are significant at a 95% level of confidence. The results in Figure 2 can be stated using the equations below:

$$PS = 0.364 \times HCT \quad (1)$$

$$RS = 0.226 \times HCT + 0.266 \times PS \quad (2)$$

$$BPP = 0.189 \times HCT + 0.310 \times PS + 0.281 \times RS \quad (3)$$

$$BIM = 0.083 \times HCT + 0.186 \times PS + 0.340 \times RS \quad (4)$$

$$EB = 0.002 \times HCT + 0.282 \times PS + 0.220 \times RS + 0.380 \times BPP + 0.250 \times BIM \quad (5)$$

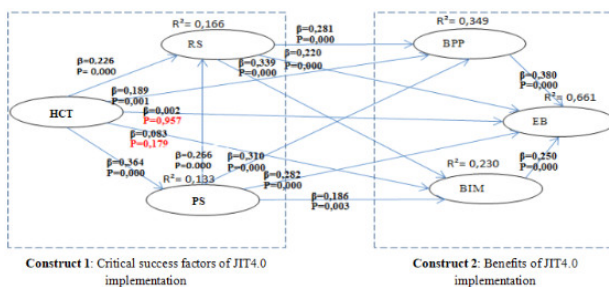


Fig. 2. Final model with hypotheses

According to the parameters in Figure 2, when the standard deviation of Human-Centric Technology (HCT) increases by one unit, Production Strategy (PS), Relationship with Suppliers (RS), Benefits of Production Process (BPP), Benefits of Inventory Management (BIM), and Economic Benefits (EB) all

increase by values of 0.364, 0.226, 0.189, 0.083, and 0.002 units, respectively. So, based on these results, it is stated that Production Strategy (PS), which has the highest parameter value, is the variable that is most influenced by Human-Centric Technology (HCT).

Similarly, Benefits of Production Process (BPP) increase by 0.310 units, Benefits of Inventory Management (BIM) by 0.186 units, and Economic Benefits (EB) by 0.282 units for every unit increase in Production Strategy (PS) standard deviation. The other dependent latent variables can be interpreted similarly. All direct effects are presented in Table 9.

Table 9
Direct effects

	HCT	PS	RS	BPP	BIM	EB
HCT						
PS	0.364					
RS	0.226	0.266				
BPP	0.189	0.310	0.281			
BIM	0.083	0.186	0.339	0.000		
EB	0.002	0.282	0.220	0.380	0.250	

When we looked at the R-squared values in Figure 2, we found that the variable Human-Centric Technology (HCT) presents 13.3% of the explanation of Production Strategy (PS), while the variables Human-Centric Technology (HCT) and Production Strategy (PS) present 16.6% of the explanation of Relation with Suppliers (RS). Human-Centric Technology (HCT), Production Strategy (PS), and Relations with Suppliers (RS) account for 35% of the Benefits of Production Process (BPP) explanations. Benefits of Inventory Management (BIM) is explained by 23% by Human-Centric Technology (HCT), Production Strategy (PS), and Relation with Suppliers (RS). While the Economic Benefits (EB) is explained by 66.1% by Human-Centric Technology (HCT), Production Strategy (PS), Relation with Suppliers (RS), Benefits of Production Process (BPP), and Benefits of Inventory Management (BIM).

Indirect effects

Human-centric Technology (HCT), the only independent latent variable, has an impact on all the other variables, as was seen in the direct effect analysis. It is easy to observe in Figure 2 that the direct effects on Economic Benefits (EB) and Benefits in Inventory Management (BIM) are not valid ($P = 0.957 > 5\%$, $P = 0.179 > 5\%$), but Human-Centric Technology

(HCT) has indirect effects through other variables, such as Production Strategy (PS) and Relation with Suppliers (RS). These indirect effects between latent variables are presented in Table 10. Although there is a statistically significant direct effect between Human-Centric Technology (HCT) and the Benefits of Production Process (BPP), it is also observed that there is an indirect effect that occurs through Production Strategy (PS) and Relationship with Suppliers (RS), which has a coefficient of 0.204. Similarly, Human-Centric Technology (HCT) has an indirect effect on the variable Economic Benefits (0.388) and an indirect impact on the variable Benefits of Inventory Management (BIM), which is 0.177.

Table 10
Indirect effects

	HCT	PS	RS	BPP	BIM	EB
HCT						
PS	0.000					
RS	0.097	0.000				
BPP	0.204	0.075	0.000			
BIM	0.177	0.090	0.000	0.000		
EB	0.388	0.274	0.191	0.000	0.000	

Total effects

Total effects shown in Table 11 were calculated by adding the direct and indirect effects between latent variables. Table 11 findings indicate that Human-Centric Technology (HCT) has total effect over all other latent variables.

Table 11
Total effects

	HCT	PS	RS	BPP	BIM	EB
HCT						
PS	0.364					
RS	0.323	0.266				
BPP	0.393	0.385	0.281			
BIM	0.260	0.276	0.339	0.000		
EB	0.391	0.556	0.412	0.380	0.250	

Additionally, it has direct effects on Production Strategy (PS), Relation with suppliers (RS), and Benefits of Production Process (BPP). Thus, results analysis demonstrates the great importance of Human-Centric Technology (HCT) in the success of JIT4.0 implementation.

Discussion and conclusions

After the analyses of the model developed in this research using partial least squares in a sample of 251 enterprises, the following conclusions can be stated:

H1: The relation between Human-Centric Technology (HCT) and Relation with Suppliers (RS) can be confirmed from statistics by observing that when the first latent variable's standard deviation rises by one unit, the second latent variable rises by 0.226.

H2: There is sufficient statistical evidence to conclude that Human-Centric Technology (HCT) has a direct and positive impact on Benefits of Production Process (BPP), since the second latent variable increases by 0.189 when the first latent variable's standard deviation rises by one unit.

H3: Since the P value is $0.957 > 5\%$, there is insufficient statistical evidence for the relationship between Economic Benefits (EB) and Human-Centric Technology (HCT). But, there are indirect effects that occur through the following factors: Production Strategy (PS), Relation with Suppliers (RS), Production Process (BPP), and Inventory Management (BIM), with a value of 0.388. Thus, this indicates that Production Strategy, Relationships with Suppliers, the Production Process, and Inventory Management are all initially affected by Human-Centric Technology before acting as mediators in the relation between Human-Centric Technology and Economic Performance, indicating that having an effective manufacturing process and high inventory turnover is the first step to economic performance.

H4: Since the P value is $0.179 > 0.05$, there is insufficient statistical evidence for the relation between Human-Centric Technology (HCT) and the Benefits of Inventory Management (BIM). But there is an indirect effect that occurs through Production Strategy (PS) and Relation with Suppliers (RS), with a value of 0.177, highlighting the importance of those mediators' factors in this relation.

The industrial implication of these results is that Human-Centric Technology (HCT) can manage inventory and material flow along the supply chain with high efficiency. As a result, managers should focus on those resources as a source of competitive advantage and consider them to be a strategic asset [52]. Moreover, Human-Centric Technology (HCT) is considered a predecessor to Inventory Management Benefits (BIM), but this depends on Production Strategy (PS) and the Relation with Suppliers (RS) that must deliver high-quality products on time for the manufacturing process. These results are consistent with those of (Grosse et al., 2023; Zhang et al., 2023) which highlighted the significance of Human-Centric Technology (HCT) on the performance of supply chain.

H5: There is sufficient statistical evidence to conclude that Human-Centric Technology (HCT) has a direct and positive impact on Production Strategy (PS), since the second latent variable increases by 0.189 when the first latent variable's standard deviation rises by one unit.

H6: There is sufficient statistical evidence to confirm that Production Strategy (PS) has a direct and positive effect on Relation with Suppliers (RS), since the second variable increases by 0.266 when the first latent variable's standard deviation rises by one unit.

H7: There is sufficient statistical evidence to conclude that Production Strategy (PS) has a direct and positive effect on Production Process (BPP), since the second variable goes up by 0.310 units when the first latent variable's increases its standard deviation in one unit.

H8: There is sufficient statistical evidence to confirm that Production Strategy (PS) has a direct and positive effect on Economic Benefits (EB) since the second variable increases by 0.282 when the first latent variable's standard deviation increases in one unit.

H9: There is sufficient statistical evidence to prove that Production Strategy (PS) has a direct and positive effect on Benefits of Inventory Management (BIM) because the second latent variable increases by 0.186 units when the first latent variable's standard deviation rises by one unit.

H10: There is sufficient statistical evidence to confirm that Relation with Suppliers (RS) has a direct and positive impact on Benefits of Production Process (BPP) because the second latent variable increases by 0.281 when the first latent variable's standard deviation rises by one unit.

H11: There is sufficient statistical evidence to confirm that Relation with Suppliers (RS) has a direct and positive effect on Economic Benefits (EB) because the second latent variable increases by 0.220 units when the first latent variable's standard deviation rises by one unit.

H12: There is sufficient statistical evidence to prove that Relation with Suppliers (RS) has a direct and positive effect on Benefits of Inventory Management (BIM) because the second variable increases by 0.339 units when the first latent variable's standard deviation rises by one unit.

H13: There is sufficient statistical evidence to confirm that Benefits of Production Process (BPP) has a direct and positive effect on Economic Benefits (EB), because the second latent variable increases by 0.380 unit when the first latent variable's standard deviation rises by one unit.

H14: There is sufficient statistical evidence to conclude that Inventory Management (BIM) has a direct and positive effect on Economic Benefits (EB), because the second latent variable increases by 0.250 when the first latent variable's standard deviation rises by one unit.

Through our validated model, we were able to confirm that the success of JIT 4.0 implementation mainly depends on critical success factors, starting from the study of the Human-Centric Technology (HCT) which can be considered as a key element of the process and that all results will depend on him in addition to the Relation with Suppliers (RS) and Production Strategy (PS).

Even if the impact of Human-Centric Technology on the success of JIT 4.0 implementation remains unclear in the literature, because there is a lack of researches related to this subject. Our empirical study which investigated 251 manufacturing organizations located in Morocco shows that its results are in accordance with a large number of studies that have already dealt with the subject of Human-Centric Technology impact on the implementation of LEAN 4.0 concept (Mayr et al., 2018; Gil-Vilda et al., 2021; Rossi et al., 2022).

Moreover, the results of our research have shown that the direct impact of Human-Centric Technology on Economic Benefits and Benefits of Inventory Management remains unclear, but Human-Centric Technology (HCT) has indirect effects through other variables, such as Production Strategy (PS) and Relation with Suppliers (RS).

The study of JIT4.0 practices and the creation of a structural equations model will provide criteria to monitor the evolution of Moroccan companies. Additionally, companies will be able to create a list of the most important activities to set up during the implementation of JIT4.0 in order to manage the project effectively and achieve the desired results.

Despite the fact that the research focuses on a diverse variety of enterprises in the Moroccan sector, this is the study's restriction. Thus, the results can be generalized to other companies within the same country and from the same industries analyzed, but not to companies from other industries or located in other countries, where other rules may be applied. However, although this limitation has an impact on the generalization of results, the approach created in this research is typically applicable to any manufacturing company located anywhere in the world and provides a valid instrument in the field. Furthermore, future studies will include a comparative analysis of Morocco and other countries.

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