“The role of technology management and real-time production control in enhancing environment and economics performance in drug and medical appliances industry: a case study of Nineveh, Iraq”

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THE ROLE OF TECHNOLOGY MANAGEMENT AND REAL-TIME PRODUCTION CONTROL IN ENHANCING ENVIRONMENT AND ECONOMICS PERFORMANCE IN DRUG AND MEDICAL APPLIANCES INDUSTRY: A CASE STUDY OF NINEVEH, IRAQ

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Abstract

This study tests the role of technology management and real-time production control in relation to perceived environmental and economic performance in the pharmaceutical and medical device industry in Nineveh, Iraq. It aims to explore the associations between technology management and perceived performance outcomes, real-time production control and perceived performance outcomes, and the statistical mediating role of real-time production control in the relationship between technology management and perceived performance outcomes. The study used a quantitative cross-sectional design, and data were gathered using a structured questionnaire administered to 280 managers, engineers, and technical supervisors. The hypotheses were tested using structural equation modeling (SEM). The results showed that technology management was positively associated with real-time production control ($\beta = 0.527$, $p < 0.001$), perceived environmental performance ($\beta = 0.339$, $p < 0.001$), and perceived economic performance ($\beta = 0.391$, $p < 0.001$). Real-time production control was also positively associated with perceived environmental performance ($\beta = 0.413$, $p < 0.001$) and perceived economic performance ($\beta = 0.325$, $p < 0.001$), and partially mediated the association between technology management and both perceived performance dimensions. The model accounted for 43.3% of the variance in perceived environmental performance and 39.3% in perceived economic performance. Findings suggest a positive association between strategic technology management and the minimization of perceived waste, perceived cost efficiency, and perceived regulatory compliance, offering valuable guidance to managers and policymakers in the pharmaceutical and medical device industries.

Keywords technology management, real-time production control, environmental performance, economic performance, medical appliances industry, Nineveh

JEL Classification O32, L65, Q55, M11

INTRODUCTION

The pharmaceutical and medical device industries are highly regulated and face increasing environmental and economic pressures. In areas like Nineveh, Iraq, there are additional problems for manufacturing companies: becoming international, being sustainable, and operating in a post-conflict environment with a lack of infrastructure, resource scarcity, and technological immaturity. On the operational side, various challenges have to be addressed to satisfy the regulatory requirements while maximizing economic efficiency and environmental re-

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sponsibility (Khalil, 2000; Monostori, 2014; Diabat & Govindan, 2011). Nineveh Governorate is one of the crucial industrial bases in Iraq in terms of production outside of Baghdad. The Iraqi Ministry of Industry and Minerals (2022) estimates that there are about 47 registered industrial businesses in the pharmaceutical and medical appliance industry in the governorate, with about 14 of these having resumed operations since 2017. Most of these facilities rely on semi-automated production lines, and there are limited digital integrations, far short of international standards (Iraqi Ministry of Industry and Minerals, 2022).

In 2021, the United Nations Industrial Development Organization (UNIDO) conducted an assessment of the operational obstacles faced by Iraqi pharmaceutical manufacturers outside the capital. This analysis identified the production monitoring system as one of the barriers, as well as the disintegration of quality control systems and the absence of real-time data infrastructure (UNIDO, 2021). Environmental compliance is likewise challenging. The Iraqi Environment Protection and Improvement Law (No. 27 of 2009) require waste reduction and emission control, but enforcement is weak and different Nineveh facilities do not have certified environmental management systems. Due to the conditions (technologically emergent, under regulatory pressure and a post-conflict setting), the sector is highly relevant and under-researched for the possibility of applying technologically centric approaches to gain in significantly improving the environmental and economic aspects of the production process.

These two approaches that have emerged in this context are technology management and real-time production control. Technology management is systematic planning, acquisition, and use of technological resources that are appropriate to the organizational strategy. Real-time production control, on the other hand, is related to digital monitoring, sensor-based tracking and feedback that is active at the productive level. Both methods have been proven to help reduce waste, conserve resources, control costs and meet regulations (Sharif, 2006; Gunasekaran et al., 2017; Sarkis et al., 2011). However, while they appear to be complementary, the effect of technology management on the capacity of real-time production control, and the effect of this enabling technology on the environmental and economic performance, have been under-researched and under-studied, especially in manufacturing systems in developing countries.

This study fills this gap. The issue that is being studied is that technology investment by many pharmaceutical and medical appliance manufacturers in Nineveh is not directly correlated with measurable performance gains, rather it will depend on operational capabilities like real-time production control. The literature on this mediated relationship is thin, as is the literature on the combined performance effects of both constructs, especially in industries in post-conflict developing countries. The study is therefore set to investigate the direct and mediated impacts of technology management and real-time production control on environmental and economic performance in the drug industry and medical appliances in Nineveh to provide both theoretical and practical insights into sustainable industrial development.

1. LITERATURE REVIEW

Technology management has received considerable attention as a strategic capability for determining the successful acquisition, deployment, and integration of technological resources to gain a competitive advantage within an organization. Khalil (2000) argued that technology management is key to industrial competitiveness. Sharif (2006) explored the evolution of technology management as a separate academic discipline supported by planning, assessment, and implementation frameworks. Teece (2018) rethought the nature of technology management in the view of dynamic capabilities theory, which states that the benefits of technological resources are realized only when they are managed by sensing, seizing, and reconfiguring capabilities at the managerial level. This distinction is important because it's not enough that we have technology, we must also be able to manage it well, and many empirical studies have exaggerated the effect of technology invest-

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ments on performance and underestimated the pathways for resources to be converted into performance (Cetindamar et al., 2009).

Real-time production control has become a hot topic in the world of smart manufacturing and Industry 4.0. Monostori (2014) has demonstrated that real-time control is based on Cyber-physical production systems (CPPS) which have been proven to continuously synchronize the physical production process with digital models to reduce deviations and stabilize the production process. Lee et al. (2015) showed that these systems can yield predictive insights that can predict failure and optimize throughput in real-time. Based on contingency analysis, Sousa and Voss (2008) found that operational practices such as real-time monitoring are mechanism factors between strategic initiatives and performance outcomes. Regarding environmental aspects, Dubey et al. (2020) demonstrated that digital production control systems embed environmental considerations into the decision-making of everyday operations, resulting in more efficient reductions in material waste and energy use than sustainability programs implemented on their own. Bag et al. (2021) reported that Industry 4.0 production systems can have a significant impact on environmental results, allowing for closed-loop resource monitoring. From an economic perspective, Gunasekaran et al. (2017) correlated the benefits of real-time agile manufacturing practices with improved productivity and cost-effectiveness. Importantly, these studies take real-time production control as an independent source of performance, without considering the organizational prerequisites including managerial and strategic that influence the success of the implementation and use of real-time systems.

The link between technology management and real-time production control has been theoretically suggested but not studied extensively, empirically, and directly. Sharif (2006) reported that technology management is essential to prepare the organizational environment for the implementation of advanced operational systems but failed to test the proposition empirically. Investments in real-time systems can lead to poor utilization, or to real-time systems that are not aligned with production goals, or to increased complexity of the production process, and all of these are reported in several implementation studies reviewed by Sousa and Voss (2008). The contingency theory perspective suggests that the effectiveness of operational practices is not universally applicable but depends on their fit with the organization's capabilities and the environment in which they operate (Sousa & Voss, 2008; Donaldson, 2001). This means that the same production system in the same real-time sense can provide significant benefits in an organization with robust technology governance and minimal benefits in an organization with weak technology governance, a difference not reflected by most published studies.

Dynamic capabilities theory (Teece, 2018) and contingency theory (Sousa & Voss, 2008) provide a theoretical foundation for the expectation that technology management will serve as an antecedent of the effectiveness of real-time production control. Teece (2018) argues that technological resources only create performance benefits when they are actively managed (through sensing, seizing, and reconfiguring capabilities); that is, technology management is not simply a supportive function but is a key part of the nature of how operational technologies are used. This perspective aligns with Eisenhardt and Martin (2000), who showed that a firm's internal resources can be reconfigured through its use of dynamic capabilities to adapt to a rapidly changing market environment. Sousa and Voss (2008) found empirical evidence that strategic-level investments in operations will actually produce better performance via intermediate operational-level practices, thereby suggesting the role of real-time production control as the operational channel that technology management will influence environmental and economic outcomes. Theoretically, this mediation model is coherent, but there is little empirical testing of this model, especially in the manufacturing context, in the published literature.

Another weakness is the lack of research on the developing world, which is particularly significant because of the rapid growth pace of developing countries. Ghobakhloo (2020) consider institutional structures that are well-developed and have stable infrastructure and high absorptive capacity. While their findings may be easily extrapolated to other post-conflict developing regions like Nineveh, where pharmaceutical and medical

appliance manufacturers are constrained by the lack of access to advanced technologies, the poor state of industrial infrastructure, and the permanent shortage of resources, as well as by the lack of regulatory enforcement. While more context-specific approaches to technology-performance research have been called for (Zhang et al., 2019; Haseeb et al., 2019), few empirical research studies responded to this call in manufacturing settings in the Middle Eastern or post-conflict contexts.

There are also considerable inconsistencies in empirical literature, which further inspire the present study. The majority of research studies show positive relationships between technology practices and performance, but a significant minority show conditions that weaken or reverse the relationships. According to Müller et al. (2018), the implementation of Industry 4.0 frequently stagnates because of a lack of skills and of the technology–process relationship. The relationship between the adoption of digital technology and operational performance is even stronger in emerging economies. Kamble et al. (2018) also found that the sustainability outcomes of advanced manufacturing technologies depend on the quality of integration and management support. Zhu et al. (2008) also showed that having a clear managerial commitment and supplier involvement is essential to the effectiveness of environmental management practices in production systems. Obviously, the impact of technology management and real-time production control on performance is not a simple direct or inverse relationship, but rather a relationship that is modified by the organizational and contextual factors that have not yet been teased out of the published studies. The present study deals with these unanswered questions by examining a mediated model in a particular under-researched industrial and geographic context.

To sum up, three gaps in the existing literature were identified:

(1) the lack of integrative empirical models that study technology management and real-time production control in tandem, rather than separately;

(2) the absence of mediation mechanisms in the literature whether or not the effects of technology management are transmitted to the outcomes of real-time production control; and

(3) the lack of empirical evidence from post-conflict or developing-country manufacturing settings where these dynamics could manifest differently.

These gaps motivated the current study, which proposed and tested a structural model that establishes the role of technology management as a determinant of the environmental and economic performance of the drug and medical appliance sector in Nineveh, Iraq, and its indirect mechanism through real-time production control (Peng et al., 2008).

Building on this rationale, the study aims to (1) examine the association between technology management and real-time production control, (2) assess the direct associations of technology management and real-time production control with perceived environmental and economic performance, and (3) test the mediating role of real-time production control in the relationship between technology management and perceived performance outcomes.

From this critical review, the following hypotheses and conceptual model (Figure 1) are advanced:

H1: Technology management has a significant positive impact on real-time production control.

H2: Real-time production control has a significant positive impact on environmental performance.

H3: Real-time production control has a significant positive impact on economic performance.

H4: Technology management has a significant positive impact on environmental performance.

H5: Technology management has a significant positive impact on economic performance.

H6: Real-time production control mediates the relationship between technology management and environmental performance.

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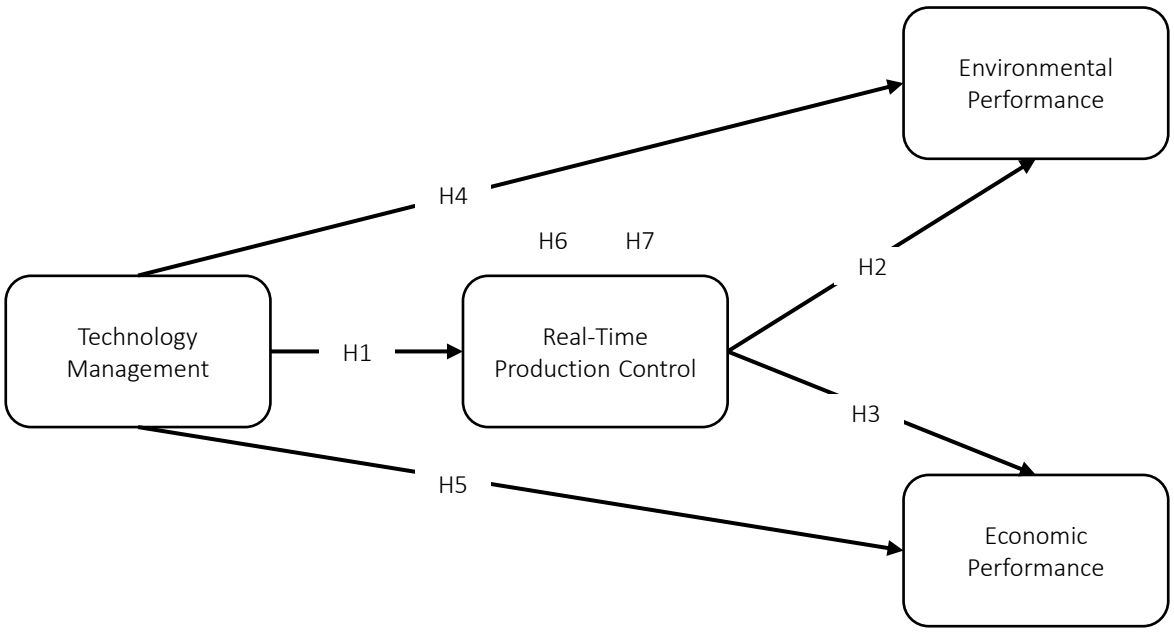


Figure 1. Research model

H7: Real-time production control mediates the relationship between technology management and economic performance.

2. METHODS

This study employed a cross-sectional quantitative design. It studies the role of technology management and real-time production control in the pharmaceutical and medical supply industry in Nineveh, concerning the aspects of environmental and economic performance. The study uses a quantitative approach to test the proposed hypotheses by examining the direct and indirect relationships within a systematic analytical framework, consistent with the cross-sectional survey methodology described by J.W. Creswell and J.D. Creswell (2018).

The study was conducted on 14 pharmaceutical and medical appliance manufacturing companies that are operating in Nineveh Governorate and include 9 pharmaceutical manufacturing companies and 5 medical appliance manufacturing companies. The unit of analysis is individual managerial perceptions of organizational technology and production control practices, as data were collected from individual managers, engineers, and supervisors rather than at the organizational level. This method is similar to the one used in PLS-SEM research designs, where organizational-level constructs are operationalized using key informant responses (Hair et al., 2022). The sample includes 280 administrative and technical staff members from these organizations, including senior management, production management, quality management, production supervisor, and engineers. The respondents were selected because of their personal experiences with technology management practices and real-time production control systems within their organizations and because of the reliability of the information gathered.

The data were gathered with a designed questionnaire, which consisted of the opinions of the participants about technology management, real-time production control, environmental performance, and economic performance of their organizations. The items in the questionnaire were adapted from validated and published items from literature on technology management, operations management and sustainability to ensure consistency and validity. All items were rated on a five-point Likert scale ranging from "strongly agree" to "strongly disagree." The questionnaire was pretested with academic experts and industry practitioners to provide clarity, contextual relevance and application to the industry environment of Nineveh.

Table 1. Demographics

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	196	70.0
	Female	84	30.0
Age	Less than 30 years	52	18.6
	30–39 years	96	34.3
	40–49 years	88	31.4
	50 years and above	44	15.7
Educational Level	Diploma or lower	38	13.6
	Bachelor's degree	162	57.9
	Master's degree	64	22.9
	Ph.D.	16	5.6
Job Position	Senior management	42	15.0
	Middle management	96	34.3
	Engineers / Technical staff	92	32.9
	Supervisors / Operators	50	17.8
Years of Experience	Less than 5 years	58	20.7
	5–10 years	94	33.6
	11–15 years	76	27.1
	More than 15 years	52	18.6
Organization Type	Drug manufacturing	162	57.9
	Medical appliances manufacturing	118	42.1

Data was analyzed using partial least-squares structural equation modeling (PLS-SEM) software. PLS-SEM is selected for the following reasons: (1) PLS-SEM is suitable for complex mediation models involving latent variables and (2) PLS-SEM is robust for small sample size as well (Hair et al., 2019). The analysis process was carried out in two stages, namely the measurement model stage (reliability and validity test) and the structural model stage (test of hypotheses using bootstrapping with 5,000 replications as recommended by Preacher and Hayes (2008) for testing indirect effect analysis). All ethical guidelines were adhered to. All the respondents gave informed consent, and participation was entirely voluntary.

Table 1 shows the demographic profile of the 280 respondents. The sample was predominantly male (70.0%), and most respondents were aged 30–49 years (34.3% aged 30–39 and 31.4% aged 40–49). Among education qualifications, a majority (57.9%) had a bachelor's degree, 22.9% had a master's degree, and 5.6% had a Ph.D. job position included middle management (34.3%) and engineers/technical staff (32.9%), followed by supervisors/operators (17.8%) and senior management (15.0%). The majority (33.6%) had moderate to extensive experience in the industry (5-10 years), while 27.1% had 11-15 years of experience.

3. RESULTS

Table 2 shows the result of measurement model. The value of the factor loading is within the acceptable range (0.748 to 0.881) and the recommended value of 0.70, indicating high indicator reliability. The convergent validity is supported by AVE values of all variables exceeding the recommended threshold of 0.50 (Fornell & Larcker, 1981). Moreover, the alpha value of Cronbach and composite reliability are higher than 0.70 (Hair et al., 2011), which is considered as good internal consistency. To evaluate potential Common Method Bias (CMB), VIF values were examined. As shown in Table 4, the VIF values range from 1.00 to 1.38, which lie well below the 3.3 threshold proposed by Kock (2015), suggesting that CMB is unlikely to pose a concern in this study.

Table 3 reports the discriminant validity results as all values were well below the recommended cut-off of 0.85 (Voorhees et al., 2016; Henseler et al., 2015). Therefore, discriminant validity was successfully established.

Table 4 summarizes the results of the direct hypothesis testing. H1 testing demonstrated that technology management was significantly and positively associated with real-time produc-

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Table 2. Measurement model

Factors	Items	Loadings	α	CR (rho_c)	AVE
Economic Performance	ECO1	0.806	0.890	0.919	0.695
	ECO2	0.81			
	ECO3	0.857			
	ECO4	0.881			
	ECO5	0.81			
Environmental Performance	ENV1	0.835	0.876	0.910	0.668
	ENV2	0.833			
	ENV3	0.784			
	ENV4	0.818			
	ENV5	0.816			
Real-Time Production Control	RTPC1	0.837	0.866	0.904	0.653
	RTPC2	0.748			
	RTPC3	0.845			
	RTPC4	0.826			
	RTPC5	0.779			
Technology Management	TM1	0.845	0.886	0.917	0.688
	TM2	0.826			
	TM3	0.815			
	TM4	0.832			
	TM5	0.828			

Table 3. Heterotrait-monotrait ratio (HTMT)

Construct	1	2	3	4
1. Economic Performance				
2. Environmental Performance	0.63			
3. Real-Time Production Control	0.60	0.68		
4. Technology Management	0.63	0.63	0.60	

tion control (Beta = 0.527, t = 12.814, p < 0.001). Similarly, H2 testing confirmed that real-time production control was positively associated with perceived environmental performance (Beta = 0.413, t = 8.815, p < 0.001). Next, H3 testing showed a significant positive association with perceived economic performance (Beta = 0.325, t = 6.347, p < 0.001). Furthermore, technology management showed a direct positive association with both perceived environmental performance (H4, Beta = 0.339, t = 7.305, p < 0.001) and perceived economic performance (H5, Beta = 0.391, t = 8.001, p < 0.001). The mediation analysis also revealed that real-time production control plays an important

Table 4. Hypotheses testing

	Path	VIF	f^2	B	2.50%	97.50%	STDEV	T value	P value	Result
H3	Real-Time Production Control → Economic Performance	1.38	0.13	0.325	0.221	0.423	0.051	6.347	0.000	Accepted
H2	Real-Time Production Control → Environmental Performance	1.38	0.22	0.413	0.318	0.500	0.047	8.815	0.000	Accepted
H5	Technology Management → Economic Performance	1.38	0.18	0.391	0.294	0.486	0.049	8.001	0.000	Accepted
H4	Technology Management → Environmental Performance	1.38	0.15	0.339	0.248	0.428	0.046	7.305	0.000	Accepted
H1	Technology Management → Real-Time Production Control	1.00	0.38	0.527	0.437	0.600	0.041	12.814	0.000	Accepted
H6	Technology Management → Real-Time Production Control → Environmental Performance	–	–	0.22	0.163	0.282	0.031	7.17	0.00	Accepted
H7	Technology Management → Real-Time Production Control → Economic Performance	–	–	0.17	0.115	0.231	0.030	5.81	0.00	Accepted

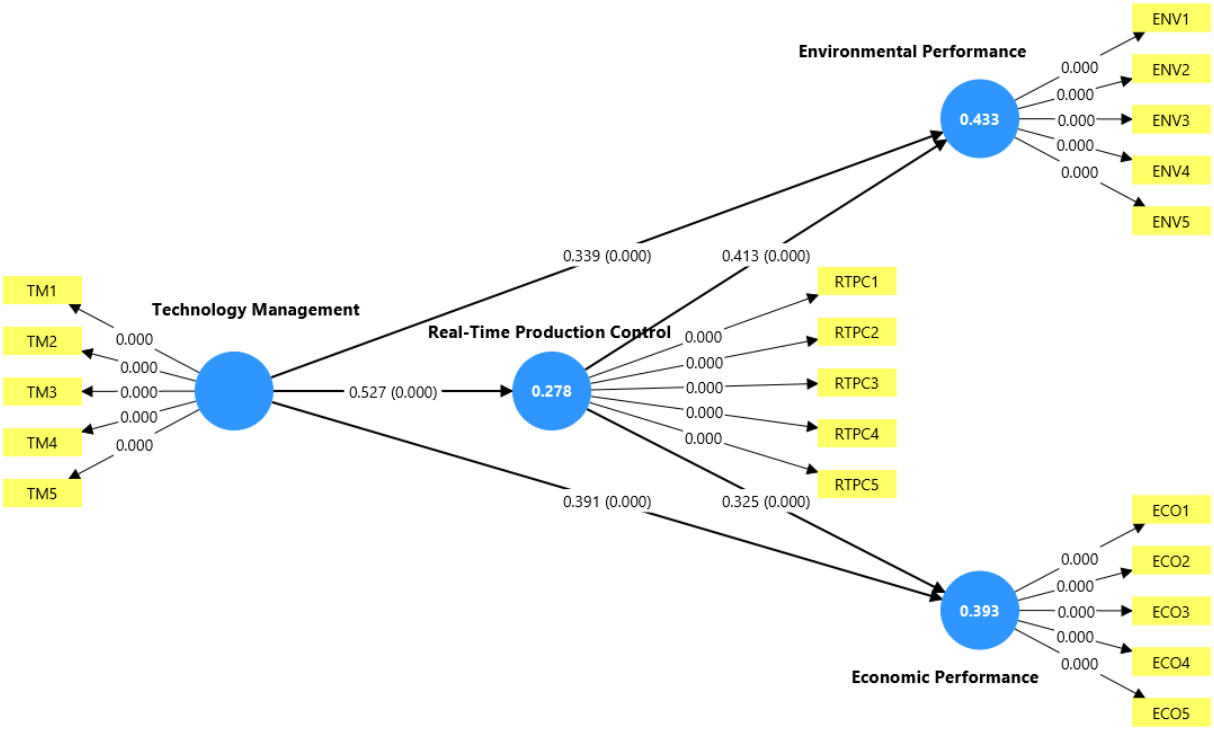


Figure 2. Structural model

role. H6 was supported, confirming its statistical mediating role between technology management and perceived environmental performance (Beta = 0.22, t = 7.17, p < 0.001), while H7 was similarly supported for the association between technology management and perceived economic performance (Beta = 0.17, t = 5.81, p < 0.001).

Regarding effect sizes (f-squared), technology management had a large effect on real-time production control (0.38). The other relationships showed moderate effects ranging from 0.13 to 0.22. Finally, Figure 2 shows the coefficient of determination (R-squared). The model explains the variance for economic performance (R-squared = 0.393), environmental performance (R-squared = 0.433), and real-time production control (R-squared = 0.378).

4. DISCUSSION

This study has confirmed all seven hypotheses and suggests that technology management and real-time production control are complementary strategic and operational capabilities which are linked together with the perceived environmental and economic performance.

The strong positive correlation between technology management and real-time production control (β = 0.527) is the strongest path and confirms the claim of Teece (2018) that managerial dynamism is a necessary condition for exploiting the operational potential of technological investments. It is extended to Sharif (2006), who theorized that technology management facilitates the process, yet did not test it empirically with respect to specific technology operational systems. In science-based industries, Pisano (2006) argued that technology governance is especially consequential because the knowledge base is complex, tacit, and difficult to imitate without structured management routines. In the pharmaceutical and medical appliance sectors, where production deviations carry serious regulatory and safety consequences, this relationship is especially critical: without purposive technology planning and governance, real-time control infrastructure tends to be underutilized or misaligned with production objectives; a risk documented in implementation studies reviewed by Sousa and Voss (2008).

Real-time production control showed a strong positive association with perceived environmental performance (β = 0.413) and perceived economic performance (β = 0.325). The environmen-

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tal association aligns with Dubey et al. (2020), who showed that digital control systems can lead to a reduction in material waste and energy use by incorporating environmental monitoring into the day-to-day operations. Similarly, Ren et al. (2019) found that manufacturing companies that implemented real-time monitoring of their production processes have significantly lower emissions and resource use than those that use batch-reporting systems. The economic association is consistent with Sousa and Voss (2008) and Gunasekaran et al. (2017), who correlated real-time agile practices with cost reduction and productivity gain. In particular, the environmental association was stronger than the economic association, which could be related to the regulatory context of the sector: pharmaceutical and medical appliance manufacturers in Nineveh are exposed to strong regulatory pressure, which means that the environmental argument for real-time control is particularly evident.

Technology management also showed strong direct associations with perceived environmental performance ($\beta = 0.339$) and perceived economic performance ($\beta = 0.391$), indicating that these associations are not fully mediated by real-time production control. This result aligns with Porter and van der Linde (1995), who claimed that "there is a tight linkage between environmental and economic benefits in the conduct of technological innovation" and with the empirical findings of Zhang et al. (2019) connecting management innovation to sustainable organizational performance. Ambec and Lanoie (2008) supported this complementary evidence as an operational strategy that is based on the opinion that environmental investments can increase profitability. The direct economic association ($\beta = 0.391$) was stronger than the direct environmental association ($\beta = 0.339$), suggesting that technology management is more closely associated with the economic aspects of perceived performance than with the environmental aspects, and that the latter is more dependent on the implementation at the operational level as described by Liker and Meier (2006).

The partial mediation of real-time production control between technology management and both perceived performance dimensions is the study's most theoretically relevant result. The indirect association with perceived environmental performance ($\beta = 0.22$) was larger than the indirect association with perceived economic performance ($\beta = 0.17$), which suggests that the perceived environmental gains associated with technology management operate more strongly through the operational control mechanism than the perceived economic gains do. The transposition of the contingency-based hypothesis by Sousa and Voss (2008) to strategic initiatives in intermediate practices to realize their performance-related associations is consistent with the mediation models established by Baron and Kenny (1986). A partial mediation suggests that technology management has a distinct association with perceived performance separate from its association via real-time control. Moreover, this finding extends the arguments of Teece (2018) that the strategic and operational aspects of technology work independently and interactively.

A contextually significant finding is that all hypothesized relationships were supported despite the challenging post-conflict operating environment of Nineveh. Most prior studies of technology management and digital production control, including Ghobakhloo (2020) and Kamble et al. (2018), are situated in advanced economies with mature institutional and infrastructural conditions. The present study suggests that similar strategic and operational mechanisms may produce significant performance-related associations even in contexts characterized by resource constraints and infrastructural limitations, although these contextual factors were not directly measured and thus represent background context rather than empirically tested moderators. This contributes to calls by Zhang et al. (2019) and Haseeb et al. (2019) for contextually grounded research in technology and operations management and suggests that technology governance frameworks developed for advanced economies may be adapted with appropriate modifications to developing-country manufacturing contexts (Asongu & Nwachukwu, 2016).

Practitioners will find the results straightforward to interpret. It is important for managers in the pharmaceutical and medical appliance sectors not to consider technology investment and operational control as two distinct issues; it is recommended that technology governance frameworks explicitly

plan for, enable, and assess the quality of real-time production control implementation (Luthra & Mangla, 2018). Coherent technology management practices such as acquisition planning, workforce development, and performance evaluation systems are likely to be correlated with higher environmental and economic returns for investments in digital monitoring, sensor networks, and data analytics. The findings offer implications for industrial development strategies in post-conflict areas: policy should not only encourage the use of new technologies, but also the management skills necessary to sustainably use these technologies as well (Acemoglu & Robinson, 2012). Future research should use longitudinal designs to provide causal directionality, include objective measures of performance in addition to self-reported data, expand the analysis to include other regulated industries (e.g., food safety, chemical manufacturing), and examine the model in other regional settings (e.g., developing or post-conflict regions) to determine the generalizability of the findings.

CONCLUSION

This study examined the associations between technology management and real-time production control and perceived environmental and economic performance in the drug and medical appliance industry in Nineveh, Iraq. Each of the seven hypotheses was confirmed. Technology management ($\beta = 0.527$) was significantly and positively associated with real-time production control, suggesting a strong correlation between strategic technology management and operational control effectiveness. Technology management and real-time production control were positively related to perceived environmental performance ($\beta = 0.339$ and $\beta = 0.413$, respectively) and perceived economic performance ($\beta = 0.391$ and $\beta = 0.325$, respectively), and real-time production control partially mediated the relationship between technology management and performance. Performance in this study is based on managerial perceptions rather than objective environmental or financial indicators. The novelty comes from three contributions. The first is the empirical test of this mediated model for the drug and medical appliance industry. The second is evidence from a post-conflict, developing-country context that is rarely represented in the operations management literature. The third is that strategic and operational technology mechanisms are associated with perceived performance in ways that are both independent and interdependent, resolving prior inconsistencies in studies that examined each construct in isolation This addresses the three gaps identified in the literature review above: the lack of integrative empirical models linking technology management and real-time production control, the absence of tested mediation mechanisms between them, and the scarcity of empirical evidence from post-conflict, developing-country manufacturing settings.

AUTHOR CONTRIBUTIONS

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Formal analysis: Bilal Tawfeeq Younes.
Funding acquisition: Baidaa Rajab Hussein.
Investigation: Baidaa Rajab Hussein, Sayf Al-Ashqar.
Methodology: Bilal Tawfeeq Younes.
Project administration: Bilal Tawfeeq Younes.
Resources: Baidaa Rajab Hussein, Sayf Al-Ashqar.
Software: Baidaa Rajab Hussein.
Supervision: Bilal Tawfeeq Younes.
Visualization: Baidaa Rajab Hussein, Sayf Al-Ashqar.
Writing – original draft: Baidaa Rajab Hussein.
Writing – review & editing: Bilal Tawfeeq Younes, Sayf Al-Ashqar.

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