Impact of Industry 4.0 Readiness on Innovation Performance in Mechanical Systems: Role of Digital Transformation and Process Change Management

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ABSTRACT

Purpose: This study examines the impact of industry 4.0 readiness on innovation performance in the mechanical industry by analyzing the mediating role of digital transformation and the moderating role of process change management. The research addresses persistent inconsistencies in prior studies regarding why industry 4.0-ready firms achieve different innovation outcomes. Method: A quantitative, cross-sectional design was employed, with data collected from 266 engineers and sub-engineers working in mechanical industry organizations. Measurement scales were adopted from prior research. The proposed model was tested using partial least squares structural equation modeling (PLS-SEM) to assess direct, mediating, and moderating relationships among the variables. Findings: The results indicate that Industry 4.0 readiness significantly influences digital transformation and innovation performance. Process change management significantly moderates the relationship between industry 4.0 readiness and digital transformation, strengthening transformation outcomes. Additionally, digital transformation significantly mediates the relationship between industry 4.0 readiness and innovation performance, confirming its role as a key mechanism through which readiness translates into innovation outcomes. Originality/Implications: This study advances Industry 4.0 literature by empirically integrating readiness, transformation, and change management into a unified framework, offering theoretical clarity and actionable insights for innovation management in mechanical systems.

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1. Introduction

The growing pace of spread of industry 4.0 technologies has fundamentally altered the logics of innovation in mechanical systems, making industry 4.0 readiness the top agenda of scholars and practitioners who want to improve innovation performance. Previous studies are becoming more concentrated when it comes to defining the advantages of smart manufacturing, cyber-physical systems, and data-driven production as not to do with the application of the technologies but rather the willingness of an organization to incorporate the technologies into its operational and innovation frameworks (Brodeur et al., 2023; Vo et al., 2025). Stated in relation to the mechanical systems, with production processes being capital-intensive, historically rigid, and interdependent, industry 4.0 readiness has been postulated to give digital investments worth the results of meaningful innovation (Kumar & Sharma, 2025).

Although more and more companies invest in industry 4.0 projects, empirical findings suggest that not every manufacturing company has a positive effect on innovation performance(Ansari et al., 2025). According to scholars, the paradox of industry 4.0 readiness is often due to the fact that the state of technological readiness is often considered as a fixed state, whereas mechanical systems must be radically rejuvenated by transforming the whole organization(Kee et al., 2025). This dislinking has changed the interest of scholars toward digital transformation, which reflects the permeation of digital technologies into organizational processes, organizational structures, and innovation practices, as opposed to using them as separate instruments(Ansari et al., 2023; Bhatti & Absamatov, 2025). As a result, digital transformation is also emerging as a possible explanatory construct in the field where industry 4.0 readiness has the effect on innovation performance(Zamora Iribarren et al., 2024).

The initial empirical studies prove that the higher the industry 4.0 readiness, the higher the firms are equipped to embark on digital transformation through the use of data integration, automation, and digital skills(Maganga & Taifa, 2023). Nonetheless, other researchers indicate contradictory results, indicating that equal degrees of industry 4.0 readiness may lead to dramatically different levels of digital transformation(Ribeiro et al., 2024). Such discrepancy indicates that preparedness might be inadequate to guarantee the success of transformation. Researchers state that the results of transformations require management of organizational changes in the processes of work, duties, and habits caused by digital projects (Pozzi et al., 2023). Such issues related to change are especially acute in mechanical systems, where the stability of the process is commonly valued more than experimentation.

In an attempt to counter these issues, process change management has gained more popularity in literature as a very important organizational ability that aids in digital initiatives(Kliestik et al., 2023). In accordance with previous research, such drivers as structured change planning, employee engagement, and process redesign contribute to the improved efficacy of digital transformation initiatives(Akbari et al., 2024). However, the majority of existing studies define process change management as a direct precursor to digital transformation or performance instead of exploring how it preconditions the effects of the industry 4.0 readiness(Antony, Sony, & McDermott, 2023). Consequently, a lack of empirical data underlies the reasons why industry 4.0 readiness results in successful digital transformation in certain companies and not others, especially in mechanical systems with a long-established process architecture(Dohale et al., 2023).

On the same note, the connection between industry 4.0 readiness and innovation performance is also debatable both theoretically and empirically(Wankhede & Vinodh, 2023). Whilst some research findings indicate that industry 4.0 readiness has a positive impact on product and process innovation(Mansour et al., 2023), some also suggest that the concept readiness does not necessarily lead to improved innovation performance unless organizations radically change the way in which innovation activities are carried out(Antony, Sony, & McDermott, 2023). According to this debate, the digital transformation can be viewed as a mediating factor that can transform industry 4.0 readiness to innovation outcomes(Mittal et al., 2024). Nevertheless, there are few empirical studies that are explicit in testing on this mediating role, particularly in manufacturing and mechanical systems.

Altogether, there are three essential gaps that are identified by preceding studies. To begin with, industry 4.0 readiness is mostly studied as a direct indicator of digital transformation or innovation performance, and ignores how readiness is converted into innovation value(Jankowska et al., 2023). Second, the mediating effect of digital transformation in the digestion of the industry 4.0 readiness-innovation performance relationship is yet to be studied (Khan & Emon, 2025). Third, less empirical research exists that focuses on the role of process change management to act as a boundary condition in developing the effectiveness of industry 4.0 readiness(Wu et al., 2024), even though it has been shown to be theoretically relevant in the context of process-intensive mechanical systems.

To fill these gaps, the current research paper explores how industry 4.0 readiness influences innovation performance using digital transformation as a mediating factor and process change management as a moderating variable. This study conceptualizes industry 4.0 readiness as a sensing capability, digital transformation as a reconfiguring capability, and process change management as a governance mechanism, which facilitates or limits the deployment of capabilities, based on the dynamic capabilities approach(Tortorella et al., 2024). Combining these constructs into one moderated mediation framework, the current study contributes to the existing knowledge in the field of how industry 4.0 initiatives produce the outcomes of innovation in mechanical systems. In such a way, the paper makes a contribution to industry 4.0 and innovation literature by going beyond technology-based explanations and disaggregating the organizational mechanisms through which the readiness transforms to innovation performance, empirically.

2. Literature Review

2.1 Industry 4.0 Readiness

The industry 4.0 readiness has become an important antecedent of the organizational change in the manufacturing and mechanical systems that indicates the degree to which companies are technologically, structurally, and strategically prepared to the advanced digital technologies(Amin et al., 2024). Previous researchers define industry 4.0 readiness as a multidimensional variable and include smart technologies, data integration, workforce capability, and organizational alignment(Galanti et al., 2023). It has been shown with empirical data that the more industry 4.0

ready firms show high flexibility of operations and strategic responsiveness(Farrukh Shahzad et al., 2025). Nevertheless, the available literature addresses industry 4.0 readiness as the immediate predictor of the performance results to a large extent and does not consider the internal transformation processes by which the readiness carries into value (Hansen et al., 2025). Furthermore, there has been a lack of focus on the effects of organizational change processes as preconditions of the viability of industry 4.0 readiness especially in mechanical systems where the structures of production are complicated and inflexible legacies(Ghobakhloo et al., 2025).

2.2 Industry 4.0 Readiness Impact on Digital Transformation

According to previous studies, industry 4.0 readiness is always linked to the capacity to launch and develop digital transformation programs in firms(Ali & Johl, 2023). Research holds that technological infrastructure, maturity of data, and digital capabilities which are the building blocks of industry 4.0 readiness, are precursors of digital transformation(Das et al., 2023). In line with the findings of the empirical research, it is found that organizations with low industry 4.0 readiness show disjointed digitalization initiatives, thus leading to dislodged automation instead of comprehensive change(Marrucci et al., 2025). On the other hand, a high industry 4.0 readiness can be used to enable the inclusion of cyber-physical systems, sophisticated analytics, and digital platforms in main processes(Brodeur et al., 2023). Although this is the consensus, most of the studies conducted on digital transformation focus on it as a strategic intention and not an operational performance, especially in manufacturing and mechanical systems sectors(Kumar & Sharma, 2025). Moreover, causal processes by which industry 4.0 readiness contributes to digital transformation are not well studied, most studies are based on descriptive or maturity-model methods(Kee et al., 2025). The given gap implies that industry 4.0 readiness should be empirically validated as a considerable factor contributing to the actual digital transformation but not digital ambition.

H1: Industry 4.0 readiness significantly influences the digital transformation.

2.3 Moderating Role of Process Change Management

Indeed, whereas industry 4.0 readiness offers the technical and organizational basis of digital transformation, more scholars tend to consider the consequences of transformation to be determined by efficient process change management(Zamora Iribarren et al., 2024). As noted before, the concept of digital transformation often fails because of resistance to change, process misalignment, and poor change governance(Ribeiro et al., 2024). Research on manufacturing environments indicates that even companies with high industry 4.0 potentials fail to transform readiness into digital transformation in situations where the change in processes is not effectively handled(Kliestik et al., 2023). Process change management is consequently placed as a pivotal contextual element that would define how the industry 4.0 readiness is implemented(Antony, Sony, & McDermott, 2023). Empirical data indicate that digital initiatives are enhanced in terms of effectiveness by structured change communication, employee involvement, and process redesign(Wankhede & Vinodh, 2023). Nevertheless, previous studies have been majorly exploring process change management as a direct antecedent of the success of the transformation itself, but not as a condition(Antony, Sony, McDermott, et al., 2023). It has not been adequately tested how process change management moderates the strength or the weakness of industry 4.0 readiness-digital transformation relationship, especially in the context of mechanical systems with high levels of process rigidity.

H2: Process change management significantly moderates the relationship of industry 4.0 readiness and the digital transformation.

2.4 Industry 4.0 Readiness impact on Innovation Performance

Industry 4.0 readiness and innovation performance relationship has been a debatable issue across innovation and manufacturing literature(Jankowska et al., 2023). Multiple authors state that industry 4.0 readiness increases the innovation performance through the ability to use data in real time, perform quick prototyping, and collaborate with other functions(Wu et al., 2024). These competencies assist in incremental and radical innovation achievements. Nonetheless, there are conflicting results that industry 4.0 readiness does not necessarily result in increased innovation performance, especially when companies do not have complementary organizational benefits(Amin et al., 2024). Other scholars say that industry 4.0 readiness can even generate innovation inertia where companies invest heavily in technology without re-arranging innovation processes(Farrukh Shahzad et al., 2025). This inconsistency shows that there is a gap in theory when it comes to the circumstances that make industry 4.0 readiness translate to innovation performance(Ghobakhloo et al., 2025). Avoiding the consideration of intermediate mechanisms that relate readiness to innovation outcomes, previous studies tend to use linear models(Das et al., 2023). Therefore, additional research is necessary to define the role of industry 4.0 readiness as an independent driver of innovation performance or the impact of the notion takes effect through more profound processes of organizational change.

H3: Industry 4.0 readiness significantly influences the innovation performance.

2.5 Mediating Role of Digital Transformation

Recent literature is placing digital transformation as one of the most important mechanisms in the connection of the technological readiness with the performance results(Vo et al., 2025). Research indicates that industry 4.0 readiness augments the innovation performance in the event in which it generates a significant digital transformation, including digitally enabled business models, integrated innovation platforms, and data-driven decision-making(Ansari et al., 2025). Empirical data shows that companies striving to undergo digital transformation can more quickly and easily excel in innovation and newness than companies that simply implement industry 4.0 technologies in a vacuum(Ansari et al., 2023). In spite of these reflections, previous studies tend to focus on digital transformation as a consequence and not as a mediator(Maganga & Taifa, 2023). There are no empirical studies directly testing digital transformation as a mediating factor between industry 4.0 readiness and innovation performance, and in the mechanical systems industry in particular(Pozzi et al., 2023). This oversight limits the knowledge of the process of turning readiness into an innovation value(Akbari et al., 2024). This gap can be filled to explain better why innovation is not as effective among other industry 4.0-ready firms, but it is the depth of transformation that can be seen as an additional factor to consider.

H4: Digital transformation significantly mediates the relationship of industry 4.0 readiness and innovation performance.

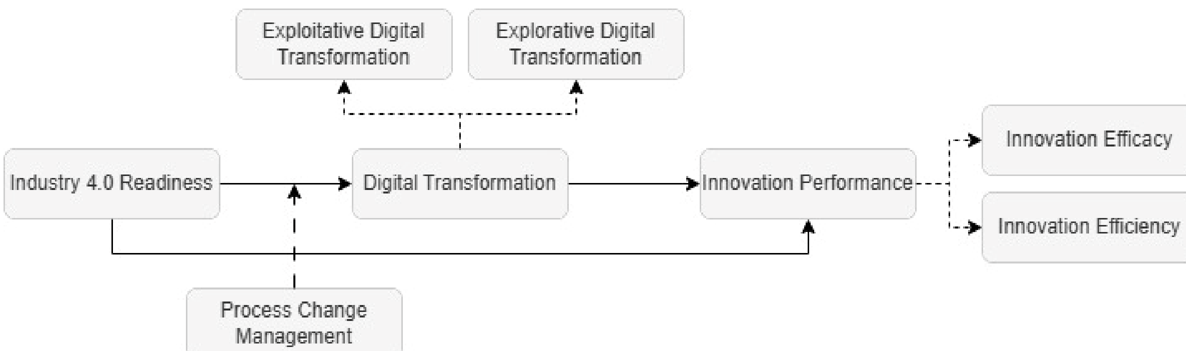

Figure 1: Conceptual Model

3. Method

The current research used a cross-sectional research design that is quantitative to investigate the effect of Industry 4.0 Readiness on Innovation Performance using Digital Transformation as a mediating variable and Process Change Management as a moderating variable. The empirical background of the study was the mechanical industry as it was chosen because it is gradually becoming dependent on Industry 4.0 technologies and sophisticated production systems. The information was gathered among engineers and sub-engineers that are in direct contact with operations, digital, and innovation operations. Out of 266 valid responses, a structured questionnaire was used to retrieve the required minimum sample size of a partial least squares structural equation modeling (PLS-SEM) due to the complexity of the research model.

Table 1: Profile of Variables Questionnaire

Variable	Items	Source
Industry 4.0 Readiness	12	(Ul Zia et al., 2023)
Digital Transformation	8	(Zhang et al., 2023)
Innovation Performance	12	(Alegre et al., 2009)
Process Change Management	7	(Aregbesola & Oluwade, 2014)

Multi-item scales that were borrowed in prior research articles were used to measure all constructs, as they provide content validity and methodological rigor (see Table 1 and Appendix). Likert-type scales were used to measure Industry 4.0 Readiness, Digital Transformation, Innovation Performance and Process Change Management. The analysis of data was performed with the help of PLS-SEM, and it was done in the two steps. First, internal consistency, convergent and discriminant validity of the measurement model were tested with Cronbach alpha, composite reliability, average variance extracted (AVE) and the heterotrait-monotrait (HTMT) ratio. Second, structural model was evaluated based on bootstrapping to examine the effect of direct, mediating and moderating effects based on path coefficients, t-statistics and p-values, as well as effect sizes (f^2), coefficients of determination (R^2), and model fit indices.

4. Results

Table 2 shows the reliability and convergent validity measures of each of the constructs that are present in the measurement model. The findings show that the internal consistency is satisfactory because the Cronbach Alpha and Composite Reliability are greater than the predetermined value of 0.70 when dealing with all constructs, which demonstrates the scale reliability. Industry 4.0 Readiness shows an indicator of high internal consistency with a Composite Reliability of 0.923 and Process Change Management pass's reliability tests with a Composite Reliability of 0.869 too. The similar values of reliability are found in Innovation Performance and Digital Transformation.

Table 2: Reliability and Validity

		Original Sample	Cronbach's Alpha	Composite Reliability	AVE
Industry 4.0 Readiness	I4R1	0.567	0.908	0.923	0.501
	I4R10	0.740			
	I4R11	0.746			
	I4R12	0.710			
	I4R2	0.606			
	I4R3	0.671			
	I4R4	0.669			
	I4R5	0.767			
	I4R6	0.747			
	I4R7	0.715			
	I4R8	0.731			
	I4R9	0.793			
Process Change Management	PCM2	0.790	0.822	0.869	0.527
	PCM3	0.703			
	PCM4	0.759			
	PCM5	0.725			
	PCM6	0.690			
	PCM7	0.680			
Innovation Performance			0.892	0.911	0.519
Innovation efficacy	ICAC1	0.523	0.853	0.890	0.540
	ICAC3	0.810			
	ICAC4	0.801			
	ICAC5	0.804			
	ICAC6	0.725			
	ICAC7	0.686			
	ICAC8	0.751			
Innovation Efficiency	ICEN1	0.795	0.745	0.839	0.567
	ICEN2	0.699			
	ICEN3	0.785			
	ICEN4	0.729			
Digital Transformation			0.834	0.873	0.565
Explorative	EXPI1	0.813	0.770	0.854	0.597
	EXPI2	0.836			
	EXPI3	0.811			
	EXPI4	0.609			
Exploitative	EXPR1	0.786	0.785	0.861	0.608
	EXPR2	0.750			
	EXPR3	0.804			
	EXPR4	0.779			

The convergent validity is determined by Average Variance Extracted (AVE) whereby all the constructs have an AVE value of above the minimum recommended which is 0.50 indicating that the indicators are sufficient to explain the variance of the respective latent constructs. The item loadings on all of the dimensions are within acceptable proportions and this contributes to the reliability of the indicators. On the whole, the findings prove that the measurement model meets the requirements of reliability and convergent validity, which makes it possible to continue the evaluation of the structural model.

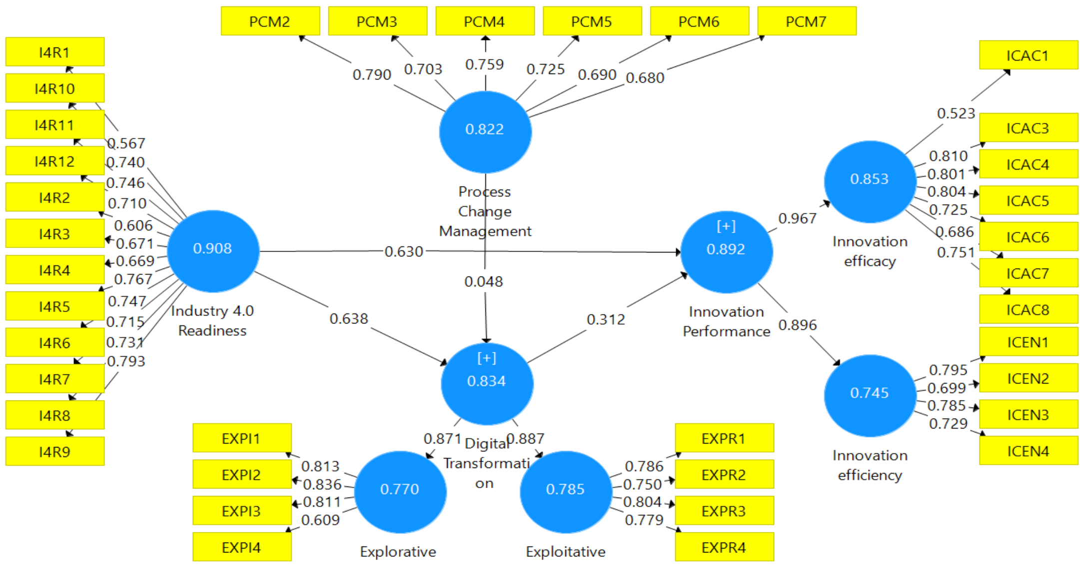

Figure 2: Estimated Model

Table 3 indicates the Heterotrait-Monotrait Ratio (HTMT) values to determine the discriminant validity between the constructs. The findings prove that all the HTMT figures fall below the conservative range of 0.85 representing an adequate discriminant validity. Digital Transformation presents a good discriminant separation to Industry 4.0 Readiness and Innovation Performance, with the HTMT values being well below recommended values. On the same note, Digital Transformation-Explorative and Exploitative dimensions demonstrate evident delimiting character as compared to other constructs. The efficacy of innovation and Innovation efficiency. The efficacy of innovation and the Innovation efficiency show satisfactory discriminant validity, which proves their uniqueness as a concept even though they are subdimensions of Innovation Performance. Process Change Management holds low HTMT values with the rest of the constructs, which only strengthens its uniqueness in the model. These results prove the constructs measure empirically different phenomena and multicollinearity issues are insignificant.

Table 3: Heterotrait-Monotrait Ratio

	1	2	3	4	5	6	7	8
Digital Transformation								
Exploitative	0.843							
Explorative	0.794	0.697						
Industry 4.0 Readiness	0.748	0.720	0.640					
Innovation Performance	0.844	0.802	0.733	0.828				
Innovation Efficacy	0.842	0.770	0.762	0.245	0.615			
Innovation Efficiency	0.810	0.824	0.647	0.792	0.799	0.839		
Process Change Management	0.342	0.301	0.322	0.444	0.445	0.479	0.366	

The values of the effect size (f^2) are shown in Table 4, which show how much exogenous constructs contribute to the endogenous variables. Industry 4.0 Readiness shows a significant effect size on Digital Transformation (f^2 = 0.607), which shows that it has a significant explanatory value. Moreover, the Industry 4.0 Readiness demonstrates a significant impact on the Innovation Performance (f^2 = 0.918), which is quite indicative of its pre-eminent role in the explanation of the innovation results. The effect size of Process Change Management on Digital Transformation (f^2 = 0.343) is moderate, which proves its significant role in influencing the result of transformation. Digital Transformation in itself has a moderate effect on Innovation Performance ($f^2 = 0.225$). Such findings indicate that the associations presented in the model are statistically significant and of a significant magnitude as well.

Table 4: F Square

	Digital Transformation	Innovation Performance
Digital Transformation		0.225
Industry 4.0 Readiness	0.607	0.918
Innovation Performance		
Process Change Management	0.343	

The values of the coefficient of determination (R^2) of the endogenous constructs are reported in table 5. The R^2 value of Digital Transformation is 0.433 which means that combining Industry 4.0 Readiness and Process Change Management explain 43.3 percent of Digital Transformation variance. The R^2 of Innovation Performance is high at 0.754, which indicates that the combined effect of Industry 4.0 Readiness and Digital Transformation can explain 75.4% of innovation performance. Adjusted R^2 values are also close to the actual R^2 values, which means the stability of the model and low overfitting. These findings indicate that the structural model has a high level of explanatory power especially on Innovation Performance.

Table 5: R Square

	R Square	R Square Adjusted
Digital Transformation	0.433	0.428
Innovation Performance	0.754	0.752

Table 6 provides the model fit test with the Standardized Root Mean Square Residual (SRMR). Both the saturated model (0.069) and the estimated model (0.071) have lower SRMR values than the recommended value of 0.08, and hence, the model fits well. The low variance between the saturated model and the estimated one indicates that the structural model is sufficiently able to estimate the observed covariance matrix. These findings prove that the research model suggested by the proposed study is appropriate to the empirical data and satisfies the usual criteria of goodness of fit of the partial least squares structural equation modeling.

Table 6: Model Fit

	Saturated Model	Estimated Model
SRMR	0.069	0.071

Table 7 indicates the structural path coefficients, standard deviations, t-statistics and p-values in the testing of hypotheses. The findings show that Industry 4.0 Readiness positively influences Digital Transformation ($b = 0.611$, $t = 5.988$, $p < 0.001$), which proves the strong empirical evidence of this correlation. The Process Change Management moderating effect on the correlation between Industry 4.0 Readiness and Digital Transformation is also significant ($b = 0.312$, $t = 6.414$, $p < 0.001$).

Table 7: Path Analysis

	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Industry 4.0 Readiness Significantly Influences the Digital Transformation.	0.611	0.102	5.988	0.000
Process change Management Significantly Moderates the Relationship of Industry 4.0 Readiness and the Digital Transformation.	0.312	0.049	6.414	0.000
Industry 4.0 Readiness Significantly Influences the Innovation Performance.	0.630	0.045	14.093	0.000
Digital Transformation Significantly Mediates the Relationship of Industry 4.0 Readiness and Innovation Performance.	0.191	0.044	4.390	0.000

Moreover, Industry 4.0 Readiness has an important impact on the Innovation Performance ($b = 0.630$, $t = 14.093$, $p < 0.001$), meaning that there is a strong direct relationship. The significant indirect effect of Digital Transformation between Industry 4.0 Readiness and Innovation Performance is supported by the significant coefficient (b = 0.191, t = 4.390, p < 0.001). Altogether, the findings furnish empirical evidence to all the relationships in the model.

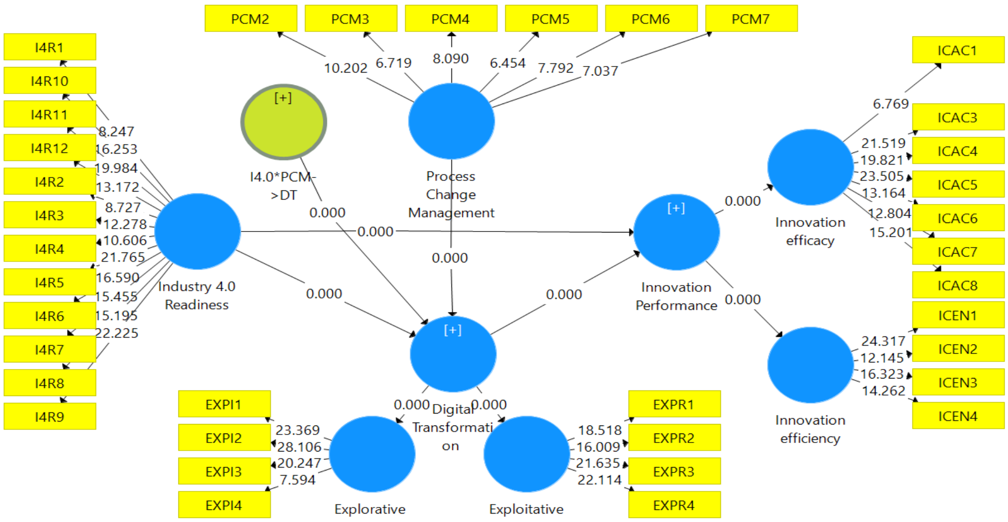

Figure 3: Structural Model

5. Discussion

Industry 4.0 studies in mechanical systems have come to focus increasingly on the issues of technological availability, and explore more fundamental questions of organizational preparedness, change processes, and innovation success. Although the initial literature mostly equated the success of industry 4.0 with the adoption of technology, as more recent works clarify that the value of innovation can only be realized once technological preparedness is transformed into organizational change and process restructuring(Pozzi et al., 2023). Among this shifting discussion, industry 4.0 readiness, digital transformation, innovation performance, and process change management are interdependent variables that influence the manner in which mechanical systems firms react to digital disruption. The current research paper adds to this discussion by proving empirically a sequential and conditional logics: industry 4.0 readiness makes digital transformation, this transforms innovation performance and process change management defines the level of success of the readiness-driven transformation. The following discussion puts these findings in the context of the previous theoretical and empirical arguments.

The fact that the first hypothesis has been accepted proves that industry 4.0 readiness is a major issue affecting digital transformation, which supports the claims that readiness is an organizational capability, not an auxiliary technological state. Previous literature implied that digital projects are not effective due to the absence of cohesive infrastructures, digital capabilities, and strategic alignment of the firms(Antony, Sony, McDermott, et al., 2023). The current results contribute to this literature by empirically confirming that industry 4.0 readiness is directly related to actual digital transformation in the mechanical systems, which facilitates the perception that readiness allows firms to overcome pilot projects and transform to the systemic digital integration(Mansour et al., 2023). This finding addresses discrepancies in the previous researches which had reported varying results on transformation even with similar technological investments suggesting that it is the readiness and not the presence of technology that creates a level of transformation.

More to the point, the strong moderating role of process change management explains the fact, why industry 4.0 readiness delivers a disproportionate digital transformation result among firms. Although the previous sources recognized the significance of change management, they mostly used process change management as a direct precursor to the success of transformation(Jankowska et al., 2023). The existing results reframe process change management as a boundary condition, whereby industry 4.0 readiness produces more impressive digital transformation due to the facilitation of structured process redesign, communication and employee engagement. This moderating role is particularly salient in mechanical systems where working routines are so entrenched. The results indicate that industry 4.0 readiness can be latent, i.e. It does not trigger any meaningful change without an effective process change management.

This engagement will contribute to the literature on industry 4.0 as it will combine perspectives on technological readiness and organizational change into one. It coincides with the dynamic capabilities theory that states that the sensing opportunities (industry 4.0 readiness) should be accompanied by reconfiguration mechanisms to produce the strategic results(Tortorella et al., 2024). Process change management becomes an effective tool of governance that allows firms to put the preparations into action instead of diluting the force of change by resisting, creating inertia, and sticking to a process. Therefore, the research empirically confirms the calls of process-based view on digital transformation in the manufacturing settings(Farrukh Shahzad et al., 2025).

The fact that the third hypothesis was accepted proves that industry 4.0 readiness has a strong impact on innovation performance in favor of the studies that correlate readiness with the increased innovation capability on the level of data-driven experimentation and flexible production structures(Ali & Johl, 2023). Nevertheless, this observation should be viewed in terms of ancient controversies. Previous studies had cast doubt on the ability of industry 4.0 readiness to drive innovation in its own right, with researchers providing the risk that too much concentration on technology would lock out exploratory innovation(Pozzi et al., 2023). This debate is resolved in the current study that demonstrates that readiness is a factor to the innovation performance, but it does not act independently as isolated of transformation processes.

The digital transformation will be used as a mediator to offer the much-needed critical explanatory mechanism absent in earlier researches. The results show that industry 4.0 readiness positively affects innovation performance by making digital transformation possible but not necessary, which supports the position that innovation gains are not due to readiness but are a result of digitally reconfigured innovation processes(Mansour et al., 2023). Digital transformation enables real-time knowledge streams, cross-functional coordination, and quick and short iteration, which is required during innovation in mechanical systems, which are complex and interdependent. This mediating role is the reason why many companies that are of equal industry 4.0 readiness tend to exhibit different results on innovation.

The empirical validation of the digital transformation as an intervening variable takes the study beyond the linear models of readiness-performance and adds to the process-oriented perspective of innovation in the context of industry 4.0. These findings are also consistent with dynamic capabilities perspective in that digital transformation has been placed under reconfiguring capability that translates technological preparedness into innovation value(Tortorella et al., 2024). This understanding is in direct response to the demand to conduct research that would define how industry 4.0 readiness can result in innovation performance, and not merely assess whether there is a relation between the two(Ghobakhloo et al., 2025).

The results obtained in all four hypotheses put forward form a logical and progressive reasoning as to why innovation occurs in industry 4.0-enabled mechanical systems. Industry 4.0 readiness becomes a requisite but inadequate requirement of innovation success; it manifests itself in digital transformation and will only have an effect on the process when it is managed with process change management. The integrated perspective can further develop the existing literature by showing that readiness, transformation, and change management are a system that should reinforce each other as opposed to being independent drivers. The empirical validation of mediation and moderation processes makes the study change the discourse on industry 4.0 from determinism on technology narratives to an organizational ability model. Finally, the results highlight the fact that digital readiness does not result in innovation of mechanical systems, but transformation of the readiness, which are governed and embedded into organizational processes.

5.1 Theoretical Implications

The study contributes to the literature on Industry 4.0 because it redefines Industry 4.0 Readiness as an organizational capability that is dynamic and not a technological state of being. The study goes beyond the linear models of readiness-performance by empirically validating Digital Transformation as a mediating mechanism, and Process Change Management as a moderating boundary condition. Incorporating these associations into a dynamic capabilities model enhances the theoretical knowledge regarding the way in which readiness is translated into Innovation Performance. The results add to the theory of innovation by showing how transformation depth and process governance can result in the formation of innovation in mechanical systems, which has resolved the long-running inconsistencies in previous empirical studies.

5.2 Practical Implications

The results offer practical advice to managers in the mechanical systems sectors who seek to pursue the Industry 4.0 efforts. To make sure that digital initiatives become significant Digital Transformation, firms must focus on the need to develop Industry 4.0 Readiness and organized practices of Process Change Management. Advanced technologies should be invested in along with conscious process redesign, involvement of employees, and communication of change. Moreover, the managers are advised to consider Digital Transformation as a strategic channel to improve Innovation Performance but not an independent IT activity. Integrating readiness, transformation, and change management can facilitate organizations to produce sustainable results of industry 4.0 investments.

5.3 Limitations and Future Research Directions

This research has a number of shortcomings though it has been helpful. To start with, the cross-sectional design limits causal inference in the relationship of Industry 4.0 Readiness, Digital Transformation, and Innovation Performance. Longitudinal studies would have the ability to reach the dynamics of transformation with time. Second, the research is specific to the mechanical systems industries and this might not be generalized to other industries. The model can be replicated in high-tech or service industries in future. Third, some reliance on the use of perceptual measures can lead to common method bias. Objective innovation indicators could be incorporated in future research. Lastly, other moderators like the organizational culture or style of leadership may be explored in order to further hone knowledge of readiness-based transformation.

6. Conclusion

This paper was aimed to analyses the translation of Industry 4.0 Readiness to Innovation Performance in mechanical systems by unravelling the functions of Digital Transformation and Process Change Management. The results show that preparedness is not enough to create innovation value unless it is transformed into meaningful Digital Transformation. Through the process of experimental confirmation of this mediating role, the research explains why comparable degrees of preparedness usually result in varying innovation performances in companies. The findings also indicate that Process Change Management plays an important role in enhancing the readiness-transformation relationship so that the management of organizational processes and technological initiatives is important. Together, the research paper brings a subtle and combined explanation of innovation in the conditions of Industry 4.0. The research contributes to the field of theory and practice by making Industry 4.0 Readiness as an enabler, Digital Transformation a value-creator, and Process Change Management a contextual amplifier. The results highlight that digital technologies alone do not influence the innovation of mechanical systems but rather the manner in which the organization prepares, manages, and integrates transformation into the process of operations and innovation. This unified view is a strong base of research and effective managerial decision-making in Industry 4.0 settings in the future.

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8. Appendix

8.1 Industry 4.0 Readiness

1. We use IoT sensors and AI to enable a proactive approach that supports team and our machines in real time.
2. We are collecting a lot of machine equipment data, but we are not sure how to use it for more than routine operation logistics.
3. Most of our data comes from routine manual data collections.
4. Custom quality assurance models use real-time data feeds to track how critical variables (e.g., temperature, sound, pressure, etc.) impact product quality and process flow.
5. We use generalized benchmarks, and workers on the floor are relied upon to identify and report any major issues.
6. We don't usually recognize a quality risk until it has been identified down the assembly line.
7. Feedback flows easily within our organization for constant communication – data is also shared with our suppliers, customers and partners.
8. We are working to connect different communication feeds internally and externally, but it's proving to be a challenge.
9. Our communication isn't integrated, so information gets stuck in silos.
10. Our organization is developing a 4.0 technical framework, and we're exploring the role our partners will need to play.
11. My team is just beginning to build a case for Industry 4.0 to put in front of senior leadership.
12. We have a basic understanding of what Industry 4.0 could do for our organization, but we need to learn more.

8.2 Digital Transformation

Explorative
1. Using digital technology to invent new products and services.
2. Adopting digital technology to discover new distribution channels.
3. Leveraging digital technologies to develop and enter new markets.
4. Utilizing digital technology to find and reach new customers in new markets.

Exploitative
1. Using digital technology to make minor improvements to existing products and services.
2. Employing digital technologies to deliver products and services more efficiently.
3. Leveraging digital technology to extend services to existing customers.
4. Employing digital technology to reduce expenses to reduce the cost of producing goods or services.

8.3 Innovation Performance

Innovation efficacy
1. Replacement of products being phased out
2. Extension of product range within main product field through technologically new products
3. Extension of product range within main product field through technologically improved products
4. Extension of product range outside main product field
5. Development of environment-friendly products
6. Market share evolution
7. Opening of new markets abroad
8. Opening of new domestic target groups

Innovation efficiency
1. Average innovation project development time
2. Average number of innovation projects
3. Average cost per innovation project
4. Global satisfaction degree with innovation projects' efficiency

8.4 Process Change Management

1. Does the organization follow a documented procedure for developing and maintaining plans for software process improvement?
2. Do people throughout your organization participate in software process improvement activities (e.g., on

teams to develop software process improvements)?
3. Are improvements continually made to the organization’s standard software process and the projects’ defined software processes?
4. Does the organization follow a written policy for implementing software process improvements?
5. Is training in software process improvement required for both management and technical staff?
6. Are measurements made to determine the status of the activities for software process improvement (e.g., the effect of implementing each process improvement compared to its defined goals)?
7. Are software process improvement efforts reviewed with senior management on a periodic basis?