Proceedings of the Fourth Australian International Conference on Industrial Engineering and Operations Management, Melbourne, Australia, November 25-27, 2025

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AU04.20250069
Published: November 25, 2025

Assessing Impact of Environmental Enablers in Digital Readiness for Industry 4.0 in Healthcare: Using a hybrid PLS-SEM and ISM Method

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Abstract

I4.0 can make a positive impact on healthcare by means of digitalization, automation, and evidence-based practices due to their potential. However, integration is still insufficient in Bangladesh because infrastructural needs have not been met, workforce is inadequate, its policies are not strong and awareness is low. This paper proposes a hybrid Model between Interpretive Structural Modeling (ISM) and Partial Least Squares Structural Equation Modeling (PLS-SEM) to assess the Digital readiness Capability. The analysis of a survey of 143 healthcare organizations was examined to test casual relationship and identify interdependencies between the barriers. In the PLS-SEM results, both organizational and technological readiness are significant factors driving the digital readiness status and environmental enablers exert their influence on digital readiness through organization mediation. The combined findings indicate that the key to the successful transformation is the necessity to address such underlying technological and organizational issues. The proposed research will make both theoretical and practical contributions through its provision of a replicable ISM PLS-SEM framework and practical recommendations to be used by healthcare policymakers and administrators in Bangladesh and other developing economies in their endeavors towards the implementation of digital health.

Keywords
Industry 4.0, Health Care, Partial Least Squares Structural Equation Modeling (PLS-SEM), Interpretive Structural Modeling (ISM).

1. Introduction
The Industry 4.0 (I4.0) technologies have rapidly evolved and reformed industries in many parts of the world due to the incorporation of the aspects of industry digitalization, automation and use of advanced data analytics (Martinelli 2021). Healthcare sector as one of the most important service sectors in Bangladesh faces the brink of this change. Despite all the potential benefits of I4.0 that might improve efficiency, the outcomes of the patients, and provide evidence-based decisions, the process of digital readiness in the Bangladesh healthcare system has been rather slow and uneven.

Infrastructure deficiency, low resources and low supporting regulation are common inhibiting factors in the healthcare sector in Bangladesh (Darkwa 2015). Due to the introduction of I4.0 technologies, e.g., Internet of Things (IoT), artificial intelligence, big data analytics, and cyber-physical systems, the possibilities to break these barriers exist. Yet to achieve successful digital readiness, there must be preparation in terms of technological capacity, organizational fit and environment (Machado 2021).

This paper examines obstacles that are deterring digital readiness of I4.0 and organizes them on a hybrid methodological procedure. Interpretive Structural Modeling (ISM) is employed to determine hierarchical interdependencies amongst barriers, whereas Partial Least Squares Structural Equation Modeling (PLS-SEM) is to be employed to test and validate such causal relationships between readiness factors (Roy 2025).

The importance of the study is that it can give healthcare policymakers, administrators, and technology providers a roadmap of addressing the challenges associated with digital readiness clearly. This paper has made an academic and practical contribution to literature on digital transformation in the developing economies by establishing the challenge of access to skilled workforce, lack of infrastructure, low awareness and ineffective government policies to be among the barriers to digital transformation.

1.1 Objectives

- To determine and classify the major obstacles to integration of the Industry 4.0 technologies in the Bangladeshi healthcare.
- To use a hybrid ISM-PLS-SEM framework to examine hierarchical interdependencies existing among these barriers and empirically prove the causal relations between the readiness factors.
- To present the strategic information and recommend policy actions

2. Literature Review

2.1 Health Care in Bangladesh

The health care systems in Bangladesh struggle with the challenges related to limitation of resources, health policy measures and technology within the environment thus making it a challenging task to adopt digital health technologies (Roy 2025). Although the industry view of Industry 4.0 is likely to proficiently streamline the operations, minimize misconducts, and an increase in the wellbeing of patients, the maturity of the healthcare sector lies in the mitigation of hindrances that embrace technological infrastructure, institutional dedication, and regulatory conformity. In this sense, it is critical to identify the equilibrium digital readiness capability to make sure that transformation strategies are both sustainable and cost-effective yet have a positive impact.

2.2 Industry 4.0

Industry 4.0 is the fourth industrial revolution that includes the incorporation of cyber-physical systems, IoT, automation, artificial intelligence, information-driven decision-making in industrial and service processes (Colombo 2017). The healthcare Industry 4.0 is set to transform the industry through smart health care systems, predictive analytics and resource utilization efficiency. But, in the developing countries like Bangladesh, there is a question mark on its digital readiness capacity because of the structural and contextual issues which militate against the transformation process. Besides technological improvements, health facilities with the highest preparedness in terms of policy, financial investment, workforce proficiency, and cultural-acceptance of cutting-edge technology are ready to adapt digitally (Citraresmi 2025). Thus, it is crucial to define the definite obstacles and overcome them to create the harmonious balance in the digital readiness of Industry 4.0 in the health care arena.

2.3 Partial Least Squares Structural Equation Modeling (PLS-SEM)

Partial Least Squares Structural Equation Modeling (PLS-SEM) is another supplementary statistic tool that can be employed to conduct empirical verification of the causal linkages amid the defined variables (Hair and Alamer 2022). Whereas ISM sheds light on the hierarchical nature of barrier to digital readiness elements, PLS-SEM lends quantities understanding to the relevance, strength and predictive activity of the same. The combination of ISM and PLS-SEM into a single methodology thereby provides a strong tool in arriving at the balance of Industry 4.0 digital readiness capability in the healthcare sector of Bangladesh.

2.4 Interpretive Structural Modeling (ISM)

Interpretive Structural Modeling (ISM) offers an organized mechanism of finding and evaluating connections among essential obstructions to the process of Industry 4.0 invasion (Karadayi-Usta 2019). In deciding which drivers are root causes and others dependent outcomes, ISM enables the decision-makers to know the factors by categorizing them hierarchically. This view on structure will aid the most in health care because all the technology, organizational, and behavioral aspects are intertwined and combine to pre-determine the digital transformation level.

2.5 Critical Factors of Bangladeshi Health Care Industry

The factors have been grouped according to their hierarchical levels in Table 1. Critical Factors affecting digital readiness entail paucity of skilled laborers (TR1), inadequate infrastructure (TR2), and weak degree of technology (TR3), which are technological problems. On organizational basis, cost of investment (OR1), government policy (OR2) and commitment of the top management (OR3) are the major deterrence. Readiness is undermined by such issues as the ecosystem-related problems of poor R&D initiatives (EE1), security and privacy of data concerns (EE2), and the lack of awareness concerning Industry 4.0 (EE3). What further complicating the way is, the challenges of an attitudinal and regulatory nature, including the resistance to change (DR1), the inability to collaborate (DR2) and the non-quality certification and standardization (DR3). This synergy among the factors justifies the need to devise a systematic ISM-PLS-SEM framework to determine the state of equilibrium and to assist the policymakers, the managers and other stakeholders in the health sector to plan effective policies.

Table 1. Critical factors of Bangladeshi health care industry to digital readiness industry 4.0

SL No.	Critical Factors	Description	References
1	Shortage of skilled workers (TR1)	Lack of properly trained or experienced staff that restrains productivity, innovation, and quality, causing the rise of the labor costs and complicated the usage of advanced technologies or sophisticated working systems.	(Brynjolfsson and McAfee 2012)
2	Insufficient infrastructure (TR2)	Lack of proper physical and digital infrastructures including transport, power or internet slow down operational performances, supply chain quality and technological progression, resulting in delays, increased expenditure and unfavorable competitiveness in the industry and service sectors.	(Kanike 2023)
3	Poor level of technology (TR3)	Ineffective or outdated technologies limit the innovation possibilities, productivity, efficiency of the processes, and hence organizations are unable to compete, keep up with the changes in the market, or deploy a more advanced such as automation or data analytics solutions.	(Houngbo 2017)
4	High cost of investment (OR1)	High initial amounts of capital spending on technology, infrastructure or skilled labor makes business less willing to move processes to higher levels thereby restricting growth, innovation and competition, particularly those small and medium enterprises that have little financial resources.	(Luce 2006)
5	Weak government policy (OR2)	The industrial growth, innovation and sustainability are all negatively affected by ineffective and unclear regulation and support systems, and the result is that the risk lacks the appropriate incentive, direction, and stability to achieve long-term business and technical success.	(Ashford and Hall 2011)
6	Poor commitment of the top management (OR3)	The absence of strategic vision, support, or engagement by the top leaders adversely affects organizational change, innovation, and performance improvement leading to poor resource allocation to the organization, poor employee motivation, and inability to execute long-term changes.	(Birken 2015)
7	Poor R&D initiative (EE1)	Narrow attention or investment in research and development curtail innovation, product development, and competitive advantage, and thus organizations do not adapt to the market needs or changes in technology with ease.	(Lei and Slocum Jr 2005)
8	Security and privacy of data issues (EE2)	Threats of unauthorized access and data breach and those of non-compliance with regulations in the systems hurt trust, operationalization and subject an organization in to legal, fiscal, and reputational harm, primarily in digital and networked systems.	(Folorunso et al. 2024)
9	Low awareness of	Incomplete comprehension of advanced digital technologies and	(Larkin 2020)

	Industry 4.0 (EE3)	their seductiveness does not permit organizations to incorporate smart manufacturing practices, productivity, competitiveness as induction and data-intensive industrial developments.	
10	Resistance to change (DR1)	Philosophical hesitation to pursue innovation, either by workers or through the enterprise as an entity, retards the change and can be rooted in fear, trepidation, or ease of doing things the way they are and inhibit growth and response to change in the market.	(Hallonsten 2023)
11	Lack of collaboration (DR2)	Weak mobility of knowledge, innovation and efficiency due to poor collaboration and communication among teams, between departments, partners or stakeholders results into lost opportunities, duplication of efforts and diluted competitive strength.	(Heckscher and Heckscher 2007)
12	Non quality certification and standardization (DR3)	Lack of established quality certificates and conformities to norms compromises the reliability of products as well as the confidence of consumers which restricts the access and competitiveness in the market and exposes defects, recalls and fines.	(Trienekens and Zuurbier 2008)

3. Methods

3.1 Research Design

The focus of this research was on healthcare institutions in Bangladesh wherein the quantitative data on Industry 4.0 (I4.0) digital readiness was to be recovered. The two study sectors, i.e., the public vs. the private hospitals, diagnostic centers, and pharmaceutical services, are sectors where the application of I4.0 technologies in the form of automization, IoT, and data analytics are becoming more and more considered. These industries have a tendency to be involved in different service providers such as IT suppliers, logistics, and equipment suppliers which demonstrates an intricate technology and organizational environment. The demographics of the respondents involved industry type, size of the organization, age of the firm, the position filled by the respondent and the duration of employment in the organization. With the dynamically changing external environment (with such events as COVID-19 pandemic and some other healthcare crisis), we made sure that the organizations that took part in our research shared their recent experience of managing such disruptions. The significance of environmental dynamism in the willingness and acceptance of Industry 4.0 technologies in medical institutions is described according to the following background. The theoretical model is shown in Figure 1.

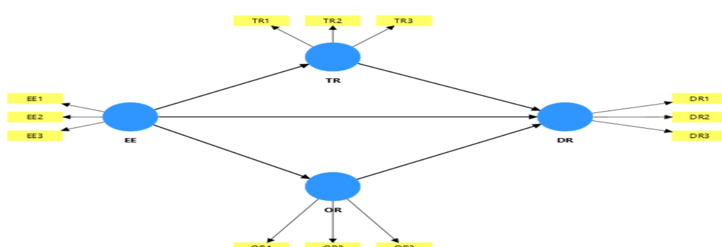

Figure 1. Theoretical Model

3.2 Survey Questionnaire Design

The measurement items of any construct were founded on the known academic literature and we have created them. In particular, four items were chosen to fit into our theoretical framework in order to measure it correctly. The survey was designed with the aid of search engine Google Forms, and the following are the validated items of the previous studies which were added. In order to get a good measure on the opinions held by the respondents; a questionnaire that would help determine the opinions was composed with a view of making them use a 5-point Likert scale and give their responses, with the answers ranging on a scale of 1(strongly disagree) to 5 (strongly agree) (Taherdoost 2019). An expert panel in different institutions was taken through a pilot test to ensure that the questionnaire was valid and in case of errors, improved it further. The email following survey allowed the receiving of the survey and thus the collection of qualitative data that was both effective and vast.

3.3 Sample and Data Collection

The survey was conducted by sending surveys through email to people in 206 of the selected companies and two reminders were sent to others who did not respond to the survey within two weeks after the first email. We then obtained 143 valid questionnaires (response rate = 69.42 %) at the expiry of the survey. We also checked in SOC-11 non-response bias (NRB) and we estimated in early and late waves t-statistics ($p > 0.05$) (Carlin and Doyle 2001). Our test results show that the problem of NRB is not significant in our research and we are free to move to the data analysis.

4. Data Collection

In this research, the Partial Least Squares Structural Equation Modeling (PLS-SEM) has been utilized with the help of Smart-PLS 4.0 software that resolves the long-standing weaknesses of the previous methodologies and is common in theory development in healthcare digital readiness studies. Interpretive Structural Modeling (ISM), to supplement the same purpose, was employed to draw the hierarchical connections and interrelationships between the factors of Industry 4.0 digital readiness. The pooled analysis involving ISM PLS-SEM has two advantages; the ISM is appropriate to know the structural sequence of factors and the PLS-SEM result supersedes the significance of factors which are statistically verified. This combination provides a combination of both conceptual understanding with the empirical quality in the evaluation of Industry 4.0 readiness in the health sector of Bangladesh.

4.1 Measurement properties of constructs

The indicator loadings, average variance extracted (AVE) and composite reliability (CR) were assessed with the help of the measurement model. All the reflective items were above the 0.6 criteria, the AVE was above the 0.5 criteria and the CR was above 0.7 (Cheung 2024). But in our model, we do not have a higher order construct. It was observed that each and every indicator (i.e. question in the data collection tool) is required or it is helpful in describing the different constructs in the model.

Table 2. Constructs, measurement items and their loadings

Construct	Measurement Items	Factor Loadings	Cronbach's α (CA)	Composite reliability (CR)	Average variance extracted (AVE)
TR	A C G	0.795 0.823 0.788	0.731	0.846	0.647
EE	B D E	0.607 0.731 0.794	0.523	0.756	0.511
OR	F J K	0.809 0.760 0.756	0.672	0.819	0.601
DR	H I L	0.833 0.800 0.778	0.722	0.844	0.643

Convergent validity is a measure of the extent to which an instrument is positively related to alternative measures of the same construct and it is computed as the average variance extracted (AVE). It shows how much of the data is accounted by each construct as compared to their sets of variables. The condition AVE >0.50 means that the construct explains more than 50 per cent of its indicators. Table 2 indicates that AVE ranged between 0.511 and 0.647 indicating that the constructions more than Half of the variance in their indicators. Thus, the model came at an acceptable solution and convergent validity was achieved. These findings indicate that the indicators used in the survey instrument are found to be consistent and produced reliable data.

Discriminant validity is used to assess the extent of differences between a construct and others in an experimental study. This is either gauged as cross loadings, or Fornell- Larcker criterion (Henseler 2015). The square root of every construct should have the value greater than the largest correlation with the others. As it can be seen in Table 3, this requirement has been met.

Table 3. Discriminant Validity-Fornell-Larcker Criterion

Construct	Digital Readiness	Environmental Enablers	Organizational Readiness	Technological Readiness
Digital Readiness	0.804			
Environmental Enablers	0.160	0.715		
Organizational Readiness	0.199	0.043	0.775	
Technological Readiness	0.395	0.116	0.001	0.802

Overall, the findings indicate that the measurement model is suitable as the latent variables prove to be reliable, consistent, and predictive enough to score the needed variables. Once the measurement model has been found to be an appropriate fit to the assessment standards, the second step would be to determine the validity of the structural model and its predictive abilities.

Table 4 demonstrates that there are several direct relationship hypotheses, and they are all supported. Environmental enablers has highly and significantly influenced on technological readiness as $\beta = 0.116$, $t = 1.603$ and $p < 0.05$. Thus, our hypothesis H1 is accepted. Therefore, the remaining direct relationships are validated.

Table 4. Results of Direct Hypotheses

Hypotheses	Hypotheses Paths	Path Coefficient	T statistics	P values	Outcomes of assessment
H1	EE -> TR	0.116	1.603	0.019	Accepted
H2	EE -> OR	0.043	0.455	0.049	Accepted
H3	OR -> DR	0.198	2.805	0.005	Accepted
H4	TR -> DR	0.395	9.909	0.000	Accepted

Table 5. Indirect hypotheses result (mediation)

Hypotheses	Hypotheses' Paths	Path Coefficient	T statistics	P values	Types of Effect	Decision
H5	EE -> OR ->DR	0.054	1.786	0.047	Partial Mediation	Accepted

Table 5 demonstrates the following results. Organizational readiness is a significant mediator between environmental enablers and digital readiness as $\beta = 0.054$, $t = 1.786$ and $p < 0.05$. Thus, the hypothesis H5 is accepted.

Table 6. Structural Self-Interaction Matrix (SSIM)

Varia ble	**Performance Measure**	**TR 1**	**TR 2**	**TR 3**	**O R1**	**O R2**	**O R3**	**EE 1**	**EE 2**	**EE 3**	**D R1**	**D R2**	**D R3**
TR1	Shortage of skilled workers		X	X	V	V	V	V	V	V	V	V	V
TR2	Insufficient infrastructure			X	V	V	V	V	V	V	V	V	V
TR3	Poor level of technology				V	V	V	V	V	V	V	V	V
OR1	High cost of investment					X	X	X	V	V	V	V	V
OR2	Weak government policy						X	X	V	V	V	V	V
OR3	Poor commitment of the top management							X	V	V	V	V	V
EE1	Poor R&D initiative								V	V	V	V	V
EE2	Security and privacy of data issues									X	X	X	X
EE3	Low awareness of Industry 4.0										X	X	X
DR1	Resistance to change											X	X
DR2	Lack of collaboration												X
DR3	Non quality certification and standardization												

Table 6 leads to the contextual interactions among the vital factors influencing to adopt with Industry 4.0 in Bangladesh healthcare. It points out in which each parameter drives or reliant on other and this list used for make the reachability matrix in ISM analysis.

Table 7. Reachability Matrix (RM)

Variable	**TR 1**	**TR 2**	**TR 3**	**OR 1**	**OR 2**	**OR 3**	**EE 1**	**EE 2**	**EE 3**	**DR 1**	**DR 2**	**DR 3**	**Drivin g Power**
TR1	1	1	1	1	1	1	1	1	1	1	1	1	12
TR2	1	1	1	1	1	1	1	1	1	1	1	1	12
TR3	1	1	1	1	1	1	1	1	1	1	1	1	12
OR1	0	0	0	1	1	1	1	1	1	1	1	1	9
OR2	0	0	0	1	1	1	1	1	1	1	1	1	9
OR3	0	0	0	1	1	1	1	1	1	1	1	1	9
EE1	0	0	0	1	1	1	1	1	1	1	1	1	9
EE2	0	0	0	0	0	0	0	1	1	1	1	1	5
EE3	0	0	0	0	0	0	0	1	1	1	1	1	5
DR1	0	0	0	0	0	0	0	1	1	1	1	1	5
DR2	0	0	0	0	0	0	0	1	1	1	1	1	5
DR3	0	0	0	0	0	0	0	1	1	1	1	1	5
Dependence Power	3	3	3	7	7	7	7	12	12	12	12	12	97/97

The reachability table is the summary of whether or not the identified factors are driving or dependent power that is shown in Table 7. Factors with high driving power that include inadequate skills labor, inadequate infrastructure, and technology come out as dominant drivers, whereas factors that are highly dependent are outcomes of such underlying obstacles.

Table 8 Final Level Partitioning (LP)

Elements	Reachability Set	Antecedent Set	Intersection Set	Level
TR1	1, 2, 3	1, 2, 3	1, 2, 3	III
TR2	1, 2, 3	1, 2, 3	1, 2, 3	III
TR3	1, 2, 3	1, 2, 3	1, 2, 3	III
OR1	4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7	4, 5, 6, 7	II
OR2	4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7	4, 5, 6, 7	II
OR3	4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7	4, 5, 6, 7	II
EE1	4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7	4, 5, 6, 7	II
EE2	8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	8, 9, 10, 11, 12	I
EE3	8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	8, 9, 10, 11, 12	I
DR1	8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	8, 9, 10, 11, 12	I
DR2	8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	8, 9, 10, 11, 12	I
DR3	8, 9, 10, 11, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	8, 9, 10, 11, 12	I

Table 8 classifies the factors into hierarchies. The most general barriers (e.g., TR1 - TR3) fill the bottom, mediating factors (e.g., OR1-OR3, EE1) the middle, and dependent barriers (e.g., DR1-DR3, EE2, EE3) the top of the hierarchy. This tier offers organized guidance toward prioritizing interventions to help with embracing Industry 4.0 in healthcare.

5. Results and Discussion

Findings obtained in this study have been reported in two combined sections; Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis, Interpretive Structural Modeling (ISM) analysis. Collectively, they give an in-depth insight into the Industry 4.0 digital readiness capacity in the Bangladesh healthcare system.

A critical evaluation of ISM barriers, with shortage of skilled labor, inadequate infrastructure, and weak technological capabilities, will tell why the situation continues to be the case in the healthcare sector of Bangladesh. Primarily, such barriers are reinforced by defective systemic governance frameworks such as irregular policy-making, volatile regulatory conditions and ineffective enforcement systems. Some past-related factors make the issue even more serious: the lack of investment in the digital health infrastructure and a comprehensive workforce training program to address the provincial health needs have consistently been channeled towards urgent and immediate measures to meet the demands of the populace instead of capacity building and digital transformation. In this regard, the result of a low historic priority given to research and development, and an organizational culture characterized by giving prominence to the lowest level of service delivery in healthcare instead of being innovative and digital impedes the adoption and scaling of advanced technologies.

These are further reinforced using the results of the SEM (Structural Equation Modeling) which empirically show that the relationship between the environmental enablers and the digital readiness is entirely mediated by organizational readiness. This implies that even when supportive policies are implemented and the overall environment is made more beneficial, the changes are not reflected in enhanced digital preparedness unless the hospitals and other healthcare organizations are adequately prepared—that is, with leadership dedication, guidance on the ways to cut down the costs, and resource distribution. The influence channel identified during the SEM thereby implies that the organizational level of behavior change is the top priority: unless, internal ability and enthusiasm to implement digital technologies exist, such environmental facilitators like national policy adjustments, awareness messages or regulation should indicate significant change. In brief the success of external reforms depends on great domestic strengths; only when the organizations are organized to benefit the possibilities of wider environmental development they become digitalize.

5.1 PLS-SEM Findings

The model used in measuring and evaluating the structures proved to have acceptable convergent and discriminant validity. All constructs the AVE of which was more than 0.50 and CR more than 0.70, proved their reliability and internal consistency. The direct hypothesis testing depicted strong ties: Environmental Enablers were positively affected Technological Readiness ($\beta = 0.116$, $p < 0.05$) and was also strongly affected by Technological Readiness

($\beta = 0.395$, $p < 0.001$), and Organizational Readiness also had significantly influenced Digital Readiness ($\beta = 0.198$, $p < 0.01$). Furthermore, there was a mediating effect when no connection between Environmental Enablers and Digital Readiness because the Organizational Readiness mediated this relationship, showing a partial mediation.

5.2 ISM Findings

There were twelve identified and categorized barriers to the digital readiness of Industry 4.0 according to the ISM methodology related to the healthcare sector. The most common obstacles according to Pareto analysis were low awareness of Industry 4.0, labor shortage, lack of infrastructure and weak technological state, are shown in Figure 2.

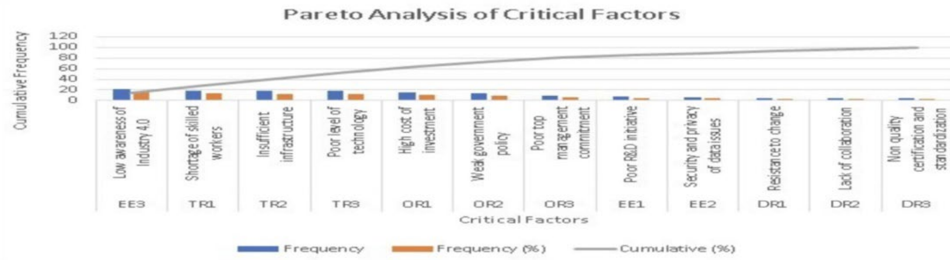

Figure 2. Pareto Diagram

In Figure 3, the reachability matrix and level partitioning assigned shortage of skilled workers, lack of infrastructure, and bad technology to the bottom (Level III) position, meaning that they have, therefore, an energetic force in driving the system. Weak government policy, high cost of investment and poor commitment of top management were factors which took intermediate (Level II) rankings. At level I (Top-level), the dependent factors, such as lack of awareness, unwillingness to change, the absence of collaboration, and non-quality certification arose as barriers.

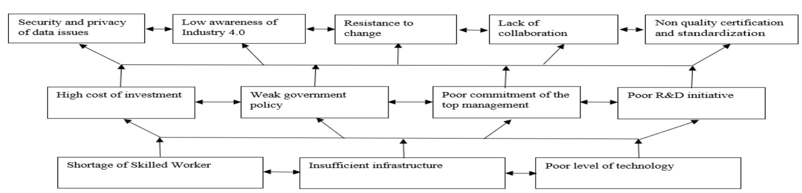

Figure 3. ISM-based structural model of critical factors to digital readiness industry 4.0 in Bangladeshi health care industry

In Figure 4, the MICMAC analysis also justified the division of barriers under the categories driver, dependent, linkage and autonomous, which could help in visualizing interdependencies.

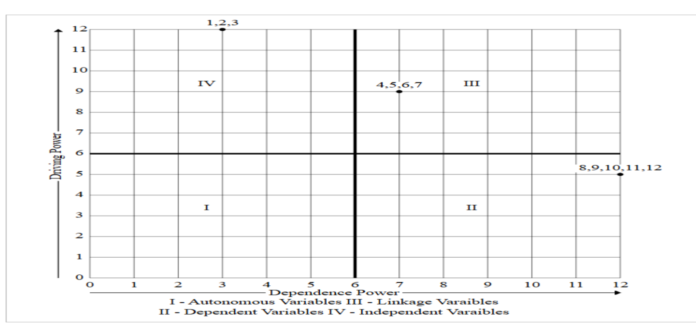

Figure 4. MICMAC Diagram

5.3 Integrated Results

Technological and organizational preparedness is not only individually relevant, but, in synergistic relationship, drives effective change. The adaptability of the hierarchy in ISM (Interpretive Structural Modeling) is that it displays enablers in distinct levels, with core factors like technology, human skills and infrastructure defining one end and awareness and cross-sector cooperation defining the other. SEM (Structural Equation Modeling), in its turn, proves that environmental catalysts cannot directly enhance digital readiness unless they are mediated by good organizational capabilities. Putting these findings together, the consistent approach is formed: ISM highlights the most effective priority of interventions, posts that the process should begin with the most basic, lower-level drivers. SEM also clarifies the channels of impact, so the interventions that may be made to one sphere (like regulation of the environment) can never lead to the stable and long-term improvements unless interconnected through organizational preparedness. As an example, whereas ISM may identify skilled labor shortages as root cause, SEM will assure that training initiatives will be most effective when institutionalized in the organizational processes-so that the interventions to institutionalized at national level will get traction and will make impact through the strong organizations.

6. Conclusion

This paper embarks on an ISM-PLS-SEM approach to help in the investigation of the preparedness and obstacles to the implementation of the Industry 4.0 technologies in the healthcare industry of Bangladesh. The findings show that technological preparedness, organizational fit and adaptability are key factors that shape digital transformation. According to PLS-SEM results, the primary mechanism is the support of digital readiness by technology and organizational readiness, whereas environmental readiness supports it indirectly. According to ISM, factors that contribute to the following barriers can be identified- lack of workforce skills, inadequate infrastructure and outdated technologies, with their grounds in low awareness, change reluctance, and difficulties in certification.

Integrated ISM-SEM results demonstrate that structural hierarchies (ISM) and causal pathways (SEM) are synergistic. Workplace, infrastructure, and technology gaps are identified as root causes in ISM and SEM shows that the organizational readiness is a channel where such environmental policies are made operational. This implies that the digital transformation of health in Bangladesh has to have a two-tier approach, in the first stage, find a solution to root-level technical and workforce shortcomings, and, at the same time, improve organizational capacity to make the environmental enablers effective.

According to the equilibrium model, a balance between technological possibilities and environmental factors must be found in order to achieve a successful digital readiness. It is required that practitioners dedicate funds to digital infrastructure, human capital, and conducive policies whereas it is the need of policymakers to develop regulations, promote R&D and increase the level of awareness about technology.

The work has a theoretical and practical value that provides a predictive and structural approach framework. Even with the restriction of methodology due to contextual issues, it could provide a model to developing other emerging economies. It is also possible to consider cross-country comparisons, cultural preparedness, and patient-centered digital healthcare outcomes in future research.

6.1 Implications

The paper contributes to theory by embracing both ISM and PLS-SEM and applying them to one comprehensive framework that has shown how technological, organizational and environmental factors of readiness interact on a hierarchical and statistical level to determine Industry 4.0 digital readiness capability in healthcare. By confirming the mediating role of organizational readiness, the study builds upon socio-technical systems theory and complements digital transformation literature in the arena of the developing economies.

The implications of the results between practice and policy include the recommendation of healthcare administrators to invest in digital infrastructures, workforce training, and executive promotion towards the practicable digital readiness. Policymakers must address the need to formulate the enabling regulatory frameworks, and encourage R&D with objectives to overcome resistance to change, by encouraging awareness programs. Understanding that barriers affect each other hierarchically will enable the stakeholders to more effectively deploy resources in light of the prioritized nature of converting barriers. Although we found several examples of grey-area presentations where lower-level issues were treated as a higher-level barrier (such as papacy and Vatican standardization as a way of dealing with skill shortages and infrastructure gaps), because of the hierarchical relationship, resource allocation towards lower-level barriers is still likely to be changed regardless of whether one is treating it as a higher-level one, so lower-level categories are still better suited to allocation of

6.2 Limitations

The limitation of the study is that it is confined to only healthcare institutions in Bangladesh limiting the applicability of the study outcomes to other sectors in other countries. Such dependence on the cross-sectional survey information might not reflect the dynamic nature of the digital readiness over a period. Besides, the study focuses on the structural and statistic relationships leaving out the qualitative validation of healthcare practitioners. Future research directions of this is a longer term study, investigation of cross-country comparisons among developing economies, and an amalgamation of patient centered digital health outcomes. The theoretical and practical implications would be further boosted by inclusion of more advanced analysis techniques including machine learning driven ISM-PLS models.

Acknowledgements

The authors would like to extend their appreciation to the individuals who participated in this study. Their assistance and cooperation were indispensable in making this research possible.

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