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Title: Modelling the Factors of Technological Innovation in the Healthcare Sector: A F-TISM-MICMAC Approach

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Modelling the Factors of Technological Innovation in the Healthcare Sector: A F-TISM-MICMAC Approach

Abstract

The healthcare (HC) sector has witnessed the proliferation of technological innovations over the last few decades aiming towards enhancing the quality of life, increased life expectancy, aspects of treatment and diagnostic options and the overall cost-effectiveness of HC services. The present study aims to identify and analyse the critical factors of technological innovations in HC services delivery. The identified factors have been validated and scrutinized using the fuzzy-Delhpi technique. The validated factors are then analysed by using the fuzzy-total interpretive structural modelling (F-TISM) modelling approach to develop the hierarchical inter-relationships among the factors and placing them at the different levels of the model. The Matrice d'impacts croisés multiplication appliquée á un classment (MICMAC) analysis has been implemented in the study to classify the factors of technological interventions into autonomous, dependent, linkage and independent group. The findings of the study highlight the six hierarchical structure and bottom level factors being the independent one affecting all the other factors above them. The most influential factors in the TISM model are public-private partnerships, integrated HC information system, health 4.0 in HC services, organizational culture and consumer demand. The hierarchical model developed in the study as well as the classification of the factors enables for the implementation at managerial level to achieve the desired organizational innovation in delivering HC services.

Keywords: Technological innovations; Healthcare (HC) services; Integrated HC information system; Organizational ambidexterity

Word count: 5541 (excluding tables and references)

1. Introduction

Healthcare (HC) innovations are considered as the induction of new concepts, ideas, products, services and processes to enhance the treatment of patients, their diagnosis, research and prevention to improve healthcare safety, quality, costs, outcomes and efficiency (Omachonuf et al., 2010; Thakur, 2021). The HC innovation is an essential feature and has global significance in terms of the rising costs of HC services (Witjas-Paalberends et al., 2018). The HC innovation is the driving force to reduce the cost of delivering the care services and at the same time increase the quality. The improvements in HC sector results in enhancing the life expectancy and accessibility to care services accompanied by developing a professional environment to cater to customizing the care services in areas that require the most (Negash et al., 2018). The improvement in the HC sector can be assessed by certain indicators such as structural measure, performance measure and outcome measure (Donabedian, 1990; Berenson et al., 2013; Hossain and Kamal, 2022). Structural measures relate to HC infrastructural settings, performance measure relates to operational HC processes and outcome measures pertains to HC interventions to deliver HC services. Additionally, the inevitability of innovations is exacerbated by the rise in the number of chronic diseases and necessitated re-thinking in delivering the HC services to the patients. Re-thinking on the HC services require integration and collaboration of the stakeholder as no single entity is independent enough to solve the multitude of the persisting complex problems (Negash et al., 2018). The Stakeholder collaboration (both internal as well as external) results is important of sustainable innovation in organizations in terms of redesigning processes, products and services (Ayuso et al., 2011).

The development in the IT services, infrastructures and health equipment has provided more frontiers in the delivery of HC services. Hence, accessibility to HC services can reach to any place, anytime using these technologies. These technological innovations open the opportunity for HC organizations, doctors and patients to access the wide array of information for real-time informed decision making and better care services (Negash et al., 2018; Hossain and Thakur, 2020). Informed decision support and better care services is furthered by integrating effective and efficient HC system accompanied by digital technologies that share information to the stakeholders beyond the boundaries of the organization (Christensen et al., 2009). The advanced technologies are quite cumbersome to implement at the organizational level but they can alter the way HC services are rendered to the patients. Therefore, a better understanding of how these technologies can change the HC industry is paramount. Specifically, the digital technological innovations are changing the way the HC services are delivered, managed and collaborated among the stakeholders (Laurenza et al., 2018). The technological innovations are deeply rooted to the HC processes that rely on knowledge, information and managing the same plays a critical role.

The HC industry in comparison to other industries, are faced with significant complexities in terms of the care services, limited resources and increased government regulatory frameworks (Laurenza et al., 2018; Thakur et al., 2021). These complexities are furthered by the highly complexed nature of the healthcare supply chain (HCSC) as compared to other sectors of the economy (Schneller and Smelzer, 2006; Hossain and Thakur, 2020; Hossain et al., 2022). There are certain factors that adds to this complexity. Firstly, the limited comprehension of HCSC management techniques and operations management, secondly, strong regulation governing the pharmaceutical industry and thirdly, the long lead times HC products influence on supply chain strategies and capacity planning (Shah, 2004; Schneller and Smeltzer, 2006). Therefore, the HC organizations are constantly striving to reduce the cost and enhance the quality and reduce complexity of delivering the care services to patients. The value creation through cost reduction and quality enhancement demands the involvement of multiple experts and several interventions throughout the complete cycle of HC service delivered to the patient (Porter, 2010). Therefore, technological intervention across the various processes of HC services can make them more efficient, increase the quality and response times.

The extant literature on innovation in HC is abundant (Goyen and Debatin, 2009; Omachonu and Einspruch, 2010; Witjas-Paalberends et al., 2017; Laurenza et al., 2018) in terms of the latest technological support and challenges in HC services delivery. However, none of them have comprehensively identified and analysed the factors that acts as drivers of robust technological innovation in the process of HC services delivery to the end users. Negash et al. (2018) expressed on the innovative approaches to IT in HC for development in low-income and middle-income countries and their performance can be achieved using services, provisions and outcomes. The study specifically, considered IT development to realize the performances but have not considered the other comprehensive factors of technological innovations in the HC sector (Hossain and Thakur, 2020). Witjas-Paalberends et al. (2017) considered the challenges and best industry practices in big-data for HC innovation in PPPs in the Netherland and the generalization of the findings study may not conform to other developing nations. Laurenza et al. (2018) focused on the extant use digital technologies in HC through the improvements in business processes. However, the study has certain limitations in terms of lacking in vigour, subjectivity of the researcher and validity from external sources. Bearing in mind the contemporary scenario and existing studies conducted in the HC innovation, the present study has identified the factors, scrutinized them through external sources and modelled them to provide an explicit understanding for better technological interventions in the processes of HC delivery.

The present study aims to answer the following research questions:

1. What are the critical factors to technological innovation that intervene the various processes of HC services delivery?
2. How are the factors scrutinized, analysed and modelled?
3. How are the factors categorized to achieve the level technological innovation in the HC services delivery?

Based on the above research questions, the following objectives of the study have been framed:

1. To identify the critical factors of technological innovation that influence the various processes of HC services delivery are identified through extant literature survey and experts' support.
2. To model the hierarchical inter-relationships among the factors of technological innovation that intervene the various processes of HC services delivery through the TISM approach.
3. To classify the factors using the MICMAC analysis based on their driving and dependence power.

The remainder of the paper is as follows. Section 2 gives theoretical foundations technological innovations in the HC. Section 3 covers the methodology considered in the study and section 4 relates to the applications of the proposed research methodology. Section 5 covers the results and discussion part as well as managerial implications of the study. Finally, the conclusion of the study has been highlighted in section 6.

2. Literature Review

Innovations in the HC sector is mostly concerned with products, process and structure (Varkey et al., 2008). The products in the HC services are generally related to goods and services that customers are willing to purchase. Innovation in the HC processes pertains to production system and the subsequent delivery methods. The structural mechanism emphasizes upon infrastructure both internal as well as external and the creation of subsequent business models. However, IT plays a crucial role in driving significant innovation in the HC sector (Gupta, 2008). This has prompted the transmission and processing of HC information to a great extent to realize the revolutionizing the delivery of HC services. The emergence of the information and communication technologies (ICTs) have paved the way forward for the creation, search and achieve to wander information and strengthened the opportunities in the collaborative HC front (Fox, 2011). The development of newer technologies in the HC domain have paced up and their potential can be felt over the quality of the care services being delivered to patients.

The current literature on the suggests HC accessibility and quality care by the recipients have led to the increased need for medical technologies to enhance care services and saving lives of the people living in the middle- and low-income countries. The ever-increasing demand for affordable and accessible care services necessitate for more innovation to make it a global phenomenon in terms of equity, low cost, efficient and enhanced quality of the HC services (Thakur, 2021). This has been realized by non-government organizations, research institutions and other HC organizations over the last decades (Thakur and Anbanandam, 2016; Thakur and Sharma, 2020; Gaspard, 2018). These aspects of the HC services have been observed concerning the lower-income and middle-income countries and regions with respect to the broad areas of measurement and instrumentation to provide cutting edge less expensive technologies to improve the quality and accessibility to HC services. The less expensive and advanced technologies include smart phone enabled technologies, 3D printing technologies, solar power technologies to increase reliability and accuracy of measurement (Gaspard, 2018).

The delivery of HC services has become complex and multi-dimensional necessitating the involvement of multiple stakeholders, namely, HC practitioners, innovator companies, patients and regulatory institutions to sustain the innovation process (Omachonu and Einspruch, 2010). The involvement of the HC stakeholders envisage furthering the public-private partnerships (PPPs) to achieve mutually acceptable goals through cooperation in generating ideas, sharing expertise and resources (Witjas-Paalberends et al., 2017; Thakur and Ramesh, 2017). Both the public and private HC facilities in order to strengthen the innovation process and faster delivery of the care services consider offshoring of HC services to reduce cost and the working loads by distributing the allied diagnostics services (Gupta, 2008). The HC services rendered by the facilities as well as the third-party offshoring services significantly relies on the integrated HC information systems to enable patients and organizations to access information with an ease (Gupta, 2008). Besides, the HC facilities has to sustain an organizational culture to foster innovation and growth that supplements the organizational ambidexterity in order to exploit and explore innovations (Christensen, 1997; Ramdorai and Herstatt, 2013). The organizational culture of promoting disruptive HC innovation acts as powerful and important source to develop and venture into new market opportunities. Disruptive innovations are anticipated and achieved through the implementation of the concepts of industry 4.0 applied in various medical fields for data processing in real-time to improve the functionalities in embedded systems (Alloghani et al., 2018).

3. Solution Methodology

The present study considers the application of fuzzy-Delphi technique to scrutinize the factors and the fuzzy-Total Interpretative Structural Modelling (F-TISM) to model the inter-relationships among the factors of technological interventions in the processes in HC services delivery. Further, the application of the Matrice d’impacts croisés multiplication appliquée á un classment (MICMAC) to classify the factors of technological interventions in the processes in HC services delivery, based on the driving and dependence power of both the fuzzy reachability matrix and the defuzzified reachability matrix to make the analysis more specific.

3.1. Scrutinizing the factors of technological interventions in the processes in HC services

The factors have been identified through literature reviews and experts’ support. The factors were then presented to the expert for the inputs and they were scrutinized using the fuzzy-Delphi method. The steps involved are as follows:

Step 1: Preparing the fuzzy-Delphi questionnaire and experts' input collection: the experts were asked to rate the factors based on linguistic variables.

Step 2: Setting up the fuzzy scales: the experts' inputs received in the form of linguistic variables are converted into triangular fuzzy numbers (shown in Table 1). The TFN for each factor is computed based on the geometric mean model of Hsu et al. (2008).

Table 1: Fuzzy linguistic scale to scrutinize the factors

Linguistic variables	**Triangular fuzzy numbers**
Very weak (VW)	(0, 0.2, 0.5)
Low (L)	(0.2, 0.4, 0.5)
Moderate (M)	(0.4, 0.6, 0.8)
High (H)	(0.6, 0.8, 1.0)
Very High (VH)	(0.8, 0.9, 1.0)

Step 3: Scrutinizing the factors: The TFNs are defuzzified using the center of gravity (CoV) method (Khairat et al., 2016). The factors are then scrutinized by keeping a threshold value by calculating the average of all the factors (Hsu et al., 2008). Only those factors whose value is found above the threshold value is considered for the purpose of the study.

3.2. Total Interpretative Structural Modelling

The existing TISM modelling is a qualitative and an interpretative approach that highlight the inter-relationships among the variables having the complex and unorganized attributes (Sushil, 2012; Dhir et al., 2021; Garg and Thakur, 2021; Hossain et al., 2021; Thakur et al., 2022). The TISM methodology helps to identify hierarchical as well as non-hierarchical relations among the factors of the technological interventions in the processes in HC services. This would help the HC facilities to identify the inter-relation and hierarchical among their concerned impeding factors to enhance performances and to achieve the desired innovation in delivering HC services. The TISM hierarchical structural model is based on the inputs received from experts. However, to address the biasedness and ambiguities in human judgements of the experts, the present study has utilized the concept of fuzziness in the form of fuzzy linguistic scales into the TISM method (Khatwani et al., 2015; Jain and Soni, 2018). The steps of implementing the F-TISM is as follows:

Step 1: Identifying the factors of technological interventions in the processes in HC services delivery from extensive literature survey and opinion of the experts. The attributes of the identified factors are such that they either influence other factors or they are influenced by other factors. The different levels of influence (Very Strong, Strong, Weak, Very Weak, No) among the factors are expressed in the form of linguistic variables (shown in Table 2). Each and all linguistic variables are indicated triangular fuzzy numbers (TFNs) respectively.

Table 2: The linguistic scales used to collect inputs from experts

Linguistic variables	**TFNs**
Very Strong (VS)	0.75, 0.1, 0.1
Strong (S)	0.5, 0.75, 0.1
Weak (W)	0.25, 0.5, 0.75
Very Weak (VW)	0, 0.25, 0.5
NO [O(N)]	0, 0, 0.25

Step 2: Developing the structural self-interaction matrix (SSIM).

The SSIM matrix is developed by collecting the responses from the experts based on the symbols V, A, X and O and the linguistic scales in Table 1. The experts are provided with the four choices as follows:

a. To indicate the forward relation (i to j and not vice-versa) between factors 'V' is used followed by ‘Very strong (VS)’, ‘Strong (S)’, ‘Weak (W)’ and ‘Very weak (VW)’. The V is integrated into the above linguistic scales as V(VS), V(S), V(W) and V(VW).

b. To indicate the backward relation (j to i and not vice-versa) among the factors, ‘A’ is used followed by VS, S, W and VW.

c. To indicate both ways relations (i to j and j to i) ‘X’ is used VS, S, W and VW.

d. To indicate no relations among factors, ‘O’ is used followed by ‘N’ and when both are integrated then it is represented as O(N).

Step 3: Computing the total SSIM and the final fuzzy-reachability matrix.

To aggregate the inputs of preferences by the experts, mode has been used and the SSIM matrix is developed and it is converted into fuzzy reachability matrix. The linguistic scales used by the experts are replaced with the TFNs. To develop the final fuzzy-reachability matrix for the entry by the experts, the following conditions (shown in Table 3) are attached:

Table 3: The TFNs for final fuzzy reachability matrix

Inputs of experts	Direction of influence (i to j)	Direction of influence (j to i)
V(VS)	0.75, 1.0, 1.0	0, 0, 0.25
V(S)	0.5, .75, 1.0	0, 0, 0.25
V(W)	0.25, 0.5, 0.75	0, 0, 0.25
V(VW)	0, 0.25, 0.5	0, 0, 0.25
A(VS)	0, 0, 0.25	0.75, 1.0, 1.0
A(S)	0, 0, 0.25	0.5, 0.75, 1.0
A(W)	0, 0, 0.25	0.25, 0.5, 0.75
A(VW)	0, 0, 0.25	0, 0.25, 0.5
X(VS)	0.75, 1.0, 1.0	0.75, 1.0, 1.0
X(S)	0.5, 0.75, 1.0	0.5, 0.75, 1.0
X(W)	0.25, 0.5, 0.75	0.25, 0.5, 0.75
X(VW)	0, 0.25, 0.5	0, 0.25, 0.5
X(VS, S), X(VS, W), X(VS, VW), X(S, VS), X(S, W), X(S, VW), X(W, VS), X(W, S), X(W, VW), X(VW, VS), X(VW, S), X(VW, W)	0.75, 1, 1	0.5, 0.75, 1.0 and accordingly follows for others
O(N)	0, 0, 0.25	0, 0, 0.25

Step 4: Developing the MICMAC analysis through the driving and dependence power

The total fuzzy-SSIM matrix has been used to compute fuzzy reachability matrix. From the fuzzy reachability matrix rows and columns are summed up and the fuzzy reachability matrix is defuzzified.

Step 5: Level partitioning using the reachability matrix

To partition the factors into the different levels of the hierarchical structural model, the reachability matrix is taken into account and prior to that the transitivity is also checked.

Step 6: Developing the F-TISM digraph and defuzzified TISM digraph

4. **Application of the Proposed Research Framework**

The application of the proposed research framework has been carried in three phases and is as follows:

Phase I: Scrutinizing the factors of technological interventions in the processes in HC services

The factors of technological interventions in the processes in HC services have validated and scrutinized using the fuzzy-Delphi method. The factors have been validated based on the inputs received based on the inputs received from the experts (details of the experts have been shown in Table 4). Initially, the study has found 13 of factors and were presented to the experts during the brainstorming session conducted with the experts. The fuzzy-Delphi method aggregated the inputs of the experts and subsequently they were analysed. The factors have been analysed and scrutinized based on the set threshold value (0.566, 0.733, 0.901 = 0.733) as shown in the Table 5.

Table 4: The details of the experts involved in the brainstorming sessions

Organization type	Profile of the experts	Academic qualification	Experience
Hospital	Neurosurgeon	MBBS, MD	11
Hospital	ENT	MBBS, MD (CMO)	17
Hospital	ENT	MBBS, MD, FRCS	14
Academic institution	Academic researcher	PhD (Professor)	8
Academic institution	Academic researcher	PhD (Professor)	5

Table 5: The factors of technological interventions in the processes in HC services

Factors	Description	References	Average de-fuzzified weights
HC innovations (F1)	Disrupting HC innovations act as powerful and important source to develop and broadens into new market opportunities.	Christensen (1997); Ramdorai and Herstatt (2013)	0.760
Monitoring drug safety (F2)	Drug safety database enables information on adverse drug reactions as well as other safety concerns on medical products.	Gupta (2008)	0.740
Health equity (F3)	HC accessibilities with respect to some critical care services are needed to cover more populace living in the farfetched areas.	Bacigalupe and Askari (2013)	0.800
Offshoring HC services (F5)	Outsourcing the HC diagnostic services that facilitates distributed workloads and cost reduction.	Gupta (2008)	0.820
Organizational ambidexterity (F6)	The capability of the organization to exploit and explore innovations.	Christensen (1997); Ramdorai and Herstatt (2013)	0.780
e-health (F7)	Mainstreaming the e-health into the regular	Bacigalupe and Askari (2013)	0.760

	HC services enables the patient to manage their health autonomously through the convergence of health IT and health electronic records.		
Stakeholder coordination (F8)	Complex HC and other multi-dimensional problems are resolved by stakeholders' coordination.	Omachonu and Einspruch (2010)	0.740
Public-private partnerships (F9)	PPPs in HC innovation enables achieving mutually benefitting goals through cooperation in generating ideas, sharing expertise and resources.	Witjas-Paalberends et al. (2017)	0.800
Integrated HC information system (F10)	Enables ready access to information and is globally integrated so that medical records can be easily accessible	Gupta (2008)	0.753
Health 4.0 in HC services (F11)	Industry 4.0 applied in various medical fields for data processing in real-time to improve the functionalities in embedded systems.	Alloghani et al. (2018)	0.733

Organizational culture (F12)	Innovation oriented organizational culture enables the HC providers to achieve competitive advantage through superior performance born out of innovation practices in the organization.	Acar and Acar (2012)	0.760
Consumer demand (F13)	Consumer demand is an important factor to receive better HC services and is directly related to the rise in the income of the patient.	Goyen and Debatin (2009)	0.760

Phase II: The F-TISM model development

The hierarchical structure of the F-TISM model is developed on the basis of the inputs received from the experts and the steps involved in the application of the proposed methodology is as follows:

Step 1: Identifying the factors of technological interventions in HCSC

The factors of technological interventions in the HCSC are identified through extensive literature review and experts' consultation. Initially, 13 factors were identified and through the scrutinization using the fuzzy-Delphi technique, 12 factors were validated (shown in Table 5).

Step 2: Collecting inputs from the exerts and developing the SSIM matrix

The data inputs collected from the experts have been used to develop the SSIM matrices that highlight the inter-relationships among the factors of technological in the HCSC as shown in Appendix B (Table 1 – Table 5).

Step 3: Computing the aggregated SSIM matrix and the fuzzy-reachability matrix

The inputs collected from the five experts are aggregated using mode (highest occurrence of preferences for individual factors are shown in Table 6) and the aggregated SSIM matrix is converted into final fuzzy-reachability matrix (shown in Table 7).

Table 6: Aggregated SSIM matrix of experts’ inputs

	F13	F12	F11	F10	F9	F8	F7	F6	F5	F3	F2	F1
F1	O(N)	V(VS)	V(VS)	O(N)	V(S)	V(VS)	V(S)	X(VS)	V(VS)	V(S)	V(VS)	
F2	X(VS)	X(VS)	V(S)	V(VS)	V(VS)	O(N)	V(VS)	A(VS)	A(VS)	A(S)		
F3	V(VS)	V(VS)	V(VS)	V(S)	V(VS)	V(VS)	V(VS)	A(VS)	X(VS)			
F5	V(VS)	V(VS)	V(VS)	V(S)	V(VS)	V(S)	V(VS)	O(N)				
F6	V(VS)	V(S)	V(VS)	V(VS)	V(S)	V(VS)	V(VS)					
F7	A(VS)	A(VS)	V(VS)	X(VS)	O(N)	O(N)						
F8	A(VS)	A(S)	V(VS)	V(VS)	X(VS)							
F9	A(VS)	A(VS)	V(S)	V(VS)								
F10	A(VS)	A(VS)	V(VS)									
F11	A(VS)	A(VS)										
F12	X(VS)											
F13												

Step 4: Computing the driving power and dependence power for MICMAC analysis

Based on the final reachability matrix the driving power and the dependence power for the factors is calculated (shown in Table 7). The Table 7 also shows the crisp values of both the driving and dependence power. In order to compute the crisp values of the driving and dependence power, the converting fuzzy data into crisp scores (CFCS) method has been implemented.

Table 7: The final fuzzy reachability matrix

	F1	F2	F3	F5	F6	F7	F8	F9	F10	F11	F12	F13	*
F1	(1,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)	(0,0,0.25)	(0.75,1,1)	(0.75,1,1)	(0,0,0.25)	8.9802
F2	(0,0,0.25)	(1,1,1)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1,1)	(0,0,0.25)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	6.7435
F3	(0,0,0.25)	(0.75,1,1)	(1,1,1)	(0,0,0.25)	(0,0,0.25)	(0.75,1,1)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.75,1,1)	8.3391
F5	(0,0,0.25)	(0.5,0.75,1)	(0.75,1,1)	(1,1,1)	(0,0,0.25)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.75,1,1)	8.9802
F6	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(1,1,1)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	10.1393
F7	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(1,1,1)	(0,0,0.25)	(0,0,0.25)	(0.75,1,1)	(0.75,1,1)	(0,0,0.25)	(0,0,0.25)	3.3648
F8	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1)	(1,1,1)	(0.75,1,1)	(0.75,1,1)	(0.75,1,1)	(0,0,0.25)	(0,0,0.25)	4.9965
F9	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1,1)	(0.5,0.75,1)	(1,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0,0,0.25)	(0,0,0.25)	4.8029
F10	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.5,0.75,1)	(0,0,0.25)	(0,0,0.25)	(1,1,1)	(0.75,1,1)	(0,0,0.25)	(0,0,0.25)	3.1583
F11	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(1,1,1)	(0,0,0.25)	(0,0,0.25)	1.3666
F12	(0,0,0.25)	(0.75,1,1)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(1,1,1)	(0.75,1,1)	7.4188
F13	(0,0,0.25)	(0.75,1,1)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(1,1,1)	7.4188
*	2.14	6.56	3.89	3.14	2.3	9.89	7.04	8.29	8.98	11.0	6.56	6.0	

*	56	02	04	39	653	15	08	74	03	937	02	712	

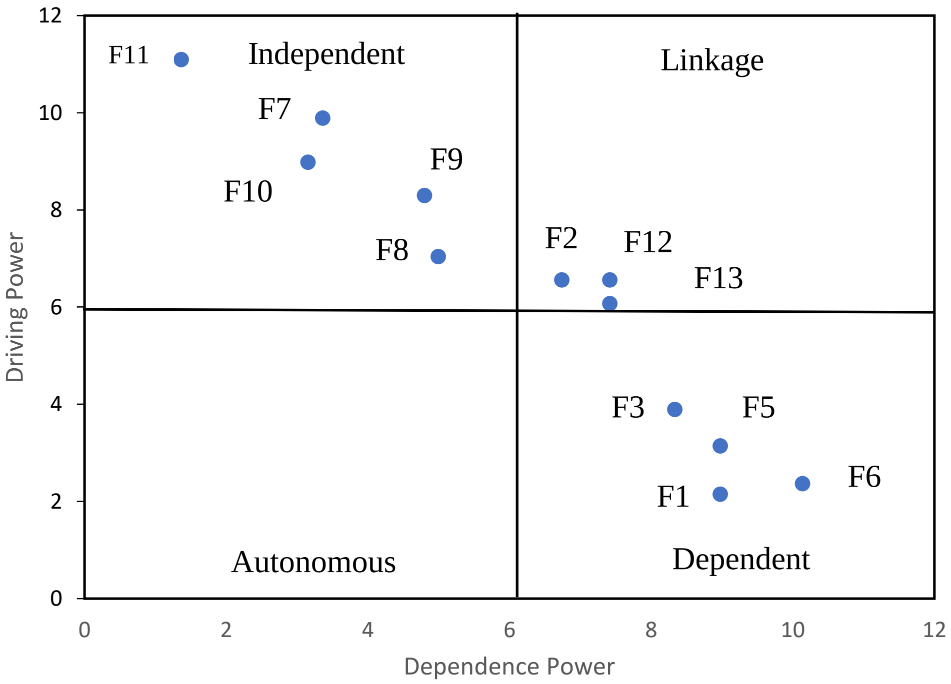

Fig. 1: MICMAC based on fuzzy reachability matrix

Step 5: Level partitioning of the reachability matrix

On the basis of the aggregated fuzzy reachability matrix, the fuzzy reachability matrix (shown in Table 8) is developed. Based on the fuzzy reachability matrix, the MACMAC analysis is carried out as shown in Fig. 1. To develop the defuzzified reachability matrix, the fuzzy linguistic variables of ‘Very strong influence’ and ‘Strong influence’ indicated by ‘1’ and the rest of others by ‘0’. The defuzzified reachability matrix (shown in Table 9) has been

Table 8: The fuzzy reachability matrix

	F1	F2	F3	F5	F6	F7	F8	F9	F10	F11	F12	F13
F1		VS	S	VS	VS	S	VS	S	N	VS	VS	N
F2	N		N	N	N	VS	N	VS	VS	S	VS	VS
F3	N	VS		N	N	VS	VS	VS	S	VS	VS	VS
F5	N	S	VS		N	VS	S	VS	S	VS	VS	VS
F6	S	S	S	S		VS	VS	S	VS	VS	S	VS
F7	N	N	N	N	N		N	N	VS	VS	N	N
F8	N	N	N	N	N	S		VS	VS	VS	N	N

F9	N	N	N	N	N	VS	S		VS	S	N	N
F10	N	N	N	N	N	S	N	N		VS	N	N
F11	N	N	N	N	N	N	N	N	N		N	N
F12	N	VS	N	N	N	VS	S	VS	S	VS		VS
F13	N	VS	N	N	N	VS	S	VS	VS	VS	S	

checked for transitivity among the factors. Subsequently, based on the deffuzified reachability matrix, the deffuzified MICMAC analysis and level partitioning of the factors have been carried out as shown in Fig. 2 and Appendix C (Table 1: Iteration 1- Table 6: Iteration 6) respectively.

Table 9: The fuzzy reachability matrix

	F1	F2	F3	F5	F6	F7	F8	F9	F10	F11	F12	F13
F1	1	1	1	1	1	1	1*	1	0	1	1	1*
F2	0	1	1	0	0	1	1	1	1	1	1	1
F3	0	1	1	0	0	1	1	1	1	1	1	1
F5	0	1	1	1	0	1	1	1*	1	1	1	1
F6	1	1	1	1	1	1	1	1	1	1	1	1*
F7	0	0	1	0	0	1	0	0	1	1	0	0
F8	0	0	1	0	0	1	1	1	1	1	0	0
F9	0	0	1	0	0	1	1	1	1	1	0	0
F10	0	1	1	0	0	1	0	0	1	1	1	1
F11	0	1	0	0	0	1	1	1	1	1	1	1
F12	0	1	0	0	0	1	1	1	1	1	1	1
F13	0	1	0	0	0	1	1	1	1	1	1	1

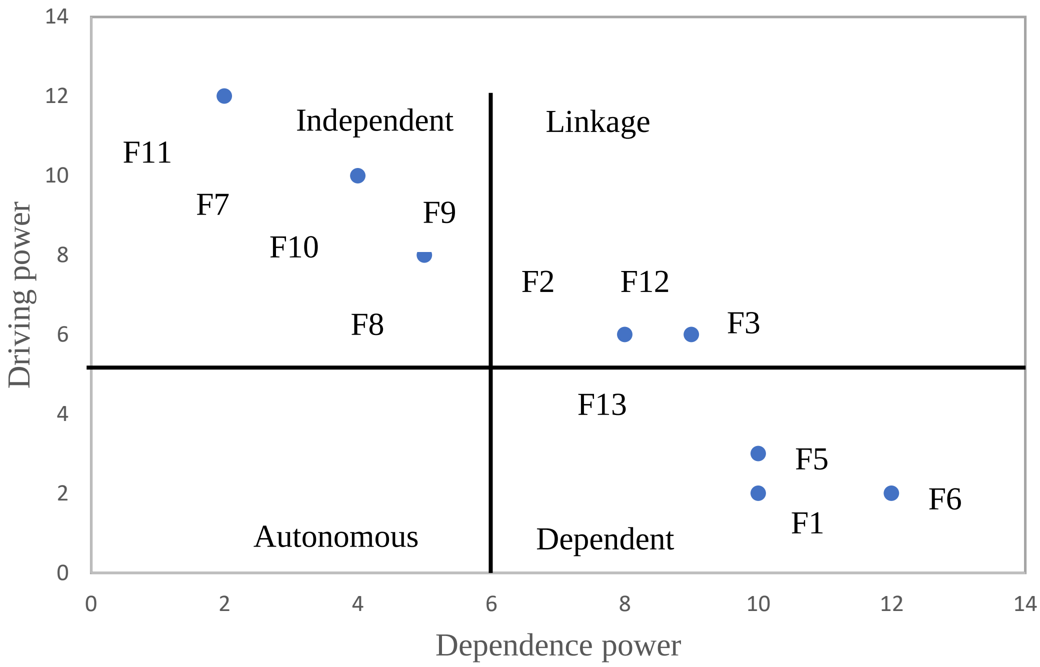

Fig. 2: MICMAC based on defuzzified reachability matrix

Step 6: Developing the defuzzified TISM digraph

The inter-relations among the factors have been represented through the defuzzified TISM digraph. The defuzzified reachability matrix, the defuzzified TISM digraph has been constructed (shown in Fig. 3).

5. Results and Discussions

The extensive literature survey and experts' suggestions enabled the identification of thirteen factors of technological interventions in the processes of HC services delivery. These drivers are critical to the promotion and sustenance of the innovation in the delivery of HC services. At this time and age, the HC sector is highly complex and susceptible to frequent disruption in the breakthrough technological advancement (Hossain and Thakur, 2020). The present study in order to continue the mission of furthering the technological advancement and interventions in the process of the HC delivery has developed a model and clustering the driving factors for better implementation at the organizational level. However, in order to achieve the set objectives of the study certain questions have been framed. The first question (*What are the critical factors to technological innovation that intervene the various processes of HC services delivery?*) enquired systematically into relevant recent literature on the concerned topic aided by suggestions from the experts helped identifying the 12 critical factors that have significant influence on the promotion and technological advancement in the HC sector. The address second question (*How are these factors scrutinized, analysed and modelled*?), the fuzzy-Delphi technique has been implemented in the study scrutinize and validate the factors of technological interventions in the processes in HC services delivery. The scrutinized factors are then analysed and modelled using the TIMS approach. The developed TISM model consists of six level of the hierarchical structure of inter-relationships among the factors. The factors in the TIMS model enable their implementation from the bottom level (independent factors) to achieve the desired topmost level factors of HC innovation. Finally, the enquiry into the last question (*How are the factors categorized to achieve the level technological innovation in the HC services delivery?*), the study implemented the MICMAC analysis based on fuzzy reachability matrix and defuzzified reachability matrix to categorized 12 factors into four group (shown in Fig. 1 and Fig. 2). The major findings of the MICMAC analysis based on the fuzzy reachability matrix is as follows:

Independent group of factors: The factors that falls under this group includes: 'e-health (F7)', 'Stakeholder coordination (8)'; 'Public-private partnerships (F9)'; 'Integrated HC information system (F10)' and 'Health 4.0 in HC services (F11)'. These factors are found at the bottom of the TISM model developed in the study and impacts the other variables just

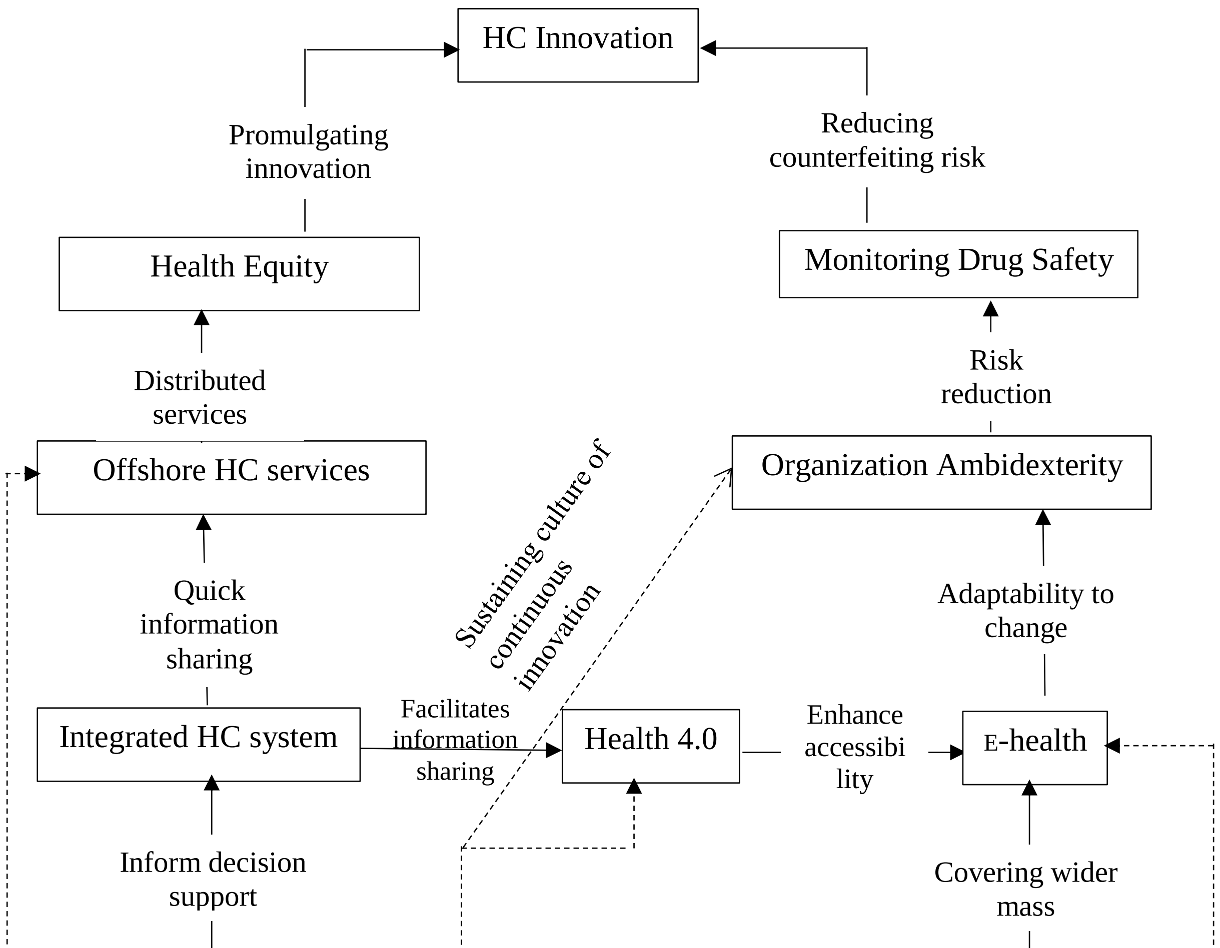

Fig. 3: The TISM model for the factors of technological interventions HC services

above them. These independent factors directly act as inputs for technological interventions in the processes of HC services.

Dependent group of factors: The factors, namely, ‘HC innovations (F1)’;; Health equity (F3) and ‘Offshore HC services (F5)’ and ‘Organizational ambidexterity (F6)’ have low driving and higher dependence power. Therefore, in order to achieve sustained level of innovation in the HC services delivery, all the other factors are needed to be pushed for performance enhancement to create impacts on the dependent factors.

Linkage group of factors: The linkage factors include: ‘Monitoring drug safety (F2); ‘Organizational culture (12) and ‘Consumer demand (F13)’. These factors have higher dependence as well as driving power. These factors are highly volatile and therefor, the HC organizations should emphasize on moulding them to suit their needs.

Autonomous group of factors: This group possess the low driving and dependence power. In the present study, no factors have been found to be included into this group.

The MICMAC analysis based on the defuzzified reachability matrix, has resulted in minor changes in the classification of factors as shown in Fig. 2. In the independent group, the same factors, namely, F7, F8, F9, F10 and F11 exist as in the MICMAC analysis based on fuzzy reachability matrix as shown in Fig. 2. The dependent group consists of the three factors (F1, F5 and F6) instead of the four factors as shown in the Fig. 2. In the linkage group, three factors (F2 and F12) have been placed. However, interestingly, two factors: ‘Health equity (F3) and ‘Consumer demand (F13) have been placed both in the exact horizontal axis indicating that both the factors possess the characteristics of the dependent and linkage group.

In the TISM model, ‘Organizational culture (F12)’ and ‘Consumer demand (F13)’ are the level 1 factors placed at the bottom of the hierarchical structure. These two factors possess higher influencing/driving power to influence the other remaining factors. Nurturing and sustaining organizational culture are crucial for the linear growth of the technological innovations in the HC organizations (Hossain and Thakur, 2020). Similarly, HC organizations have to follow the trends on the growth in the consumer income level and set its course to opt for the path of technological innovations in the HC. The rise in the level on consumer income urges them to aspire them to access innovative and highly quality HC services (Goven and Debatin, 2009). The level 2 of the TISM model consists of two factors, namely, Public-private partnerships (F9) and Stakeholder coordination (F8). These two factors also crucial for influencing the factors above them and bears significant results in the technological advancement in the HC organizations. The PPPs among the HC among the HC organizations are needed to develop capacity and aid the transfer of technology sharing as well knowledge on their operations (Witjas-Paalberends et al., 2017).). The factor stakeholders’ coordination is crucial for the much-needed flexibility to meet the unplanned technological requirement of the organizations to meet the fluctuated demands of the patents seeking care services (Omachonu and Einspruch, 2010). On a broader spectrum, the much-needed coordination of both the internal and external stakeholders of HC providers inevitably facilitates minimizing the HCSC complexities (Shah, 2004; Hossain and Thakur, 2021). The complexities in the HCSC is triumphed through a better comprehension of operations and supply chain practices and subsequently, strategies are devised and capacity is capacity specifically, with respect to inventory management is planned accordingly (Bhakoo et al., 2012). The third level of the TISM hierarchical model consists of ‘Integrated HC information system (F10)’, ‘Health 4.0 in HC services (F11)’ and ‘e-health (F7)’. The integrated HC information system aided by the health 4.0 technologies such as cyber-physical system, big data, cloud computing and inter of things enable the HC organizations manage data and information that can be accessed instantly both by the organizations as well as the patient to enhance the efficiency and effectiveness in HC services delivery (Gupta, 2008; Alloghani et al., 2018)). In the age high predictability of the disruption in HC services, necessities furthering delivery of the care services to the wider masses and e-health provide important pathways to achieve the same (Bacigalupe and Askari, 2013). The level 4 of the TISM model includes the factors of ‘Offshore HC services (F5)’ and ‘Organizational ambidexterity (F6)’. HC organizations to lighten the burden of excessive demand for care services and put maximum thrust on HC innovation, outsource their diagnostic and other supplementary services through offshoring to a third-party vendor (Gupta, 2008). The HC organizations through ambidexterity constantly exploits and explore technological upgradation within the organizations and looks for future possible innovations externally (Christensen, 1997; Ramdorai and Herstatt, 2013). The level 5 includes the factors of ‘Health equity (F3)’ and ‘Monitoring drug safety (F2)’. Finally, the factor considered at the topmost level of the hierarchy of the TISM model is ‘HC innovation’. This factor is highly dependent factor whose performance is highly dependent on the factors below it to achieve the desired level of technological innovation the HC services delivery.

5.1. Practical managerial implications

The present study bears important practical managerial implications that caters to the need for implementation at the managerial level to achieve the technological innovations required in health facilities. The important managerial implications are as follows:

i) The managers at the health facilities should emphasize on developing, nurturing and benchmarking the organizational culture of continuous process improvement and documenting the same to further the needed technological advancement in HC services delivery. At the same time, consumer demand for HC is needed to be focused as the rise in the income level pushes them for better care services. Hence, the pattern of consumer demand has to be followed by the organization for their effectiveness.

ii) In order to meet the challenges of HC complexities and capacity building, the managers should focus on strengthening the PPPs and engage the stakeholders on the same table. Consequently, more consumer demands can be met and the desired level of flexibility as well as the innovations can be achieved.

iii) The managers in the HC sector need to develop an integrated HC system using the recent development taking place by considering the technologies of the health 4.0. This would enable both the organization as well as patients to safely access information at ease.

iv) In the case of much workloads faced by the HC organizations and to concentrate more the innovation path, the manager should consider offshoring the diagnostic and pharmaceutical services to the third party.

v) The HC managers should emphasize upon organizational ambidexterity to make the organization dynamic to cope up with internal as well as external uncertainties. This would enable the HC organization to be more accessible and innovative.

6. Conclusion of the study

The contemporary scenario on the technological interventions in the processes of care services require significant attention from the HC practitioners as well as researchers to alleviate the persisting gaps to meet the expectations of the patients as well as their safety through precision care services. Additionally, the technological innovations in developing countries like India is inadequate that results in the skyrocketing the costs of HC services. Resultantly, the rise in the cost of HC services leads to the higher out-of-pocket expenditure of the patients. Hence, the main objective of the present study was to pave the way forward for technological interventions in the processes of HC services through modelling the incumbent and crucial factors to implement them at the organizational level. The study identified 12 important factors through literature support and experts' suggestion and validated them using the fuzzy-Delphi technique. Once the factors have been validated and scrutinized, they were further analysed using the TISM modelling approach. The TISM model by considering the impeding factors in HC suggests that the high driving independent enablers at the bottom of the hierarchy are crucial to develop a policy framework to achieve the impactful technological innovations. Further, the implementation of the MICMAC analysis has delineated the factors into four quadrants, namely, independent, dependent, linkage and autonomous groups. The delineation of the factors has helped in identifying the attribute and role of each and every factor from the perspective of technological innovations in the HC sector. The most important and highly influencing factors considered by the MICMAC analysis are 'Public-private partnerships (F9)', 'Integrated HC information system (F10)', 'Health 4.0 in HC services (F11)', 'Organizational culture (F12)' and 'Consumer demand (F13)' to influence the HC organizational orientation towards technological innovations and patient safety.

The study however, is not free from certain limitations and thus opens the window of opportunities for future researchers. Firstly, the research has been conducted from the perspective of the India and other developing countries. Hence, this makes generalizability of the study to other developed nations not feasible and hence inputs and thrust are needed from the future researchers to widen the scope of the study. Secondly, the study has implemented the modelling approach of TISM and MICMAC analysis. The future research studies can consider the fuzziness into the study to bring to light the existence of any inconsistencies found. The fuzziness would enable elimination of the inconsistency of the biasedness of the human judgments. Thirdly, findings of the study can be strengthened by conducting an empirical study by applying the Structural Equation Modelling (SEM) and SWARA analysis.

References

Acar, A. Z., & Acar, P. (2012). The effects of organizational culture and innovativeness on business performance in healthcare industry. Procedia-Social and Behavioral Sciences, 58, 683-692.
Alloghani, M., Al-Jumeily, D., Hussain, A., Aljaaf, A. J., Mustafina, J., & Petrov, E. (2018, September). Healthcare services innovations based on the state-of-the-art technology trend industry 4.0. In *2018 11th International Conference on Developments in eSystems Engineering (DeSE)* (pp. 64-70). IEEE.
Ayuso, S., Rodríguez, M. Á., García-Castro, R., & Ariño, M. Á. (2011). Does stakeholder engagement promote sustainable innovation orientation? *Industrial Management & Data Systems*.
Bhakoo, V., Singh, P., & Sohal, A. (2012). Collaborative management of inventory in Australian hospital supply chains: practices and issues. Supply Chain Management: An International Journal.
Christensen, K., Doblhammer, G., Rau, R., & Vaupel, J. W. (2009). Ageing populations: the challenges ahead. *The lancet*, *374*(9696), 1196-1208.
Dhir, S., Rajan, R., Ongsakul, V., Owusu, R. A., & Ahmed, Z. U. (2021). Critical success factors determining performance of cross-border acquisition: Evidence from the African telecom market. *Thunderbird International Business Review*, *63*(1), 43-61.

Fox, S. (2011). *The social life of health information, 2011* (pp. 1-33). California Healthcare Foundation.
Garg, S., & Thakur, V. (2021). Modeling the factors of productivity in airline industry in India: A hybrid TISM-P and fuzzy-MICMAC approach. *International Journal of Global Business and Competitiveness*, *16*(1), 39-47.
Gaspard, S. (2018). Healthcare innovations for low- and medium-income countries or environments today and visions for the future. *Ieee Instrumentation & Measurement Magazine*, *21*(5), 11-18.
Goyen, M., & Debatin, J. F. (2009). Healthcare costs for new technologies. *European journal of nuclear medicine and molecular imaging*, *36*(1), 139-143.
Gupta, H. D. (2008). Identifying Health Care Quality Constituents: Service Providers' Perspective. *Journal of Management Research (09725814)*, *8*(1).
Hossain, M. K., & Thakur, V. (2020). Benchmarking health-care supply chain by implementing Industry 4.0: a fuzzy-AHP-DEMATEL approach. *Benchmarking: An International Journal*.
Hossain, M. K., Thakur, V., & Kazancoglu, Y. (2022). Developing a resilient healthcare supply chain to prevent disruption in the wake of emergency health crisis. International Journal of Emerging Markets, (ahead-of-print).
Hossain, M. K., Thakur, V., & Mangla, S. K. (2021). Modeling the emergency health-care supply chains: responding to the COVID-19 pandemic. *Journal of Business & Industrial Marketing*.
Hsu, P. F., Wu, C. R., & Li, Y. T. (2008). Selection of infectious medical waste disposal firms by using the analytic hierarchy process and sensitivity analysis. *Waste Management*, *28*(8), 1386-1394.
Khairat, S., Sandefer, R., Marc, D., & Pyles, L. (2016). A review of biomedical and health informatics education: a workforce training framework. *J Hosp Adm*, *5*(05), 10-20.
Laurenza, E., Quintano, M., Schiavone, F., & Vrontis, D. (2018). The effect of digital technologies adoption in healthcare industry: a case-based analysis. *Business process management journal*.
Negash, B., Gia, T. N., Anzanpour, A., Azimi, I., Jiang, M., Westerlund, T., ... & Tenhunen, H. (2018). Leveraging fog computing for healthcare IoT. In *Fog computing in the internet of things* (pp. 145-169). Springer, Cham.
Omachonu, V. K., & Einspruch, N. G. (2010). Innovation in healthcare delivery systems: a

conceptual framework. *The Innovation Journal: The Public Sector Innovation Journal*, *15*(1), 1-20.

Porter, M. E. (2010). What is value in health care. *N Engl J Med*, *363*(26), 2477-2481.

Ramdorai, A., & Herstatt, C. (2013). Lessons from low-cost healthcare innovations for the base of the pyramid markets: how incumbents can systematically create disruptive innovations, working paper, no. 74, Hamburg University of technology (TUHH), Institute for technology and innovation management (TIM), Hamburg.

Scheller, E.S. and Smeltzer, L.R. (2006), Strategic Management of the Health Care Supply Chain, 1st ed., Wiley, San Francisco, CA.

Shah, N. (2004), "Pharmaceutical supply chains: key issues and strategies for optimisation", Computers & Chemical Engineering, Vol. 28 Nos 6/7, pp. 929-41.

Thakur, V. (2021). Framework for PESTEL dimensions of sustainable healthcare waste management: Learnings from COVID-19 outbreak. *Journal of cleaner production*, *287*, 125562.

Thakur, V., & Anbanandam, R. (2016). Healthcare waste management: an interpretive structural modeling approach. *International journal of health care quality assurance*.

Thakur, V., Parida, D. J., & Raj, V. (2022). Sustainable municipal solid waste management (MSWM) in the smart cities in Indian context. *International Journal of Productivity and Performance Management*.

Varkey, P., Horne, A., & Bennet, K. E. (2008). Innovation in health care: a primer. *American Journal of Medical Quality*, *23*(5), 382-388.

Witjas-Paalberends, E. R., van Laarhoven, L. P. M., van de Burgwal, L. H. M., Feilzer, J., de Swart, J., Claassen, E., & Jansen, W. T. M. (2018). Challenges and best practices for big data-driven healthcare innovations conducted by profit–non-profit partnerships–a quantitative prioritization. *International Journal of Healthcare Management*, *11*(3), 171-181.

Supplementary File

Appendix A:

Table 1: Sample of the first set of questionnaires presented to expert 1

Please indicate your response/agreement on the credibility of the factors using a fuzzy linguistic scale ranging from *Very weak (VW)* to *Very high (VH).*

	Very weak (VW)	Low (L)	Moderate (M)	High (H)	Very High (VH)
HC innovations				✓	
Monitoring drug safety			✓		
Health equity					✓
Offshoring HC services					✓
Organizational ambidexterity			✓		
e-health				✓	
Stakeholder coordination					✓
Public-private partnerships			✓		
Integrated HC information system		✓			
Health 4.0 in HC services				✓	
Organizational culture				✓	
Consumer demand			✓		

Table 2: The TFNs and the defuzzification process to scrutinize the factors

	Factor1			**Factor2**			**Factor3**		
	l	**m**	**u**	**l**	**m**	**u**	**l**	**m**	**u**
Expert1	0.6	0.8	1	0.4	0.6	0.8	0.8	0.9	1
Expert2	0.4	0.6	0.8	0.6	0.8	1	0.6	0.8	1
Expert3	0.8	0.9	1	0.8	0.9	1	0.8	0.9	1
Expert4	0.8	0.9	1	0.4	0.6	0.8	0.4	0.6	0.8
Expert5	0.4	0.6	0.8	0.6	0.8	1	0.6	0.8	1
Average fuzzy numbers	**0.6**	**0.76**	**0.92**	**0.56**	**0.74**	**0.92**	**0.64**	**0.8**	**0.96**
	l1	**m1**	**u1**	**l1**	**m1**	**u1**	**l1**	**m1**	**u1**
Defuzzification process Amax=1/3*(l1+m1+u1)	**0.760**			**0.740**			**0.800**		

Continued…

Factor4			**Factor5**			**Factor6**			**Factor7**		
l	**m**	**u**	**l**	**m**	**u**	**l**	**m**	**u**	**l**	**m**	**u**
0	0.2	0.5	0.8	0.9	1	0.4	0.6	0.8	0.6	0.8	1
0.4	0.6	0.8	0.6	0.8	1	0.6	0.8	1	0.4	0.6	0.8
0	0.2	0.5	0.8	0.9	1	0.6	0.8	1	0.8	0.9	1
0	0.2	0.5	0.4	0.6	0.8	0.8	0.9	1	0.8	0.9	1
0.2	0.4	0.5	0.8	0.9	1	0.6	0.8	1	0.4	0.6	0.8
0.12	**0.32**	**0.56**	**0.68**	**0.82**	**0.96**	**0.6**	**0.78**	**0.96**	**0.6**	**0.76**	**0.92**

l1	m1	u1	l1	m1	u1	l1	m1	u1	l1	m1	u1
0.333			**0.820**			**0.780**			**0.760**		

Continued…

Factor8			Factor9			Factor10			Factor11		
l	**m**	**u**	**l**	**m**	**u**	**l**	**m**	**u**	**l**	**m**	**u**
0.8	0.9	1	0.6	0.8	1	0.2	0.4	0.5	0.6	0.8	1
0.4	0.6	0.8	0.8	0.9	1	0.8	0.9	1	0.2	0.4	0.5
0.6	0.8	1	0.4	0.6	0.8	0.8	0.9	1	0.6	0.8	1
0.4	0.6	0.8	0.8	0.9	1	0.6	0.8	1	0.8	0.9	1
0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1
0.56	**0.74**	**0.92**	**0.64**	**0.8**	**0.96**	**0.6**	**0.76**	**0.9**	**0.56**	**0.74**	**0.9**
l1	**m1**	**u1**	**l1**	**m1**	**u1**	**l1**	**m1**	**u1**	**l1**	**m1**	**u1**
0.740			**0.800**			**0.753**			**0.733**		

Continued…

Factor12			Factor13		
l	**m**	**u**	**l**	**m**	**u**
0.6	0.8	1	0.8	0.9	1
0.8	0.9	1	0.6	0.8	1
0.4	0.6	0.8	0.8	0.9	1
0.4	0.6	0.8	0.4	0.6	0.8
0.8	0.9	1	0.4	0.6	0.8

Appendix B:

Table 1: The SSIM matrix (recorded inputs of expert 1)

Ex 1	F13	F12	F11	F10	F9	F8	F7	F6	F5	F3	F2	F 1
F1	O(N)	V(VS)	A(W)	O(N)	V(S)	V(VS)	V(S)	X(VS)	V(VS)	V(S)	V(VS)	
F2	X(S)	X(VS)	V(S)	V(VS)	V(S)	A(VW)	V(VS)	A(VS)	A(S)	A(S)		
F3	V(VS)	V(S)	V(W)	V(S)	V(S)	V(VS)	V(VS)	A(VS)	X(VS)			
F5	V(S)	V(VS)	V(VS)	V(VW)	V(S)	V(S)	V(VS)	O(N)				
F6	O(N)	V(VS)	V(VS)	V(VS)	V(S)	V(S)	V(VS)					
F7	A(VS)	A(S)	V(VS)	X(VS, S)	A(W)	O(N)						

F8	A(VS)	A(S)	V(VS)	V(S)	X(VS)							
F9	A(VS)	A(S)	V(S)	V(S)								
F10	A(S)	A(W)	V(VW)									
F11	A(S)	A(VS)										
F12	X(W)											
F13												

Table 2: The SSIM matrix (recorded inputs of expert 2)

Ex 2	F13	F12	F11	F10	F9	F8	F7	F6	F5	F3	F2	F1
F1	A(VW)	A(S)	V(VS)	O(N)	V(S)	V(VS)	V(VS)	V(S)	V(S)	V(S)	V(VS)	
F2	X(S)	A(VS)	V(VW)	V(VS)	V(VS)	O(N)	A(VS)	A(S)	A((VS)	A(VS)		
F3	A(VS)	V(VS)	V(S)	V(S)	V(VS)	V(W)	V(VS)	A(S)	X(VS)			
F5	V(VS)	V(VS)	V(S)	V(S)	O(N)	V(S)	V(S)	A(VW)				
F6	V(S)	V(S)	V(S)	V(VS)	V(S)	V(VS)	V(VS)					
F7	O(N)	A(VS)	V(S)	A(VW)	O(N)	O(N)						
F8	A(VW)	A(S)	V(W)	V(VS)	X(S)							
F9	A(VW)	A(VS)	V(S)	A(VS)								
F10	A(VS)	A(VS)	V(S)									
F11	A(VS)	V(VW)										
F12	X(S)											
F13												

Table 3: The SSIM matrix (recorded inputs of expert 3)

Ex 3	F13	F12	F11	F10	F9	F8	F7	F6	F5	F3	F2	F1
F1	O(N)	V(S)	V(V	O(N)	A(S)	V(V	V(S)	X(V	O(N)	V(S	A(S	

			S)			S)		S)		)	)	
F2	X(VS)	X(VS)	V(VS)	V(VS)	V(VS)	O(N)	V(VS)	O(N)	A(VS)	A(S)		
F3	V(VS)	V(VS)	V(VS)	V(S)	V(VS)	V(VS)	V(S)	A(VS)	X(VS)			
F5	V(VS)	V(VS)	V(VS)	V(S)	V(VS)	V(VS)	V(VS)	O(N)				
F6	V(S)	A(VS)	V(S)	V(VS)	V(VS)	V(VS)	V(VS)					
F7	A(VS)	O(N)	V(VS)	X(VS)	V(VW)	O(N)						
F8	V(W)	A(VS)	V(S)	V(VS)	X(VS)							
F9	A(VS)	A(VS)	V(VS)	V(VS)								
F10	V(VW)	A(VS)	V(VS)									
F11	O(N)	A(VS)										
F12	X(VS)											
F13												

Table 4: The SSIM matrix (recorded inputs of expert 4)

Ex 4	F13	F12	F11	F10	F9	F8	F7	F6	F5	F3	F2	F1
F1	O(N)	V(VS)	V(S)	O(N)	A(W)	V(VS)	A(S)	X(W)	V(VS)	O(N)	V(VW)	
F2	X(VS)	O(N)	V(S)	A(VS)	A(VW)	O(N)	V(VS)	A(VS)	O(N)	A(VS)		
F3	V(S)	A(W)	O(N)	V(VW)	V(VS)	V(S)	V(VS)	A(VS)	X(VS)			
F5	V(VW)	V(VS)	V(S)	A(VS)	V(VS)	V(W)	V(S)	O(N)				
F6	V(VS)	V(S)	V(VS)	A(VS)	V(S)	VS)	V(VS)					
F7	V(S)	A(VS)	V(W)	X(S)	O(N)	A(VW)						
F8	A(VS)	V(VW)	V(S)	V(S)	O(N)							
F9	V(S)	A(VW)	V(W)	V(VS)								
F10	A(S)	A(VS)	V(S)									
F11	A(VS)	O(N)										

F12	X(VS)											
F13												

Table 5: The SSIM matrix (recorded inputs of expert 5)

Ex5	F13	F12	F11	F10	F9	F8	F7	F6	F5	F3	F2	F1
F1	O(N)	V(VS)	V(VS)	O(N)	V(S)	V(VW)	V(S)	X(VS)	V(VS)	V(VS)	O(N)	
F2	X(W)	X(VS)	V(S)	V(VS)	V(S)	V(VW)	V(S)	A(S)	A(VS)	A(S)		
F3	V(S)	A(S)	V(VS)	V(VS)	V(VS)	V(VS)	V(W)	A(S)	X(VS)			
F5	V(S)	V(S)	V(VS)	V(S)	V(S)	V(S)	V(VS)	O(N)				
F6	V(VS)	V(S)	V(VS)	V(S)	V(S)	V(VS)	V(VS)					
F7	A(S)	A(VS)	V(S)	X(VS)	O(N)	A(W)						
F8	A(VS)	A(S)	V(VS)	V(VS)	X(S)							
F9	A(S)	A(VS)	V(S)	V(S)								
F10	A(VS)	A(VS)	V(VS)									
F11	A(VS)	A(VS)										
F12	X(VS)											
F13												

Appendix C:

Iterations to partition the levels for structuring the F-TISM model

Table 1: Iteration 1

	Reachability set	**Antecedent set**	**Intersection set**	**Level**
F1	1,2,3,5,6,7,8,10,11,12,13	1,6	1,6	
F2	2,7,8,10,11,12,13	1,2,3,5,6,12,13	2,12,13	

F3	2,3,5,7,8,9,10,11,12,13	1,3,5,6	3,5	
F5	2,3,5,7,8,9,10,11,12,13	1,3,5,6	3,5	
F6	1,2,3,5,6,7,8,9,10,11,12,13	1,6	1,6	
F7	7,10,11	1,2,3,5,6,7,8,9,10,12,13	7,10	
F8	7,8,9,10,11	1,3,5,6,8,9,12,13	8,9	
F9	7,8,9,10,11	1,2,3,5,6,8,9,12,13	8,9	
F10	7,10,11	2,3,5,6,7,8,9,10,12,13	7,10	
F11	11	1,2,3,5,6,7,8,9,10,11,12,13	11	I
F12	2,7,8,9,10,11,12,13	1,2,3,5,6,12,13	2,12,13	
F13	2,7,8,9,10,11,12,13	2,3,5,6,12,13	2,12,13	

Table 2: Iteration 2

	Reachability set	**Antecedent set**	**Intersection set**	**Level**
F1	1,2,3,5,6,7,8,10,12,13	1,6	1,6	
F2	2,7,8,10,12,13	1,2,3,5,6,12,13	2,12,13	
F3	2,3,5,7,8,9,10,12,13	1,3,5,6	3,5	
F5	2,3,5,7,8,9,10,12,13	1,3,5,6	3,5	
F6	1,2,3,5,6,7,8,9,10,12,13	1,6	1,6	
F7	7,10	1,2,3,5,6,7,8,9,10,12,13	7,10	II
F8	7,8,9,10	1,3,5,6,8,9,12,13	8,9	
F9	7,8,9,10	1,2,3,5,6,8,9,12,13	8,9	
F10	7,10	2,3,5,6,7,8,9,10,12,13	7,10	II
F12	2,7,8,9,10,12,13	1,2,3,5,6,12,13	2,12,13	
F13	2,7,8,9,10,12,13	2,3,5,6,12,13	2,12,13	

Table 3: Iteration 3

	Reachability set	**Antecedent set**	**Intersection set**	**Level**
F1	1,2,3,5,6,8,12,13	1,6	1,6	
F2	2,8,12,13	1,2,3,5,6,12,13	2,12,13	
F3	2,3,5,8,9,12,13	1,3,5,6	3,5	

F5	2,3,5,8,9,12,13	1,3,5,6	3,5	
F6	1,2,3,5,6,8,9,12,13	1,6	1,6	
F8	8,9	1,3,5,6,8,9,12,13	8,9	III
F9	8,9	1,2,3,5,6,8,9,12,13	8,9	III
F12	2,8,9,12,13	1,2,3,5,6,12,13	2,12,13	
F13	2,8,9,12,13	2,3,5,6,12,13	2,12,13	

Table 4: Iteration 4

	Reachability set	**Antecedent set**	**Intersection set**	**Level**
F1	1,2,3,5,6,12,13	1,6	1,6	
F2	2,12,13	1,2,3,5,6,12,13	2,12,13	IV
F3	2,3,5,12,13	1,3,5,6	3,5	
F5	2,3,5,12,13	1,3,5,6	3,5	
F6	1,2,3,5,6,12,13	1,6	1,6	
F12	2,12,13	1,2,3,5,6,12,13	2,12,13	IV
F13	2,12,13	2,3,5,6,12,13	2,12,13	IV

Table 5: Iteration 5

	Reachability set	**Antecedent set**	**Intersection set**	**Level**
F1	1,3,5,6	1,6	1,6	
F3	3,5	1,3,5,6	3,5	V
F5	3,5	1,3,5,6	3,5	V
F6	1,3,5,6	1,6	1,6	

Table 6: Iteration 6

	Reachability set	**Antecedent set**	**Intersection set**	**Level**
F1	1,6	1,6	1,6	VI
F6	1,6	1,6	1,6	VI