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Modeling the Barriers of Indian Healthcare Supply Chain Management Using ISM

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Abstract

The purpose of this study is to identify the barriers to the Indian healthcare supply chain (HCSC). The barriers influencing the Indian healthcare supply chain were identified in this research via a review of the literature, a group discussion with healthcare specialists, and an assessment of academic domains. The barriers were studied using the ISM "Interpretive Structural Modeling" technique with the goal of identifying factors that might help enhance the Indian healthcare supply chain system. The model and research findings indicate that barriers, such as a lack of healthcare supply chain education and ineffective supply chain implementation in hospitals and the healthcare sector, lack of coordination between the public and private sectors, irregular funding to multiple departments and supply chain staff, inconvenient human resource coordination, and a lack of implementation of cutting-edge technologies, are adversely affecting the Indian healthcare supply chain. This research addressed the barriers affecting the healthcare supply chain and how they may be overcome to benefit the whole healthcare supply chain system, i.e. manufacturers of healthcare products, buyers, and healthcare providers, who in turn benefit end-users, i.e. patients and consumers.

Keywords: Healthcare supply chains; ISM; interpretive structural modelling; MICMAC.

1. Introduction

The healthcare system is one of the world's largest and fastest-growing systems, including multiple sectors like healthcare industries, hospitals, clinics, medical infrastructure, medical appliances, medicines and telemedicine, biotechnology, health insurance etc. With unconscionable pricing stress on healthcare services providers, delivering the best quality healthcare at the minimum and reduced cost is the main fundamentality. Healthcare is a basic need of every human being and community on earth which provides superior health that renovates lifestyle. The investigators and policymakers constantly considering healthcare systems and public expending of financial tools so far as they diagnose the demotic strength and overall gratitude of preserving healthcare for existing and forthcoming generations Abreu et al. (2005).

Supply chains deliver healthcare products, medicines and various types of health services to the population as well as collects the data and information about requirements, supply and circulation to the healthcare management system. Supply chain management (SCM) is a well-designed and evolved scholarly discipline, but in developing and low-income countries it is not implemented effectively which results in ineffectual and inefficient in delivering good health to patients.

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Due to competition in every sector, the prices of products and healthcare system services are continuously increasing which are not affordable by patients and as a result failing to deliver proper treatment and services to patients. Schoonveld (2020) discussed in their research to meet patient and customer's hope of getting the best treatment and different healthcare services at affordable prices. Proper training on healthcare supply chains management regulations like communication with patients as well as internal and external departments, information and reporting system, executive support and all healthcare services to enhance logistic and cold storage transportation in the pharmaceutical industry as well as for transporting various blood and medical samples (Bourke, 2013). Göleç and Karadeniz (2020) identified weak processes through the modeling and fuzzy system to get a competitive advantage against their competitors. This study analyses the barriers of the healthcare supply chain (HCSC) which are responsible for the poor and ineffectual Indian healthcare system to implement SCM and TQM in hospitals effectively.

Section 2 of this study discusses the literature review on healthcare supply chain (HCSC). Section 3 discusses the identification of factors affecting HCSC. Section 4 discusses the ISM methodology. Section 5 and 6 presents the Modeling the factors affecting the healthcare supply chain and MICMAC analysis respectively. Section 7 and 8 presents the discussion and conclusion respectively. Section 9 discusses the research's limitations and future scope of research work.

2. Literature Review

Supply chain management (SCM) is the pillar of healthcare delivery. Quality healthcare delivery is contingent on timely and adequate supply availability of medical goods to patients, which may lead to consumer dissatisfaction if they are not available. In the literature, a number of studies have been done on healthcare supply chain techniques that may increase performance.

Mathur et al. (2018) created a conceptual model to illustrate the link between supply chain practises (SC), supply chain performance (SCP), and organisational performance (OP) in the healthcare industry. The model was developed only for the SCP of the medical device and equipment supply chain, which represents a small percentage of the total healthcare supply chain and hence needs more study in different other areas of the healthcare supply chain.

Yanamandra (2018) developed an integrated healthcare supply chain model in the view of reducing cost of healthcare supply chain. But it is not validated by empirical study.

Ageron et al. (2018) have explored different instruments and approaches for improving lean management, logistics functions and process quality, which have been executed by healthcare managing directors for the last 15 years. The problems and future challenges of healthcare logistics and HCSC have been analyzed by editorial research.

SCM is implemented in almost every sector which increases overall performances of organizations and increases customer satisfaction, but it is not implemented effectively and that is the basic cause of its failure as well as various losses in organizations. The factors which can decrease overall costs for providing a high quality of healthcare services have been discussed by Yanamandra (2018) through developing an integrated healthcare supply chain prototype. The model is highly productive and profitable for healthcare industries and organizations to reduce various costs in various sectors of HCSC.

Yadav (2015) has discussed the structure of the healthcare supply chain (HCSC) and focused on challenges and basic causes that distract and decrease the performance of the healthcare supply chain system. Ineffective supply chains in developing countries affect the delivery of medicines, medical devices, vaccines and other medical products which are the most important part of the healthcare system. Such problems in the various sectors of the healthcare system can be removed by implementing effectual HCSC. The modulated ideas based on the combination of various modeling studies, case studies, simulation studies, experimental approaches and theories can be used for effectual HCSC reform. Decreasing multiple levels in the whole system can decrease the waste of various resources which will result in the improvement of product flow, financial flow and information flow.

The topic of healthcare supply chain management in India has been discussed by Gupta and Ramesh (2015) about the dynamic factors which reduce the performance of healthcare supply chains by utilization of the ISM approach. The dynamic effects of such dynamic factors can be easily investigated and improved with the help of the ISM model. As compared to various quantitative approaches, the ISM approach provides better results and easy to use for analyzing various problems of any sector. The research work helps in developing new structures in healthcare supply chain operations.

At present HSCM is at its defining moment. There is a huge role in healthcare in the service economy of India as it sustains a big stake. Therefore, it is a terrifically difficult task to incorporate dissimilar processes related to its SC. Afshan and Sindhuja (2015) discussed several opportunities and exceptions in the healthcare supply chain in India.

Brandenburg et al. (2014) Analyzed quantitative and formal models for achieving sustainability in supply chain management (SCM) by concluding that multiple techniques can be obtained for enhancing the types of tools and modeling approaches. Mostly the life cycle analysis, AHP, or its close relative and analytical network processes are used.

SCM is main healthcare services which are the most demanding. But there is a lot of improvement is needed in this sector. Structured analysis of healthcare operation management and healthcare supply chain management have been carried out by Dobrzykowski et al. (2014) by reviewing a vast literature of 9979 papers and concluded the present state of HCSC and healthcare operation management with various qualitative and quantitative methods.

In this competitive era, all industries consider so much to reduce product cost to a minimum as well as minimize other expenditures wherever and however possible for their survival. But in the case of healthcare sectors and industries, it is compulsory to provide the best quality products and various healthcare services. Which ultimately increases the overall cost of products and services for healthcare industries. New and latest updated technologies, supply chain management practices, virtual centralization, use of analytical data, streamline the workflow of healthcare supply chains can reduce overall operations costs have been described by (Mathew et al., 2013).

Many behavioral problems have been observed in the healthcare provisions i.e. the methods of traditional systems are against non-traditional technologies. To tackle the different demands of customers there is a need for proper system and technologies that satisfies the customer requirements. De Blok et al. (2013) have discussed how healthcare providers can deliver caring to aged people with the application of humanization and customization.

During the last decade, the health care sector has reformed speedily. Because of the growing population, there is a need to improve healthcare services productively and advantageously. There are many proposals related to the treatment protocol, information exchange, sufferer's logistics, etc. An exploratory and qualitative approach was used by De Vries and Huijsman (2011) on existing HSCM literature and concluded that there is a need for an interdisciplinary focus on HCSC.

Rohini and Mahadevappa (2010) used a method of qualitative design by collecting quantitative elements from hospitals of Karnataka and highlighted the importance of the involvement of different stakeholders and top-level management for generating CSR in the hospitals for developing a non-profit organization, which helps in providing treatment to everybody.

Samuel et al. (2010) analyzed that healthcare supply chains show dynamic behavior as a supply chain with finished goods inventory by developing a system dynamics simulation model. The study is based on a service-aligned supply chain with proportionally progressing i.e. containing more than one stage or multiple stages to execute comparable operations. The bullwhip effect can help in the healthcare supply chain to improve various factors affecting a service-oriented supply chain. By applying the Bullwhip effect in case studies of service-oriented healthcare supply chains required performances can be obtained.

In current years, various theoretical and practical approaches of SCM have been implemented to eradicate the barriers. But most of them haven't concentrated on individual sectors. The logistics and distribution of medicines to clinics from wholesalers in private hospitals of Malaysia were facing issues in their inventory management. Mustaffa and Potter (2009) evaluated inventory management by the case study approach.

Patients travel throughout the world for getting treatment of some special diseases from expert and skilled healthcare professionals which is motivated by medical tourism. Due to uninterrupted transformation in markets and patient's demands, Indian medical tourism is facing multiple issues that have been discussed by Jain and Ajmera (2018) through the ISM approach and MICMAC analysis.

The researchers, managers and doctors are researching endlessly to develop inventive techniques to deliver the best quality and services at minimum cost. Such services and quality can be provided at minimum costs only if each sector and activity of HCSC is analyzed deeply. But most of the managers focus on investment and profit, only a few of them works on reducing the overall expenditures. With the help of the case study, Kumar et al. (2008) investigated price relaxation in logistics and supply chain of medical product distribution by applying process reengineering.

When e-business is completely implemented throughout a supply chain, it will be widely beneficial in the whole healthcare sector. Public and private organizations are not entirely executing e-technologies. Zheng et al. (2006) discussed the advantages, risks and problems of e-adoption in HCSC through a strategic case applied on four different HCSC.

Internal supply chains of hospitals are poorly managed as compared to external chains and spotted as weak connections in supply chain integration. In this competitive era, all healthcare industries and organizations are facing issues in reducing

the cost of healthcare services as increasing new demands of aged people, new diseases and cures, increasing population. Landry and Philippe (2004) implemented new managing techniques on a case study with a different coalescence of activity-based costing and reengineering for improving integrated logistics services and activities in healthcare.

The necessity of planning and monitoring the hospital and healthcare services, Ramani (2004) designed and developed a management information system (MIS) by understanding the functioning of divisional, sub-divisional, municipal, district and state govt. healthcare centers that face various types of complex managing issues. It is compulsory to develop and supervise a detailed hospital MIS to provide efficient and effective hospital services.

Al-Shaqha and Zairi (2001) have explored the conventional medicines and drug therapies and traditional pharmacy models are failing and not appropriate now anymore. Healthcare providers, professionals and patients should renovate their work to achieve better treatments and positive outcomes.

Healthcare services should be available to anyone and for everyone as part of human society. Healthcare insurance is beneficial for many purposes as covering various charges of doctors, medicines, maternity, surgeries, etc. Policies are very helpful to the current and upcoming generations in case of any premature and unexpected death of a person who is the sole income source of the family. Insurance companies are bringing up new ideas and policies so that everyone can afford health insurance. There are essential requirements of corporate social responsibility, healthcare development, infrastructures and various governmental controlling systems (Abreu et al., 2005).

In the year 1994 Portugal was one of the worst countries in Europe with a falling economy. Santana (2002) analyzed that people affected due to poverty, social separation and social disallowance in the Portuguese community have affected the health of primary children, women, homeless and ethnic minorities.

3. Identification of factors affecting HCSC

Based on studies and discussion with the managers and authorities of the healthcare services and academic domains, 15 barriers were selected and used for developing the ISM model. These barriers are explained below and enlisted in Table 1.

3.1 Lack of healthcare supply chain education

Due to poor knowledge and lack of implementation of supply chains in hospitals results in poor healthcare performance (Lauer, 2004). Improper knowledge of the healthcare supply chain affects the whole system as improper planning and decisions for managing all the procedures of SC. Basically, the ineffectual execution of SC in the healthcare system reduces the services and overall performances of healthcare providers. The whole system becomes complicated and fails in delivering good healthcare services to patients.

3.2 Non-coordination of government and private sectors

It's a difficult task to unite government and private sectors to work and run their services together with the current scenario as cash or cashless mode. The dominant healthcare systems are managed by the government which either doesn't provide multi-specialties services or poorly controlled due to which private parties and hospitals take advantage as delivering multi-specialties and highly controlled services at high prices to the patients for best treatment (Afshan and Sindhuja, 2015).

3.3 Lack of inter-personal communication with patients/ customers

Healthcare supply chain performance is affected due to misunderstandings and unhealthy inter-personal communication because that affects the working environment and consumer gratification (Yanamandra, 2018). Such type of communication breaks the trust and cooperation of internal customers and patients. Also, the flow of information gets affected by a lack of interpersonal communication as wrong information is shared among multiple tiers and departments of the healthcare supply chain.

3.4 Unconcerned in funding operating cost

In the majority of countries, democratic leaders are primarily concerned in capital projects and not in running expenses like as vehicle operator and maintenance, fuel costs, transportation taxes, and logistical costs. The delivery cost of products in healthcare supply chains changes from 13-44% according to country and product. The unavailability of such records of distribution and logistics costs weakens the sustainability of the healthcare supply chain due to the incapability of recording and managing such costs. According to the Crane et al. (2019) analysis, unfunded expenditures reduce the entire system's efficiency by preventing many tasks from being done on time and workers from being motivated to work.

3.5 Lack of recognition of skilled for system design

Unskilled and poor decision-making staff in hospitals, clinics, inventories of manufacturing units and wholesalers, pharmacies, nursing homes and physicians etc. creates a weak system and poor planning which ultimately influences the whole healthcare supply chain system from manufacturing to end customer use i.e. patients who have to face multiple problems regarding their demands and treatments (Vian, 2003). If such staff is not available in various departments of the healthcare system where skill and experience are needed, that creates a weak and faulty system design which leads to theory versus experimental mismatch. This type of faulty system mostly affects the healthcare supply chain as a lack of understanding of the comparison between judgment making about order size and the detailing pairs utilized for making judgments about order size.

3.6 Diffuse responsibility

Issues in the prediction of demand, supply and requirement by particular zone or district, clinics, hospitals and pharmacies create stockouts problems due to poor accountability framing. These problems are developed in the absence of good leadership. Because these responsibilities are governed by authorities at different levels like the ministry of health, central pharmacies, etc. the supply chain of the healthcare system is a huge network of various sectors, any negligence at any level will affect the further chain. Such kind of irresponsibility creates problems like corruption, distribution of products and social wellbeing(Vian, 2003).

3.7 Irregular funding

Mostly in government sector purchasing of various healthcare tools and medicines have a long cycle and procedure which takes a lot of time for funding from the various ministry of healthcare and finance. Such time is taken in funding the suppliers and manufacturers' imbalances in inventory and various healthcare services and ultimately decelerate the healthcare supply chains. Ultimately patients have to suffer for getting proper good treatment and multiple healthcare services (Mehrotra and Natarajan, 2020).

3.8 Unnecessary level of complexity

The low-income countries like India which are existing in the developing stage have the administrative structure of the combination of multiple levels and committees i.e. for controlling various services multiple processes have to be followed which are poorly managed. Such systems become unnecessarily complicated and affect inventories, forecasting, procurement and ultimately to the manufacturer and the patients at national, state and local zones. This phenomenon of multiple levels in SC, lack of accountability, and poor communication and information between multiple committees or tiers is known as the “Bullwhip Effect” (Lee et al., 1997).

3.9 Inconvenience in the coordination of human resources

HCSC includes all the sectors that are manufacturers, warehouses, logistics, wholesalers, retailers, healthcare providers, customers and etc. All the sectors are either directly involved or indirectly. Ultimately, all the managers and their staff aim to provide the best quality healthcare product and best treatment to sufferers, which needs good coordination of inspiration, education, professionalism, and capability. But managers are not able to implement such coordination in India. Due to an organization's human resources being improperly coordinated, negative consequences are visible in healthcare organisations and, ultimately, throughout the healthcare supply chain (Perron, 2005).

3.10 High prices in the private sector

Various researchers have concluded that the prices to consumers and others of a variety of medical tests, treatments, and medications offered by the private sector are much higher than those given by the public sector. Because not everyone can afford such treatments, the healthcare system falls short of providing adequate primary healthcare services to everyone. Numerous intermediates are used across the healthcare supply chain, increasing the total cost of therapies (Yadav, 2015).

3.11 Lack of incentives for SC staff

The person who services in the public and private sector of the healthcare supply chain has a work ethic oriented toward public service and a sense of the job. Due to the absence of their work and performance records incentives are not paid which decreases the encouragement of staff working in healthcare supply chains (Yadav, 2015).

3.12 Long resupply intervals

The resupply gap or time between resupplies is a critical component to consider while designing the supply chain. Forecasting accurately for a large-scale distribution on a national and worldwide scale is quite challenging. Yadav (2015) highlighted that procurement departments have very sophisticated procedures and make purchases just once a year, resulting in product discontinuation/deterioration and stockouts.

3.13 Lack of mobile healthcare services

The mobile healthcare services fully equipped with necessary medical tools and medicines can help the patients anywhere, anytime and in case of emergencies. Due to lack of funding operating costs ambulances are not properly maintained in India and also such fully facilitated vehicles are not available for everyone everywhere. Ultimately patients don't get treatment at times and loses life in case of casualty. Adoption of various information technologies in mobile healthcare vehicles such as wireless technology and networks, GPS tracking, an electronic prescription can improve patient care as well as the healthcare supply chain in India (Afshan and Sindhuja, 2015).

3.14 Lack of logistics and material management

All the clinical and non-clinical healthcare organizations should implement non-conventional approaches to managing materials and logistics instead of conventional methods. Which means effective, efficient and sustainable maintenance of the organization, to neutralize the adverse effects. In this way, logistics and material management become constructive, profitable and dynamic for the organization (Landry and Philippe, 2004).

3.15 Poor positioning of new technologies in services

For proper implementation of new technologies like information technologies (IT), artificial intelligence (AI), etc., needs deep analysis and planning. There are many drawbacks by which the clinical professionals and patients don't realize the advantages of new technologies i.e. technical failure, uneconomical for both organizations and patients, lack of stakeholder's interests, lack of infrastructure, the requirement of skilled operators, improper management and expensive maintenance. Outcomes of the new technologies are overall efficient and patient-centric(Zheng et al., 2006).

Table 1. Factors affecting Indian HCSC

S.No.	Issue	Reference
1	Lack of healthcare supply chain education	Lauer (2004),Yanamandra (2018)
2	Non-coordination of government and private sectors	(Cachon and Lariviere (2005); Afshan and Sindhuja (2015))
3	Lack of interpersonal communication with patients/ customers	(Chang et al. (2013); Yanamandra (2018))
4	Unconcerned in the funding of operating cost	Crane et al. (2019)
5	Lack of recognition of skilled for system design	Vian (2003)
6	Diffuse accountability	Vian (2003)
7	Irregular funding	(Churi et al., 2021; Mehrotra and Natarajan (2020))
8	Unnecessary level of complexity	(Kasthuri, 2018; Lee et al. (1997))
9	Inconvenience in the coordination of human resources	(Jagnoor et al., 2018; Perron (2005))
10	High prices in the private sector	Yadav (2015)
11	Lack of incentives for SC staff	(Dobrzykowski, 2019; Yadav (2015))
12	Long resupply Intervals	Yadav (2015)
13	Lack of mobile healthcare services	(Jain et al., 2015; Afshan and Sindhuja (2015))
14	Lack of logistics and material management	(Callender and Grasman, 2010; Landry and Philippe (2004))
15	Lack of implementation of new technologies in service	(Nilsen et al., 2020; Zheng et al. (2006))

4. ISM Research Methodology

Interpretative structural modeling is a tool of the One Page Management System (OPMS) invented by Warfield (1974) in a three-decennary long study of "complexity in systems and how to enable people to cope with it". Interpretative structural modeling is a qualitative and interpretive approach that develops outputs for complicated issues through structural modeling of complicated relationships of different variables. The elements, issues and factors which are added in this approach are structural. In this approach, the structure is developed with the help of a set of various elements that are directly and indirectly connected. The model generated through interpretative structural modeling forms a clear picture of the factors affecting the system and easily understandable for solving complicated issues. ISM is an effectual methodology that can be applied to almost every field. The important traits of ISM are as follows:

(i) This approach is interpretive as the group of experts in the particular field judges whether and how the various variables are connected.
(ii) The complete structure is carried out from the complicated set of variables, that's why it is structural.
(iii) This is a modeling approach, as the contextual relationship between variables and the whole structure is drafted in the digraph model.
(iv) The order and direction of the variables are imposed with the help ISM approach.

The applications of ISM have seen in various studies as shown in Table 2.

Table 2. ISM applications

S.No.	References	Purpose of ISM
1	Jain and Raj (2021)	Constraints of FMS
2	Mittal et al. (2021)	TB Barriers
3	Priya et al. (2021a)	Factors of global economy
4	Priya et al. (2021b)	Assessment of government measures
5	Jain and Ajmera (2020)	Enabler of Industry 4.0
6	Ajmera and Jain (2019a)	Lean factors in the Indian healthcare industry
7	Ajmera and Jain (2019b)	QOL suffering from diabetes.
8	Ajmera and Jain (2019c)	Barriers of Health 4.0
9	Jain and Soni (2019)	Performance variables of the FMS
10	Patri and Suresh (2018)	Lean implementation in healthcare organizations
11	Jain and Ajmera (2018)	Used ISM for modeling medical tourism factors.
12	Chauhan et al. (2018)	Analyzed the waste recycling barriers
13	Malviya and Kant (2017)	Modeling of green SCM
14	Dube and Gawande (2016)	Analyzed the barriers of green supply chain
15	Jain and Raj (2016)	FMS performance factors.
16	Gupta and Ramesh (2015)	Used ISM for detecting the factors influencing HCSC in India.
17	Jain and Raj (2015a)	Used ISM for analyzing flexibility in a flexible manufacturing system.
18	Jain and Raj (2014)	FMS productivity factors.
19	Sharma et al. (2013)	Variables of assembly line balancing
20	Balasubramanian (2012)	Used ISM for evaluating the barriers of GSCM
21	Colin et al. (2011)	Various stages of the supply chain.
22	Ramesh et al. (2010)	Variables affecting the Indian textile industries.
23	Raj et al. (2008)	Enablers of FMS
24	Faisal et al. (2007)	Barriers in the supply chains of SMEs.

The several steps of the ISM approach are as following:

i) The variables decreasing the overall performance of the system obtained by case studies or surveys are enlisted.
ii) The pairs of variables which should be examined are drawn by framing a contextual relationship between the variables.
iii) In this step, an SSIM "structural self-interaction matrix" is designed for variables, which demonstrate pairwise relationships between variables of the system under consideration.
iv) RM "Reachability matrix" is generated from SSIM which is investigated for transitivity and that states, if an element X is concerned with Y and Y, is concerned with Z, then X is inevitably concerned with Z.
v) The next step is partitioning of the RM into various levels.
vi) A graph is plotted and transitivity links are eliminated based on relationships obtained from the reachability matrix (RM).
vii) After substituting variable nodes with pronouncements ISM model is developed by converting the graph.
viii) In the final step, the ISM model is rechecked for hypothetic incompatibility and essential modifications are made.

5. Modeling the factors affecting the healthcare supply chain

In order to construct the ISM model, a number of steps must be performed as:

5.1 Various factors and contextual relationship among them is emplaced

The list of 15 concerning issues or factors has been analyzed and established by discussing multiple management techniques and literature reviews with experts and academia in the same area of work. A contextual relationship of "approaches to" type is used which explains that one factor approaches another factor. The relationship between two factors (i and j) as illustrated in Table 3. was determined for analyzing the issues affecting the healthcare supply chain management.

Table 3: Contextual relationship

Symbol	Illustrations
V	"variable i" approaches to "variable j"
A	"variable j" approaches to "variable i"
X	"variable i and j" approach one another
O	"variable i and j" are not related

5.2 Evolution of SSIM

Table 4 shows the SSIM is evolved for selected issues that fall under the concerned relationship. The symbols shown in table 3 are used in developing SSIM are as:

Table 4: SSIM

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	V	V	V	V	V	V	V	V	V	O	V	V	V	V
2		1	O	O	O	V	X	V	V	V	O	V	V	V	V
3			1	O	X	O	O	V	A	O	O	V	O	O	O
4				1	V	O	A	O	V	O	X	V	V	V	X
5					1	V	O	V	A	V	A	V	V	V	O
6						1	A	A	A	V	A	V	A	V	A
7							1	V	O	V	V	V	V	V	V
8								1	A	V	A	V	V	V	A
9									1	V	O	V	V	V	O
10										1	A	A	A	A	A
11											1	V	V	V	X
12												1	A	A	A
13													1	X	A
14														1	A
15															1

5.3 Evolution of initial RM

The initial RM is evaluated from SSIM by converting the symbols V, A, X and O into binary digits of 0 and 1. SSIM is converted by altering V, A, X, and O to develop an initial Reachability Matrix (RM) with the help of criteria as shown in Table 5. The initial RM is shown in Table 6.

Table 5. Symbol entry

Symbol	Cell (i,j) entry	Cell (j,i) entry
V	1	0
A	0	1
X	1	1
O	0	0

Table 6. Initial RM

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
2	0	1	0	0	0	1	1	1	1	1	0	1	1	1	1
3	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0
4	0	0	0	1	1	0	0	0	1	0	1	1	1	1	1
5	0	0	1	0	1	1	0	1	0	1	0	1	1	1	0
6	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0
7	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1
8	0	0	0	0	0	1	0	1	0	1	0	1	1	1	0
9	0	0	1	0	1	1	0	1	1	1	0	1	1	1	0
10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
11	0	0	0	1	1	1	0	1	0	1	1	1	1	1	1
12	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
13	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0
14	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0
15	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1

5.4 Evolution of final Reachability Matrix (RM)

The final RM is derived from the initial RM by introducing transitivity in it. Final RM is evaluated by denoting transitivity as 1* in Table 7.

5.5 Segmentation of Reachability Matrix (RM)

Steps for partitioning the final reachability matrix are as following:

(i) For each barrier, the "reachability and antecedent set" is extracted from the final RM.
(ii) The intersection of both of the sets is derived for each variable and the top level is given to the variable whose reachability and antecedent sets are the same.
(iii) In this step, the variable whose level is defined will be eliminated from other variables.
(iv) Similarly to this, iterations will be done until every variable gets its level.

Table 7. Final RM

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	1	1	1	1	1	1*	1	1	1	1
2	0	1	1*	1*	1*	1	1	1	1	1	1*	1	1	1	1
3	0	0	1	0	1	1*	0	1	0	1*	0	1	1*	1*	0
4	0	0	1*	1	1	1*	0	1*	1	1*	1	1	1	1	1
5	0	0	1	0	1	1	0	1	0	1	0	1	1	1	0
6	0	0	0	0	0	1	0	0	0	1	0	1	1*	1	0
7	0	1	0	1	1*	1	1	1	1*	1	1	1	1	1	1
8	0	0	0	0	0	1	0	1	0	1	0	1	1	1	0
9	0	0	1	0	1	1	0	1	1	1	0	1	1	1	0
10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
11	0	0	1*	1	1	1	0	1	1*	1	1	1	1	1	1
12	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
13	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0
14	0	0	0	0	0	1*	0	0	0	1	0	1	1	1	0
15	0	0	0	1	1*	1	0	1	1*	1	1	1	1	1	1

Table 8. Iterations "Level of barriers

Barriers No.	Reachability set of barriers	Antecedent set of barriers	Intersection set of barriers	Level of Barriers
10	10	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	10	I
12	12	1,2,3,4,5,6,7,8,9,11,12,13,14,15	12	II
6,13,14	6,13,14	1,2,3,4,5,6,7,8,9,11,13,14,15	6,13,14	III
8	8	1,2,3,4,5,7,8,9,11,15	8	IV
3	3,5	1,2,3,4,5,9,11	3,5	V
5	3,5	1,2,3,4,5,7,9,11,15	3,5	V
9	9	1,2,4,7,9,11,15	9	VI
4,11,15	4,11,15	1,2,4,7,11,15	4,11,15	VII
2,7	2,7	1,2,7	2,7	VIII
1	1	1	1	IX

5.6 Evaluation of conical matrix

To evaluate the conical matrix, barriers whose levels are the same will be combined in ascending order across the various rows and columns. Driving and dependence power will be obtained as shown in Table 9.

Table 9. Conical matrix

Barriers	10	12	6	13	14	8	3	5	9	4	11	15	2	7	1	D.P.
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
12	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
6	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
13	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
14	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
8	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	6
3	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8
5	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8
9	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	9
4	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	12
11	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	12
15	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	11
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	14
7	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	13
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Dep. P.	15	14	13	13	13	10	7	9	7	6	6	6	3	3	1	126

5.7 Development of ISM model

The structural model is evolved with the help of vertices or nodes and lines of edges from the final reachability matrix (RM), which is called a digraph or directed graph as shown in figure 1. The directed graph represents the relationship between barriers affecting the Indian healthcare supply chain. An arrow will be drawn between the barriers if they are influencing each other. The ISM Model is shown in Figure 2, which was produced by replacing the nodes of all components.

6. Analysis by MICMAC

"Matriced Impacts Croises-Multiplication Applique and classment" i.e. MICMAC, analyzed by Raj et al. (2012) which is created on "multiplication properties of matrices" is to explore driving and dependence power of the barriers (Jain and Ajmera, 2020; Jain and Raj, 2015b). The barriers are classified into four groups or sets and shown in figure 3 (Ajmera and Jain, 2019c).

(i) *Autonomous barriers***:** The variables that have weak driving and dependence power which are described in 1st quadrant. These variables are comparatively disengaged, which have few connections with the system.

(ii) *Dependent barriers:* These variables are described in 2nd quadrant which has weak driving power and sturdy dependence power.

(iii) *Linkage barriers:* Linkage variables have strong driving as well as dependence power and they also have less stability. They are represented in 3rd quadrant.

(iv) *Independent barriers:* The variables whose driving power is strong but dependence power is weak. They are also known as "key factor". These variables are described in 4th quadrant.

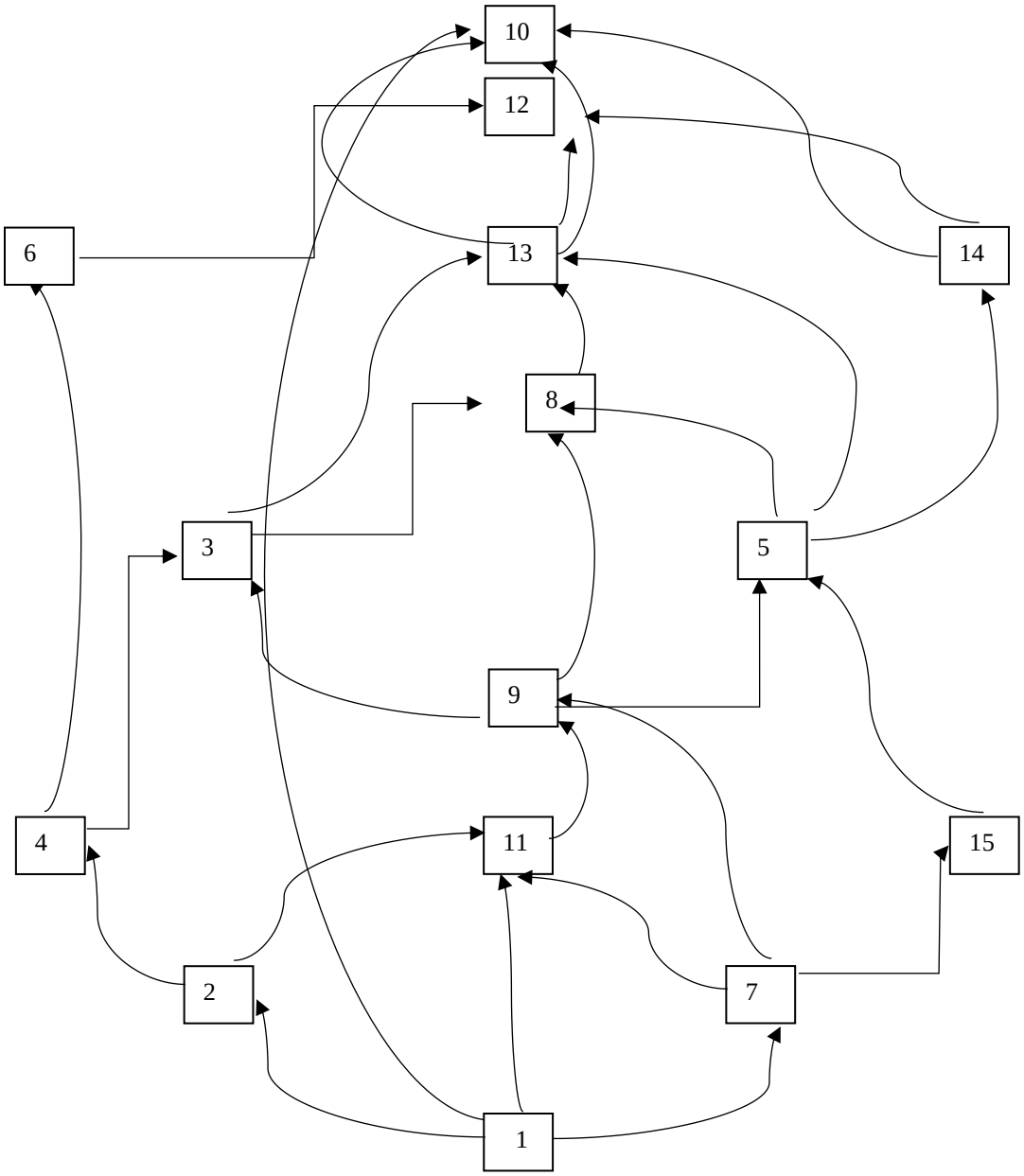

Figure 1. Digraph of barriers affecting Indian HCSC

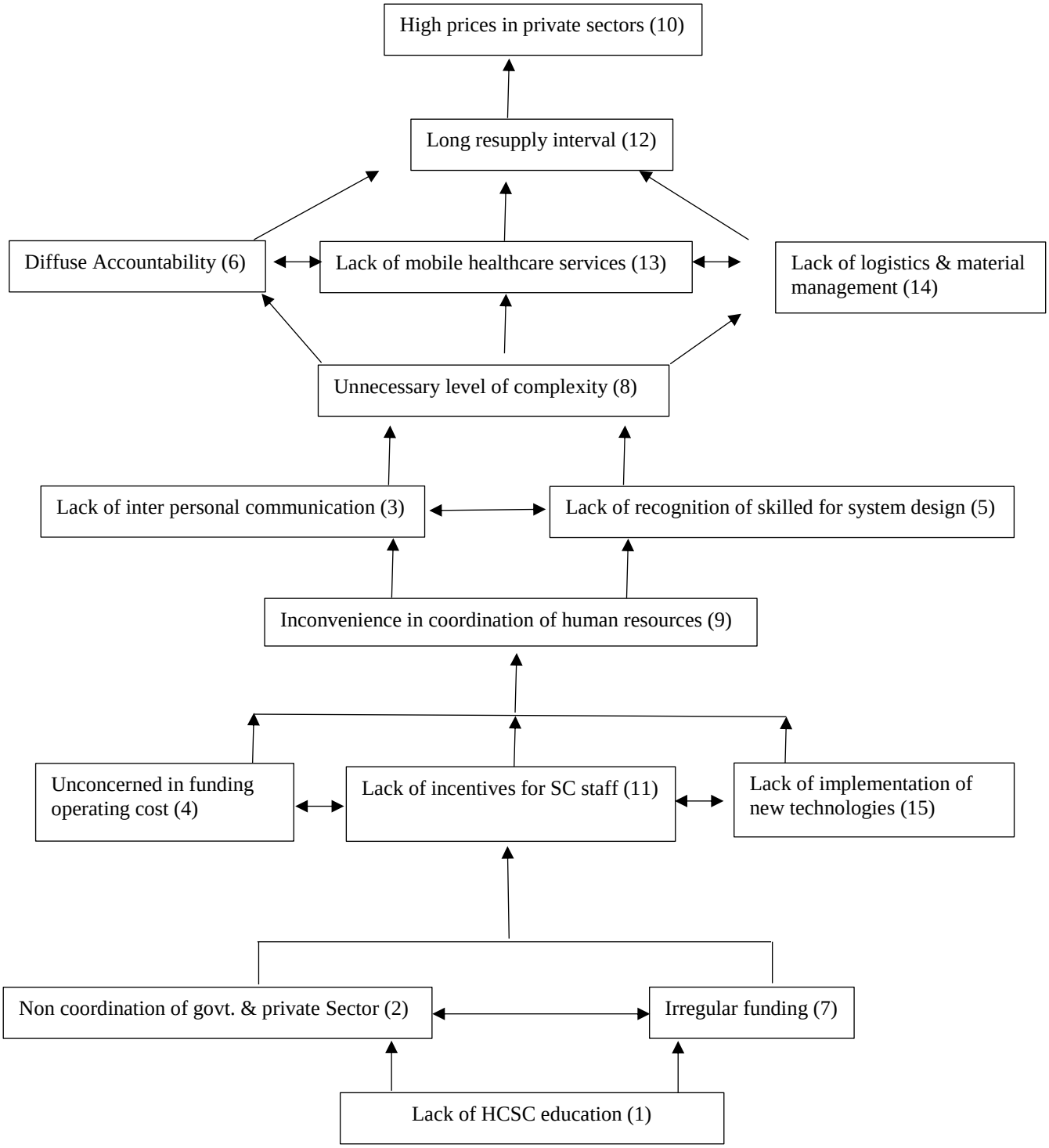

Figure 2. ISM model of barriers of Indian healthcare supply chains

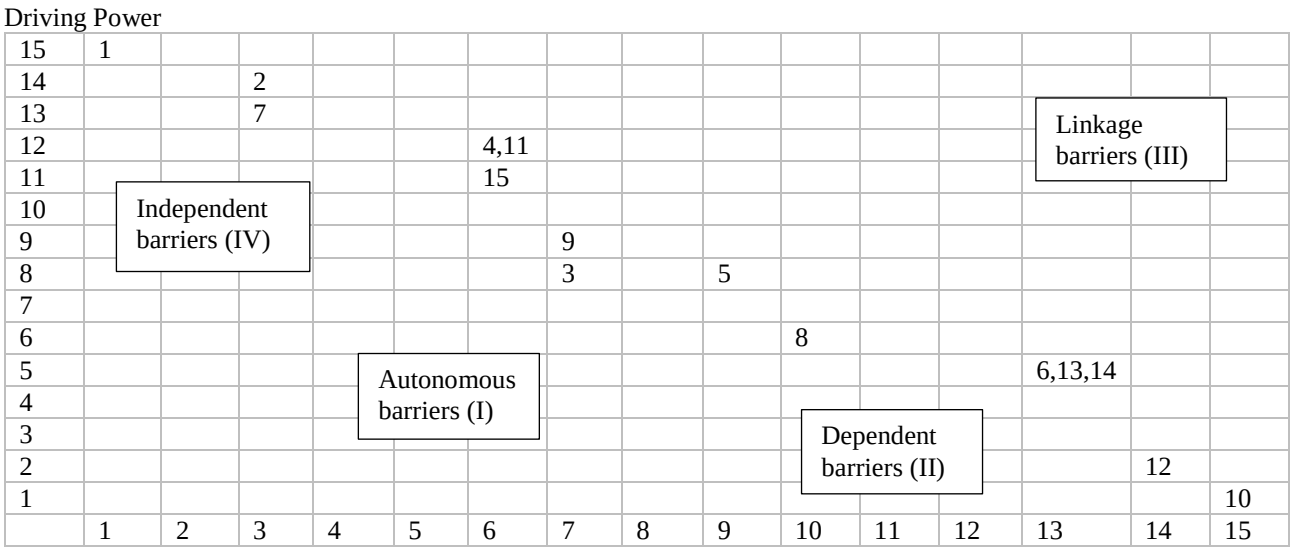

Figure 3. Group of barriers

7. Discussion

The purpose of this study is to identify barriers influencing the Indian healthcare supply chain and to establish various interconnections between complex issues using the interpretative structural modelling (ISM) approach. This model establishes a hierarchy of various activities that may be performed by the various departments and organisations within the healthcare system to ensure the supply chain is implemented effectively and to remove barriers to the supply chain. Managers, physicians, healthcare professionals, legislators, patients, and all other members of the healthcare supply chain may get knowledge about complicated challenges and their contextual linkages from the drive and dependency power. According to the analysis and results, the structural model indicates that the factors such as a lack of healthcare supply chain education, a lack of coordination between the public and private sectors, a lack of inter-personal communication with patients/customers, a lack of concern for funding operating costs, diffuse accountability, inconvenient human resource coordination, a lack of incentives for supply chain staff, and a lack of implementation of new technologies in healthcare services all have a significant impact. These parts must be successfully controlled in order to improve the overall system of the healthcare supply chain.

(i) *Autonomous barriers:* There is no autonomous barrier that has weak driving and dependence power. The barriers that fall under this category don't affect so much to the system.

(ii) *Dependent barriers:* Diffuse accountability (Barrier 6), unnecessary level of complexity (Barrier 8), high prices in the private sector (Barrier 10), long resupply interval (Barrier 12), lack of mobile healthcare service (Barrier 13), Lack of logistics and material management (14) fall under this category whose driving power is weak and dependence power is strong. All these barriers have to be managed primarily as well as considering their effect on other barriers at various levels in ISM.

(iii) *Linkage barriers:* Linkage barriers have strong driving as well as dependence power and the factor lack of recognition of skilled for system design (Barrier 5) is lying under this zone. As this barrier has strong driving and dependence power, the action taken on this barrier will develop a positive environment in healthcare supply chain management.

(iv) *Independent barriers:* Lack of healthcare supply chain education (Barrier 1), non-coordination of government and private sector (Barrier 2), lack of inter-personal communication with patient/customer (Barrier 3), unconcerned in the funding of operating cost (Barrier 4), suspensory in financing (Barrier 7), inconvenience in the coordination of human resources (Barrier 9), lack of incentives for supply chain staff (Barrier 11), lack of implementation of new technologies in healthcare services (Barrier 15) are independent barriers who have strong driving power but weak dependence power. That means all these barriers are to be considered for the root cause of all the problems in the healthcare supply chain and immediate and strong actions should be taken for removing these barriers.

All barriers impacting the healthcare supply chain must be successfully managed in order to provide patients with the finest treatments and healthcare services possible. The entire healthcare supply chain management (HSCM) process, which includes various departments and organizations such as healthcare product manufacturers, healthcare providers, healthcare institutions, and political departments, should be planned and managed effectively to achieve the best and most effective results.

8. Conclusion

The ISM model developed in this research demonstrates how different barriers or issues influence the Indian HCSC. As an overpopulated, developing, and low-income nation, India's whole economy faces several new challenges; similarly, its healthcare supply chain faces various new challenges. This study demonstrates how HCSC restrictions eventually impact consumers and end users, i.e. patients. The obstacles identified via a study of the literature and interaction with healthcare practitioners and academic disciplines must be properly controlled using the modelling methodologies used in this research. This study has identified critical complicated problems and their interrelationships in a readily accessible manner, and those concerns may be easily addressed in order to establish a high-quality health care supply chain.

9. Limitations and future scope of research work

A structural framework or model for several factors impacting the Indian healthcare supply chain (HCSC) has been examined using data from a literature review and a focus group discussion with healthcare management experts. Because the interpretative structural modelling technique does not quantify the impact of each barrier, the well-developed structural prototype may differ from current conditions and the interrelationships between barriers may differ from the assessed prototype.

Additionally, in the upcoming era, barriers affecting the Indian healthcare supply chain may be identified. When the model is implemented in practise, the generated model and the relationships between variables may vary. Graph theory may be utilised more effectively to provide a quantitative assessment of the barriers.

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