Modelling hospital inventory management using interpretive structural modelling approach

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Abstract: The inventory management process is an essential concern for a hospital because it affects the clinical, managerial and financial outcomes and comprises a large part of overall supply chain cost. It is responsible to supervise and control on the inventory at central stock and various individual care units (ICUs). This paper presents an interpretative structural modelling (ISM) for the hospital inventory management with 16 key factors. Expert's opinions on all factors have been translated into the structural model to establish some interrelationships among the factors. Matriced impacts croises multiplication applique and classment (MICMAC) analysis has been done to categorise the factors on the basis of their driver and dependence powers. The study may offer directions to the hospital administration to take key decisions to improve overall inventory management performance and reduction of cost.

Keywords: interpretive structural modelling; ISM; health service sector management; decision making; inventory management structure.

Reference to this paper should be made as follows: Kumar, D. and Kumar, D. (2015) 'Modelling hospital inventory management using interpretive structural modelling approach', *Int. J. Logistics Systems and Management*, Vol. 21, No. 3, pp.319–334.

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Dinesh Kumar is a Professor in Department of Mechanical and Industrial Engineering, Indian Institute of Technology, Roorkee. He has a vast research and publications in modelling and simulation of supply chain, reliability engineering, maintenance engineering, process planning and optimisation. He has published more than 200 papers in national/international/ journals/conferences. He is a senior member of Operation Research Society of India and ISTE life member.

1 Introduction

The health challenges are much diverse in India, having population more than 1.21 billion. Miscellaneous diseases like, communicable and non-communicable diseases have become a threat to the society as well as to the Government. It is the responsibility of a Government to provide the access the highest possible healthcare facilities to all the people of the country. Various healthcare units at central and state level are dedicated to run a number of healthcare systems in rural and urban areas all over the country. These healthcare units consist of sub centres, primary health centres (PHCs), community health centres (CHCs) and district level hospitals. All the facilities are funded by the government. Also, a number of research institutes like post graduate institutes (PGIs) and All India Institute of Medical Sciences (AIIMSs) are dedicated to provide advance research and medical facilities across India. Over the last few decades, the industrial research and management has identified the detrimental blow in the healthcare operation management across the globe. As healthcare is a main concern area, the requirement of proper management for waiting line, drug/equipment procurement, blood bank, human resource, financial, and inventory management within the hospital, etc., attains the superior priority to function appropriately. Among other healthcare products drugs contribute about 20–30% of global healthcare spending as per WHO report in 2008.

In this paper, various factors/enablers/barriers related with the inventory management have been identified to develop a structural model indicating their interrelationships. The structural modelling using interpretive structural modelling (ISM) approach of a public district hospital inventory management process has been presented in this paper which may be helpful to the management in effective decision making process.

The remaining of this paper is organised as follows. Problem definition of existing hospital inventory management system has been presented in Section 2. Relevant literature survey in this particular area has been discussed in Section 3. Section 4, consists of the identification of the key factors related to the hospital inventory management. Section 5 introduces the methodology. Section 6 describes the various steps followed to develop the structure model. Section 7 discusses the matriced impacts croises multiplication applique and classment (MICMAC) analysis followed by result and discussion in Section 8. Conclusions, managerial implications and future scope have been covered in Section 9.

2 Literature review

Since last decade, tremendous efforts have been made in design and analysis of healthcare supply chain and inventory management systems. Also different issues have been discussed associated to healthcare supply chain on the basis of various factors/enablers/barriers (Gorane and Kant, 2013; Ganesh et al., 2011). Factors related to green supply chain such as supplier and stakeholder commitment, cost benefits, environment issues and customer redundancy have been modelled using ISM and MICMAC approach (Mangla et al., 2014). It has been noticed that the inventory policy depends on the space constraints and delivery patterns (Little and Coughlan, 2008) also; the inventory policy depends on existence of multiple stakeholders as they possess different goals (Vries, 2011). Changing consumption patterns, increasing exposure to variation in products and increase in purchase power can make profound impact on rural supply chain (Kumar and Babu, 2013). The optimal stock level for the entire healthcare inventory at central stock depends upon space constraints and delivery frequency (Awaya et al., 2005; Bhakoo et al., 2012). Also, automated drug inventory management has been studied which is responsible of automatic packaging, searching the drug with lot number along with expiration date and placing the order automatically. Information technology also plays a vital role to enhance the performance of a supply chain (Tyagi et al., 2014). Various factors related to blood supply chain management have been described such as stock levels and order patterns, inventory management process, tools, equipment, internal collaboration within a hospital, wastage and transparency within a hospital (Sebastian et al., 2012) and the hospitals or even particular departments are ranked on the basis of wastage as percentage of issues (WAPI). A model is discussed to capture the perishable items in the stock which assesses the cost of disposal (Masoumi et al., 2012; Anand et al. 2013). A model is presented to optimise the reorder and order up to level in an individual care unit (ICU) by minimising the ordering cost, holding cost and shortage cost of inventory and discussed the trade-off among refill workload, variety of drugs and workload in emergency (Kelle et al., 2012). Some key factors responsible to increase the cost of medicine such as role of technology, government and WHO policies, reimbursement and prescription by the physician are highlighted (Iannone et al., 2013). Researchers conferred two models to minimising total holding cost of medicines (Lapierre and Ruiz, 2007). They have assumed direct and indirect delivery to ICUs, delivery frequency and space constraints at central stock as well as ICUs. The performance of inventory management can be enhanced by integration of holding cost and demand patterns. Overall supply chain cost is affected by the introduction of new drugs in the market (Prosser and Walley, 2006) which turn into variation in prescription among the physicians. The healthcare inventory management cost can be optimised on the basis of various criteria such as criticality and usage value of items (Al-Qatawneh and Hafeez, 2011). Few cases of hybrid stockless inventory management are studied (Royer et al., 2002). A hybrid stockless policy directs the distributor to supply the inventory at central stock as well as ICU (wherever is required) resulting a huge cost saving is noticed (Lapierre and Ruiz, 2007). On the basis of various economic order quantity (EOQ) models, it is found that cost of inventory decreases with the increase of service rate (Dellaert and van de Poel, 1996; Alstrom, 2001).

3 Problem definition

In the present scenario, hospitals face many challenges such as variation in patient demand, low visibility of products, diversity in the patient care processes, complexity in distribution, managing the patient queues, workforce, social, political, financial and economic constraints, environmental and financial issues. To overcome such issues, hospital administration is concerned with the organising, coordinating, planning, staffing, evaluating and controlling the cost-effective and satisfactory health services for the population. High variation in demand seems a large challenge, which may lead to drug stock out and wastages due to expiry and lack of space. Both the situations may be tragic in terms of emergency and financial losses respectively which trigger to take key decisions related to the control over inventory. The inventory is generally categorised as; raw material inventory, work-in-process inventory, finished product inventory and distribution inventory. In case of healthcare supply chain, the inventory arrives at the drug manufacturer is raw material inventory, the inventory under manufacturing processes is work-in-process inventory, inventory ready to dispatch is finished goods inventory and inventory at the stock of hospital is the distribution inventory. Inventory management is an important functionary part of a hospital management. It affects the overall (clinical, managerial and financial) performance and total expenditure of a hospital supply chain. Therefore, to control the supply, movement of drugs and other essential items in the public district level hospitals, a structure model has to be developed which could assist the hospital administration to take key decisions related to inventory management.

4 Identification of key factors in hospital inventory management process

For inventory management in district hospitals in India, a total of 16 key factors (F1 to F16) have been identified (Table 1) with the help of relevant literature and in discussion with the medical officers, pharmacists, and general staff during a collective survey.

Table 1 Factors identification

Factors no.	*Factor*	*Description*	*References*
F1	Losses due to wastages	Wastage of drugs and other healthcare items such as blood components is one of the biggest challenges. There are basically four types of wastages as; 1 time expiry 2 out of temperature control 3 refrigeration failure 4 miscellaneous wastages like dropping and damaging the packaging due to unsafe handling and transportation.	Sebastian et al. (2012) and Ghandforoush and Sen (2010)
F2	Transparency in inventory	The purchase cell is intended to know the actual inventory stock level at central stock/ICUs which is helpful to order an optimum lot size for a particular drug/item.	Sebastian et al. (2012)
F3	Internal collaboration	This is probably the most important driver of a hospital inventory management. Mutual collaboration and coordination among medical surgical and pharmacists within a hospital leads to an effective inventory management.	Sebastian et al. (2012)
F4	Stock levels and order patterns	Stock level indicates the reorder points. Minimum stock level is the least quantity of inventory in the store when the new delivery is ordered. Maximum stock level is the quantity of inventory just after the receiving the delivery. The order pattern depicts, how much quantity of inventory the hospital purchasing cell places the order/s for a particular medicine.	Kelle et al. (2012) and Little and Coughlan (2008)

Table 1 Factors identification (continued)

Factors no.	*Factor*	*Description*	*References*
F5	On-demand prescription	In most of the cases the patient insists the physician to prescribe him/her the drugs which are generally sold on private medical stores because of patient's doubt regarding the medicines which are distributed in the public hospitals on the government's subsidy. Such behaviour of patient influences the drug stock levels and wastages, thus the whole inventory management process is affected.	Suggested by the experts in survey
F6	Transportation cost	The cost associated to carry the drugs and other items from the distributors to the hospital central stock.	Ghandforoush and Sen (2010)
F7	Daily demand	The quantity of a particular drug is required in all the units within a hospital.	Ghandforoush and Sen (2010)
F8	Space constraints	There are numerous types of drugs required in a hospital for particular diseases. To maintain the transparency, each type of drug has to be stocked inside a separate box at central stock and ICUs results a huge stock space is required	Kelle et al. (2012) and Little and Coughlan (2008)
F9	Workload	It implies the loading and unloading manpower required in inventory handling, involves manpower cost	Kelle et al. (2012) and Royer et al. (2002)
F10	Inventory holding cost	The inventory holding cost consists of cost of occupancy, cost of manpower at central stock, electricity expenses and refrigeration cost	Kelle et al. (2012)
F11	Government subsidies	State governments all over the India have been subsidising all the healthcare expenses in public hospitals. Therefore each activity affects the yearly expenses to a particular hospital by the state government.	Suggested by the experts in survey
F12	Physician prescription	The quantity of a particular drug prescribed by the physician to the patient for specific dieses	Almarsdottir and Traulsen (2005), Alturki and Khan (2013) and Iannone et al. (2013)
F13	Distribution cost	The cost involved in the distribution of drugs and other items from central stock to ICUs	Royer et al. (2002)
F14	Delivery frequency	Total number of deliveries received on a particular day	Royer et al. (2002)
F15	Lead time of product replenishment	This is the time between placing the order and receiving the order.	Suggested by the experts in survey
F16	Frequency of patients	Total number of patients at particular time intervals. The variety and quantity of drugs depends upon the population and frequency of patients.	Suggested by the experts in survey

5 Interpretive structure modelling

ISM was developed by J.N. Warfield in 1973 (Warfield, 1973, 1974) to solve the social and economic problems. ISM is an interactive process where a set of directly and indirectly related elements for a specific case are hierarchically organised. The technique is useful when the data are collected from an organised team of key peoples or experts on the basis of their practical experience and knowledge. It facilitates the experts to decompose a complex problem into a variety of sub-problems to assemble a structure model. The complexity of the model increases with an addition of the number of factors. Some characteristics of ISM are stated as:

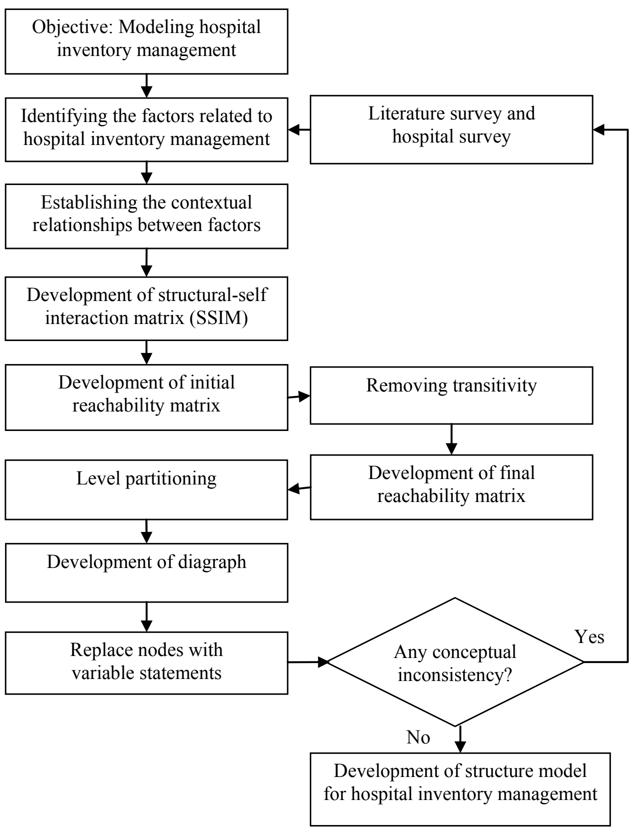
a ISM clearly gives the relations among various factors.

b The structure is extracted from the complex real world system.

c The diagraph gives the relations between different factors. Consequently, it is an essential tool to take necessary managerial actions.

d The limitations of ISM such as the contextual relations depend on the practical experience/knowledge of the peoples which may lead to deviation of the model. Steps for ISM model are shown in Figure 1 (Mangla et al. 2014).

Figure 1 Steps for ISM



6 Application of proposed model

6.1 Questionnaire development and SSIM

Since, all the processes in the district hospitals are similar all over the country .Hence, questionnaire with 16 factors has been prepared and provided to the officials of three district level hospitals (Dehradun, Haridwar and Saharanpur, India). The responses for Structural self-interaction matrix (SSIM) have been collected from 20 physicians and ten pharmacists across three district hospitals.

Guidelines for filling the X_{ij} spaces in the given table in the response matrix are given below:

a if ‘i’ is responsible to achieve ‘j’ then write V

b if ‘j’ is responsible to achieve ‘i’ then write A

c if both ‘i and ‘j’ are related together equally then write X

d if both ‘i’ and ‘j’ are unrelated then write O.

Since ISM technique indicates that it is not feasible to take the average responses. So a volunteer group was made from one district hospital to finalise the SSIM and is given in Table 2.

Table 2 Structural self-interaction matrix

i \ *j*	*F16*	*F15*	*F14*	*F13*	*F12*	*F11*	*F10*	*F9*	*F8*	*F7*	*F6*	*F5*	*F4*	*F3*	*F2*
F1	A	O	A	O	A	V	O	V	A	A	V	A	A	A	A
F2	O	O	O	X	X	O	X	X	X	V	O	O	V	A	
F3	O	O	O	X	X	A	O	V	O	V	O	O	V		
F4	V	O	V	O	A	A	V	O	A	A	V	A			
F5	V	O	V	V	X	V	X	O	V	V	V				
F6	A	A	A	O	A	V	O	O	O	A					
F7	A	X	V	V	A	A	X	V	X						
F8	V	X	V	V	X	V	X	V							
F9	A	O	O	O	A	V	A								
F10	A	X	A	O	A	A									
F11	A	A	A	A	A										
F12	O	A	V	V											
F13	A	O	O												
F14	A	A													
F15	O														

6.2 Reachability matrix

Initially the SSIM (Table 2) is transformed into a binary format 0 or 1 called as initial reachability matrix given in Table 3 by adopting the following rules:

a if the entry in cell (i, j) in SSIM is V, then X_{ij} is replace by 1 and X_{ji} is replaced by 0 in the initial reachability matrix

b if the entry in cell (i, j) in SSIM is A, then X_{ij} is replace by 0 and X_{ji} is replaced by 1 in the initial reachability matrix

c if the entry in cell (i, j) in SSIM is X, then X_{ij} is replace by 1 and X_{ji} is replaced by 1 in the initial reachability matrix

d if the entry in cell (i, j) in SSIM is O, then X_{ij} is replace by 0 and X_{ji} is replaced by 0 in the initial reachability matrix.

The final reachability matrix (Table 4) has been prepared by incorporating transitive rule (Janes, 1988) such that, 'if A is related to B, and B is related to C, then A is related to C' (Figure 2).

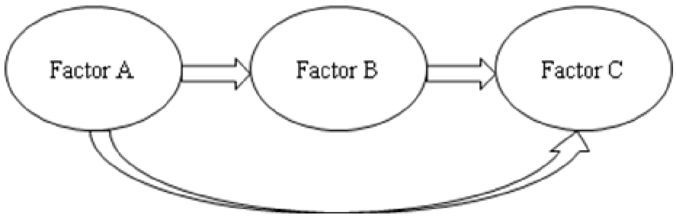
Table 3 Initial reachability matrix

Factors	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*F8*	*F9*	*F10*	*F11*	*F12*	*F13*	*F14*	*F15*	*F16*
F1	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0
F2	1	1	0	1	0	0	1	1	1	1	0	1	1	0	0	0
F3	1	1	1	1	0	0	1	0	1	0	0	1	1	0	0	0
F4	1	0	0	1	0	1	0	0	0	1	0	0	0	1	0	1
F5	1	0	0	1	1	1	1	1	0	0	1	1	1	1	0	1
F6	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
F7	1	0	0	1	0	1	1	1	0	1	0	0	1	1	1	0
F8	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1
F9	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0
F10	0	1	0	0	0	0	1	1	1	1	0	0	0	0	1	0
F11	0	0	1	1	0	0	1	0	0	1	1	0	0	0	0	0
F12	1	1	1	1	0	1	1	1	1	1	0	1	1	1	0	0
F13	0	1	1	0	0	0	0	0	0	1	1	0	1	0	0	0
F14	1	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
F15	0	0	0	0	0	1	1	1	0	1	1	1	0	1	1	0
F16	1	0	0	0	0	1	1	0	1	1	1	0	1	1	0	1

Table 4 Final reachability matrix

Factors	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*F8*	*F9*	*F10*	*F11*	*F12*	*F13*	*F14*	*F15*	*F16*
F1	1	1	1	1	0	1	1	0	1	1	1	0	0	0	0	0
F2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
F3	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
F4	1	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1
F5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
F6	0	0	1	1	0	1	1	0	0	1	1	0	0	0	0	0
F7	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
F8	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
F9	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0
F10	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
F11	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
F12	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0
F13	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	0
F14	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	0
F15	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
F16	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1

Figure 2 Procedure for transitive rule



6.3 *Level partitioning*

The reachability sets, antecedent sets and intersection sets (Warfield, 1974) are derived from the final reachability matrix and is given in Table 5. If a factor possesses the reachability set similar to the intersection set then it is given the first level in the ISM hierarchy (Mathiyazhagan and Haq, 2013) as shown in Table 5. For level partitioning in next step the previous levelled factor is deleted from the entire matrix and the procedure is repeated until the all factors are levelled. In the present case, the factors F4, F6, F7, F9, F10 and F11 are given first level (15–17) and all the factors are levelled I to V.

Table 5 Iterations and level partitions

Factors	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
F1	1 2 3 4 6 7 9 10 11	1 2 3 4 5 7 8 9 10 11 12 13 14 15 16	1 2 3 4 7 9 10 11	II
F2	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16	1 2 3 4 5 7 8 9 10 11 12 13 14 15 16	1 2 3 4 7 8 9 10 11 12 13 14 15 16	II
F3	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16	1 2 3 5 6 7 8 9 10 12 13 14 15 16	1 2 3 6 7 8 9 10 12 13 14 15 16	II
F4	1 2 4 6 7 8 9 10 11 13 14 15 16	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	1 2 4 6 7 8 9 10 11 13 14 15 16	I
F5	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	III
F6	4 5 6 7 10 11	1 2 3 4 5 6 7 8 10 11 12 14 15 16	4 5 6 7 10 11	I
F7	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16	I
F8	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16	2 3 4 5 7 8 9 10 11 12 13 14 15 16	2 3 4 6 7 8 9 10 11 12 13 14 15 16	III
F9	1 2 3 4 7 8 9 10 11 12 13	1 2 3 4 5 7 8 9 10 11 12 13 14 15 16	1 2 3 4 7 8 9 10 11 12 13	I
F10	1 2 4 6 7 8 9 10 11 12 13 14 15 16	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	1 2 4 6 7 8 9 10 11 12 13 14 15 16	I
F11	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16	I
F12	1 2 3 4 6 7 8 9 10 11 12 13 14	2 3 5 7 8 9 10 11 12 13 15	2 3 7 8 9 10 11 12 13	IV
F13	1 2 3 4 7 8 9 10 11 12 13 15	2 3 4 5 7 8 9 10 11 12 13 15 16	2 3 4 7 8 9 10 11 12 13	IV
F14	1 2 3 4 6 7 8 9 10 11 14 15	2 3 4 5 7 8 10 11 12 14 15 16	2 3 4 7 8 10 11 14 15	III
F15	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16	2 3 4 5 7 8 10 11 13 14 15 16	2 3 4 7 8 9 10 11 12 13 14 15 16	III
F16	1 2 3 4 6 7 8 9 10 11 13 14 15 16	2 3 4 5 7 8 10 11 15 16	2 3 4 7 8 10 11 15 16	V

6.4 Development of ISM

From the final reachability matrix, a relationship diagram is drawn called as diagraph (3) Figure 3. All the factors are shown by their particular symbols. The diagraph indicates the relationship among various factors and different levels by means of arrows in one or both directions depending upon the type of relationship between them. Further the ISM is prepared by replacing the symbols with the text as shown in Figure 4.

Figure 3 Diagraph showing interrelations

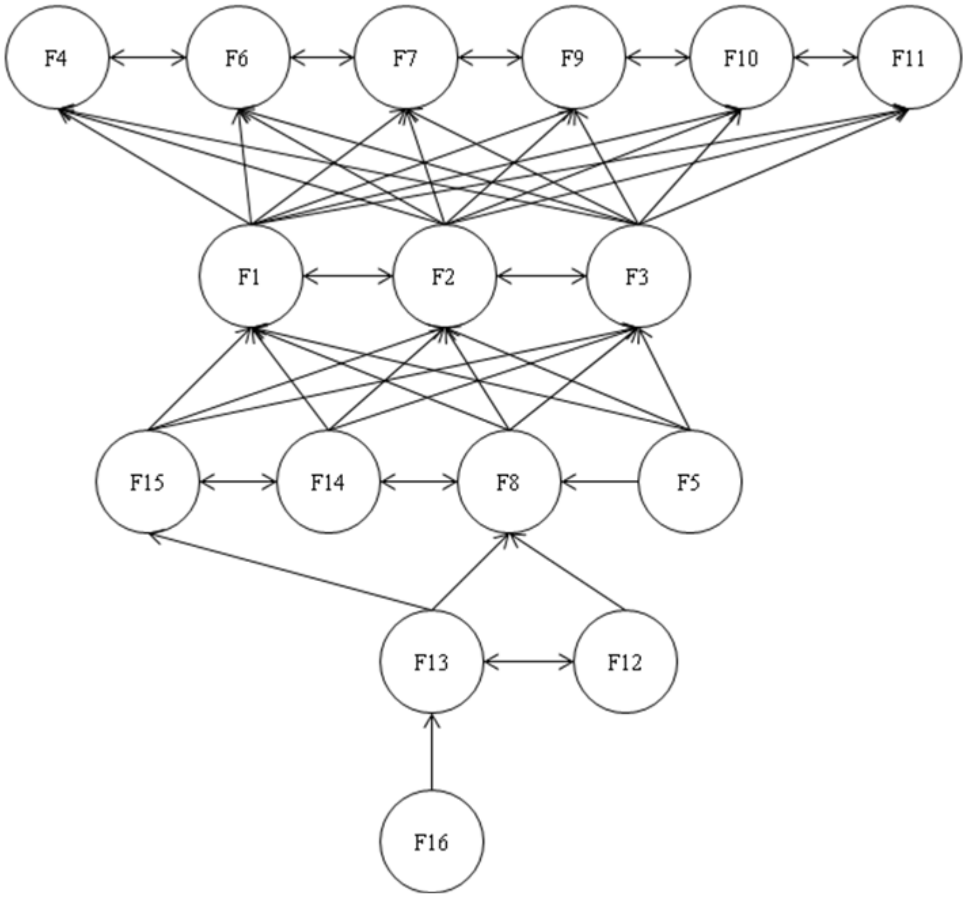
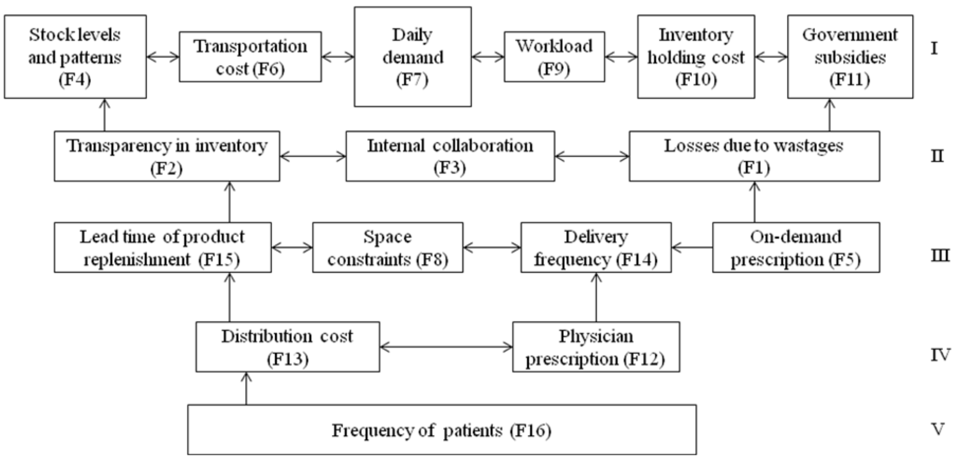


Figure 4 ISM for hospital inventory management process



7 MICMAC analysis

The aim of MICMAC analysis (Figure 5) is to analyse the dependence power and driving power (Table 6) of various factors. MICMAC principle is based on multiplication properties of matrices. It is done to identify the key factors that drive the system in various categories. A scattered chart (Gorane and Kant, 2013) with four regions as given below is drawn.

a Region I: it consists of the factors which have low driving power as well as low dependence power. Such factors are called as autonomous factors. These factors appear disconnected from the system but they may possess some strong links. None of all the factors comes in this region.

b Region II: the factors having low driving power and high dependence power come under the region II. These factors are termed as dependent factors. Factor F6 comes in this region.

c Region III: this region embraces the factors which consist of high driving as well as high dependence power. These factors are called as linkage factors and cause an effect on all related factors in response to any alteration and behave like unstable factors. All factors, except F5, F6 come in this region.

d Region IV: these factors possess high driving power and low dependence power as known as independent factors. Factor F5 appears in this region.

Figure 5 Driver-dependence power diagram (see online version for colours)

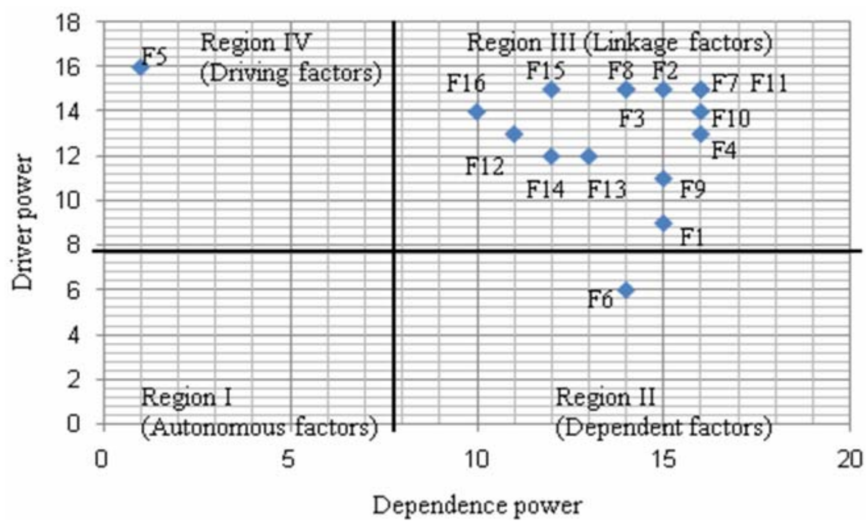


Table 6 Driving and dependence matrix

Factors	*F1*	*F2*	*F3*	*F4*	*F5*	*F6*	*F7*	*F8*	*F9*	*F10*	*F11*	*F12*	*F13*	*F14*	*F15*	*F16*	*Driving power*
F1	1	1	1	1	0	1	1	0	1	1	1	0	0	0	0	0	9
F2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	15
F3	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	15
F4	1	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	13
F5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
F6	0	0	1	1	0	1	1	0	0	1	1	0	0	0	0	0	6
F7	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	15
F8	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	15
F9	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0	11
F10	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	14
F11	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	15
F12	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	13
F13	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	0	12
F14	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	0	12
F15	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	15
F16	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	14
Dependence power	15	15	14	16	1	14	16	14	15	16	16	11	13	12	12	10	

8 Results and discussion

Inventory management for hospitals is very crucial to improve the overall performance of the system and patient's satisfaction. In emergency conditions, it becomes almost essential to human life. To attain this goal, 16 related factors have been identified. The MICMAC analysis categorises the factors on the basis of their driver and dependence power. The interrelationships among various factors have been derived by developing a diagraph (Figure 3) with five hierarchical levels (Table 5). The ISM (Figure 4) may be helpful to the hospital administration to take necessary decisions needed to improve the overall service level of a hospital.

1 Figure 5, Region II shows that factor F6 possesses high dependency power and least driving power; i.e., affected by almost all other factors.

2 Factor F16 affects almost all the factors being at fifth level (Figure 4). The hospital management may apply forecasting techniques to assess the frequency of the patients (F16) for a particular period of time and the factors like F4, F7, F9 and F14 can be predicted.

3 Factors Fi (i = 1–5, 7–16) (Figure 5, Region III) hold high driving as well as dependency powers. These factors do not drive directly other factors but facilitate the driving factor F16 to achieve the dependent factors. F12 affects F13 and F14, since more the physician prescription (F12) for a particular drug, greater will be the distribution cost (F13) and delivery frequency (F14).

4 Third level factor F5 seems to be more important for consideration since it shows greatest driving power and affects directly to F1, F8, F14 and F15 because more the on demand prescription by the patient, lesser will be delivery frequency, larger requirement of space at hospital stock and larger the wastages. F5 may also generate an uncertainty in the delivery frequency which may result an increase in F15. During the questionnaire session the physicians have enlightened that many of the patients have disbelieve on the medicines available at the central stock and the physician is requested to recommend the medicines from any of the private medical stores. Therefore, the hospital administration should make policies to discourage such requests made by the patients and the hospital administration should approach reverse logistics in case of access of medicines.

9 Conclusions

This work focuses on identification and organisation of some key factors related to the inventory management in a district hospital in India. On the basis of the survey a structured model (Figure 4) has been prepared which may assist the hospital administration to implement certain changes in system or processes. The MICMAC analysis also plays an important role to identify the driving (F5) and driven factors (F6). ISM also possesses certain managerial implications because the model has been developed on the basis of physicians and pharmacists' opinions. Furthermore, various other techniques such as structural equation modelling (SEM), Delphi method, and decision making trial and evaluation laboratory (DEMATEL) considering fuzziness can be utilised to rank the key managerial factors related to inventory management.

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