MODELLING AND ANALYSIS OF HEALTH CARE SUPPLY SYSTEM IN EMERGENCY SITUATIONS

Submitted in partial fulfillment of the
requirements for the award of the degree
of

MASTER OF TECHNOLOGY
in
Mechanical Engineering

(With specialization in Production and Industrial System Engineering)
by

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Under the supervision of

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CANDIDATE'S DECLARATION

I hereby declare that the work carried out in this dissertation titled "**Modelling and Analysis of Health Care Supply System in Emergency Situations** " is presented on behalf of partial fulfilment of the requirement for the award of the degree of **Master of Technology** with specialization in **Production and Industrial System Engineering** submitted to the department of **Mechanical & Industrial Engineering, Indian Institute of Technology Roorkee, India**, under the supervision and guidance of **Dr. DINESH KUMAR** ,Professor MIED, IIT Roorkee, India.

I have not submitted the matter embodied in this report for the award of any other degree or diploma.

Date: 14 May 2019

Place: Roorkee **ABHISHEK KUMAR**

CERTIFICATION

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

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Date: 14 May 2019 **ABHISHEK KUMAR**

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ABSTRACT

In today's era, the healthcare supply chain, compared to the supply chain of other products, is amongst the most valuable and crucial supply chain. It has a direct effect on the quality of life of people, therefore, proper planning and commitment are required from any healthcare organization for its better management. The aim of the healthcare supply chain system is to deliver right healthcare products and services in the right quantity, in the right cost, in the right condition, in right place, and in the right time to the patients who need them. When it comes to the emergency situations the pressure builds up on the health care organization, where life of individual depends on response time i.e. how good treatment he receives during Golden Hour i.e. the right first hour for need of medical treatment. However, in the context of India, due to the large population and varied demographic patterns, it becomes difficult for the government healthcare organizations to fulfil the demand and deliver healthcare products and services at a timely manner to the patients.

From the field survey and literature review, it was observed that a large number of stock outs was observed in hospitals and at various levels of the supply chain in India, which is one of the primary reasons for the poor performance of healthcare supply chain system. Hence, based on the above discussions, the objective of this study is to identify and analyses the issues related to inventory management within the healthcare supply chain. To do so, first, an overview of the current scenario of the healthcare supply chain has been discussed. Then using systems dynamics technique, the entire supply chain has been modelled and simulated. As a part of systems dynamics, a causal loop diagram (CLD) is made which shows all the stages of the supply chain of the entire hospital system. The factors such as lead time, frequency of patients, demand fulfilment loop has been considered for making causal loop diagram. The CLD is then translated into a stock-flow diagram (SFD) for the total supply chain on Stella® platform. In addition, an improved model has been discussed to help the decision-makers in better management of inventory.

Next, seventeen issues that control the demand during emergency situations, supply, movement of drugs and other essential items in the hospital, have been analysed using interpretive structural modelling (ISM). The analysis results reveal that the improved systems model has a positive effect to reduce stock-outs as well as inventory carrying cost. The results also reveal that factors like density and average age of population (F1), accessibility to other hospitals (F2), pollution in environment (F4), season change (F5), and physician prescription (F16) have high driving and low dependence power during emergency situations. These factors are the key factors or success factors for achieving end results and are very important from the management point of view.

1.1 Overview

A Supply Chain consists of all peoples involved directly or indirectly in satisfying a customer request. Along with manufacturers and supplier's transporters, warehouses, retailers, and even customer are integral part of supply chain. In every organisation, supply chain comprises of all work/functions involved in receiving and filling a customer request.

Organisations like Wal-Mart and Dell has their own supply chain networks which they have managed efficiently to become industry leaders. Supply chain is basically divided into two areas – inventory management and distribution. Even these two areas are not new in the retail environment, but in the health industry this is considered as traditional area of low value. By enhancing the inventory management and distribution we can generate revenue and save cost[1].

The purpose of this report is to outline and discuss issues related to inventory management and study of flow of medicine in a hospital using system dynamics software, and its behaviour with change in different entities of that environment along with its interpretive structural modelling (ISM) and MICMAC analysis. Practices such as over ordering, poor inventory management and leaving inventory management to hospital staff leads to current problem. This is mainly due to tracking of the inventory by manual procedure which is outdated. So, in order to improve inventory management hospitals, need to update the inventory policies, which we are going to discuss in this report. Providing the right care, to the right patient, at the right time is not only the definition of providing quality healthcare, but also the key to the long-run viability of our healthcare system. However, our healthcare delivery system is often unable to match the supply of healthcare services with the demand for that care.

Intense, inherent change in demand or variability renders this synchronization almost not possible to keep for any specific period of time. The mismatch among patients and providers has been proven to result in huge adverse eeffects: demand variability has been suggested as a main driver for increasing healthcare delivery costs, unexpected surges in admission rates have been linked to increased likelihoods of unplanned patient readmission, and the inability to maintain a desired patient provider ratio has been correlated to increased patient mortality. Demand variability may be the most pressing problem facing healthcare delivery today.

1.2 Modelling and Simulation of Engineering Systems

In health care domain simulation is potentially the most common and widely used Operational Research technique. It has mainly agility, potential to handle issues like variability and uncertainty, and to make easy communication between different professions.

Each method is unique, and few methods are more efficient in specific problems than other methods. So, identifying the most desirable approach is necessary for purpose of any project. Before finalizing any modelling, approach analyze all possible methods and identify their characteristics.

1.2.1 Modelling and Simulation of Health Care Systems

With the possibility of modelling the Indian Health Care system the question follows: how is modelling used in health care?

Mustafee*et al.* answered this questions after reviewing 210 research papers from best renowned journals published between 1971 and 2008. The research papers that had been reviewed were categorized beneath different simulation strategies. For every technique health care utility is investigated.

All the four pertinent simulation techniques that have been diagnosed after reviewing the papers are: Monte Carlo simulation, Discrete occasion simulation, Systems Dynamics, and Agent-based simulation.

1.2.2 Monte Carlo simulation

Monte Carlo simulation (MCS) was chosen as name of code by John von Neumann and Stanislaw M. Ulam for their work in 1946. This code name was chosen because of the sensitive nature of his work (Manhattan Project). The name was chosen to reflect the modelling approach's close to staking. Monte Carlo Simulation is a random technique it uses the random qualities of a detail and simulates processes as consistent with that. As in keeping with defined statistical distribution random numbers are created. The abnormal numbers are then controlled to form values that's utilized in replication and calculated in a distinct sample. To get a stochastic illustration of the simulation, a huge quantity of awesome calculations is completed with the assist of the stochastic inputs. The condensation of this information illustrates the simulation.

Limitations:

Unfortunately, the usage of MCS heavily depends on the statistical accuracy of the data provided in the input. So, in the cases where availability of the data is limited, the use of MCS is limited. The method used to model the real time situation can heavily affect the result from the model. It then becomes essential to make a right decision the way how a model represents real situation. As Monte Carlo simulation utilizes reproduction of certain cases, consequently the modelling of uninterrupted systems is limited.

1.1.3 Discrete Event Simulation

One of the most frequently used techniques for operations research problems is Discrete Event Simulation (DES). DES is concept based on events/activities happening keeping time as variable throughout the state of the system. Throughout the system entities/things flow which is processed by the events. Any activity or process is represented by events within the model the incoming events and processing greatly have an effect on the variables used inside the machine. Variables are defined so that you can represent the reality in the version and measure the adjustments within the model. According to Ross DES carries typically 3 variables specifically; Counter variable, Time Variable and System State variable.

<u>Limitations DES approach:</u>

The version is extraordinarily complex and the complexity increases substantially because the variables in device queue facilitates developing the intuitive this is modelled will increase. The procedure to be modelled should be acknowledged intensive for building the necessary good judgment to symbolize version.

1.2.4 System dynamics

System dynamics (SD) is used to represent the behaviours of a system over time. It is a CAD, graphical and analytical approach. Professor Jay Wright Forrester first invented and presented System Dynamics to his research students at MIT, Massachusetts in late 1950s. This method of developing models gives clear understanding of system behaviour to the managers, planners and policymakers. In various dynamic situations we can apply SD in various complex environments like, industrial, managerial, economic, social, ecological systems and public health etc. The system behaviour is affected by all the causal factors and interrelationships between them. In SD system structure is represented by two methods, i.e. CLD causal loop diagrams and SFD stock-flow diagrams are discussed further in this report.

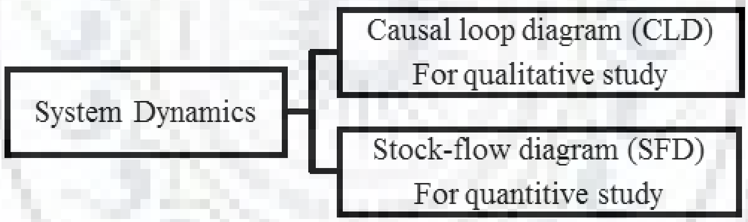


Figure 1: System dynamics branches

<u>Limitations:</u>

The limitations associated with SD modelling is that it is based on large amount of data and data have uncertainty in associated with them also lots of assumptions are to be considered while developing a model and making these assumptions is difficult for modelling a human behaviour.

1.3 Most Common Areas of Application in the Health Care Environment

Application areas are categorised from most frequently used to the least frequently used.

Monte Carlo simulation:

- Assessing risk associated with health.
- Method for evaluating different cost-effective strategy or technology.

- Diagnosing and assessing certain medical interventions
- Improving Methods

Discrete Event Simulation

- Costing economics of Health.
- Strategies and Policies evaluation models.
- Reviewing papers
- Improving and Comparing methods
- Emergency and Accident departmental modelling.
- Public response to infective diseases

System Dynamics

- Evaluation of policies related to public health.
- Training tool to illustrate dynamics of epidemiology
- Developing Models related to health care systems.
- Modelling of Infrastructures

1.4 Interpretive Structural Modelling and MICMAC Analysis

The inventory management process is an issue of concern for a health centre because it incorporates of predominant a part of common supply chain cost that affects the medical, managerial and monetary consequences. It can direct and regulating the stock at fundamental keep in addition to several man or woman care gadgets (ICUs).

An interpretative structure model (ISM) is a methodology for managing hospital main inventory with key components. Sentiment of experts on all elements are taken and afterward converted into structural model and interrelationships among the factor is built up. Each factor is classified based on their driver and reliance powers utilizing MICMAC analysis.

Interpretive auxiliary displaying (ISM) is an entrenched procedure for recognizing connections among explicit things, which characterize an issue or problem. ISM has been generally utilized by different scholars to signify the interrelationships amongst different components linked with the issue. ISM approach begins first factors are distinguished, which are related to the problem. After this a significant subordinate relation is selected. Having chosen the relevant connection, pairwise evaluation of variable is done to build up a structural self-interaction matrix (SSIM). After this, SSIM is transformed into a reachability matrix (RM) and then the transitivity of the matrix is examined. A matrix model is attained in the wake of finishing transitivity embedding. At that point, the parting of the factors and an extraction of the structural model called ISM is obtained.

ISM is a technique designed for assisting the people to apprehend the matters that he or she believes and to distinguish really what she/she do not realize. The statistics covered (in the manner) is zero. The esteem blanketed is structural. The ISM procedure changes misty, ineffectively verbalized mental models of frameworks into substantive and very a good deal characterized fashions.

Matrixed' Impactscroises-multiplication appliqúeanclassment (cross-impacts matrix multiplication implemented to classification) is condensed as MICMAC. The reason for MICMAC exam is to examine force strength alongside dependence power of elements. The properties of matrix on which MICMAC is primarily based on is multiplication. Crucial factors that drive the elements in distinct groups are distinguished. On the idea of their driving and dependence power, factors had been classified in 4 regions that is linkage elements, autonomous

Literature review was done by gathering and evaluation of relevant papers by systematic approach. Appreciable number of articles were searched from various databases of published articles upto Dec2017 on topics related mainly with system dynamics and health care supply chain. The databases include PubMed, Web of Science, Science Direct and Google Scholar databases.

Papers that were considered for inclusion were those which described applications of system dynamics modelling of 'A System Dynamics Model of Health Care Surge Capacity[2], 'Reviewing emergency care systems I: insights from system dynamics modelling[3]', 'Modelling rural healthcare supply chain in India using system dynamics[4]. 'Enablers for Competitiveness of Indian Manufacturing Sector an ISM-Fuzzy MICMAC Analysis[5]',' Modelling Hospital Inventory Management using Interpretive Structural Modelling (ISM) approach[1]'. The reference lists of each article were reviewed to identify additional resources.

AUTHORS	TITLE	WORK	CONCLUSION
Dinesh Kumar*, D. Kumar	Modelling rural healthcare supply chain in India using system dynamics.[4]	The supply of Iron Folic Acid tabs in state government owned rural health care systems.	System Dynamics turned into used to version the scenario. A massive stock out at numerous levels leaving a huge number of patients unserved become located. On the opposite hand, few degrees maintain extra quantity of medication after the finishing touch of the year.
Dinesh Kumar[1], Dinesh Kumar[2]	Modelling Hospital Inventory Management using Interpretive Structural Modelling (ISM) approach[1]	This paper gives an interpretative structural model (ISM) for the health center inventory management with 16 key factors. MICMAC evaluation has been finished to categories the factors on the basis in their motive force and dependence powers.	The hospital management may apply forecasting techniques to assess the frequency of the patients for a particular period of time.

Vishal Ashok Bhosale* and Ravi Kant	An integrated ISM fuzzy MICMAC approach for modelling the supply chain knowledge flow Enablers[6]	To perceive supply chain know-how flow enablers to look at interrelationships among these enablers and classify these enablers into using power and dependence energy the usage of an integrated ISM and fuzzy MICMAC method.	This studies paper investigates and identifies the SCKFEs that influence the effectiveness of expertise float in SC operations.
Devendra Kumar Dewangan Rajat Agrawal Vinay Sharma	Enablers for Competitiveness of Indian Manufacturing Sector: An ISM-Fuzzy MICMAC Analysis[5]	The present study Argues that innovation can play a totally crucial role in providing this competitiveness of Indian manufacturing area. The have a look at identifies 11 enablers for advertising of innovation within the Indian manufacturing zone.	The manufacturing competitiveness enablers are iterated in different levels. From the analysis of this study a structural self-interaction matrix (SSIM) the basis for ISM was formed in which the top most level was occupied by Continuous Improvement (10)
Adam, Tsan Sheng Ng CharlleSy Jie Li	A system Dynamics model of Singapore Health Care Affordability	Model accounted for the call for for health centre services and various essential resources and charges related to them. Model accounted for the demand for health centre offerings and numerous essential assets and costs associated with them.	4 different class of policies were tested for their effectiveness in improving healthcare affordability in Singapore. These works focus was on the investigation of more fundamental root Causes such as the aging population.
MisaghFaezipoura*, Susan Ferreiraa	A system dynamics perspective of patient satisfaction in healthcare[7]	A system thinking is applied and in healthcare system social aspects are also considered, factor relationships in healthcare social sustainability related to patient satisfaction using a system dynamics approach.	The perspective of patient satisfaction was explained and a new concept of healthcare sustainability was introduced
HengSHAOa, Hong ZHAOb, Feng HUc	A Study on Modelling and Simulation Engineering of Emergency Resources	This examine makes use of system dynamics to Model emergency resources deliver and	Simulation effects display that emergency assets Supply is decided by way of the want, the intention of using

	Supply Based on System Dynamics[8]	simulate to offer engineering presentation..	quantity and mobilizing quantity is to bridge using mistakes and mobilizing mistakes, show oversupply of emergency sources, namely immoderate employing and excessive mobilization
Alexander Lubyansky	A System Dynamics Model of Health Care Surge Capacity[2]	Created a system dynamics model to investigate how health care providers can and should respond to increase in patient demand for treatment above usual levels.	How treatment providers should craft policies that ensure the ability of treatment providers to sustainably provide medical treatment for long periods of time.
Tom Christopher Rust	Dynamic Analysis of Healthcare Service Delivery: Application of Lean and Agile Concepts[9]	Agile – which was developed in to optimize product delivery in volatile demand environments with highly variable customer requirements.	This literature applied supply chain management concepts in healthcare, and a new path for designing healthcare systems that provide the right care, at the right time, to the right patient, at the lowest price.

2.1 Gaps and Opportunities

- Various researchers' uses ISM and MICMAC analysis approach to represent the interrelationships among various elements related to the issue but is hardly used in healthcare supply chain management. It can be very effective tool in knowing the major factors affecting Inventory at hospital where a large number of interrelated factors are involved.

2.2 Objective and Scope

- Model and simulate a real time case study of a hospital in system dynamics software (Stella) and analyse the problems associated with its inventory management.

- List out key factors which affect the inventory of emergency healthcare supply chain management and using ISM and MICMAC analysis develop an ISM model showing the key factors and interrelationship among themselves.

- Developing a new improved model using Q.R inventory management tool in Stella and also performing sensitivity analysis.

Health care supply chain is developed into vertical and horizontal integration, managed care pressure, changes in federal reimbursement, the rise of e commerce.

There also been many other changes and few are as follows: -

The rise of e commerce has a affected all the sectors and their ways to manage inventory and it also has major effect on health care supply chain[10]. Web technology has speeded up trading and the transactions which provides a better visibility of products and information across this operation. In many countries, healthcare expenditure has witnessed an expanded increase of growth over time. This has positioned a strain on each public and personal sectors to correctly mitigate the surmounting pressures of healthcare expenses.[11], affordability and accessibility. Organisation along with hospitals are vertically included into health insurance business such as, starting their personal health upkeep firms and care practices.

3.1 Causal Loop Diagram

Causal loop Diagram is to visualise how all variables in the whole system are interrelated. The diagram consists of set of nodes and edges, Nodes represents the variables and edges are the links that represent a connection or a relation between the two variables i.e. if the node in which the link starts decreasing, the other node also decreases. Similarly, if the node in which the link starts increasing, the other node also increases.

3.1.1 Reinforcement Loop

A reinforcing loop is one wherein an motion produces a end result which affects extra of the same action for this reason resulting in boom or decline.

3.1.2 Balancing Loop

A balancing loop attempts to move some current state (the way things are) to a desired state (goal or objective) though some action (whatever is done to reach the goal).The balancing loop is one of the two foundational structures of systems thinking, the other being the Reinforcing Loop.

- Positive causal link manner that the two nodes exchange inside the identical course, i.e. if the node wherein the hyperlink starts decreases, the other node additionally decreases. Similarly, if the node in which the link begins increases, the alternative node increases.
- Negative causal link means that the two nodes exchange in contrary directions, i.e if the node wherein the hyperlink starts off evolved will increase, then the alternative node decreases, and vice versa.

3.2 Development of causal loop diagram (CLD)

On the basis of the survey conducted in the hospital, a causal loop diagram (CLD) has been constructed depicting the flow of medicines through all the stages for a healthcare supply chain in the considered hospital[12]. The explanations of the CLD have been discussed below. There are numerous different factors which when combined determine the overall flow of medicines and those factors are:

- Patients arrival
- Current stock
- Patients satisfaction
- Lead time
- Reorder quantity and Reorder point
- EOQ (economic order quantity)
- Frequency of order placed
- Total cost

These factors were combined to make some loops which are inter related and which effects inventory in the hospital.

3.2.1 Demand fulfilment

These loop deals with the fulfilment of the total demand that is prevailing in the hospital. The major factor affecting the loop are current stock and the total demand.

3.2.2 Inventory loop

This loop deals with the inventory level that is there in the hospital at a particular instant of time. Reorder quantity and the current stock are the major factors affecting this loop.

3.2.3 Lead time

It is one of the crucial loop because it tells when to reorder and when we are going to receive our order. The knowledge of lead time can prevent the condition of stock outs. Reorder point and the lead time are the major factors.

3.2.4 Total cost loop

In order to optimize the condition in the hospital total cost is an important factor that plays a vital role. The optimised quantity that we should order depends on total cost that is incurring in the system. Ordering cost and Holding Cost determines total cost.

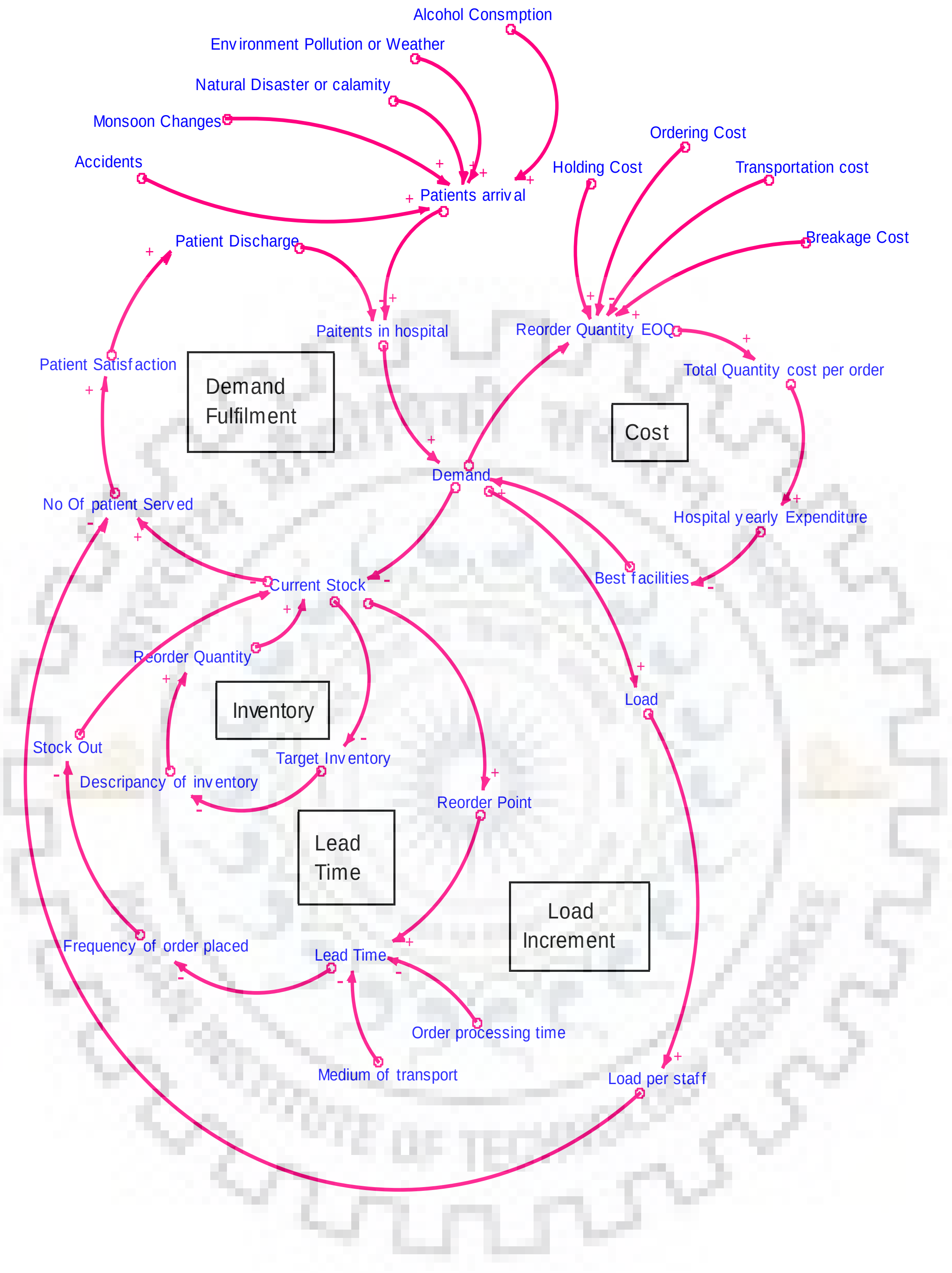


Figure 2. Causal loop diagram for hospital

3.3 Stock Flow Diagram

3.3.1 Inventory Management

It is largely controlling of the ordering, storage and use of additives that a corporation will use in the manufacturing of items it'll promote as well as overseeing and controlling of quantities of finished merchandise on the market. The most important objective of inventory control is to offer uninterrupted manufacturing sales and or customer support levels on the minimal fee. Since for lots groups' inventory is largest item at cutting-edge belongings category. Inventory problems can and do make a contribution to losses or maybe commercial enterprise failure.

3.3.2 Inventory Management in Hospital

We are dealing with the inventory management of a hospital which consists of four wards. On an average 80-90 patients are arriving to hospital and each patient was given on an average 3 medicines per day. By this we came to know the demand of the hospital.

3.3.3 Current Model

The hospital considered was Nirogi Hospital, Shahabad (M.) Distt. Kurukshetra, Haryana with areal population of 200,000 peoples. Hospital consists of four wards, mainly eye, dental, general ward and emergency ward and the daily average patient arrival rate is approximately 80-90. As per hospital, on an average around 30 % of the total no. of patients go to ward 1, 20% in ward 2,30% inward 3 and 20% in emergency ward (Accidents and casualty). Each patient is provided with two pain killer tablets on an average. The hospital procures its necessary quantity of medicines from PHC supplier and have lead time of 1 day. The total cost has 3 components associated with it mainly transportation cost, ordering cost and holding cost. Per unit cost of medicine was 6 rupees.

3.4 Problems observed in Current Model

After gathering the data, we made stock flow diagram to visualise the inventory prevailing in the hospital at particular instant of time. Inventory depends on two factors: -

3.4.1 Quantity Received and Total Demand

Total Demand further depends on tablets per patients and daily patients arriving in the hospital. The difference between quantity received and the total demand gives the hospital stock at any a point of time. This was the result that was obtained.

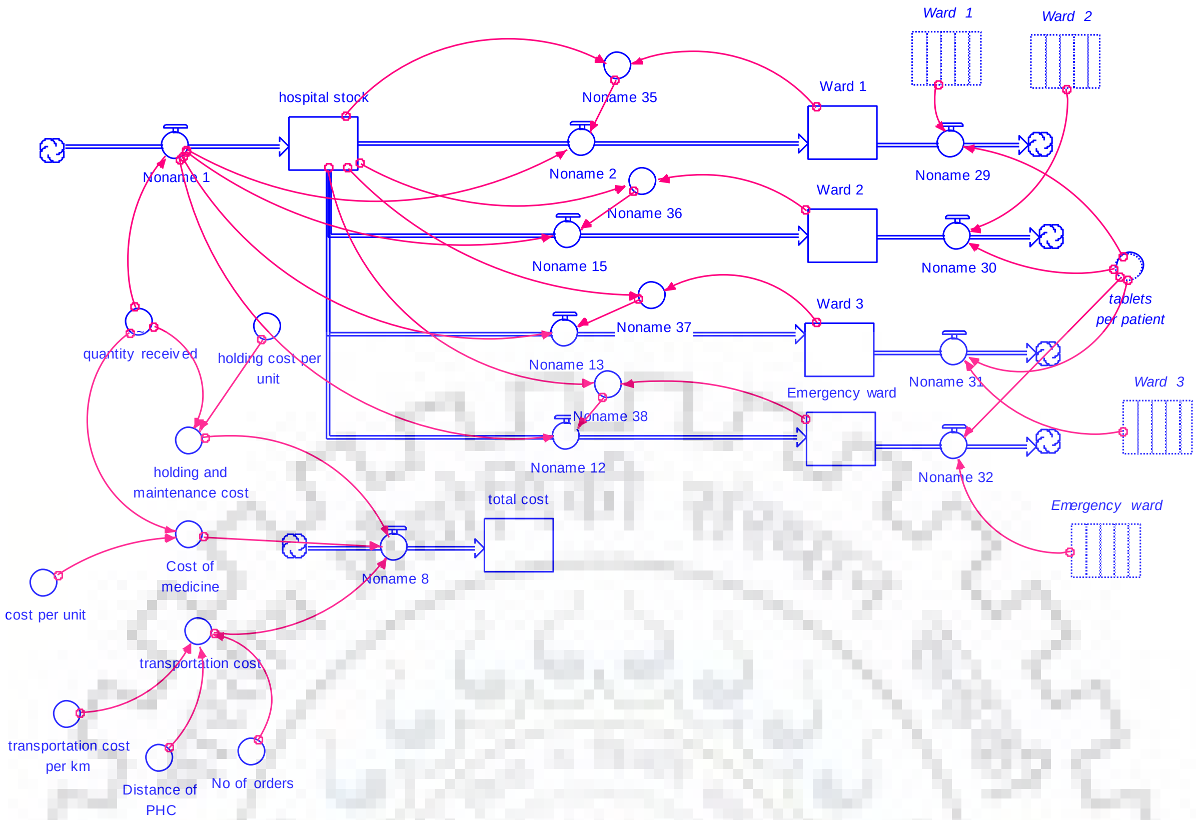


Figure 3 - Stock Flow diagram of current situation

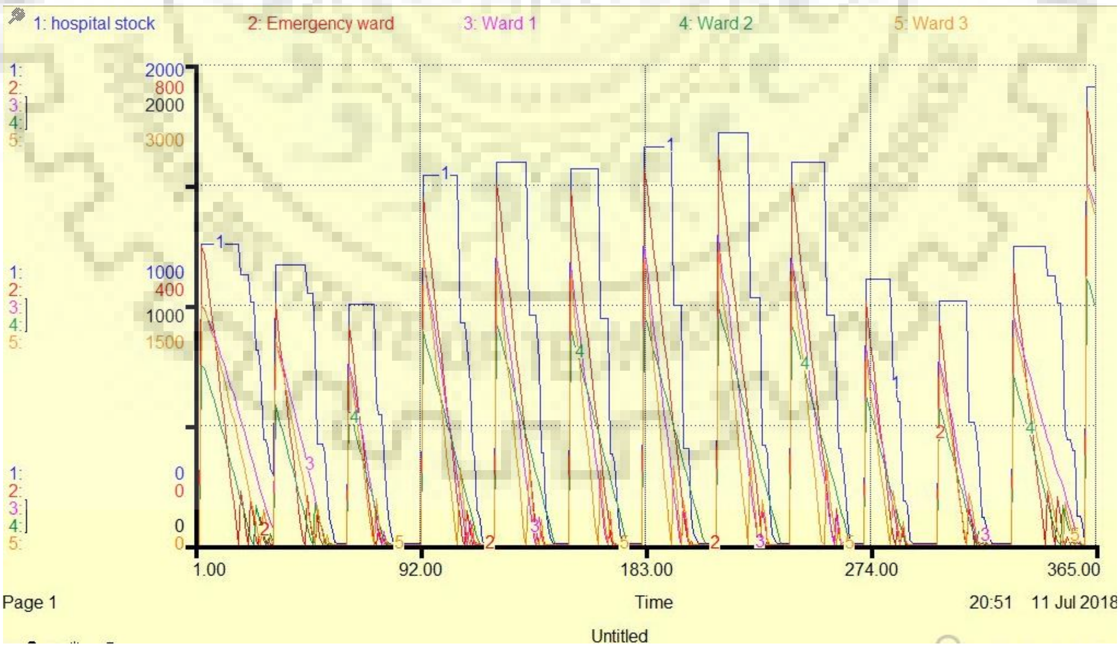


Figure 4: Results of Stocks (Current)

3.4.2 Frequency of orders

From the above results we noticed that there are frequent prevailing stock outs which we are shown by red lines. We can also observe from the graph, for few days there are stockout in hospital stock and all the respective wards simultaneously.

And as per hospital data the frequency of ordering is too high i.e. 100 orders/year. The frequency of orders in the hospital is too high, due to this ordering cost is too high, which is also affecting total cost.

3.5 New Model

After defining the existing problems in the current model, we developed a new improvised model in order to eliminate all the flaws that are existing in the current model.

In the improved model we have used EOQ (economic order quantity) with unit discount model for deciding ordering quantity. We have also considered safety stock in the main hospital stock as well as in each ward to avoid stock outs.

Formula used:

Safety stock = z*σ*sqrt(L)

Where z = Service level

Sigma = Standard deviation

L = lead time

In order to maintain a certain level of safety stock we have considered a reorder point. We have chosen reorder point equal to the safety stock so that, whenever the hospital stock reaches the level of safety stock then at that particular time we will make an order.

Reorder Quantity = EOQ + Safety Stock.

To avoid stock out in each ward and to increase patient satisfaction we have maintained a week's safety stock in each ward.

Safety Stock in each ward= 7* Patients * tablets per patient

While developing a new model we have also considered the discounts that were given on different price windows. According to data that we gathered, from price range Rs.0-50000 there was no discount offered, in the price range Rs.50000-100000 offered discount of 2 percent and for the price above Rs.100000 offered a discount of 3 percent.

In the above model

$$Z(Q) = C_j\lambda + (R_j - C_jq_j + K)\frac{\lambda}{Q} + \frac{IC_jQ}{2} + \frac{I(R_j - C_jq_j)}{2},$$

Refrence :- Principles of inventory management, Muckstadt, J.A. Sapra

K =holding cost

q_j = quantity at different levels

q_1= 0, q_2=8334and q_3=16667

c_j = unit cost of medicine

c_1= Rs.6, c_2= Rs.5.88and c_3= Rs.5.82

R_j =sum of terms independent of Q

$R_j=c_1(q_2-q_1)+c_2(q_3-q_2)+\ldots\ldots\ldots\ldots+c_i-1(q-q_i-1)$

$R_1=0$

Q_j=ordering quantity at different price discount

$Z_i(Q_j)$=total cost corresponding to Q_i

λ = demand rate

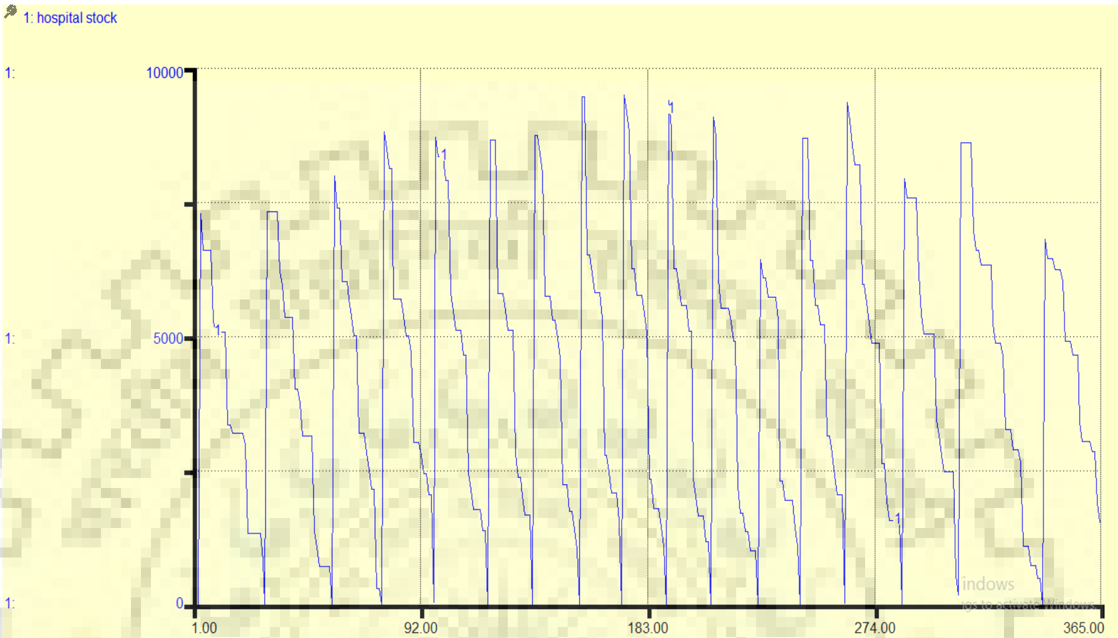
We have applied the above equations to find out Q_1,Q_2,Q_3 which lies between the range $<q_1$, $(q_1,q_2)$and $>q_3$ respectively. Then we have calculated total cost corresponding to Q_1,Q_2,Q_3 which are denoted by z_1,z_2,z_3 respectively and then we compared the value of z_1,z_2,z_3 in order to find out the minimum of these three. Then corresponding to the minimum cost optimal ordered quantity is determined.

Then EOQ=(minimum order quantity + safety stock)

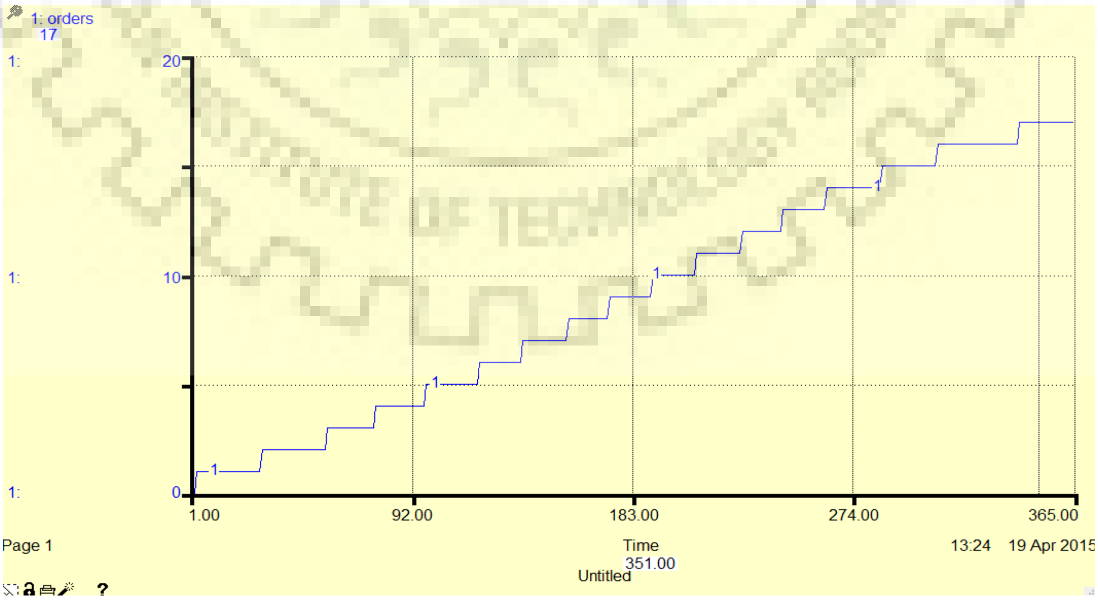
Utilization factor for ward= No. of beds in ward / ward capacity

As total cost is one of crucial factor in determining the overall condition of hospital and its is dependent on number of medicines. As we are ordering at optimal level so in an indirect way we are reaching at an optimal level of total cost. The transportation cost is also vital factor in determining the total cost so the reduction in frequency of orders will lead to reduction in total cost. In our new model where frequency of orders has been reduced to more than 80 percent finally which leads a drastic change in total cost.

4.1 Inventory flow in hospitals



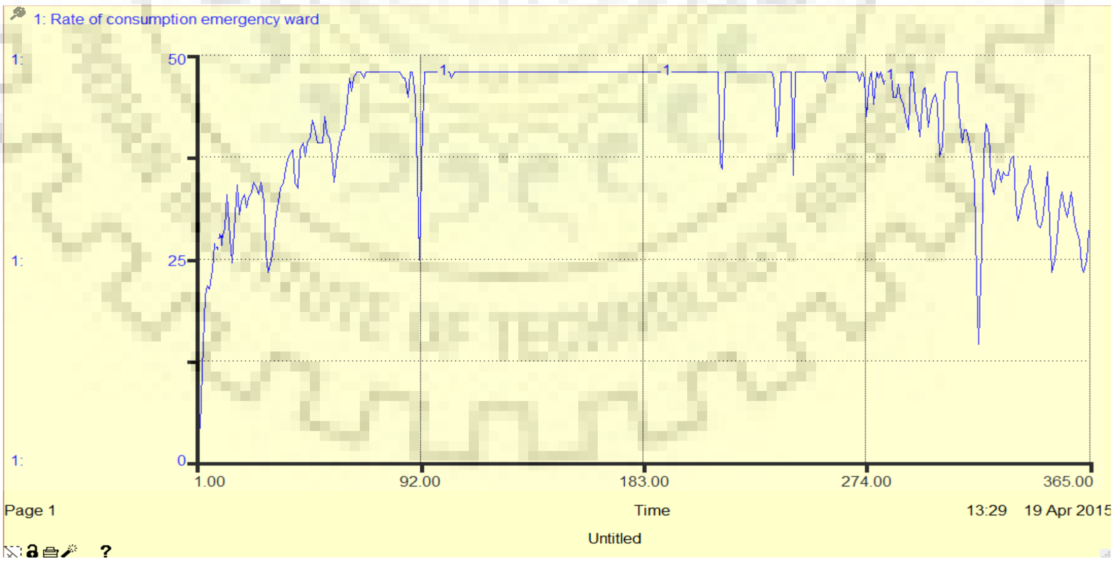
4.2 No. of Orders – 17



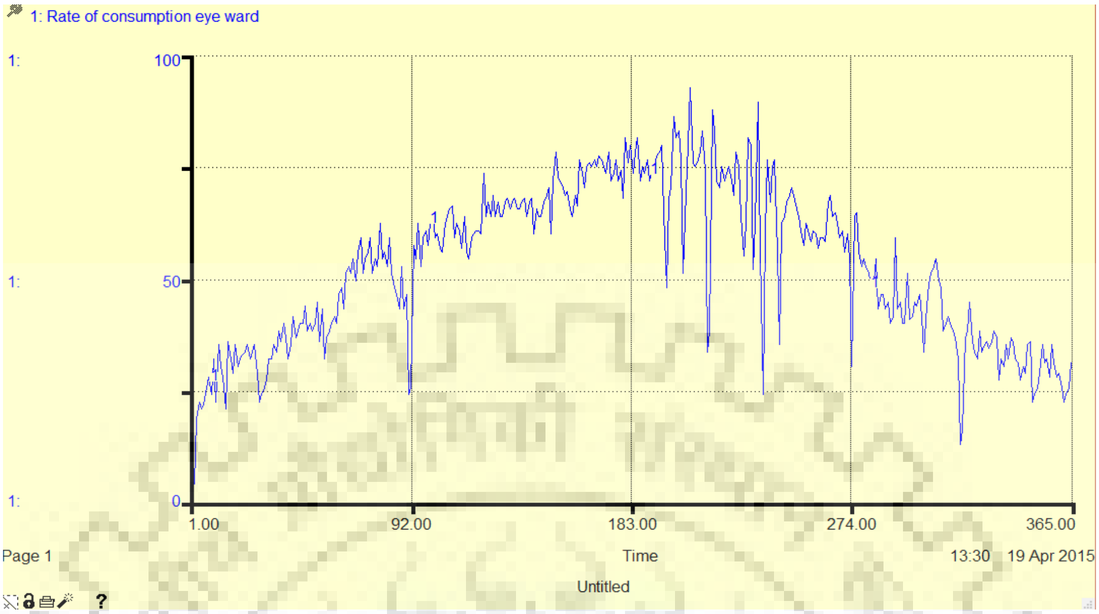
4.3 Patient Satisfaction

Rate of consumption in dental ward

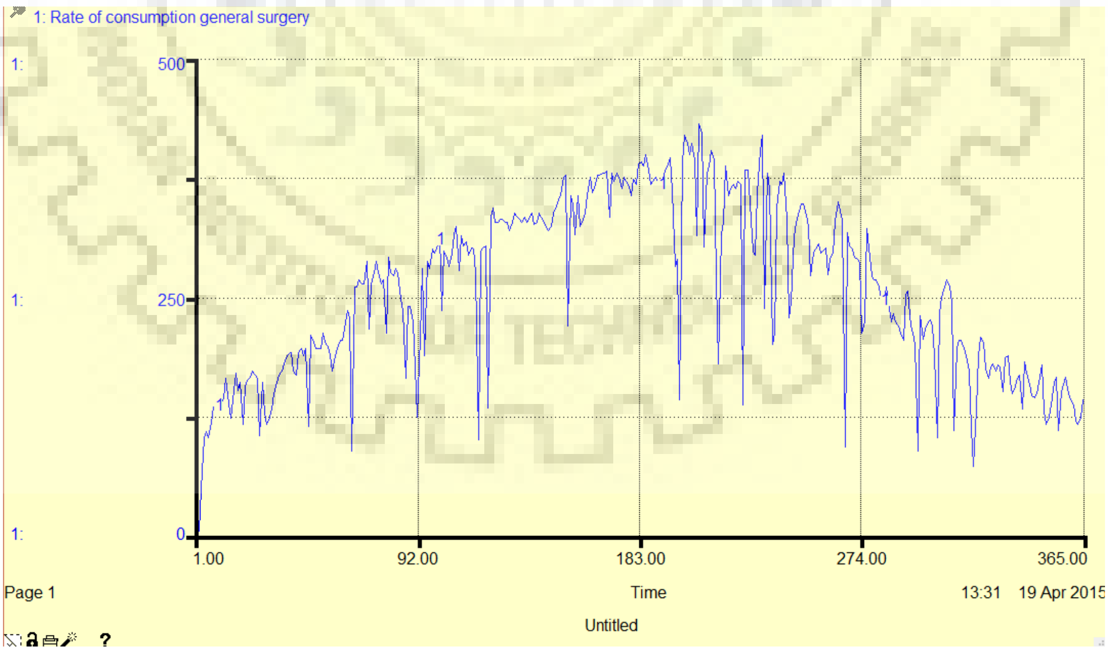
Rate of consumption in emergency ward



Rate of consumption in eye ward



Rate of consumption in general ward



15:16 19-04-2015 Table 2 (Untitled Table)

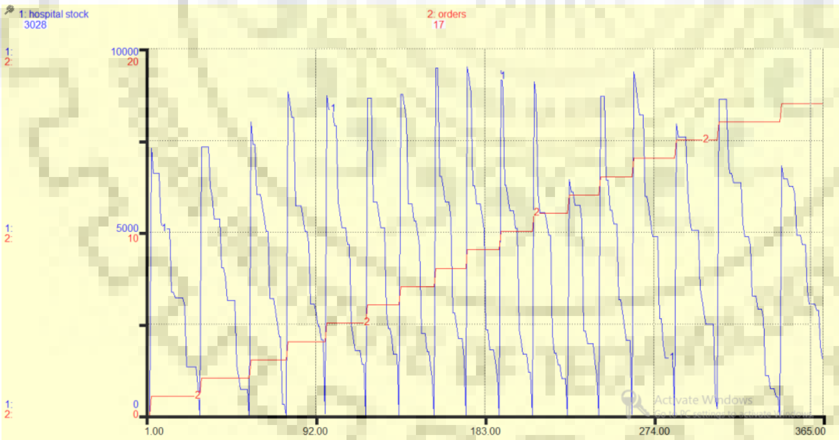
Time	hospital stock	Ward 1 eye	Ward 2 dental	Ward 3 general surgery	Emergency ward
3	6,597.26	134.40	146.40	312.00	91.20
4	6,597.26	112.00	105.60	210.00	70.80
5	6,597.26	91.20	62.40	102.00	49.20
6	6,597.26	69.60	20.00	0.00	28.00
7	5,275.66	44.00	303.20	708.00	169.60
8	5,079.66	212.00	251.20	574.00	142.80
9	5,079.66	188.00	200.80	444.00	116.80
10	5,079.66	156.00	148.80	304.00	88.80
11	5,079.66	133.60	98.40	168.00	61.60
12	5,079.66	98.40	46.40	24.00	32.80
13	3,338.06	68.00	358.40	1,008.00	229.60
14	3,338.06	40.00	308.00	862.00	200.40
15	3,192.46	164.80	259.20	740.00	176.00
16	3,192.46	128.80	207.20	598.00	147.60
17	3,192.46	96.80	155.20	428.00	113.60
18	3,192.46	68.00	105.60	276.00	83.20
19	3,192.46	32.80	53.60	116.00	51.20
20	2,979.66	215.20	1.60	0.00	18.40
21	1,305.26	183.20	313.60	936.00	205.60
22	1,305.26	150.40	261.60	774.00	173.20
23	1,305.26	116.80	209.60	608.00	140.00
24	1,305.26	81.60	157.60	436.00	105.60
25	1,305.26	49.60	105.60	268.00	72.00
26	1,305.26	16.00	53.60	104.00	39.20
27	818.06	227.20	1.60	0.00	245.60
28	0.00	198.40	0.00	658.06	213.60
29	7,318.99	176.00	307.20	530.06	188.00
30	7,318.99	152.00	260.80	414.06	164.80
31	7,318.99	126.40	211.20	290.06	140.00
32	7,318.99	99.20	159.20	158.06	113.60
33	7,318.99	67.20	107.20	10.06	84.00
34	6,198.99	35.20	55.20	970.06	52.00
35	5,952.59	246.40	3.20	802.06	18.40
36	5,347.79	212.80	315.20	630.06	224.80
37	5,347.79	174.40	263.20	450.06	188.80
38	5,347.79	138.40	211.20	264.06	151.60
37	5,347.79	174.40	263.20	450.06	188.80
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

From the above graphs it is observed that no patient is going with empty hand thus defines satisfaction of patients has been increased[13]. In our new model we have eliminated the flaws which are there in existing model such as stock outs and high frequency of orders. After simulating our new model, we observed that, stock out has been eliminated, by that patient satisfaction increased, and after applying our new model frequency of order was reduced from 100 to 17. From the below table we can observe that there is some stock out in the all the wards, but we can see clearly that the stock out doesn't occur simultaneously. If there is stock out in main hospital stock, then at that moment medicines are present in all other wards as we have considered safety stock for each ward, or if there is stock out in one of the eye, dental, general or emergency ward, there is stock in main hospital ward.

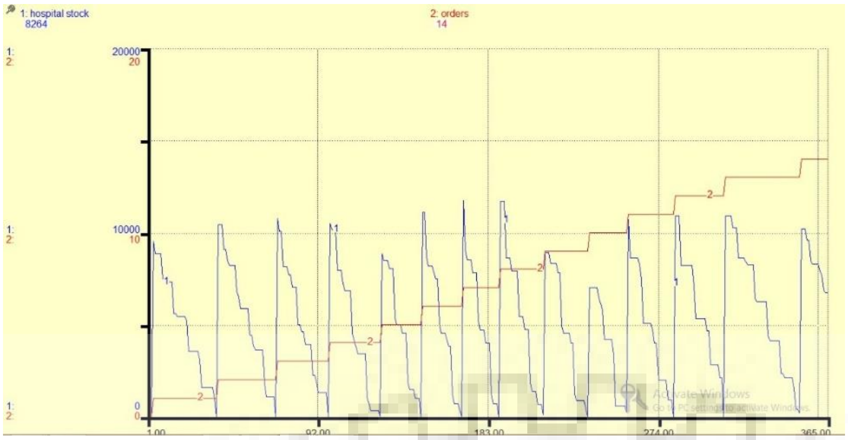
4.4 Sensitivity Analysis

To know how uncertainty in input affects the output of a system of the mathematical model or system and what are different sources of uncertainty in input of system Sensitivity analysis is done. Apart from improving the current model, we have also performed sensitivity analysis to check as if sudden change happens in the system then what effect it will have on our stock and what is optimum stock we have to maintain. For doing the sensitivity analysis we have considered different factors such as the total cost at different quantity levels, lead time and the level of confidence (service level). We have changed one of the quantity and kept all the other quantity constant and observed the changes in the behaviour of the system.

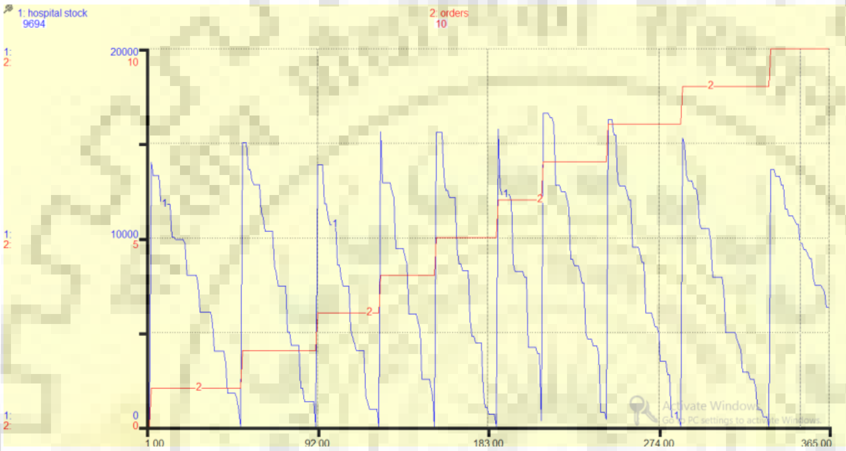
4.4.1 Change in Lead Time



Lead time
1 day



Lead time
2 day



Lead time
5 day

Lead time is defined as the latency between the initiation and execution of a process. Thus, it is a very crucial factor and it effects several major factors such as overall inventory level, customer satisfaction, the total numbers of orders that should be placed as well as the time at which the orders should be placed.

In the current scenario the lead time is equal to 1 day and which we can see in above figure that the total number numbers of order in a year is equal to 17 and the inventory level reaches to a maximum value of 9508 units. Now, suppose that if the lead time becomes 2 days then the corresponding effect can be seen in the figure above. For the lead time equal to 2 days, the total number of orders has decreased to only 14 per year and the maximum inventory is equal to 11728 units. This change in the maximum inventory level can be explained by the common logic that increment in the lead time will increase the safety stock level as safety stock is directly proportional to the lead time thus overall increasing the total quantity that should be ordered.

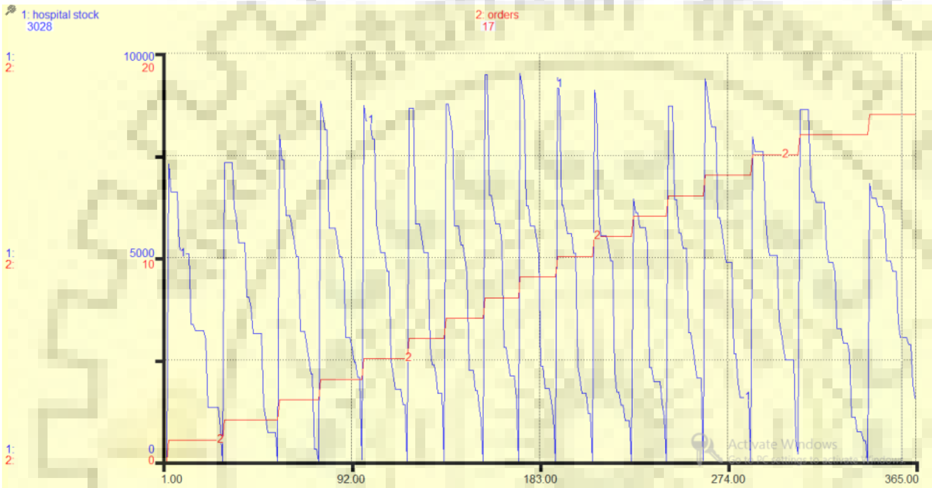
Similarly, if the lead time is equal to 5 days then the total number of orders per year has further reduced to 10 orders per year and the maximum inventory level reached is equal to 16600 and this can be seen in above figure. These changes can be explained by the reason given above.

4.4.2 Service Level

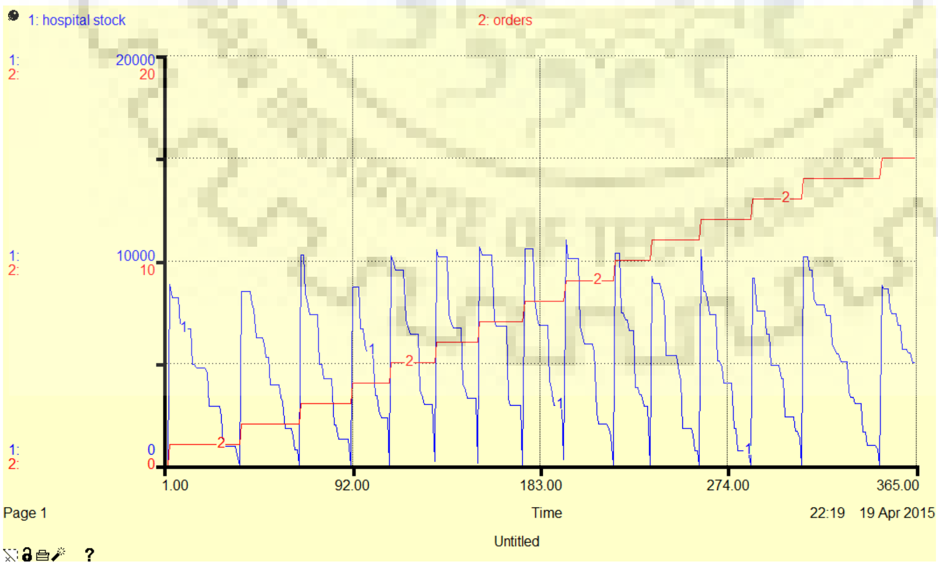
Service degree is a measure to understand of ways a system plays. Certain desires are described and the provider stage gives the share to which the ones goals should be completed.

If we compare figure below. We can observe that the inventory level has been increased. This is due to the fact that safety stock is dependent directly on the service level. Thus increment in the service level leads to the increment in safety stock and thus inventory level increases.

This can be attributed to the fact that in case of uncertainty if we want to satisfy more number of patients then we need to have extra inventory.



Service level = 95 %



Service level = 99 %

Chapter 5: Interpretive Structural Modelling (ISM) and MICMAC analysis

Inventory management is unavoidable and crucial functionary part of a hospital management. It is an important part of supply chain and affects overall (clinical, managerial and financial) performance of a healthcare system. To control the supply, movement of drugs[14] and other essential items in the hospital, analysis of various issues using ISM approach has been done and which is helpful to the management in making decision effectively. For Inventory management, using literature and with the help of questionnaire and with medical officers, doctors, pharmacists, and general staff brainstorming sessions are conducted for analysing emergency situations and factors affecting them. Major factors affecting emergency situations are illustrated below.

(a). Density and Average age of Population (F1)

(b). Accessibility to other hospitals (F2)

(c). Capability of hospital (range of service offered) (F3)

(d). Pollution in Environment (F4)

(e). Season Changes (F5)

(f). Alcohol Consumption (F6)

(g). Transportation Cost (F7) [15]

(h). Loss due to wastage (refrigeration failure, out of temperature control, etc.) (F8) [15][16]

(i). Stock level and Order Pattern (F9) [17][18]

(j). Daily Demand (F10) [15]

(k). Space Constraints (F11) [17] [18]

(l). Inventory holding Cost (F12) [17]

(m). Workload (F13) [17] [19]

(n). Delivery Frequency (F14) [19]

(o). Lead Time (F15)

(p) Physician Prescription (F16) [20][21][22]

(q) Natural Calamity or Disaster (F17)

Today’s word is highly competitive and there is competition for providing service and customer satisfaction in between hospitals too. For this managing inventory became very important and when it comes to the emergency situations this become even more important. Interpretive structural modelling (ISM) was developed by J. N. Warfield in 1973 [11-12] to solve the social and economic problems. ISM is an interactive process in which factors which are directly and indirectly related are hierarchically organized for certain cases. The technique is useful when the interrelationship between factors is not clear and is complex and the data is collected from an organized team of resource persons on the basis of their knowledge and practical experience.

It facilitates the management to break a complicated problem into a variety of sub-problems which is then assembled to form a structure model. The model becomes more and more complex with increase in factors. Some features of ISM are described below:

1. ISM provides the relations among all of the elements.
2. The structure is more or less uprooted from the complex but real-world system.
3. The diagraph indicates the relations amongst all the factors. Hence, a crucial device for the managers to take key selections.

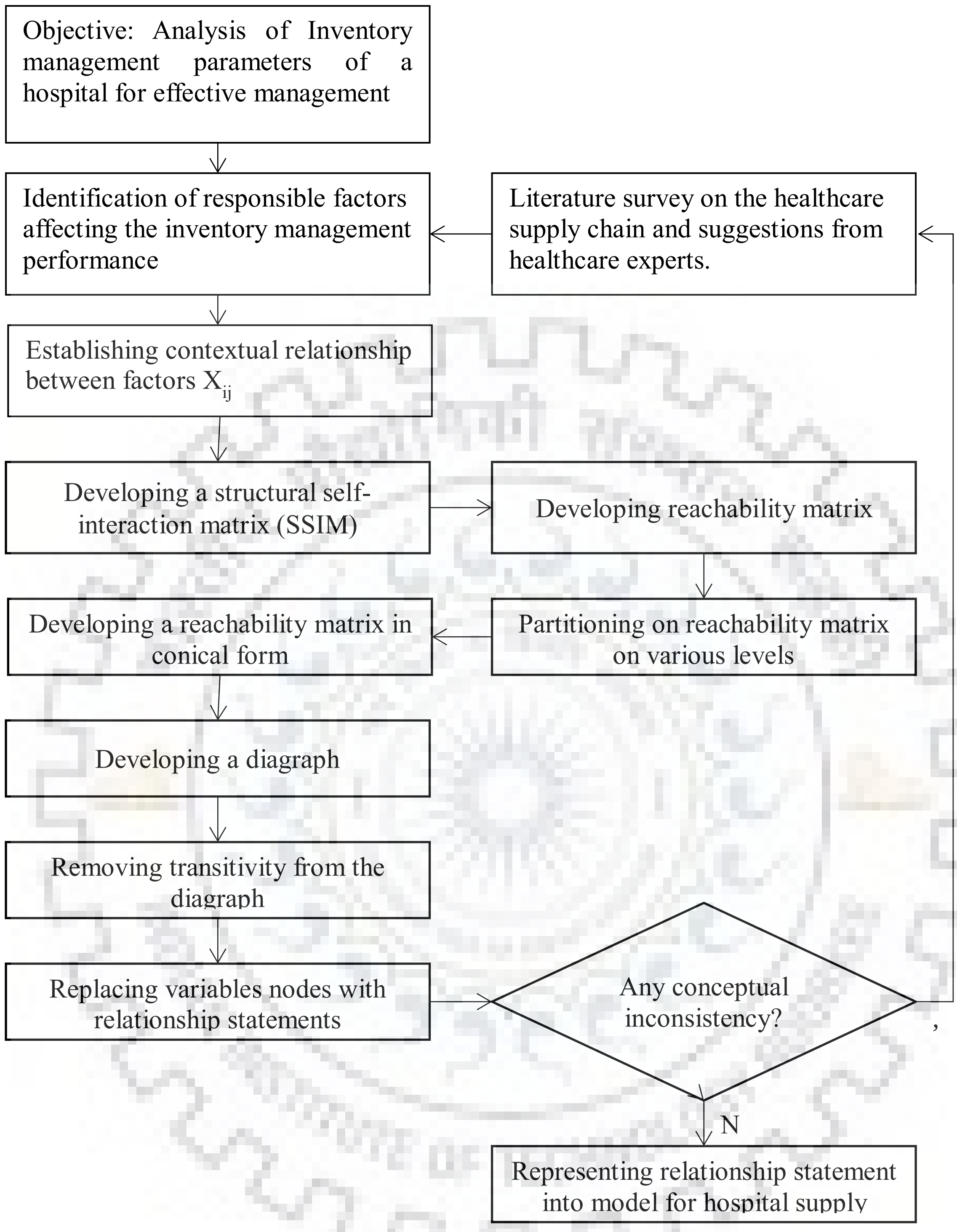


Figure 5: Steps for Interpretive Structural Modelling

A questionnaire with seventeen elements has been considered and given to the clinical officials and team of workers of each the medical institution (Nirogi and Dr Bhim Rao Ambedkar Hospital). The responses for Structural self-interplay matrix (SSIM) have been collected from twenty-five physicians and twelve pharmacists from each the hospitals.

Instructions for filling the X_{ij} spaces in the given table in the response matrix are as follows:

(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.

Table 1- Structure self-interaction matrix (SSIM)

j / i	F17	F16	F15	F14	F13	F12	F11	F10	F9	F8	F7	F6	F5	F4	F3	F2
F1	O	O	O	O	V	O	O	V	O	O	O	V	O	V	O	O
F2	O	O	O	O	V	O	O	V	O	O	O	O	O	O	O	
F3	O	O	O	X	X	V	O	V	O	O	O	O	O	O		
F4	X	O	O	O	V	O	O	V	O	O	O	O	X			
F5	X	O	O	O	V	O	O	V	O	O	O	O				
F6	O	O	O	O	V	O	O	V	O	O	O					
F7	O	O	A	A	O	O	O	A	A	O						
F8	O	O	O	A	V	O	A	A	A							
F9	A	A	X	A	A	V	A	A								
F10	V	A	X	V	V	V	X									
F11	O	O	X	X	A	X										
F12	O	O	X	X	A											
F13	A	A	O	O												
F14	O	A	A													
F15	O	A														
F16	O															

5.1 Reachability matrix:

Initially the SSIM (Table 1) is transformed into a binary format 0 or 1 called as initial reachability matrix given in Table 2 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.

Transitive rule is used for preparing final reachability matrix (Table 3) by incorporating transitive rule such that "if P is related to Q, and Q is related to S, then P is related to S".

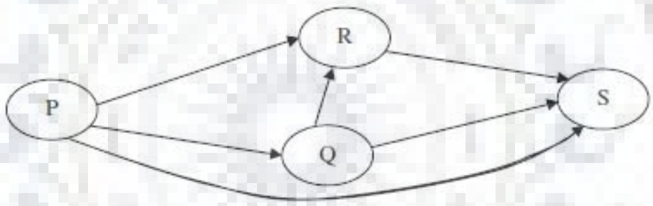


Figure 6. Transitive Rule

5.2 Level Partitions

For figuring out hierarchy amongst elements they may be classified in extraordinary degrees. The reachability set antecedent set are located for each factor from very last reachability matrix. The reachability set consists of the all of the factors and the alternative factors which have an effect on them. When factors of reachability set is much like the intersection set[23] then first degree is allotted in the hierarchy. When a level is given to a detail/component it is deleted from entire matrix for level partitioning and the whole method is repeated until all of the factors are levelled. In the elements/elements F7 and F8 are allocated degree I (Iteration I) and all other elements/factors are levelled II to VI as shown below.

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17
F1	1	0	0	1	0	1	0	0	0	1	0	0	1	0	0	0	0
F2	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
F3	0	0	1	0	0	0	0	0	0	1	0	1	1	1	0	0	0
F4	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	1
F5	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	1
F6	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0
F7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
F8	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
F9	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	0	0
F10	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1
F11	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	0
F12	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0
F13	0	0	1	0	0	0	0	0	1	0	1	1	1	0	0	0	0
F14	0	0	1	0	0	0	1	1	1	0	1	1	0	1	0	0	0
F15	0	0	0	0	0	0	1	0	1	1	1	1	0	1	1	0	0
F16	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	0
F17	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1

Table 2- Reachability Matrix

Factors	F 1	F 2	F 3	F 4	F 5	F 6	F 7	F 8	F 9	F 10	F 11	F 12	F 13	F 14	F 15	F 16	F 17	Driving Power
F1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	15
F2	0	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	12
F3	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	11
F4	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	13
F5	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	13
F6	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	12
F7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
F8	0	0	1	0	0	0	0	1	1	0	1	1	1	0	0	0	0	6
F9	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	9
F10	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	13
F11	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	11
F12	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	0	0	8
F13	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	10
F14	0	0	1	0	0	0	1	1	1	1	1	1	0	1	1	0	0	9
F15	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	11
F16	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	12
F17	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	13
Dependence Power	1	1	14	5	5	2	16	16	16	15	16	16	14	15	15	1	11	

Table 3- Final Reachability Matrix

Iteration I

Factors	Reachability set	Antecedent set	Intersection set	Level
F1	1 3 4 5 6 78 9 10 11 12 13 14 15 17	1	1	
F2	2 3 7 8 9 10 11 12 13 14 15 17	2	2	
F3	3 7 8 10 11 12 13 14 15 17	1 2 3 4 5 6 8 10 11 12 13 14 15 16 17	3 8 10 1112 13 14 15 17	
F4	1 3 4 5 7 8 9 10 11 12 13 14 15 16 17	1 4 510 12 17	1 4 5 10 1217	
F5	3 4 5 7 8 9 10 11 12 13 14 15 17	1 4 5 10 17	4 5 10 17	
F6	3 6 7 89 10 11 12 13 14 15 17	1 6 12	6 12	
F7	7	1 2 3 4 5 6 7 9 10 11 13 14 15 16 17	7	I
F8	3 8 9 11 12 13	1 2 3 4 5 6 8 9 10 11 12 13 14 15 16	3 8 9 11 12 13	I
F9	7 8 9 10 11 12 13 14 15	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	7 9 10 11 12 13 14 15	
F10	3 4 5 7 8 9 10 11 12 13 14 15 17	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	3 4 5 9 10 11 12 13 14 15 17	
F11	3 7 8 9 10 11 12 13 14 15 17	1 2 3 4 5 6 8 9 10 11 12 13 14 15 16 17	3 8 9 10 11 12 13 14 15 17	
F12	7 8 9 10 11 12 14 15	1 2 3 4 5 6 8 9 10 11 12 13 14 15 16 17	8 9 10 11 12 14 15	
F13	3 7 8 9 10 11 12 13 14 15	1 2 3 4 5 6 8 9 10 11 12 13 14 15 16 17	3 8 9 10 11 13 15	
F14	3 7 8 9 10 11 12 14 15	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	3 9 10 11 12 14 15	

F15	3 7 8 9 10 11 12 13 14 15 17	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	3 9 10 11 12 13 14 15 17
F16	3 7 8 9 10 11 12 13 14 15 16	16	16
F17	3 4 5 7 8 9 10 11 12 13 14 15 17	1 2 3 4 5 6 10 11 15 16 17	3 4 5 10 11 15 17

Iteration II				
Factors	Reachability set	Antecedent set	Intersection set	Level
F1	1 3 4 5 6 9 10 11 12 13 14 15 17	1	1	
F2	2 3 9 10 11 12 13 14 15 17	2	2	
F3	3 10 11 12 13 14 15 17	1 2 3 4 5 6 10 11 12 13 14 15 16 17	3 10 11 12 13 14 15 17	II
F4	1 3 4 5 9 10 11 12 13 14 15 16 17	1 4 5 10 12 17	1 4 5 10 12 17	
F5	3 4 5 9 10 11 12 13 14 15 17	1 4 5 10 17	4 5 10 17	
F6	3 6 9 10 11 12 13 14 15 17	1 6 12	6 12	
F9	9 10 11 12 13 14 15	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	9 10 11 12 13 14 15	II
F10	3 4 5 9 10 11 12 13 14 15 17	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	3 4 5 9 10 11 12 13 14 15 17	II
F11	3 9 10 11 12 13 14 15 17	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	3 9 10 11 12 13 14 15 17	I I
F12	9 10 11 12 14 15	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	9 10 11 12 14 15	II
F13	3 9 10 11 12 13 14 15	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	3 9 10 11 13 15	
F14	3 9 10 11 12 14 15	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	3 9 10 11 12 14 15	II
F15	3 9 10 11 12 13 14 15 17	1 2 3 4 5 6 9 10 11 12 13 14 15 16 17	3 9 10 11 12 13 14 15 17	II
F16	3 9 10 11 12 13 14 15 16	16	16	
F17	3 4 5 9 10 11 12 13 14 15 17	1 2 3 4 5 6 10 11 15 16 17	3 4 5 10 11 15 17	

Iteration III

Factors	Reachability set	Antecedent set	Intersection set	Level
F1	1 4 5 13 17	1	1	
F2	2 17	2	2	
F4	1 4 5 13 16 17	1 4 5 10 12 17	1 4 5 10 12 17	
F5	4 5 13 17	1 4 5 17	4 5 17	
F6	6 13 17	1 6	6	
F13	13	1 2 4 5 6 13 16 17	13	III
F16	13 16	16	16	
F17	4 5 13 17	1 2 4 5 6 16 17	4 5 17	

Iteration IV

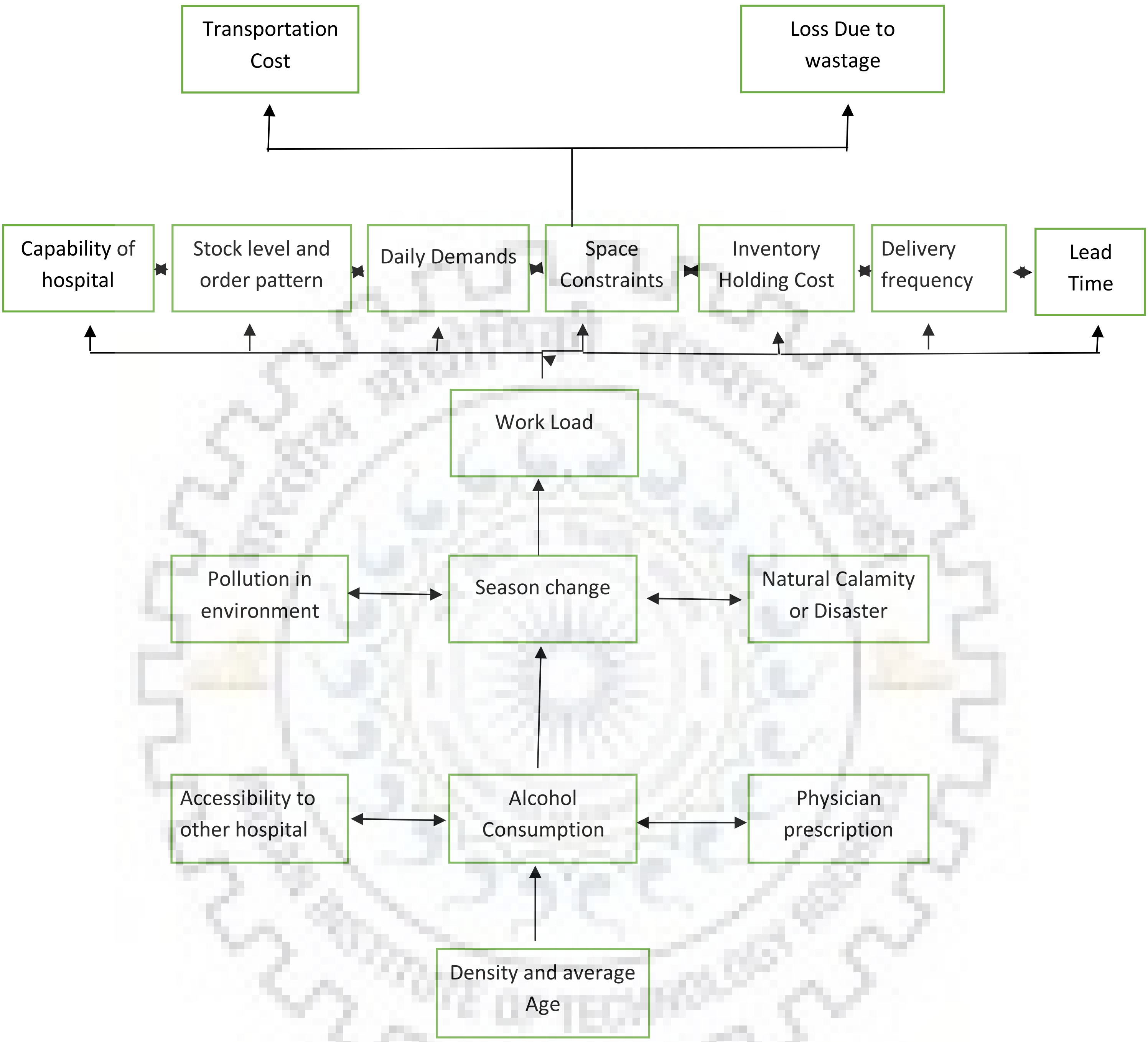
Factors	Reachability set	Antecedent set	Intersection set	Level
F1	1 4 5 17	1	1	
F2	2 17	2	2	
F4	1 4 5 16 17	1 4 5 10 12 17	1 4 5 10 12 17	
F5	4 5 17	1 4 5 17	4 5 17	IV
F6	6 17	1 6	6	
F16	16	16	16	IV
F17	4 5 17	1 2 4 5 6 16 17	4 5 17	IV

Iteration V				
Factors	Reachability set	Antecedent set	Intersection set	Level
F1	1 4 17	1	1	
F2	2	2	2	V
F4	1 4	1 4	1 4	V
F6	6	1 6	6	V

Iteration VI				
Factors	Reachability set	Antecedent set	Intersection set	Level
F1	1	1	1	VI

5.3 Building ISM Model

Using degree partition of things and very last reachability matrix a courting diagram is drawn known as diagraph[24]. In diagraph all of the relation among elements is shown through arrows in one or each course based totally on relationship between them. The diagraph is ultimately transformed into ISM primarily based version.


Transportation Cost
Loss Due to wastage
Capability of hospital
Stock level and order pattern
Daily Demands
Space Constraints
Inventory Holding Cost
Delivery frequency
Lead Time
Work Load
Pollution in environment
Season change
Natural Calamity or Disaster
Accessibility to other hospital
Alcohol Consumption
Physician prescription
Density and average Age

5.4 MICMAC Analysis

MICMAC is advanced by using Duperrin and Godet (1973) and is a way for analysing complicated issues. ISM outputs are used as an input to MICMAC analysis in which driving and dependence factors is calculated from reachability matrix and scattered chart with four areas. Autonomous Region: - The drive–dependence strength diagram suggests that there are no autonomous factors present on this cluster. These factors have low driving strength and dependence power. So they don't have a great deal effect on the system. Dependent Region: - Dependent factors are strongly on other factors. F7 and F8 have less driving and more dependence power and are more performance oriented.

Linkage Factors: - The presence of linkage factors in this examine indicates that F3, F9, F11, F12, F13, F14, F15, F17 factors are not solid among all of the 17 factors chosen for this take a look at. These elements consist of excessive riding as well as high dependence power. Special Care ought to be taken to handle such factors.

Independent Factors: - This cluster includes strong using strength however vulnerable dependence power. F1, F2, F4, F5, F6 and F16 are impartial elements. The factors on this vicinity have very high dependence power and are taken into consideration as key factors.

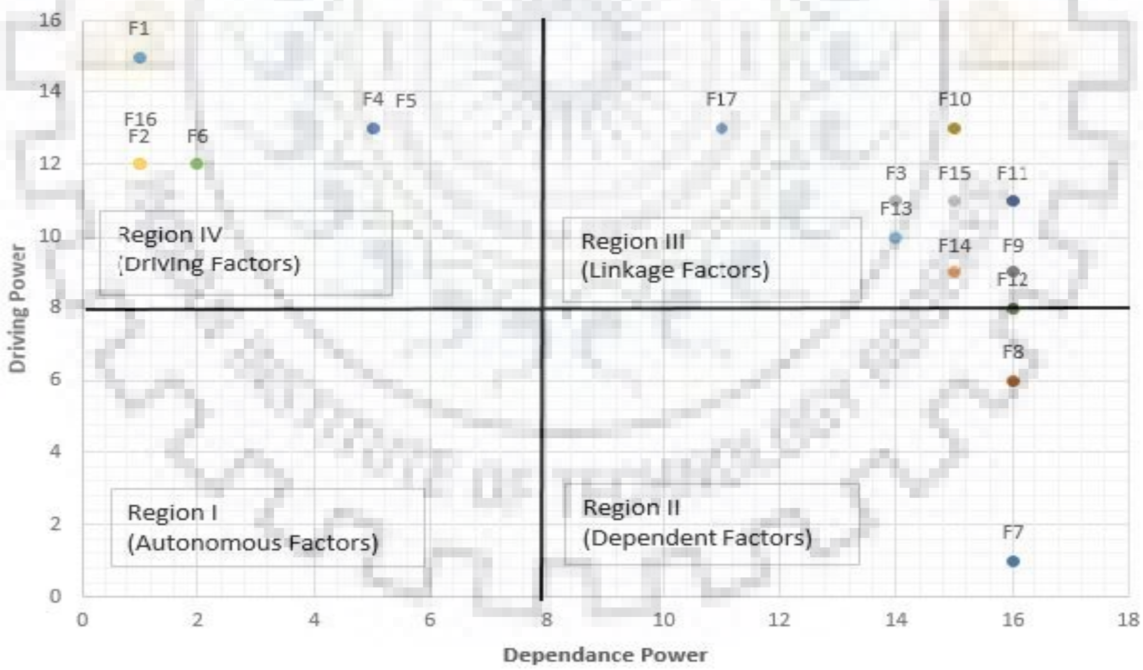


Figure 7. MICMAC analysis

Inventory management is important not only for the manufacturing, fmcg sectors but also plays vital role in hospitals and during emergency when life depends on medicines then cost of stock out is huge which cannot be calculated.

In this project we have modelled the real time scenario of a hospital in Stella using causal loop diagram and stock flow diagram and then using Q,R model made a new improved model, and performed sensitivity analysis.

As per the new model which performed in Stella using incremental Q,R model as the information provided by the hospital complete stock out in all the wards has been eliminated. If there is stock in some of the main ward, medicines are present in other wards from where medicines can be taken.

We have also analysed the effect of change in Lead Time and Service Level. With increase in lead time by 1 day changes number of orders to 17 and inventory level increases to 9500, lead time increase by 5 days, the level of inventory increases to 16600 and number of orders reduced to 10 per year.

If we want to satisfy more customers by maintaining service level 95 %, inventory level increases more and number of orders reduced further.

This paper we have identified 17 factors by reviewing research articles and also through questionnaire filled by medical officer and pharmacists. Inventory of a ospital does not depend on a particular factor so it is important to know the interrelationship among all the factors.

MICMAC analysis categorizes them on the basis of their driving and dependence power.

Level I factor like Transportation Cost and loss due to wastage have high dependence power and least driving power they are affected by almost every other factor.

Factor F1 Density and Average age of population affects almost all other factors being at level VI and has highest driving power, and factors like Pollution in the environment and Alcohol Consumption they affect Rate of Patient arrival during emergency situations.

Factors such as F3, F9, F11, F12, F13, F14, F15, F17 shows high driving as well as dependence powers they do not influence directly but influence the driving factor F1.

Factors like Density and average age of population (F1), Accessibility to other hospitals (F2), Pollution in Environment (F4), Season Change (F5), and Physician Prescription (F16) have high driving and low dependence power. These factors are the key factors or success factors for achieving end results and are very important from the management point of view.

Density and average age of population (F1) is the major driver of patients in hospital during emergency situations, as more will be density in an area large number of people will be affected by any calamity, disaster or epidemic.

Pollution in Environment(F4) is also one major factor for increasing of patients in hospitals as more is the pollution, chances of disease like asthma, lung disease, breathing problem increases which itself is supported by F1. If any area with more pollution in environment along with high density and average age of population, number of patients in hospital in that area increase exponentially.

One more driving force is Season Change (F5), due to increase in pollution and greenhouse effect, the chances of calamity and disaster increase which surges number of patients in hospital.

Accessibility to other hospital (F2) and Physician prescription (F16) are other factor which increases number of patients. But their effect is for a particular hospital. Due to it patients may increase in a particular hospital which is nearest to the person who is been affected.

Transportation Cost (F7) is having high dependent power and is affected by almost every factor. Since the driving factors increases number of patients for emergency which means more demand of medicines which means increase in the transportation cost.

The results obtained from ISM and MICMAC analysis can be used by hospitals as if hospital lies in an area which is having high density and average age of population (F1) and along with high pollution (F4) the management of hospital can decide to maintain more number medicines as safety stock which can be determined using Q,R model with minimum service level 99% to take care of any increase in number of patients so that the patient life can be saved with minimum bare increase in inventory carrying cost as during emergency situation transportation cost is affected by every driving factors.

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Appendix 1

Equations used in the software

Stocks

Hospital

hospital_stock(t) = hospital_stock(t - dt) + (supply_to__hospital_stock - Rate_of_flow_of_madicine_in_eye__ward - Rate_of_flow_of__medicines_in__emergency_ward - Rate_of_flow_of_medicine_in_GS_ward - rate_of_flow_of__medicine_in_dental_ward) * dt
INIT hospital_stock = 0

Eye Ward

Ward_1_eye(t) = Ward_1_eye(t - dt) + (Rate_of_flow_of_madicine_in_eye__ward - Rate_of_consumption_eye_ward) * dt
INIT Ward_1_eye = 0

Dental Ward

Ward_2_dental(t) = Ward_2_dental(t - dt) + (rate_of_flow_of__medicine_in_dental_ward - Rate_of_consumption_dentral_ward) * dt
INIT Ward_2_dental = 0

General Surgery Ward

Ward_3__general_surgery(t) = Ward_3__general_surgery(t - dt) + (Rate_of_flow_of_medicine_in_GS_ward - Rate_of_consumption_general_surgery) * dt
INIT Ward_3__general_surgery = 0

Emergency ward

Emergency_ward(t) = Emergency_ward(t - dt) + (Rate_of_flow_of__medicines_in__emergency_ward - Rate_of_consumption_emergency_ward) * dt
INIT Emergency_ward = 0

Inflows/outflows

Hospital Stock

Inflow

supply_to__hospital_stock = if hospital_stock<=Reorder_Point
then EOQ
else 0

Outflow

Rate_of_flow_of_madicine_in_eye__ward = if Ward_1_eye<ROP_eye
then Ward__1*tablets__per_patient*7
else 0
Rate_of_flow_of__medicines_in__emergency_ward = if Emergency_ward<ROP_emergency_ward
then Emergency__ward*tablets__per_patient*7
else 0
Rate_of_flow_of_medicine_in_GS_ward = if Ward_3__general_surgery<ROP_General_Surgery
then Ward__3*tablets__per_patient*7
else 0
rate_of_flow_of__medicine_in_dental_ward = if Ward_2_dental<ROP_dental
then Ward__2*tablets__per_patient*7
else 0

Eye Ward

Inflows

Rate_of_flow_of_madicine_in_eye__ward = if Ward_1_eye<ROP_eye
then Ward__1*tablets__per_patient*7
else 0

Outflows

Rate_of_consumption_eye_ward = Ward__1*tablets__per_patient

Dental Ward

Inflows

rate_of_flow_of__medicine_in_dental_ward = if Ward_2_dental<ROP_dental
then Ward__2*tablets__per_patient*7
else 0

Outflows

Rate_of_consumption_dentral_ward = tablets__per_patient*Ward__2

General Sergery

Inflows

Rate_of_flow_of_medicine_in_GS_ward = if Ward_3__general_surgery<ROP_General_Surgery
then Ward__3*tablets__per_patient*7
else 0

Outflows

Rate_of_consumption_general_surgery = Ward__3*tablets__per_patient

Emergency Ward

Inflows

Rate_of_flow_of__medicines_in__emergency_ward = if Emergency_ward<ROP_emergency_ward
then Emergency__ward*tablets__per_patient*7
else 0

Outflows

Rate_of_consumption_emergency_ward = Emergency__ward*tablets__per_patient

Conveyers

Eye Ward

Eye(t) = Eye(t - dt) + (Arrival_rate_ward_1 - rate_of_patient_discharge_ward_1) * dt
INIT Eye = 1
    TRANSIT TIME = 1
    INFLOW LIMIT = INF
    CAPACITY = INF

Inflows

Arrival_rate_ward_1 = 0.2*Rate_of_patient_arrival

Outflows

rate_of_patient_discharge_ward_1 = CONVEYOR OUTFLOW

Dental Ward

Dental(t) = Dental(t - dt) + (Arrival_rate_ward_2 - Rate_of_patient_discharge__ward_2) * dt
INIT Dental = 1
    TRANSIT TIME = 2
    INFLOW LIMIT = 15
    CAPACITY = 13

Inflows

Arrival_rate_ward_2 = 0.2*Rate_of_patient_arrival

Outflows

Rate_of_patient_discharge__ward_2 = CONVEYOR OUTFLOW

General Surgery

General_surgery(t) = General_surgery(t - dt) + (Arrival_rate_ward_3 - Rate_of_patient_discharge_ward3) * dt
INIT General_surgery = 1
    TRANSIT TIME = 2
    INFLOW LIMIT = INF
    CAPACITY = INF

Inflows

Arrival_rate_ward_3 = 0.5*Rate_of_patient_arrival

Outflows

Rate_of_patient_discharge_ward3 = CONVEYOR OUTFLOW

Emergency Ward

Emergency__ward(t) = Emergency__ward(t - dt) + (Arrival_Rate - Patient_discharge__emergncy) * dt
INIT Emergency__ward = 1
    TRANSIT TIME = 2
    INFLOW LIMIT = 15
    CAPACITY = 12

Inflows

Arrival_Rate = 0.1*Rate_of_patient_arrival

Outflows

Patient_discharge__emergncy = CONVEYOR OUTFLOW

EOQ

Qv1 = sqrt((2*(R1-C1*q1+Ordering_cost)*tablets__per_patient*patients_per_day) / (Holding_Cost*C1))

Total Cost

Z1 = C1*tablets__per_patient*patients_per_day+(R1-C1*q1+Ordering_cost)*tablets__per_patient*patients_per_day/Qv1+Holding_Cost*C1*Qv1/2+Holding_Cost*(R1-C1*q1)/2

Reorder Point

Reorder_Point = Service_Level*Standard_Deviation*sqrt(Lead_Time)

Safety Stock

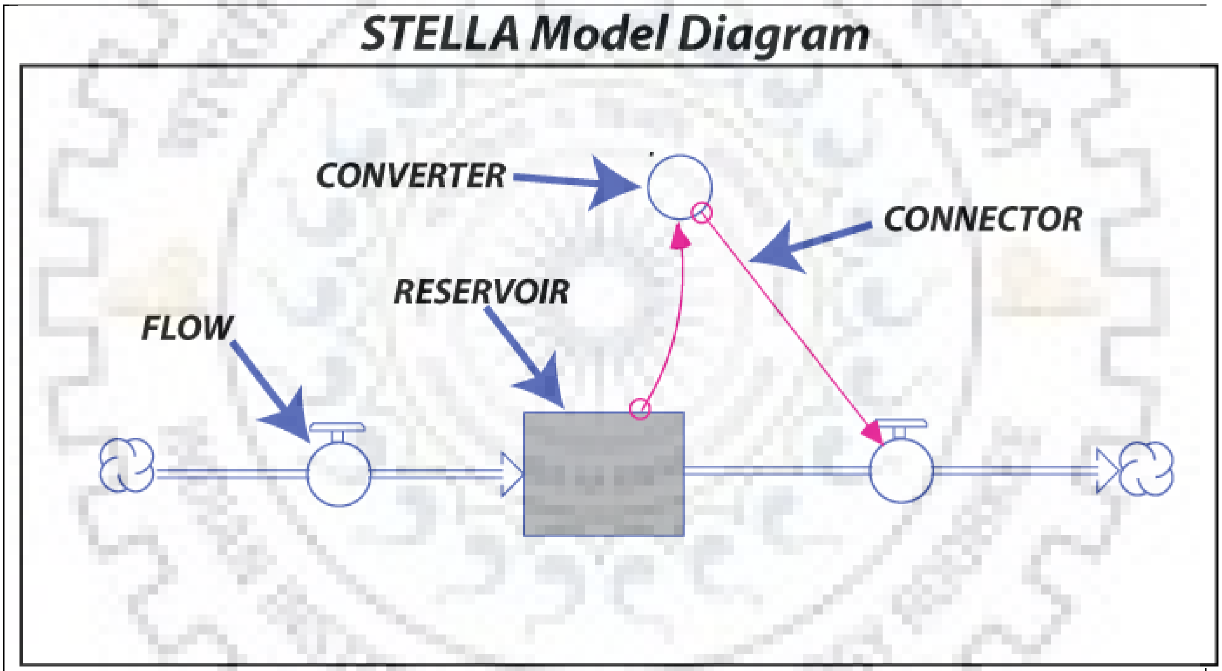
safety_stock = Service_Level*Standard_Deviation*sqrt(Lead_Time)

Utilization

utilisation_ward_1 = No_of_beds_Ward_1/Eye

Appendix 2

Symbols used in Stella



Reservoir:- It is the stock i.e total inventory in the system.

Convertor:- The quantities which affect the inventory are represented by converter.

Connector:- They connect the convertor with the stock with a relation.

Flow:- This represents the flow of consumables in the system