Methodological Development of Mathematical Modeling Techniques in Health Care

V. J. Chakravarthy, P. Hakkim Devan Mydeen, M. Seenivasan

***Abstract:** The advancement of mathematical model has utilized for simulating the output of medical is a development area over medicine whereas the modeling can be mentioned with several activities namely simulation or decision analysis and predictive modeling. However, the traditional modeling technique utilized in planning of health service, assessment reports and its efficiency, financing about health care and assessment in budget impact, assessment in health economics, surveillance of infectious disease and other health care application. Therefore, the mathematical modelling is performed as a frequent and timely benefit in order to make rapid decision making while facing investigation with several issues like time elapsing, unusual and unethical particularly projected for future. This paper focused in applying the mathematical modeling to accomplish an optimal decision making in healthcare whereas this study discuss about the specific modeling concepts namely decision tree and fuzzified rule tables on evaluation of health economics and better service planning that my replicate the individual experience or patients cohorts.*

***Keywords :** Health care, Mathematical Modelling, Medicine, Patients*

I. INTRODUCTION

There are various aspects in healthcare systems which are quantitative, the quantity of information rises by the minute and in fact it makes it hard to define insights for healthcare systems into what is most important to patients [1-3].The paradigm of health and social care systems globally has been increasingly influenced by modifications in population demography, medical, technological developments and others. These modifications directly affect the organization and functioning of health care systems irrespective of whether they are hospitals, long-term care or general practitioners. An effective and well-organized health care system is essential to society's high quality of life. Recently, the main difficulties encountered by health care systems are precise diagnosis, hospital reform, patient flow streamlining, operational problems (namely bottlenecks, low output, and low use of resources), workforce planning and development, performance management, evaluation of health technology and disease monitoring. In the past decade, management science and academics of operations research science have introduced their original methods and expertise to enhance systems of health care.

It still has a lot of untouched and uncertain problems, however, which involve attention. In addition, many methods have been tested in other industries and effectively introduced which can be used for significant improvements in this area [4].Mathematical modeling is a main instrument in the health sphere for decision-making, especially when there is no alternative for direct assessment of interferences. Mathematical modeling is controlled by a set of equations or rules which depends on important assumptions regarding the connection between input parameters and outcomes and defines a vibrant real-life system [5].

Though the contemporary mathematical modeling has become more complicated and sophisticated over time for public health reasons, we can trace its roots far back in history. Daniel Bernoulli used predictions of smallpox mortality to support enhanced vaccination, even without a full knowledge of all manipulating factors [6][7].Modeling is often only feasible and timely way to inform fast decision-making when direct experimentation is time-consuming, unethical or impractical, particularly when projected into the future. Modeling and simulation can demonstrate to be efficient in solving scheduling issues in many industries in health care systems. Medicine modeling is a useful instrument for planning and evaluating interventions, particularly if a clinical trial is either logistically or ethically difficult [8, 9].An increasing area in medicine is developing such mathematical models used to simulate medical consequences [10].

II. LITERATURE REVIEW

This section focusing special issues by rapidly growing, promising the mathematical simulation and modeling that has attracted much responsiveness from researchers over the previous century. Though, there is still scarcity in their use in health care systems. Providing the strategy of data based modeling approach and also predicted the complications of diabetes [11]. The proposed system has to improve the workflow of hospital which are systematic and combined the of simulation models [12][13][14]. Model the effective and operational positioning in a region of radiotherapy units [15].

Revised Manuscript Received on January 30, 2020.
* Correspondence Author
M. Seenivasan*, Department of Mathematics, Annamalai University, Annamalai nagar, Tamilnadu, India.
V. J. Chakravarthy, P. G. Department of Computer Science, The New College, Chennai, Tamilnadu, India.
P. Hakkim Devan Mydeen, P. G. Department of Computer Science, The New College, Chennai, Tamilnadu, India.

The literature on multiple modelling and simulation methods taken for financial evaluation of alcohol and drug health interventions has been extensively reviewed [16].Modeling and simulation can demonstrate to be efficient in solving scheduling issues in many industries in health care systems.

This distinctive problem helps to bridge the break between several groups namely clinicians, management consultants, health care manager on one hand and operational research, simulation professionals, computer scientists and management science on other hand. The special issue concentrate the healthcare industry by simulating and modeling with few elements. In particularly, hospital inventories have established an approach for improved management of supply chains of hospital medicines [17]. There are two models of simulation are being created namely stockless and centralized, to simulate supply chains in hospitals. The research findings recommend adopting a classification-based approach to assist strategic decision-making in the supply chain linked to inventory management. The suggested an incorporated quick response management model containing transmission of infectious diseases and logistics planning [18]. This paper reflects smallpox attack by large scale measures. In reaction, logistical limitations and material flow, they explore the shift in multiple assumptions to better achieve the regional mass immunization movement. To demonstrate the implementation of the suggested methodology, a numerical instance is used. The differences between discrete wavelet transformation, wavelet transformation packet and dual-tree complex wavelet transformation for epileptic form pattern detection have been investigated [19].The classifier's efficiency is demonstrated and contrasted. The outcome shows that the classifier diagnoses epilepsy rapidly and reliably.

III. MODELLING METHODS

The major goal of forecasting decision making which may be available in several factors in order to model the process of decision making using mathematical and can be analyzed the effects quantitatively by influencing the factor towards the process of decision making. Moreover, this methodology of model involves two specific decision making model namely decision trees and fuzzified rules tables with an average weighted factor scheme for analyzing the outputs to identifying the most signified decision nodes as a function for the inputs of decision makers. In evaluating health economics and service planning the model in mathematical has replicated the individual experiences and patient cohorts that may be investigated in terms of weighted factors of the decision events with an average.

A. Decision trees

One of the traditional decision model form of mathematical is decision model whereas it act as an usual cohort model in order to follow people cohort with in available span but cannot able to distinguish among the characteristics of individual. This represent the event probabilities occurred over a model get associated with an average weighted factor. Moreover, the decision trees consists of decision nodes which illustrate all kind of probable decision options whereas the change nodes may described the event probabilities occurred based on decision node and the outcome nodes have illustrated the all outcome probabilities. The key factor from outcome node used for manipulation is folding back by multiplying the chance nodes that leads to an outcome. This is an instance of decision tree shown in figure.1 has illustrated about calculating the probabilities of being pregnant in a sexually active 18-years old groups are either by providing contraceptive advice or not. According to this decision tree, the expected probabilities of being pregnant without contraceptive advice are 0.006+0.016 that associated as 2.2% and the expected probabilities of being pregnant with contraceptive advice are 0.008+0.008 that associated as 1.6%. In order to calculate the cost difference and output differences among the two decisions for every tree branches can be manipulated and hence the ratio of accumulative cost efficiency in both decisions. The decision trees are beneficial while the decision process may get simply segregated into tree branch like structure as child node with event interest occurred over a short span. However, decision tree is not suitable for the complex issues but the major advantage in this model is comparatively easy to understand and develop. During an instance, the event risk is constant or events occurred count is relatively high and subsequently the branches count may become uncontrolled which is also desirable for utilizing other modeling method while the event timing or variability among individuals over model gets significant.

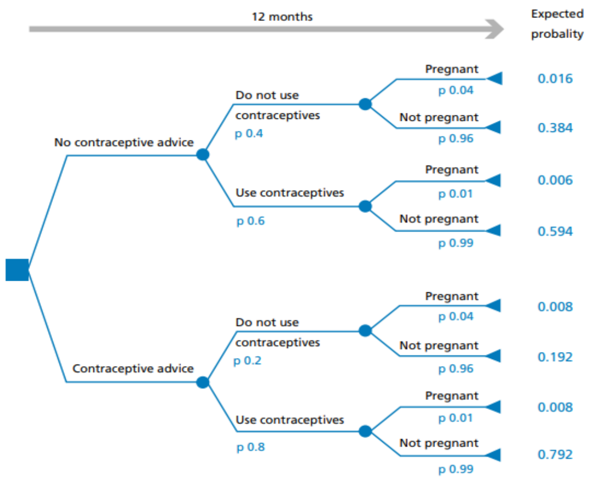

Fig.1. DECISION TREE MODEL OF PROVIDING CONTRACEPTIVE ADVICE TO 18-YEAR OLDS

B. Fuzzified Rule Tables

In order to control the rate of intravenous fluid which need to be administered for the patients over Intensive Care Units (ICU) can presently done without physician using fuzzy logic control by consideration of two major variables namely Mean Arterial blood Pressure (MAP) and Hourly Urine Output (HUO). Therefore, the usage of both MAP and HUO as hourly measurement, the Intravenous Fluid

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Table-I: Rules table for decision making

l.NO	HUO	MAP		
		Low	Normal	High
1	Low	Very High	Moderate	Low
2	Normal	High	Support	Low
3	High	Moderate	Support	Low

Rate (IFR) can able to measure every time while measurement has done. The general rules of table using appropriate fuzzified sets for determining the clinical status of a patient every time a pair of MAP and HUO measurement arrived. Measurement with every pair may lead for more sets memberships pairs. Once the MAP and HUO are high the IFR required for minimizing and in the case of MAP and HUO are low then IFR need to be increased.

At an instance, the patient with MAP 100mm Hg and HUO as 110 ml/Hr while illustrating the finite membership over combination sets are mentioned below

- Normal$_{MAP}$ with Normal$_{HUO}$
- High$_{MAP}$ with Normal$_{HUO}$
- Normal$_{MAP}$ with High$_{HUO}$
- High$_{MAP}$ with High$_{HUO}$

According to this situation, the actions need to be performed are decided for every combination whereas the rule table has been build up by specifying each probability combination of fuzzy set membership to MAP and HUO. Based on this scheme, there are five categories present in IFR namely Low, Moderate, Support, High and Very High. Therefore, this kind of membership combination to both HUO and MAP are selected to these categories are shown in table.1.

The specified rules in table.1 has consider an intuitive senses which need to be implemented for any available patients whereas it is essential for making few mode of transformation terms such as Low and High into exact modification in IFR as ml/Hr. In despite of IFR categories utilized in table.1 doesn't represent anything precise over absolute sense but it can able to fuzzify IFR as a mode for some reasons. Thus an instance has represented that IFR is certainly over the Support range among 100 to 200 ml/hr whereas the classification of Support may probably get extended upto 400 ml/hr. Similarly, the other fuzzy sets like Low, High, Moderate and Very High are gets rooted by same consideration. According to the mathematical model with fuzzy set which lead to 0.6 in Normal$_{MAP}$ and 0.4 in High$_{MAP}$, 0.3 in Normal$_{HUO}$ and 0.7 in High$_{HUO}$. Based on the each pair combination of these sets in the rule tables as the following actions are

- Normal$_{MAP}$and High$_{HUO}$=Support$_{IFR}$
- Normal$_{MAP}$and Normal $_{HUO}$ = Support$_{IFR}$
- High$_{MAP}$and High$_{HUO}$ = Low$_{IFR}$
- High$_{MAP}$and Normal$_{HUO}$ = Low$_{IFR}$

However, the ultimate performance is done with weighted sum of all other four activities whereas every action may be executed from two fuzzy set of membership value. Moreover, the development of algorithm with feed control and algorithm stability is a major consideration whereas the conservation response tends for favor stability. The option of least over two set membership of about 0.6 in High$_{MAP}$ and 0.3 in High$_{HUO}$. Thus the Low$_{IFR}$ has perform received with weighting of 0.3 and these weighting factors are definitely transformed into a crisp IF value shown in figure.2 whereas every fuzzy action set needed to a level similar to its weighting factors. Moreover, the fuzzy logic has the capability for capturing the experience based on specific expertise individual and codes it as an algorithm which needs to be continued for involving further fuzzy variable namely heart rate or central venous pressure. Hence, the modified rate of MAP and HUO may be accomplished by considering various among succeeded hourly measurements. These modification rates may get fuzzified into sets namely stables, decreasing and increasing has been served for indicating the trend in the patient's fluid status that permits an exact fluid balancing control.

C. Result of the Model:

This region of centroid is shown by the vertical arrow and the patient's last "crisp" form of IFR.

Table 2 describes the IFR ranges for which the five fuzzy sets have unity membership as -60 to 60, 100 to 200, 400 to 600, 800 to 1000 and 1500 to 2000 ml / hr.

Table 2 Five overlapping fuzzy sets with IFR value

Fuzzy Set	**IFR Value(ml/hr)**
LOW$_{IFR}$	-60 to 60
SUPPORT$_{IFR}$	100 to 200
MODERATE$_{IFR}$	400 to 600
HIGH$_{IFR}$	800 to 1000
VERYHIGH$_{IFR}$	1500 to 2000

For the LOW set, Figure 2 states the lower limit of 60 ml / hour, although by itself practically irrelevant, implies that the lowest package centroid is just above zero. If only the LOW set is invoked, this enables a very low IFR.

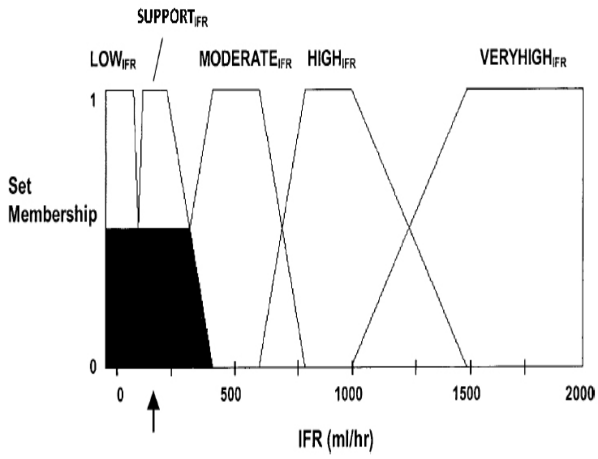

Fig.2. CONTROLLED QUANTITATIVE IFR WITH FIVE OVERLAPPING FUZZY SET MEMBERSHIP

IV. CONCLUSION

There are several concepts in management of health care system are measurable in this both model with mathematical concepts have been involved for adding an expertise to the clinicians. The model has illustrating with an instances with simulation that plays significant role in understanding the improvement of healthcare system in various levels.

The several complexness issues and time consumption which get formalized by applying weighted factors scheme in both model in order to reduce unwanted variation in clinical practices and thus the cost of the application gets minimized. Hence, the mathematical models can able to be utilized and determined its applicability to an optimal decision making in health care.

REFERENCES

1. A. X. Costa, S. A. Ridley, A. K. Shahani, P. R. Harper, V. De Senna, and M. S. Nielsen, "Mathematical modelling and simulation for planning critical care capacity," Anaesthesia, vol. 58, no. 4, pp. 320–327, 2003.
2. R. B. Chambers, "#e role of mathematical modeling in medical research: "research without patients?"," 3e Ochsner Journal, vol. 2, no. 4, pp. 218–223, 2000.
3. M. Calder, C. Craig, D. Culley et al., "Computational modelling for decision-making: where, why, what, who and how," Royal Society Open Science, vol. 5, no. 6, article 172096, 2018.
4. Nagesh Shukla, Pascal Perez, Manoj Kumar Tiwari, DarekCeglarek& Joana Matos Dias, "Modelling and simulation in health care systems", 2016, International Journal of Systems Science: Operations & Logistics, DOI: 10.1080/00207721.2016.1222772.
5. Garnett GP, Cousens S, Hallett TB, Steketee R, Walker N. Mathematical models in the evaluation of health programmes. The Lancet. 2011 Aug 12; 378(9790):515–25.
6. Klein E, Laxminarayan R, Smith DL, Gilligan CA. Economic incentives and mathematical models of disease. Environment and development economics. 2007 Oct 1; 12(05):707–32.
7. Emmanuel Njeuhmeli, Melissa Schnure , Andrea Vazzano , Elizabeth Gold , Peter Stegman , Katharine KripkeID , Michel Tchuenche , Lori Bollinger , Steven Forsythe and Catherine Hankins, "Using mathematical modeling to inform health policy: A case study from voluntary medical male circumcision scale-up in eastern and southern Africa and proposed framework for success" , 2019, PLoS ONE 14(3): e0213605. https://doi.org/10.1371/ journal.pone.0213605.
8. G. P. Garnett, S. Cousens, T. B. Hallett, R. Steketee, and N. Walker, "Mathematical models in the evaluation of health programmes," 3e Lancet, vol. 378, no. 9790, pp. 515–525, 2011.
9. W. Crown, N. Buyukkaramikli, M. Y. Sir et al., "Application of constrained optimization methods in health services research: report 2 of the ISPOR Optimization Methods Emerging Good Practices Task Force," Value in Health, vol. 21, no. 9, pp. 1019–1028, 2018.
10. GiedriusVanagas , Tomas Krilavicˇius and KaLok Man, "Mathematical Modeling and Models for Optimal Decision-Making in Health Care" , Hindawi Computational and Mathematical Methods in Medicine Volume 2019, Article ID 2945021, 4 pages https://doi.org/10.1155/2019/2945021.
11. Sangi, M., Win, K., Shirvani, F., Namazi-Rad, M., & Shukla, N. (2015). Applying a novel combination of techniques to develop a predictive model for diabetes complications. PLoS One, 10(4), 1–22.
12. Shukla, N., Keast, J., &Ceglarek, D. (2014a). Improved workflow modelling using role activity diagram-based modelling with application to a radiology service case study. Computer Methods and Programs in Biomedicine, 116(3), 274–298.
13. Shukla, N., Keast, J., &Ceglarek, D. (2014b). Modelling variations in hospital service delivery based on real time locating information. Applied Mathematical Modelling, 38(3), 878– 893.
14. Shukla, N., Lahiri, S., &Ceglarek, D. (2015). Pathway variation analysis (PVA): Modelling and simulations. Operations Research for Health Care, 6, 61–77.
15. Shukla, N., Wickramasuriya, R., Miller, A., & Perez, P. (2015). An approach to plan and evaluate the location of radiotherapy services and its application in the New South Wales, Australia. Computer Methods and Programs in Biomedicine, 122(2), 245–256.
16. Hoang, V.P., Shanahan, M., Shukla, N., Perez, P., Farrell, M., & Ritter, A., (2016). A systematic review of modelling approaches in economic evaluations of health interventions for drug and alcohol problems. BMC Health Services Research, 16, 1–14. doi:10.1186/s12913-016-1368-8.
17. Smith, K.N., Vila-Parrish, A.R., Ivy, J.S., Abel, S.R. (2016). A simulation approach for evaluating medication supply chain structures. Journal of Systems Science: Operations & Logistics. Advance online publication. doi:10.1080/23302674.2015.1135355.
18. Dasaklis, T.K., Rachaniotis, N., Pappis, C. (2016). Emergency supply chain management for controlling a smallpox outbreak: the case for regional mass vaccination. Journal of Systems Science: Operations & Logistics. Advance online publication. doi:10.1080/23302674.2015.1126379.
19. Swami, P., Gandhi, T.K., Panigrahi, B.K., Bhatia, M., Santhosh, J., Anand, S. (2016). A comparative account of modelling seizure detection system using wavelet techniques. Journal of Systems Science: Operations & Logistics. Advance online publication. doi:10.1080/23302674.2015.1116637.

AUTHORS PROFILE

Dr. V. J. Chakravarthy was born in India in 1979. He received the MCA degree in 2003 from Bharathidasan University, M.Phil degree from Periyar University in 2005 and Ph.D in from University of Madras 2015. He is currently working as an Assistant Professor in New College, Chennai. He has published 25 papers in reputed journals both national & international levels. His main areas of research interest are Computer Networks, Data Mining, Artificial Intelligence, Machine Learning, Big Data Analytics& Data Sciences. Dr. V. J. Chakravarthy is a member of the Indian Science Congress, ICT Academy.

Dr.M.Seenivasan is working as Associate Professor in Department of Mathematics, Annamalai University. He was awarded Ph.D degree by Annamalai University in the year 2012. He was 17 years of teaching and 15 years of research experience. His area of research is Stochastic Processes, Graph theory and Computer Networks. He has published more than 20 research articles in reputed indexed international journals. He has guided 20 M.Phil scholars. At present, he is guiding three Ph.D scholars. He acted as editorial members of more than 13 international journals. He organized four international conferences in abroad. He visited Thailand , Malaysia, Singapore and USA.

Dr. P.Hakkim Devan Mydeen has a rich experience of teaching and administration over two decades. An insatiable and innovative personality has pursued Doctor of Philosophy in Computer Science. His area of specialization include Cloud computing. He is currently holding the position of Head of Department of Computer Science, The New College(Autonomous),Chennai,India. An admirable and dedicated academician has strived for the development of scholars and upliftment of teaching fraternity. To his credit four articles has been published in Journals of International repute. A visionary and hardwork individual has dreamed to attain goals of excellence through his vibrant and sound determination.