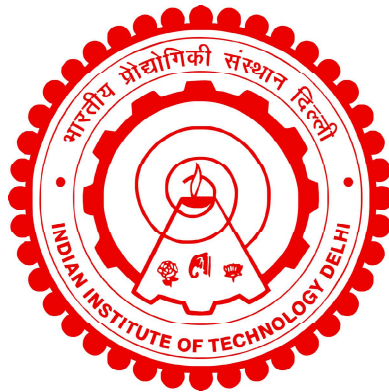


**ANALYSIS OF HEALTHCARE-SEEKING
BEHAVIOUR AND REFERRAL MECHANISM
MODELLING AT PUBLIC HEALTHCARE
FACILITIES**

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DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY DELHI

JUNE 2024

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MODELLING AT PUBLIC HEALTHCARE
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by

NAJIYA FATMA

Department of Mechanical Engineering

Submitted

in fulfillment of the requirements of the degree of **Doctor of Philosophy**

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

JUNE 2024

Dedicated to my dearest father...

Certificate

This is to certify that the thesis entitled “**Analysis of Healthcare-Seeking Behaviour and Referral Mechanism Modelling at Public Healthcare Facilities**” being submitted by **Ms. Najiya Fatma** to the Indian Institute of Technology Delhi for the award of the degree of Doctor of Philosophy is a record of original research work carried out by her. She has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

Prof. Varun Ramamohan
Department of Mechanical Engineering,
Indian Institute of Technology Delhi.

Acknowledgements

All praise and thanks to the Almighty Allah for His abundant blessings and kindness, providing me with the strength needed to successfully complete my research work on time.

I would like to thank my thesis advisor, Prof. Varun Ramamohan, for his guidance, constructive feedback, and continuous encouragement throughout my PhD journey. His enthusiasm and mastery of the subjects, especially in the field of simulation modelling, has been a great source of knowledge for me. I will try to incorporate these skills into my learning and research journey as I move forward.

I appreciate the feedback provided by Prof. Naresh Bhatnagar, Prof. Nimesh B. Bolia, and Prof. Jitender Madaan from the dissertation committee on my research work. Special acknowledgment goes to Prof. Deshmukh for the teaching assistantship role; it was a great learning experience.

I thank the Ministry of Education, Government of India, for awarding me the esteemed Prime Minister's Research Fellowship Scheme to pursue the doctoral programme at IIT Delhi. I also extend my appreciation to all healthcare providers and patients who actively participated in the data collection process during the survey.

I thank everyone, including my friends Aisha, Farheen, Rumysa, and others, for contributing to a memorable and unforgettable stay on the campus. Many thanks to Mehreen, Iqra, and Sufia for our research discussions, early morning explorations in Delhi, and countless cooking sessions upon returning from the labs. I also extend my gratitude to Asiya, my youngest friend and teacher, and to Wala, my Palestinian friend, for teaching me the correct recitation of the Quran during my Ph.D.

I am grateful to my father for his unwavering love and support, and for the invaluable lesson of staying strong in every circumstance- he is a true role model for me. I hold deep admiration for my mother for her enduring love and belief in me. Thanks to my siblings for their continuous encouragement throughout my life.

Najiya Fatma

Abstract

Healthcare facilities aim to provide accessible, affordable, and quality care to the target population. Multiple operational challenges such as shortage of medical resources, underutilisation of lower-level facilities, and higher patient turnout at the specialised facilities hinder easy access to medical care worldwide, including in India. Nonadherence to the hierarchy of the Indian healthcare delivery system by a significant proportion of patients disrupts the patient flow leading to overcrowding, higher delays, and overall length of stay.

In this context, multiple questions arise- what factors motivate patients to bypass lower-level facilities and seek care directly from the specialised facilities, what are the experiences of patients and healthcare providers with existing referral mechanisms, what are their perceptions and concerns on potential new referral mechanisms, or how the implementation of potential new referral mechanisms will affect the operational outcomes across the public healthcare facility networks? In an effort to quantitatively analyse these questions, we worked on two broad themes: (a) statistically analyse the healthcare-seeking behaviour of patients and their perceptions towards the implementation of potential new referral mechanisms that can be developed in consultation with the healthcare providers at the Indian public healthcare facilities, and (b) computationally model a framework for the implementation of the various aspects of certain potential new referral mechanisms proposed in part (a) at the Indian public healthcare facilities.

We provide a general introduction to the problem and review the relevant literature in the first two chapters. In the third chapter, we statistically analyse the healthcare-seeking behaviour of the patients visiting public primary and secondary healthcare facilities in the Southwest Delhi district in India using logistic regression technique. As part of this, we administered cross-sectional surveys to ascertain from patients at these facilities about their healthcare-seeking behaviour, pathways followed while seeking care, and operational information regarding the surveyed facilities.

A significant proportion of patients bypassed lower-level facilities and preferred seeking care from higher-level facilities for their first visits, and hence in the fourth chapter, we recorded and analysed the experiences of patients and healthcare providers

(the key stakeholders) on the existing referral mechanisms operational at the surveyed facilities. Later we recorded their perceptions and concerns on willingness towards the implementation of potential new referral mechanisms, aimed to improve the operations of the public healthcare facility network. This included medical referral with a centralised electronic medical record system and noncompliance penalties, telemedicine-based consultation and referral, and operational referral, which involves referring patients to similar-level facilities in case of high patient loads.

In the fifth chapter, we developed a computational framework for referring patients to similar-level healthcare facilities using operational referral mechanism proposed in the preceding chapter. This was illustrated via a discrete-event based network simulation model of nine primary healthcare facilities in a given region. As part of this, we also developed a novel approximate real-time delay predictor and compared its performance with respect to the existing delay predictors. We showed that the extent to which operational outcomes become equitably distributed across healthcare facility networks depends upon the accuracy of the delay predictor employed in diversion mechanism.

Implementing diversion using real-time delay prediction did not appear appropriate in cases of very high service rates of healthcare providers and high patient demands. The impact of high demand was instead reflected in the overall length of stay and hence, in the sixth chapter, we proposed a real-time healthcare facility assignment algorithm that utilised length of stay estimates in assigning a healthcare facility to patients from their points of origin. We employed methods from queueing theory to develop predictors of simple and complex queueing systems represented by the healthcare delivery process. The assignment algorithm effectively managed patient flow, dissuading patients from visiting already congested health facilities and evenly distributing the patient load across the network. We make concluding remarks and discuss future avenues of current work in the final chapter. Via this thesis, we provide numerical evidence on how to improve patients' and healthcare providers' experiences at healthcare facilities. Upgrading the infrastructure of healthcare facilities and adopting new information technologies in service operations is essential to address the psychological needs of the patients and the healthcare providers for information.

सार

स्वास्थ्य देखभाल सुविधाओं का लक्ष्य लोगों को सुलभ, किफायती, और गुणवत्तापूर्ण देखभाल प्रदान करना है। कई परिचालनात्मक चुनौतियाँ जैसे चिकित्सा संसाधनों की कमी, निचले स्तर की सुविधाओं का कम उपयोग, और विशेष सुविधाओं पर मरीजों की अधिक उपस्थिति भारत सहित दुनिया भर में आसान चिकित्सा देखभाल में बाधा डालती है। रोगियों के एक महत्वपूर्ण अनुपात द्वारा स्वास्थ्य सेवा वितरण प्रणाली के पदानुक्रम का पालन न करने से रोगी प्रवाह बाधित होती है, जिससे कई बार भारतीय चिकित्सालय में भीड़भाड़, अधिक देरी, और ठहरने की कुल अवधि बढ़ जाती है।

इस संदर्भ में, कई प्रश्न उठते हैं – मरीज किस कारण से निचले स्तर की सुविधाओं को छोड़कर सीधे विशेष सुविधाओं से देखभाल लेने के लिए प्रेरित होते हैं, मौजूदा रेफरल तंत्र के साथ मरीजों और स्वास्थ्य सेवा प्रदाताओं का कैसा अनुभव रहा है, संभावित नए रेफरल तंत्र के बारे में उनकी धारणाएं और चिंताएं क्या हैं, या संभावित नए रेफरल तंत्र का इस्तेमाल सार्वजनिक स्वास्थ्य सुविधा नेटवर्क की परिचालन परिणामों को कैसे प्रभावित करेगा? इन सवालों के मात्रात्मक विश्लेषण करने के प्रयास में, हमने दो व्यापक विषयों पर काम किया: (ए) रोगियों की स्वास्थ्य देखभाल प्रवृत्ति और संभावित नए रेफरल तंत्र जिन्हें स्वास्थ्य सेवा प्रदाताओं के परामर्श से विकसित किया जा सकता है, इनके कार्यान्वयन के प्रति उनकी धारणाओं का सांख्यिकीय विश्लेषण, और (बी) भारतीय सार्वजनिक स्वास्थ्य सुविधाओं में भाग (ए) में प्रस्तावित संभावित नए रेफरल तंत्र के विभिन्न पहलुओं के कार्यान्वयन के लिए एक कम्प्यूटेशनल ढांचा विकसित करना।

इस थीसिस के पहले दो अध्यायों में हम स्वास्थ्य सेवाओं में होने वाली समस्या का सामान्य परिचय प्रदान करते हैं और प्रासंगिक साहित्य की समीक्षा करते हैं। तीसरे अध्याय में, हम लॉजिस्टिक रिग्रेशन तकनीक का उपयोग करके भारत के दक्षिण-पश्चिम दिल्ली ज़िले में सार्वजनिक प्राथमिक और माध्यमिक स्वास्थ्य सुविधाओं का दौरा करने वाले रोगियों की स्वास्थ्य देखभाल प्रवृत्ति का सांख्यिकीय विश्लेषण करते हैं। इस सन्दर्भ में, हमने इन सुविधाओं पर मरीजों से उनके स्वास्थ्य देखभाल प्रवृत्ति, देखभाल की मांग करते समय अपनाए जाने वाले रास्ते और सर्वेक्षण की गई सुविधाओं के परिचालन जानकारी के बारे में पता लगाने के लिए क्रॉस-सेक्शनल सर्वेक्षण किए।

मरीजों के एक महत्वपूर्ण अनुपात निचले स्तर की सुविधाओं को नज़रअंदाज़ करके पहली बार उच्च स्तर की सुविधाओं से देखभाल लेने को प्राथमिकता देते हैं, और इसलिए चौथे अध्याय में, हमने स्वास्थ्य सुविधाओं में चल रहे मौजूदा रेफरल तंत्रों पर मरीजों और स्वास्थ्य देखभाल प्रदाताओं (प्रमुख हितधारकों) के अनुभवों को दर्ज और विश्लेषण किया। बाद में हमने सार्वजनिक स्वास्थ्य सुविधा नेटवर्क के संचालन में सुधार लाने के उद्देश्य से संभावित नए रेफरल तंत्र के कार्यान्वयन की इच्छा पर उनकी धारणाओं और चिंताओं को भी दर्ज किया। इसमें मेडिकल रेफरल जो एक केंद्रीकृत इलेक्ट्रॉनिक मेडिकल रिकॉर्ड प्रणाली और गैर-अनुपालन दंड, टेलीमेडिसिन-आधारित परामर्श

और रेफरल, और संचालनात्मक रेफरल शामिल है, जिसमें उच्च रोगी भार के मामले में मरीजों को समान स्तर की सुविधाओं में रेफर किया जाता है।

पांचवें अध्याय में, हमने पिछले अध्याय में प्रस्तावित संचालनात्मक रेफरल तंत्र का उपयोग करके मरीजों को समान स्तर की स्वास्थ्य सुविधाओं में रेफर करने के लिए एक कम्प्यूटेशनल ढांचा विकसित किया। इसे नौ प्राथमिक स्वास्थ्य सेवा संस्थानों के एक निर्दिष्ट क्षेत्र में डिस्क्रीट-इवेंट आधारित नेटवर्क सिमुलेशन मॉडल के माध्यम से दर्शाया गया। इसमें हमने एक नया अनुमानित वास्तविक समय विलंब भविष्यवक्ता भी विकसित किया और मौजूदा विलंब भविष्यवक्ताओं के संबंध में इसके प्रदर्शन की तुलना की। हमने दिखाया कि स्वास्थ्य सुविधा नेटवर्क में संचालनीय परिणामों का यथार्थता से वितरण डिवर्शन मेकेनिज़्म में प्रयोग किए जाने वाले देरी पूर्वानुमानकर्ता की सटीकता पर निर्भर करता है।

स्वास्थ्य सेवा प्रदाताओं की बहुत उच्च सेवा दरें और मरीजों की उच्च मांग के मामलों में वास्तविक समय में देरी का पूर्वानुमानकर्ता का प्रयोग करके डायवर्जन को लागू करना उचित नहीं लगा। उच्च मांग का प्रभाव मरीज के अस्पताल में ठहरने की कुल लंबे अवधि में परिलक्षित होता था, और इसलिए, छठे अध्याय में, हमने एक वास्तविक समय स्वास्थ्य देखभाल सुविधा असाइनमेंट एल्गोरिदम का प्रस्ताव रखा, जो की मरीजों की अनुमानित रहने की अवधियों का उपयोग करके उनके मूल स्थान से उन्हें एक ऐसी स्वास्थ्य देखभाल सुविधा असाइन करता है, जहाँ पूरी लम्बाई के हिसाब से सबसे पहले सेवा मिल सके। हमने स्वास्थ्य सेवा प्रक्रिया द्वारा प्रतिनिधित सरल और जटिल पंक्ति प्रणालियों के पूर्वानुमानकर्ताओं का विकास करने के लिए क्यूइंग सिद्धांत से विभिन्न विधियों का इस्तेमाल किया। असाइनमेंट एल्गोरिथ्म एक प्रभावी रोगी प्रवाह प्रबंधन उपकरण के रूप में कार्य करता है जो रोगियों को पहले से ही भीड़भाड़ वाली स्वास्थ्य सुविधा में जाने से रोकता है और स्वास्थ्य सुविधा नेटवर्क में रोगी भार को संतुलित करता है। हम अंतिम अध्याय में निष्कर्षण रूप देते हैं और वर्तमान काम के भविष्य के रास्ते पर चर्चा करते हैं। इस थीसिस के माध्यम से, हम स्वास्थ्य सुविधाओं में मरीजों और स्वास्थ्य सेवा प्रदाताओं के अनुभवों को कैसे बेहतर बनाया जाए, इस पर संख्यात्मक साक्ष्य प्रदान करते हैं। स्वास्थ्य सुविधाओं के बुनियादी ढांचे को अपग्रेड करना और सेवा संचालन में नई सूचना प्रौद्योगिकियों को अपनाना, मरीजों और स्वास्थ्य सेवा प्रदाताओं की मानसिक आवश्यकताओं को सूचना प्रदान करने के लिए महत्त्वपूर्ण है।

Keywords: Healthcare-Seeking Behaviour, Public Healthcare, Referral Mechanisms, Logistic regression modelling, Cross-Sectional Survey, Discrete-Event Simulation, Analytical-Queueing Theoretic, Simulation-driven Machine Learning, Personalised Delay and Length of Stay Prediction

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Abbreviations

AIC	A kaike's I nformation C riteria
AQT	A nalytical Q ueueing- T heoretic
ANC	A n t e N atal C are
BLR	B inomial L ogistic R egression
CHC	C ommunity H ealth C entre
DBN	D ynamic B ayesian N etwork
DES	D iscrete- E vent S imulation
ED	E mergency D epartment
EMR	E lectronic M edical R ecord
ENT	E ar, N ose, and T hroat
GM	G eneric M odelling
HSB	H ealthcare- S eeking B ehaviour
IPD	I npatients D epartment
IT	I nformation T echnology
LMICs	L ower and M iddle I ncome C ountries
LOS	L ength of S tay
MR	M edical R eferral
MLR	M ultinomial L ogistic R egression
OPD	O utpatients D epartment
OpR	O perational R eferral
PHC	P rimary H ealth C entre
PUHC	P rimary U rban H ealth C entre
RTDP	R eal- T ime D elay P rediction
SD	S tandard D eviation
SimML	S imulation-driven M achine L earning
TSE	T otal S quared E rror
USD	U nited S tates D ollar