

**EFFICIENT PLANNING AND MANAGEMENT IN INDIAN
SCHOOL EDUCATION**

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by

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CERTIFICATE

This is to certify that the thesis entitled “**Efficient Planning and Management in Indian School Education**” being submitted by **Mr. Abhishek Bhatnagar** to 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 him. He 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.

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(Abhishek Bhatnagar)

ABSTRACT

Sustainable development goals (SDGs) are a set of 17 interlinked goals set by the United Nations in order to achieve prosperity for all. These goals focus on improving the standard of living broadly through better education, environmental consciousness, poverty reduction, equality, good health and sustainable cities and communities. A key goal, SDG 4 aims to provide quality education for all and ensure equity and inclusivity. There is a need to develop action plans at the global as well as local level to achieve these goals. The needs of developed and developing countries such as India are quite dissimilar given its scale and diversity. It is manually not possible to take decision for large scale problems. The current work deals with the planning and management aspects in the Indian school education through quantitative models which can be solved using algorithms and software. The thesis presents mathematical models that aid in school education decision-making and can be replicated to other contexts and geographical locations with minor alternations. The models need to be efficient in terms of solving problems at scale as well as be effective to consider the requirements of all stakeholders with conflicting objectives.

The thesis presents work that is at the intersection of SDG 11, SDG 12 and SDG 13 along with SDG 4, which is the key focus. The overall objective is to improve the education governance and delivery for better satisfaction of people's aspirations and expectations. It starts with a literature review to develop an understanding of factors that affect academic performance of schools and their interrelationships. These factors vary in different education systems and geographical locations. An empirical study of about 800 government schools in Delhi, India for three academic years attempts to uncover these factors. This study helps to identify the schools that need improvement and a set of interventions that can help enhance their performance using statistical analysis and geotagging of schools. This part also provides a conceptual model using game theory to understand school inspections with respect to the probability of violation by schools and their chances of being caught. The performance of schools depends on its resources, that is, manpower and infrastructural resources, and its operations as identified through a literature survey. Teachers are arguably the most important manpower resource in schools and their distribution is skewed towards areas with good accessibility. There are two ways to improve teacher distribution. The first way is to transfer teachers followed by recruitment in case of large deficits within the network or recruiting teachers in a decentralized manner that would incur heavy cost and reduce utilization. The second way is to consolidate schools in case of a presence of a large number of schools with

low enrolments, since it is not economically viable to provide good quality resources in all schools. This work explores both these aspects.

The next study provides empirical insights into teacher distribution in Delhi, India over the three academic years using statistical methods. The results indicate that the teacher distribution depends on school location, years of existence, medium of instruction, number of inspections, school type and school size. We develop mathematical models that help achieve an equitable distribution of teachers through centralized transfer of teachers by optimizing the deficits and transfer distance. The models help formulate fair and transparent transfer policies. The results indicate a good amount of reduction in the number of teacher deficit schools and maximum deficit in each school.

Next, the thesis presents mathematical models for school consolidation, a special case of facility location problem to ensure walking accessibility versus quality trade-off in school education. This involves school closures and reallocation of students and teachers to nearby schools without opening any new schools, due to a presence of a large number of small schools. The suite of models can be helpful for the decision-makers in a variety of situations based on the needs of a given administrative area. In this context, we present two case studies of a district each in the states of Karnataka and Andhra Pradesh in India. The first case study illustrates the effect of a model to minimize the disruption while consolidating different types of schools with variable number of grades. The second case study shows the effect of all school consolidation models on primary schools and assists the decision-makers on usage of these models customizing their needs.

Students often travel distances beyond the scope of walking for better educational opportunities. They use school buses, public transport and private vehicles for this purpose. Studies show school commute affects academic performance in schools. In India, schools plan their transportation autonomously. Hence, it is required to develop a holistic framework that provides safe and convenient commute to school and also considers the environmental aspects. In this regard, it is important to understand the enablers for the use of school buses and shift non-bus users to school buses for operational efficiency. We develop a framework for this purpose to incorporate the views of experts, parents of current bus users and non-bus users. The survey of experts helps to rank the factors that affect bus usage while the survey of parents of current users gives their perception of buses to help formulate improvement strategies. The survey of non-bus user parents helps to understand the reasons that inhibit use of school buses

and possible interventions that can cause a likely shift to school buses. A key factor that affects school bus usage/ non-bus usage is the design of bus routes that may be long in terms of distance and time. The last part of the thesis provides a model to minimize the operational costs of school buses for schools whose buses are not stationed at the school, but located at third-party depots throughout the city. We apply the framework to improve school buses and the mathematical model to a prominent school in Delhi, India that helps reduce their operational costs by about 12% per annum and lead to a potential shift of more than 50% of non-bus users to buses.

Overall, the thesis provides models that aid decision-making in the planning and management aspects of school education. We demonstrate the models through case studies and examples to assist decision-makers and planners to make efficient decisions using quantitative techniques.

Keywords: School performance, Resource planning, Modelling, Optimization, Regression, Geotagging, Sustainable transportation, School bus routing problem.

सारांश

सतत विकास लक्ष्य (एसडीजी) सभी की समृद्धि के लिए संयुक्त राष्ट्र द्वारा निर्धारित सत्रह अंतराबन्ध लक्ष्यों का एक समूह है। ये लक्ष्य बेहतर शिक्षा, पर्यावरण चेतना, गरीबी में कमी, समानता, अच्छे स्वास्थ्य एवं स्थायी शहरों और समुदायों के माध्यम से व्यापक तौर पर जीवन स्तर में सुधार लाने पर ध्यान केंद्रित करते हैं। एक प्रमुख लक्ष्य, एसडीजी 4 का उद्देश्य सभी के लिए उत्तम शिक्षा प्रदान के साथ ही निष्पक्षता और समावेशिता को सुनिश्चित करना है। इन लक्ष्यों को प्राप्त करने के लिए वैश्विक और स्थानीय स्तर पर कार्य योजना बनाने की आवश्यकता है। बड़े पैमाने और विविधता को देखते हुए भारत जैसे विकासशील देशों की जरूरतें विकसित देशों से काफी भिन्न हैं। बड़े पैमाने की समस्याओं के लिए मैन्युअली निर्णय लेना संभव नहीं है। वर्तमान कार्य भारतीय स्कूली शिक्षा के योजना और प्रबंधन के पहलुओं से संबंधित है। थीसिस गणितीय मॉडल्स प्रस्तुत करती है जिसे एल्गोरिदम और सॉफ्टवेयर का उपयोग करके हल किया जा सकता है। यह मॉडल्स स्कूली शिक्षा के योजना और प्रबंधन सम्बंधित निर्णय लेने में सहायता करते हैं और इसे अन्य संदर्भों और भौगोलिक स्थानों पर मामूली परिवर्तन के साथ उपयोग में भी लाया जा सकता है। ये मॉडल्स बड़े पैमाने पर समस्याओं को दक्षता से हल करने के साथ-साथ परस्पर विरोधी उद्देश्य वाले सभी साझेदारों की आवश्यकताओं को पूर्ण करने के ध्येय से विकसित किये गए हैं।

थीसिस एसडीजी 4 के साथ-साथ एसडीजी 11, एसडीजी 12 और एसडीजी 13 के अंतःप्रतिच्छेदन पर काम प्रस्तुत करता है। इस थीसिस का मुख्य उद्देश्य लोगों की आकांक्षाओं और अपेक्षाओं की बेहतर संतुष्टि के लिए शिक्षा प्रशासन और वितरण में सुधार करना है। स्कूलों के शैक्षणिक प्रदर्शन और उनके अंतर्संबंधों को प्रभावित करने वाले कारकों को समझने के लिए यह कार्य साहित्यिक समीक्षा (लिटरेचर रिव्यू) से आरम्भ होता है। ये कारक विभिन्न शिक्षा प्रणालियों और भौगोलिक स्थानों में भिन्न भिन्न होते हैं। इसके बाद हमने तीन शैक्षणिक वर्षों के लिए

दिल्ली, भारत में लगभग 800 सरकारी स्कूलों का अनुभवजन्य अध्ययन कर इन कारकों को उजागर करने का प्रयास किया है। यह अध्ययन न सिर्फ उन स्कूलों को चिन्हित करने में मदद करता है जिनमें सुधार की आवश्यकता है, बल्कि सांख्यिकीय विश्लेषण और स्कूलों की जियोटैगिंग का उपयोग करके उनके प्रदर्शन को बेहतर करने में मदद कर सकता है। यह भाग स्कूलों द्वारा उल्लंघन की संभावना और उनके पकड़े जाने की संभावना के संबंध में, स्कूल निरीक्षणों को समझने के लिए गेम थ्योरी का उपयोग करके एक वैचारिक मॉडल भी प्रदान करता है। लिटरेचर सर्वे के अनुसार विद्यालयों का प्रदर्शन उसके संसाधनों, अर्थात् जनशक्ति और अवसंरचनात्मक संसाधनों और संचालन पर निर्भर करता है। स्कूलों में सबसे महत्वपूर्ण संसाधन शिक्षक हैं और उनका वितरण अच्छी पहुंच वाले क्षेत्रों की ओर ज्यादा है। शिक्षक वितरण में सुधार के दो मुख्य तरीके हैं। पहला तरीका, शिक्षकों की कमी वाले स्कूलों में शिक्षकों को स्थानांतरित करना और इसके बाद बड़े आभाव वाले स्कूलों में भर्ती करना या विकेंद्रीकृत तरीके से शिक्षकों की भर्ती करना है, हालांकि, विकेंद्रीकृत भर्ती में लागत भारी होती है जबकि उपयोगिता कम होती है। दूसरा तरीका कम नामांकन वाले स्कूलों को संगठित करना है क्योंकि अगर कम नामांकन वाले काफी स्कूल मौजूद हैं, तो सभी स्कूलों में अच्छी गुणवत्ता वाले संसाधन प्रदान करना आर्थिक रूप से संभव नहीं है। यह काम इन दोनों पहलुओं की पड़ताल करता है।

अगला अध्ययन सांख्यिकीय विधियों का उपयोग करके तीन शैक्षणिक वर्षों में दिल्ली, भारत में शिक्षक वितरण में अनुभवजन्य अंतर्दृष्टि प्रदान करता है। परिणाम इंगित करते हैं कि शिक्षक वितरण स्कूल के स्थान (लोकेशन), अस्तित्व के वर्ष, शिक्षा का माध्यम, निरीक्षणों की संख्या, स्कूल के प्रकार और स्कूल के आकार पर निर्भर करता है। इसके बाद हम गणितीय मॉडल विकसित करते हैं जो कमियों और स्थानांतरण की दूरी को अनुकूलित करके शिक्षकों के केंद्रीकृत स्थानांतरण के माध्यम से शिक्षकों के समान वितरण में मदद करते हैं। ये मॉडल निष्पक्ष और

पारदर्शी स्थानांतरण नीतियां बनाने में मदद करते हैं। परिणाम शिक्षकों की कमी वाले स्कूलों की संख्या और प्रत्येक स्कूल में अधिकतम कमी को कम करने के संकेत देते हैं।

इसके बाद, यह थीसिस स्कूल संगठन के लिए गणितीय मॉडल प्रस्तुत करती है जो स्कूल शिक्षा में 'पैदल पहुंच के अंदर' बनाम गुणवत्ता संतुलन सुनिश्चित करने के लिए फैसिलिटी लोकेशन प्रॉब्लम का एक विशेष मामला है। इसमें बड़ी संख्या में छोटे स्कूलों की उपस्थिति के कारण स्कूल बंद करना और बिना कोई नया स्कूल खोले पास के स्कूलों में छात्रों और शिक्षकों का पुनः आवंटन शामिल है। प्रशासनिक क्षेत्र की जरूरतों के अनुसार विभिन्न प्रकार की स्थितियों में मॉडल्स निर्णयकर्ताओं के लिए सहायक हो सकते हैं। इस संदर्भ में हम भारत में कर्नाटक और आंध्र प्रदेश राज्यों में प्रत्येक जिले के दो मामलों का अध्ययन प्रस्तुत करते हैं। पहली केस स्टडी विभिन्न प्रकार के स्कूलों को संगठित/ समेकित करते हुए व्यवधान को कम करने के लिए एक मॉडल के प्रभाव को दर्शाती है। दूसरी केस स्टडी प्राथमिक स्कूलों पर सभी स्कूल समेकन मॉडल्स के प्रभाव को दिखाती है और निर्णय लेने वालों को उनकी आवश्यकताओं के अनुरूप इन मॉडलों के उपयोग में सहायता करती है।

छात्र अक्सर बेहतर शैक्षिक अवसरों के लिए पैदल चलने के दायरे से बाहर की दूरी तय करते हैं। वे इस उद्देश्य के लिए स्कूल बसों, सार्वजनिक परिवहन और निजी वाहनों का उपयोग करते हैं। पूर्व अध्ययनों से पता चलता है कि स्कूल से आवागमन अकादमिक प्रदर्शन को प्रभावित करता है। भारत में स्कूल स्वायत्त रूप से अपने परिवहन की योजना बनाते हैं। इसलिए, एक समग्र ढांचा विकसित करने की आवश्यकता है जो स्कूल से सुरक्षित और सुविधाजनक आवागमन प्रदान करे और पर्यावरण पहलुओं पर भी विचार करे। इस संबंध में, उन कारकों को समझना है जो स्कूल बसों का उपयोग सुनिश्चित करते हैं एवम गैर बस उपभोगताओं के स्थानांतरण करने में मदद करते हैं। हम एक रूपरेखा विकसित करते हैं जो विशेषज्ञों और

वर्तमान बस उपयोगकर्ताओं एवं गैर-बस उपयोगकर्ताओं के माता-पिता के विचारों को शामिल करती है ।

विशेषज्ञों का सर्वेक्षण बस उपयोग को प्रभावित करने वाले कारकों को क्रम से स्थापित करने में मदद करता है। स्कूल बस यात्रा के सुधार की रणनीति तैयार करने में वर्तमान उपयोगकर्ताओं के माता-पिता का सर्वेक्षण मदद करता है। गैर-बस उपयोगकर्ता के माता-पिता का सर्वेक्षण उन कारणों को समझने में मदद करता है जो स्कूल बसों के उपयोग को बाधित करते हैं और संभावित हस्तक्षेप जो उन्हें स्कूल बसों के प्रयोग के लिए प्रोत्साहित करते हैं। स्कूल बस उपयोग/गैर-बस उपयोग को प्रभावित करने वाला एक प्रमुख कारक बस मार्गों का डिज़ाइन है जो दूरी और समय के मामले में लंबा हो सकता है। थीसिस का अंतिम भाग उन स्कूलों के लिए स्कूल बसों की परिचालन लागत को कम करने के लिए एक मॉडल प्रदान करता है। हमारे संदर्भ में बसें स्कूल के बजाये तीसरे पक्ष द्वारा संचालित हैं जो पूरे शहर में स्थापित डिपो से कार्यान्वित हैं। हमने दिल्ली, भारत के एक प्रमुख स्कूल में स्कूल बसों और गणितीय मॉडल को बेहतर बनाने के लिए रूपरेखा को लागू किया है। यह रूपरेखा परिचालन लागत को लगभग 12% प्रति वर्ष कम करने में मदद करती है और लगभग 50% से अधिक गैर-बस उपयोगकर्ताओं को बस उपयोग में स्थानांतरित कर सकते हैं।

कुल मिलाकर, थीसिस ऐसे मॉडल प्रदान करती है जो स्कूली शिक्षा के नियोजन और प्रबंधन पहलुओं में निर्णय लेने में सहायता करते हैं। हम मात्रात्मक तकनीकों का उपयोग करके कुशल निर्णय लेने के लिए निर्णयकर्ताओं और योजनाकारों की सहायता के लिए केस स्टडी और उदाहरणों के माध्यम से मॉडल प्रदर्शित करते हैं।

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LIST OF ABBREVIATIONS

SDG: Sustainable Development Goals

UN: United Nations

UDISE: Unified District Information System for Education

NEP: National Education Policy

GoI: Government of India

PTR: Pupil-teacher Ratio

PISA: Programme for International Student Assessment

VRP: Vehicle Routing Problem

SBRP: School Bus Routing Problem

RTE: Right to Education

QI: Quality Index

PP: Pass Percentage

BRC: Block Resource Centre

CRC: Cluster Resource Centre

SMC: School Management Committee

NUEPA: National University of Educational Planning and Administration

GIS: Geographic Information System

FOC: Family of Constraints

MCDM: Multi-criteria Decision-making

BWM: Best-Worst Method

FBWM: Fuzzy Best-Worst Method

TFN: Triangular Fuzzy Numbers

MTZ: Miller-Tucker-Zemlin

DFJ: Dantzig–Fulkerson–Johnson