Epidemic-logistics Modeling: A New Perspective on Operations Research

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Science Press
Beijing

Springer

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ISBN 978-981-13-9352-5 ISBN 978-981-13-9353-2 (eBook)
https://doi.org/10.1007/978-981-13-9353-2

Jointly published with Science Press
The print edition is not for sale in China. Customers from China please order the print book from: Science Press.

ISBN of the China Mainland edition: 978-7-03-062587-8

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

Infectious disease outbreaks have unfortunately been very real threats to the general population and economic development in the past decades whether they are caused by nature or bioterrorism. A typical example was the H1N1 outbreak in 2009, which spread quickly around the world and ultimately affected millions of people in 214 countries, including 128,033 confirmed cases in China. In 2010, more than 600,000 infected cases were reported, and 8000 lives were lost because of the cholera outbreak in Haiti. A more recent example of an epidemic outbreak was the 2014–2015 Ebola pandemic in West Africa, which infected approximately 28,610 individuals, and approximately 11,300 lives were lost in Guinea, Liberia, and Sierra Leone. Therefore, it can be observed that the global burden of epidemics has tremendously increased in recent years.

To our knowledge, many countries have drafted emergency response plans and operational frameworks for immediately implementing the related strategies within 24 hours after the severity of an unexpected pandemic is confirmed. In China, a certain amount of emergency budget will be allocated for quick response according to the severity level of the unexpected epidemic. Emergency medical center will designate several local hospitals to treat infected individuals. Usually, this means a certain section of the appointed hospital will be isolated for quarantining and treating the infectious patients, but not the entire hospital. However, determining the optimal resource allocation to control an unexpected epidemic is a complex optimization problem. On the one hand, managers should understand how the disease propagates and how to model the epidemic dynamics. On the other hand, managers need to know how to bridge the gap between epidemic dynamics and resource allocation. Therefore, an integrated model for epidemic control should foresee the impacts of different resource allocation scenarios on epidemic development, simultaneously and interactively. This is the focus and main contribution of our book. The objective of this book is to develop a general optimization modeling framework to help decision makers minimize infections and death due to an epidemic. The model provides information on the spread dynamics of infections, and where and when to allocate limited resources. To facilitate readers understanding of this book, we briefly introduce all contents as follows:

In Chap. 1, we introduce the basic concept of epidemic-logistics, including the basic knowledge of epidemic dynamics, literature review of epidemics control and logistics operations, and several future directions for epidemic-logistics research.

In Chap. 2, we present epidemic dynamics modeling and analysis, including epidemic dynamics in anti-bioterrorism system, epidemic dynamics modeling for influenza, and epidemic dynamics considering population migration.

In Chap. 3, we design a mixed distribution mode for emergency resources in anti-bioterrorism system, which can find a trade-off between the point-to-point delivery mode and the multi-depot, multiple traveling salesmen delivery systems.

In Chaps. 4 and 5, we propose a discrete time–space network model for allocating medical resource following an epidemic outbreak. It couples a forecasting mechanism for dynamic demand of medical resource based on an epidemic diffusion model and a multistage programming model for optimal allocation and transport of such resource. In Chap. 4, we consider the scenario of that emergency medical resource is enough. While in Chap. 5, we conduct the scenario of that emergency medical resource is limited.

In Chaps. 6 and 7, we research the integrated optimization models for epidemic-logistics network. With the consideration of emergency resources allocated to the epidemic areas in the early rescue cycles will affect the demand in the following periods, we construct two integrated and dynamic optimization model with time-varying demand based on the epidemic diffusion rule.

In Chap. 8, we present a novel FPEA model for medical resources allocation in epidemic control. It couples a forecasting mechanism, constructed for the demand of medicine in the course of such epidemic diffusion and a logistics planning system to satisfy the forecasted demand and minimize the total cost. The model is built as a closed-loop cycle, comprising forecast phase, planning phase, execution phase, and adjustment phase.

In Chap. 9, we modify the proposed epidemics-logistics model in Büyüktahtakın et al. (2018) by changing capacity constraint and then apply it to control the 2009 H1N1 outbreak in China. We formulate the problem to be a mixed-integer nonlinear programming model and simultaneously determine when to open the newly isolated wards and when to close the unused isolated wards.

In Chap. 10, we conduct the logistics planning for hospital pharmacy trusteeship under a hybrid of uncertainties. We present two medicine logistics planning models by using a time–space network approach, one with deterministic variables and the other with stochastic variables.

In Chap. 11, we propose two optimal models for medical resources order and shipment in community health service centers, with a dual emphasis on minimizing the total operation cost and improving the operation level in practice. The first planning model is a deterministic planning model. It considers constraints including the lead time of the suppliers, the storage capacity of the medical institutions, and the integrated shipment planning in the dimensions of time and space. Considering the stochastic demand, the second model is constructed as a stochastic programming model.

In Chap. 12, we continuously use time–space network technologies to conduct the problem of medical resources order and shipment. The optimization models are mixed 0-1 integer programming model and chance-constrained programming model, respectively.

In Chap. 13, we present two optimization models for optimizing the epidemic-logistics network. In the first one, we formulate the problem of emergency materials distribution with time windows to be a multiple traveling salesman problem. While in the second one, we propose an improved location allocation model with an emphasis on maximizing the emergency service level.

Although there are only three names on the cover of this book, we want to thank all contributors for their excellent contributions without which this book is impossible. Specifically, we would like to thank Prof. Lindu Zhao from Southeast University (China), Prof. Ding Zhang from State University of New York, Oswego (USA), Prof. Jennifer Shang from University of Pittsburgh (USA), and Prof. Hans-Jürgen Sebastian from RWTH Aachen University (Germany). We thank them for their suggestions and comments when we write the initial manuscripts. Of course, we would like to acknowledge the support of National Natural Science Foundation of China (No. 71771120), National Social Science Foundation of China (No. 16ZDA054), MOE (Ministry of Education) Project of Humanities and Social Sciences (No. 17YJA630058), and Six Major Talents Peak Project of Jiangsu Province (XYDXXJS-CXTD-005). Without financial support, this book cannot be published. Finally, we wish to thank the staff at Science Press and Springer Press for their support, encouragement, and assistance.

There is an old Chinese saying that states “May you live in interesting times.” For both academics and practitioners of emergency management, those times are now, and we should take full advantage of the opportunity, and enjoy it while doing so!

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Dr. Ming Liu is currently an Associate Professor in School of Economics and Management, Nanjing University of Science and Technology, China. He earned his Ph.D. degree in System Engineering from Southeast University, China. He is also a visiting researcher at RWTH Aachen University, Germany and University of Pittsburgh, USA. His research interests lie in the areas of epidemic logistics, data analysis, and medical operations management. In recent five years, Dr. Liu has published several papers on famous international journals like *International Transactions in Operational Research*, *Transportation Research Part E*, *Journal of the Operational Research Society*, *Journal of Systems Science and Systems Engineering* and *International Journal of Systems Science*, etc. He is a co-author of three books in Chinese. He is an editor for International Journal of Transportation Engineering and is a regular reviewer for several other journals.

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