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Budget Allocation for Humanitarian Logistics: A Data-Driven Approach

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Abstract

In recent years, Humanitarian Organizations (HOs) have been coping with increasing humanitarian needs while faced with budget cuts. It is thus crucial for the HO to efficiently utilize the limited budget in providing humanitarian aids. In this paper, we focus on a HO relief program with a fixed scarce amount of budget to purchase and distribute multitype relief items to beneficiaries with heterogeneous demands. Given the budget, the HO first makes item purchase from external suppliers and then distributes each type of the items equally to the beneficiaries. Equal distribution strategy is a normal practice currently employed in humanitarian operations. However, the strategy fails to tackle demand heterogeneities that inherently exist among beneficiaries, causing significant mismatch between supply and demand. On the other hand, in this study, we point out that the true demand is hardly known by the HO and thus equal distribution can be first taken for fairness concern. To further deal with the mismatch, we borrow the idea from exchange economy and facilitate the HO to set up an item barter channel for beneficiaries. To cope with the demand uncertainty, we employ data-driven analytics taking advantage of the summary statistics about Ukraine refugees during Russo-Ukrainian War and model the demand using moment-based ambiguity set. Consequently, a two-stage distributionally robust optimization (DRO) framework is developed where in the first stage the HO purchases and distributes equally among beneficiaries with a fraction of the fixed budget and in the second stage the HO promotes relief item exchange among refugees with the remaining budget with the goal of minimizing the worse-case expected demand shortage cost. The key decision to make for the HO is to budget allocation for each stage. The DRO model is reformulated into a mixed-integer linear program and solved via cutting plane algorithm efficiently. Numerical experiments show that using a small part of the budget to allow item exchange among refugees could further reduce demand shortage compared to the state-of-the-art approaches.

Keywords

Humanitarian operations, demand shortage cost, exchange economy, distributionally robust optimization, Russo-Ukrainian War

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Hongzhang Yang is a master student majoring in Electrical and Computer Engineering in the Department of Electrical and Computer Engineering at the Georgia Tech Shenzhen Institute, Tianjin University, Shenzhen, China. He earned B.E. in Ocean Technology and Second B.S. in Computer Science and Technology from Dalian University of Technology, Dalian, China. He was awarded the Learning Excellence Award for two consecutive years and the honorary title of Merit Student by the university during undergraduate.

Lei Xu is an Assistant Professor at George Tech Shenzhen Institute, Tianjin University. She is also an Adjunct Assistant Professor at the Stewart School of Industrial & Systems Engineering at Georgia Tech. Before joining GTSI, she was a Research Scientist at Smart City, Transportation, Logistics Big Data Lab in Shenzhen Research Institute of Big Data, affiliated with The Chinese University of Hong Kong, Shenzhen. Dr. Xu's research interests include resilience of transportation systems and humanitarian logistics. Her works have been published in Transportation Science, Reliability Engineering & System Safety, Computers & Operations Research, etc. Dr Xu received the B.E. degree in Transportation Engineering from Shanghai Jiao Tong University in 2015, and Ph.D. degree in Industrial Engineering from National University of Singapore in 2020. During 2015-2020, she was affiliated with the Future Resilient Systems programme in Singapore-ETH Centre. Dr. Xu was recognized as Shenzhen Overseas High-Caliber Personnel (Level C), and the receiver of Shenlong High-level Talent in 2021.

Adam Ng Tsan Sheng is an Associate Professor and Deputy Head with the Dept of Industrial and Systems Engineering Management, National University of Singapore (NUS). He obtained his PhD in Industrial and Systems Engineering, 2005 and Beng in Electrical (Hons 1st Class), 2000 from the National University of Singapore. His research interests are broadly in systems modelling and operations research applications in energy sustainability and resilience. These include developing risk and resilience performance metrics that for decision making under uncertainty in environmental and energy economic problems that can be implemented using optimization solvers. Other contributions include developing computational models for optimizing and planning of energy systems under uncertainty, such as waste-to-energy systems. He has led industrial and research projects involving natural gas network planning, robust optimization modelling, environmental and energy sustainability, and future resilience systems. He has published widely in journals such as Production and Operations Management, Transportation Science, Transportation Research, IISE Transactions, Energy Economics, European Journal of Operations Research, etc. He is also an associate editor for the Journal of Simulation, and an editorial board member of the International Journal of Automation and Logistics.

Xiaoqiang Cai is a Presidential Chair Professor and Associate Vice President at The Chinese University of Hong Kong, Shenzhen. Professor Cai received his PhD from Tsinghua University in 1988. After postdoctoral research at the University of Cambridge and the Queen's University of Belfast, UK, he was appointed as Lecturer in Applied Mathematics at the University of Western Australia during 1991-1993. He joined The Chinese University of Hong Kong in 1993, holding Lecturer (1993-1996), Senior Lecturer (1996-2000), and full Professor (2000-2014), at the Department of Systems Engineering and Engineering Management (SEEM). He served as Chairman of SEEM during 1996-2003, Head of Graduate Division of SEEM during 2009-2012, and founding Dean of General Education of Lee Woo Sing College during 2010-2014. Professor Cai's research interests are in industrial engineering, operations research, and logistics and supply chain management science. He has published over 300 papers in journals, books, and conferences, such as Operations Research, Management Science. He was the chair/co-chair for several international conferences, and a member of the organizing committee/program committee/advisory committee for numerous international conferences. He has been an editor/associate editor/editorial board member of several academic journals. He received the IEOM Award of Outstanding Professor in Logistics and Supply Chain in 2021. Professor Cai is a recipient of the Outstanding Young Scientist award (overseas category) from the National Natural Science Foundation of China. He is Academician of the International Academy for Systems and Cybernetic Sciences, Fellow of the Hong Kong Institute of Engineers, and Fellow of the Asia-Pacific Artificial Intelligence Association.