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Editors

Dynamics of Disasters

Impact, Risk, Resilience, and Solutions

Springer

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ISSN 1931-6828 ISSN 1931-6836 (electronic)
Springer Optimization and Its Applications
ISBN 978-3-030-64972-2 ISBN 978-3-030-64973-9 (eBook)
https://doi.org/10.1007/978-3-030-64973-9

Mathematics Subject Classification: 90, 91, 65, 93

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

This volume is a collection of thoroughly reviewed papers presented at the 4th International Conference on Dynamics of Disasters held in Kalamata, Greece, July 1–5, 2019, with additional invited papers. The conference was organized by Ilias S. Kotsireas, Anna Nagurney, and Panos M. Pardalos and gathered disaster researchers to present and to discuss their latest scientific work. This volume of 16 chapters is organized alphabetically by the first initial of the last name of the first author of each chapter with highlights of each chapter given below.

The co-editors acknowledge the chapter authors and thank the reviewers for their thorough reports. Given that the number of disasters is growing, along with the number of people affected by them, and that we are in the midst of the COVID-19 pandemic, which is a global healthcare disaster, we believe that this edited book is especially timely.

Birce Adsanver, Elvin Coban, and Burcu Balcik in the first chapter of this volume, "Drone Routing for Post-disaster Damage Assessment," focus on rapid damage assessment operations through the use of drones, specifically after an earthquake. They note that in the past seven decades, the number and severity of disasters has risen exponentially and that earthquakes are among the deadliest disasters. It is essential to assess earthquake damage to buildings rapidly since the survival rate for people rescued from collapsed buildings decreases dramatically over time. Hence, the use of available resources, such as drones, appropriately post disaster to ascertain building damage can save many lives. The chapter presents mathematical models and a solution approach for managing drones to scan an area affected by a disaster quickly. The authors' approach divides the disaster-affected area into grids, with the grids clustered based on their attributes. Given a set of drones and a limited time for assessments, the authors tackle the problem of determining the grids to scan by each drone and the sequence of visits to the selected grids. The goal is to maximize the total priority score collected from the assessed grids while ensuring that the prespecified coverage ratio targets for the clusters are met. Interestingly, the authors adapt formulations from the literature for electric vehicle routing problems with recharging stations and propose two alternative mixed-integer linear programming models for the problem. Using an optimization

solver to assess the computational difficulty of solving the formulations, they find that both formulations perform similarly. Since time is of the essence in humanitarian operations, the authors also propose a practical constructive heuristic for their drone routing problem, which identifies high-quality solutions quickly. With a limited literature on the use of drones in humanitarian operations, this paper makes a valuable contribution.

Fuad Aleskerov and Sergey Demin in their chapter, "DEA for the Assessment of Regions' Ability to Cope with Disasters," construct modifications of Data Envelopment Analysis (DEA) methods in order to take into account inaccuracies in data, which, in real life, often consist of expert estimates or approximate values. DEA is based on the idea of efficiency assessment of different decision-making units (DMUs). To date, DEA has been applied for different disasters, including floods and technological disasters, as well as the vulnerability of certain regions to typhoons. The proposed two modified DEA methods are termed IDEA (interval DEA) methods by the authors. The first IDEA method, called the best tubed IDEA, is based on the idea that some DMUs might be near the efficiency frontier. The authors' second proposed IDEA method is based on the idea that any parameter (both input and output) might be the most important during the comparison of the DMUs. They call the second method Pareto IDEA. They then apply the basic DEA and the two IDEA methods to rank preventive measures against wildfires in 46 regions of Russia and compare the results obtained.

Gerasimos Antzoulatos, Anastasios Karakostas, Stefanos Vrochidis, and Ioannis Kompatsiaris in their chapter, "The Crisis Classification Component to Strengthen the Early Warning, Risk Assessment and Decision Support in Extreme Climate Events," propose the open-source holistic beAWARE framework to tackle the urgent need to enhance awareness and preparedness to assess risks and to support decision-making, aiming to increase the social resilience to climate change via novelty tools. Climate change is considered as one of the most important challenges of modern times, having multiple and significant impacts on human societies and environment. The negative effects, which are revealed through extreme weather events and cause distress and loss of property and human lives, will become more intensive in the future, especially in poor countries. The authors propose the open-source holistic beAWARE framework which encompasses technological achievements that enable first responders and authorities to manage efficiently the preemergency and emergency phases of a hazardous natural event. Specifically, the Crisis Classification component of beAWARE platform consolidates functionalities to provide dual services: (a) firstly, as an Early Warning system, aiming to estimate the crisis level of the upcoming extreme conditions such as the hazard from flood, fire, or heatwave (preemergency phase); (b) secondly, as a Real-Time Monitoring and Risk Assessment system, aiming to assess the risk and support to make accurate and timely decisions when a crisis is evolved.

Buket Cilali, Nafiseh Ghorbani-Renani, Kash Barker, and Andrés D. González in their chapter, "Toward Decentralized Decision Making for Interdependent Infrastructure Network Resilience," discuss interdependence among infrastructure and community networks, as it is an important aspect to consider when planning for

disruptive events. Further, decision-makers within different infrastructures often make decentralized decisions to protect and restore their own networks after a disruption. They extend a resilience-based optimization model in various ways to depict different decentralized decision-making structures and hierarchies: divided budget, isolation assumption, and dominance assumption. Among others, they use social vulnerability scores to show the effect of community resilience and analyze different scenarios to reveal the effect of decentralization. They illustrate the model with a system of interdependent electric power, water, and gas infrastructure networks in Shelby County, TN.

Stefania Corsaro, Pasquale Luigi De Angelis, Ugo Fiore, Zelda Marino, Francesca Perla, and Mariafortuna Pietroluongo in their chapter, "Wavelets in Multiscale Time Series Analysis: An Application to Seismic Data," tackle the important problem in earth science of forecasting earthquakes due to their potentially devastating consequences. Specifically, the authors focus on investigating the possibility of being able to determine when an earthquake will take place. The authors formulate the problem as a multiple change-point detection problem in the time series. In particular, they make use of a multiscale formulation, where, at each stage, multiple neighboring regions which correspond to locally constant underlying signals are merged. The authors emphasize that wavelets are suitable as basis functions, due to their multiscale structure, since the coefficients of the representation contain local information. The pre-processing stage, according to the authors, includes the discrete unbalanced Haar transform, which is a wavelet decomposition of one-dimensional data with respect to an orthonormal Haar-like basis, where jumps in the basis vectors do not necessarily occur in the middle of their support. Their algorithm is tested on data from a well-characterized laboratory system.

Ugo Fiore, Zelda Marino, Francesca Perla, Mariafortuna Pietroluongo, Salvatore Scognamiglio, and Paolo Zanetti in their chapter, "Effectiveness of Investments in Prevention of Geological Disasters," address the topic of geological disasters, which are ubiquitous, and the awareness of such disasters is also growing. Furthermore, it is thought that climate change will exacerbate geological disasters in terms of both frequency and magnitude. Specifically, the authors, in their study, investigate the relationship between the number of prevention projects and the number of subsequent geological disasters, accounting for the effect of geographical distribution. They perform their analysis on historical data provided by the Chinese Statistics Bureau. The dataset details the number of disasters that occurred and the number of prevention projects that were carried out in China between 2004 and 2017, by region. The authors utilize a recurrent neural network of the Long Short-Term Memory (LSTM) type to forecast the number of geological disasters in China. The accuracy of predictions was measured with and without including data relative to the number of prevention projects. In addition, well-known statistical methods provided a verification. The authors note that an LSTM recurrent neural network is a powerful and versatile tool in the analysis of time series data and can yield insights when it is also coupled with a module able to handle grouping information. Their results show

that it is possible to identify evidence of a connection between prevention projects and a reduction in the number of disasters.

Bernhard Garn, Klaus Kieseberg, Dominik Schreiber, and Dimitris E. Simos in their chapter, "Cyber Crises and Disaster Preparation in Austria: A Survey of Research Projects," provide an overview and analysis of research projects within the security research-orientated KIRAS funding scheme in Austria dealing with issues of disaster preparation, giving special attention to projects concentrating on threats originating from the cyber domain. They analyze several projects dealing with crisis management and disaster response, in particular those focusing on ex-postcoordination efforts in conjunction with software supporting these activities. Regarding the cyber domain, they illustrate and exemplify how multiple research projects addressed issues arising in cyber crisis management, cyber disaster scenario generation, and cyber incident response trainings. Major parts of their chapter deal specifically with efforts conducted in Austria, but they also point out similar activities in other countries and on an international as well as European level. They conclude with a list of recommendations for the general conduct of disaster preparation activities, highlighting universal best practices and instilling motivation for future research endeavors geared towards strengthening disaster and crisis preparation efforts.

Mehdi Ghazanfari, Mohammadmehdi Hakimifar, Tina Wakolbinger, and Fuminori Toyasaki in their chapter, "Disaster Preparedness at the Municipality Level: A Scenario-Based Multi-stage Measurement Methodology," present a framework for assessing disaster preparedness of municipalities or local governments of urban areas that can be used by policy-makers. The framework considers multi-stage aspects of disaster preparedness by integrating the pre- and post-disaster status, with preparedness being based on the four areas of hazard assessment, mitigation capabilities, resource assessment, and management performance. The authors provide a methodology incorporating several dimensions over three phases: the pre-disaster study, post-disaster prediction, and assessment. Their methodological framework differs from those reported on in the the existing literature which focus on specific aspects of preparedness such as social, technical, and infrastructural. The authors discuss in detail the delineation of the three phases into further stages and the associated dimensions and their components that need to be examined. Radar diagrams for illustrative purposes are provided. The authors illustrate how the preparedness levels over different dimensions or resources or parameters in different phases for distinct disaster scenarios can be presented. Implementation of the comprehensive methodology can help municipal governments in identifying their level of disaster preparedness. Furthermore, the methodology can contribute to strengthening their readiness, as the authors note, by highlighting areas of weakness.

Yutaka Matsuno, Futaba Fukanuma, and Shigenobu Tsuruoka in their chapter, "Development of Flood Disaster Prevention Simulation Smartphone Application Using Gamification," develop a smartphone application for simulating flood disaster evacuation that is based on gamification. Their study is inspired by the need to increase public awareness of disaster preparedness knowledge, including hazard maps, especially in the setting of Japan and its frequent flood disasters. According

to the authors, it is predicted that the frequency of heavy rain, the amount of floods, and the frequency of short-term heavy rain is expected to increase in Japan in the future due to global warming. The authors state that a hazard map is one that displays disaster-predicted areas and locations of disaster prevention facilities such as evacuation points and routes. The authors report on the design and development of a disaster prevention smartphone application with such characteristics as ease of use, continuity (users want to use it continuously), learning effects, and interest improvement. Their evaluation of the smartphone application using subject experiments with 20 participants revealed that the smartphone application is effective as compared to only using hazard maps.

John A. Mpekiaris and George D. Tsiotras in their chapter, "Natural Disasters and Their Impact on Business Units: The Greek Case," contain the result of a survey questionnaire consisting of 45 items, with a focus on disaster types often encountered within Greece, such as floods, wildfires, and earthquakes. The study addresses the current situation in terms of Greek companies' awareness, preparedness, and resilience against catastrophic events. The study seeks to document the implications of catastrophic events on business activities as well as the perception of entrepreneurs on business continuity and post-disaster recovery. The findings in the authors' study reveal that crucial business continuity matters depend on particular company features. In particular, large corporations of complex legal form with many years of operation seem to be more prepared both in terms of prevention and post-disaster measures. Furthermore, the study found that only one of every four Greek entrepreneurs is aware of the nature and content of business continuity and recovery plans. The authors emphasize the clear need for governmental actions geared to emphasize the importance of business continuity planning when addressing the aftermath of a disaster.

Anna Nagurney in her chapter, "Perishable Food Supply Chain Networks with Labor in the COVID-19 pandemic," bridges operations research and economics by constructing a supply chain generalized network optimization model for perishable food products that explicitly includes labor availability associated with the supply chain activities of production, transportation, storage, and distribution. The model is in response to the challenges of quantifying the impacts on perishable food supply chains of the COVID-19 pandemic, which was declared by the World Health Organization on March 11, 2020. The pandemic, which is a global healthcare disaster, has resulted in millions of illnesses and hundreds of thousands of deaths and has affected a plethora of food supply chains, including meat and fresh produce, due to disruptions in the labor supply, the need for social distancing to reduce contagion, losses in productivity, as well as transportation issues. The author considers a food firm that seeks to maximize profits (for its business sustainability) with the objective function including revenue and operational and discarding costs as well as costs of labor. The author utilizes linear production functions to map labor on a link to product flow. A variational inequality formulation of the problem is derived, and an algorithm is proposed that computes the optimal food product flows and the Lagrange multipliers associated with the capacities on labor. Numerical examples are presented for a fresh produce product – cantaloupes, in which the quality

deterioration is also captured. The numerical examples quantify the impacts of labor disruptions, in terms of reductions in availability as well as in productivity, on the food firm's profit, the demand market prices, product flows, and demands. They also reveal the potential positive effects of adding direct demand markets, as in the case of farm stands and farmers' markets, and enhanced marketing resulting in change in the demand market prices.

Anna Nagurney, Patrizia Daniele, and Giorgia Cappello in their chapter, "Capacitated Human Migration Networks and Subsidization," address one of the greatest challenges of the twenty-first century – that of large-scale human migration flows with drivers ranging from climate change and various disasters to wars, violence, and poverty. They build on the literature of human migration networks and construct extensions of multiclass user-optimized (U-O) and system-optimized (S-O) models to incorporate capacities associated with locations in the network economy. The authors introduce a policy framework, in the form of subsidies, that, when applied, guarantees that the system-optimized solution of the multiclass capacitated human migration network problem is also user-optimized. Such policies enable governments, and policy-making bodies, to achieve optimal societal welfare in terms of the location of the migrants in the network economy, while the migrants locate independently in a U-O manner. The authors provide alternative variational inequality formulations of the novel U-O and S-O models, which include Lagrange multipliers associated with the location capacity constraints. The values of the Lagrange multipliers at the equilibrium/optimal solutions provide valuable economic information for decision-makers. Analogies to transportation networks and associated U-O and S-O behavior are drawn, along with policies, in the form of tolls. An effective algorithm, which exploits the special network structure of the models, is detailed and applied to compute solutions to a series of examples, both uncapacitated and capacitated ones, along with the subsidies for the latter. The authors note that their modeling and computational approach allows for the investigation and evaluation of different disaster scenarios as when there are population changes and/or modifications to utility functions because of impacted infrastructure.

Stamatis Papangelou and Zinos Alexios Charalampidis in their chapter, "Land Property Data Logging on Blockchain Ledger," turn to the important problem of evaluating property risk, since there are many different types of risk that can affect properties, including wildfire risk and even excessive moisture. The underlying motivation for this work stems, in part, from the problems that arise, post-disaster, when retrieving information about damaged land properties, which may be both time consuming and may involve a lot of bureaucracy. Their goal is to combine a wide range of parameters associated with risk indexes that not only evaluate each property individually but different sub-indexes within a property in the case of different types of disasters. The different types of disasters relevant to their problem are natural disasters, man-made disasters, and types of construction. The authors, in this chapter, discuss a specific method that uses block-chain technology and specialized equipment to collect and register land property information. Such information is critical for individuals, governments, as well as insurance-based

companies for evaluating risk associated with disasters. For reasons of data integrity and transparency, all of this information is available on a public blockchain ledger. As noted by the authors, blockchain is an ordered list of records that are called blocks, which contain crypto-graphic stamps that are connected with every previous block and all the information within the block. It is a decentralized, usually public, and distributed digital ledger that is used to record transactions and data across many computers so that any involved record cannot be modified retroactively, without the modification of all subsequent blocks. The authors also describe how blockchain technology can ensure risk evaluation transparency and discuss a specific system that acquires data from the field as well as the processing of such data in the cloud.

Urmila Pyakurel and Stephan Dempe in their chapter, "Universal Maximal Flow with Intermediate Storage for Evacuation Planning," address the important problem of evacuation modeling and solution, which is very relevant in disaster settings. In evacuation models, one wishes to shift evacuees from emergency areas (sources) to places of safety (sinks) as quickly and as efficiently as possible. The majority of the flow over time models used in evacuation planning, they note, are based on the flow conservation constraints, that is, the inflow must be equal to the outflow at each node with the exception of at the sources and sinks. The authors study, in contrast, the universal maximum flow problem with intermediate storage. In this evacuation problem type, the inflow may be greater than the outflow at intermediate nodes, which maximizes the number of evacuees leaving the emergency areas at each point of time. The authors construct efficient algorithms to solve the problem on two-terminal series-parallel and general networks. In addition, they also discuss an algorithm for the problem with arc reversal capability, as would occur in the case of contraflow, and compare these solutions without and with intermediate storage. Enabling contraflow in an evacuation network increases the outbound road capacities by reversing the direction of the flow. This chapter enriches the literature on evacuation planning for disasters.

Alexander Streicher, Rainer Schönbein, and Stefan Wolfgang Pickl in their chapter, "A General Framework and Control Theoretic Approach for Adaptive Interactive Learning Environments," argue how disaster risk management can gain from the application of serious games as motivational and engaging tools to foster disaster response competencies through personalized or adaptive interactive learning environments. Their study proposes the transfer of adaptive control to adaptive learning systems with special focus on interactive learning environments such as educational serious games (also known as digital game based learning) or computer simulations. The general idea is to adapt systems theory and control theory to the control processes of adaptive learning systems. Adaptive learning environments should adapt to the context-related needs of the user in order to ensure and optimize learning success, especially for disaster management training. Furthermore, since the setting is that of complex systems with nonlinear and stochastic processes, they also propose to adopt adaptive control theory with reference models. This chapter is a contribution to the state of the art for adaptive games or simulations in disaster risk management.

Georgios Tsaples, Josep Maria Salanova Grau, Georgia Aifadopoulou, and Panagiotis Tzenos in their chapter, "A Simulation Model for the Analysis of the Consequences of Extreme Weather Conditions to the Traffic Status of the City of Thessaloniki, Greece," present a decision-support tool that allows for the efficient and effective monitoring of the status of the transportation network and crisis management planning in the case of flooding. They develop a simulation model, which is combined with real-time Floating Car Data from a fleet of taxis in the city of Thessaloniki, Greece. Hence, in their study, two methodological frameworks are combined: data analytics and simulation. Thessaloniki regularly suffers from flooding that results in dire traffic conditions and obstructs the movement of vehicles. The authors emphasize that extreme weather conditions – such as flooding or snow blizzards – that were once considered events of low probability have become a recurring concern for local authorities, high-level policy-makers, and also citizens. The model was tested for two different scenarios that simulate different types of rain. The results obtained by the authors reveal that the consequences can be seen long after the rain has stopped and can last for lengthy periods resulting in a transportation system with extremely low level of service and in a state of disequilibrium. The chapter shows that policy-makers must integrate their decision-making processes regarding the transportation sector in a crisis management framework.

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