

Humanitarian Medical Allocation for Public Health Emergencies

by

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Abstract:

Emerging and re-emerging epidemic diseases pose an on-going threat to global public health security. Recent examples of epidemics, including the outbreak of Ebola virus disease, cholera and Middle East respiratory syndrome coronavirus (MERS-CoV), have caused physical and psychological pain of millions of people. The recent outbreak of Ebola disease has had a total of 28,141 confirmed, probable, and suspected cases reported, with 11,291 deaths. Epidemic outbreaks are also very common in the aftermath of natural disasters and bioterrorist actions. According to the World Health Organization (WHO)'s Twelfth General Programme of Work, the improvement of prevention, preparedness, response and recovery activities is set as one of the WHO's five strategic imperatives.

In response to a large-scale epidemic, satisfying medical needs is crucial to the success of humanitarian-oriented operations and management. The needs in medical supply include medicines and disposable medical products. However, humanitarian medical allocation problems differ from the general business logistics problems in that the former problems involve many challenges, such as urgency and sudden outbreak, which increase the complexity and difficulty of solving the related logistical problems. This research underscores the importance of humanitarian medical allocation for public health emergencies, and aims to explore a novel analytical approach for improving humanitarian allocation of medical reliefs for response to unconventional large-scale epidemics, and draw managerial insights for health care practice.

Specifically, three sub-topics are conducted focusing on spatial allocation, temporal allocation and cross-sector cooperation in allocation, respectively. Several methods are adopted, including stochastic dynamic programming, linear programming, epidemic diffusion models and game theory. This inter-disciplinary research would contribute to the decision analysis of humanitarian medical allocation. The descriptions of the three sub-topics are as follows:

- (1) In the sub-research of spatial allocation of humanitarian medical relief, we present a novel model of emergency medical logistics for quick response to public health emergencies. The proposed methodology consists of two recursive mechanisms: (i) the time-varying forecasting of medical relief demand and (ii) relief distribution. The medical demand associated with each epidemic area is forecast according to a modified susceptible-exposed-infected-recovered (SEIR) model. A linear programming approach is then applied to facilitate distribution decision-making. Both the physical and psychological situations of those affected are considered. The modified SEIR model contributes to forecasting by considering not only physical factors, such as the differences in the infection conditions of survivors and the spatial interaction relationships among epidemic areas, but also the psychological demand of exposed and undiagnosed individuals. In the distribution model, psychological fragility is formulated and discussed in detail, unlike previous studies. The relationship between emergency medical logistics and the psychological effects on affected people is highlighted as well. Numerical studies are conducted. Results show that the consideration of survivor psychology significantly reduces the psychological fragility of affected people, but it barely influences physical fragility.
- (2) In the sub-research of temporal allocation of humanitarian medical relief, this research proposes a model of time-varying allocation of emergency medical supply for response to large-scale epidemics. Based on the trend of epidemic disease spreading, a stochastic dynamic programming model is developed to optimize the allocation policy of emergency medical supply in each time period. This sub-research contributes to the fields of logistics and healthcare in the following two ways: (i) The stochastic dynamic programming model characterizes the temporal allocation problem of medical supply based on the trend of epidemic disease spreading. This new formulation is closer to the real logistics practice during epidemic outbreaks. (ii) This research obtains a general form of the optimal medical allocation decision in each time period and further develops a case study based on real data to demonstrate the applicability of the proposed model. According to the above analytical and numerical studies, some properties are provided and their implementations for policy makers are discussed.
- (3) Typically, humanitarian logistics engages a large number and variety of sectors, including central governments, local governments, the military, international organizations and private companies. Modern information technologies provide potential opportunities to share information among different sectors, and to work together to pursue effective and efficient relief operations. However, each of these sectors may have different missions and capacities, which contributes to cooperation difficulties. Thus, in this sub-research of cross-sector cooperation in allocation, a series of cross-sector decision models are developed to discuss different types of cooperation and information sharing between public and private sectors. The basic model, which consists of a public sector (usually the government) and a private sector, is formulated to obtain the optimal decisions of the two sectors. Then this research presents three more cooperation mechanisms: semi-cooperation with a private leader, semi-cooperation with a government leader, and full cooperation. The optimal solutions of these four models are provided and compared. By solving and comparing their optimal solutions, this sub-research makes the first step to understand the differences among these four mechanisms. The results illustrate that full cooperation is not always the best choice, while semi-cooperation with information sharing would also achieve potential advantages, even if two sectors made their own decisions separately.

Bio:

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All are welcome!