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Epidemics control and logistics operations: A review

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ABSTRACT

Outbreaks of epidemics account for a great number of deaths. Communicable or infectious diseases are also a major cause of mortality in the aftermath of natural or man-made disasters. Effective control of an epidemic outbreak calls for a rapid response. Available resources such as essential medical supplies and well-trained personnel need to be deployed rapidly and to be managed in conjunction with available information and financial resources in order to contain the epidemic before it reaches uncontrollable or disastrous proportions. Therefore, the establishment and management of an emergency supply chain during the containment effort are of paramount importance. This paper focuses on defining the role of logistics operations and their management that may assist the control of epidemic outbreaks, critically reviewing existing literature and pinpointing gaps. Through the analysis of the selected literature a series of insights are derived and several future research directions are proposed. In conclusion, this paper provides both academics and practitioners with an overview of literature on epidemics control and logistics operations aiming at stimulating further interest in the area of epidemics control supply chain management.

1. Introduction

Among disasters, outbreaks of epidemics account for excessive damages of human and material capital, including a great number of deaths. Polio, smallpox, cholera and HIV are among the diseases that continue to pose a threat for many developing and developed countries. Human history is full of public health incidents where pandemics occurred in a certain period of time causing suffering and death. For example, plague epidemics in late Medieval Europe characterized by high mortality rates caused many fatalities, while the 1918–1919 Spanish influenza pandemic killed an estimated 20 to 50 million people worldwide (Benedictow, 1987; Tumpey et al., 2005). Epidemic outbreaks may occur in the context of natural causes such as the recent outbreak of novel influenza A(H1N1) virus where, according to the World Health Organization (WHO), from the start of the pandemic until May 28, 2010, the virus had already spread over 214 countries causing 18,114 deaths (http://www.who.int/csr/don/2010_05_28/en/index.html). Epidemic outbreaks are also very common in the aftermath of natural disasters. Acute respiratory infections, measles, malaria and diarrhea are the most prevalent infectious diseases after natural disasters and all of them are closely related to unsanitary health conditions and malnutrition of the population affected (Watson et al., 2007). Finally, deliberate bioterrorist actions and the release of biological warfare agents could also lead to epidemic outbreaks. According to Henderson (1999) smallpox and anthrax are considered to be among the two most feared biological agents that could be used in a probable bioterrorist attack "as they have the potential to be grown reasonably easily and in large quantities and are sturdy organisms that are resistant to destruction". The anthrax attacks of 2001 in the United States demonstrated the threat of a possible bioterrorist action and its severe impacts.

The importance of addressing epidemic outbreaks nowadays is even greater as the general framework in which they may occur has dramatically changed during the last years. New challenges have arisen and certain drivers like climate change, population density and urbanization could serve as catalysts for the acceleration of pandemic incidents. Climate change is expected to play a crucial role in the birth and transmission of specific diseases (McMichael, 2003). Many studies suggest that diseases such as yellow fever, dengue and cholera are re-emerging due to climate change among other factors (Shope, 1991). Specific arbovirus diseases have recently emerged outside their usual endemic range and this could be attributed to changes in climate patterns (Gould and Higgs, 2009). Apart from climate change, the witnessed rapid urbanization of the world's population along with a substantial growth in general population could lead to accelerated epidemic outbreaks, rendering socioeconomic systems even more vulnerable. A possible outbreak combined with changes in demographic conditions like population distribution, size and density could potentially lead to a pandemic of unprecedented

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proportion where available capacities and resources could be strained to their limits.

The control of an epidemic's outbreak calls for a prompt response. Certain control protocols should be followed and huge amounts of supplies together with the necessary human resources (medical and other personnel) should be available in order to be utilized during the containment effort. For example, if a smallpox attack happens, vaccination of the affected population should take place within 4 days while in the case of an anthrax outbreak the distribution of antibiotics should take place within 2 days of the event (Lee, 2008). As a consequence, any control of an epidemic's outbreak should rely on the establishment of an emergency supply chain as a plethora of logistics issues is raised according to the control strategy adopted and the very nature of the agent triggering the outbreak. All the logistics operations such as transportation of medical supplies and commodities or the deployment of medical personnel must be managed in conjunction with available information and financial resources in order to contain the epidemic before it reaches critical proportions. This is the reason why leading international health organizations like World Health Organization and the Pan American Health Organization explicitly recognize the importance of logistics operations to any successful health task undertaken for the control of an outbreak. A basic component of the World Health Organization's Epidemic and Pandemic Alert and Response program addresses logistic issues in order "*to provide operational assistance in the ongoing management of logistics required for epidemic and pandemic preparedness and response and for the rapid deployment of medical and laboratory supplies, transport, communications as well as the rapid deployment of outbreak response teams*" (http://www.afro.who.int/en/divisions-a-programmes/ddc/epidemic-a-pandemic-alert-and-response/programme-components/logistics.html). International aid organizations, like the United States Agency for International Development (USAID), also pay attention to logistical issues in the case of epidemic outbreaks control. The USAID|DELIVER PROJECT, Task Order 2-Supply Chain Management for Outbreak Response supports USAID's efforts to mitigate existing and emerging pandemic threats by procuring, stockpiling, and distributing outbreak response commodities (http://deliver.jsi.com/dhome/topics/health/outbreakresponse).

Although logistics operations are very important for controlling an epidemic's outbreak, the scientific community has yet to produce a large amount of well-established approaches that explicitly incorporate epidemics logistics features. Even further, issues of appropriately managing epidemics logistics operations have been paid limited attention. So far, epidemics logistics operations have been seen through the lens of resource allocation or have been implicitly incorporated as qualitative variables into preparedness and response plans. For example, a considerable volume of scientific research has been conducted in the case of resources allocation for the control of infectious diseases (Brandeau, 2005; Rachaniotis et al., 2012; Zaric and Brandeau, 2001,2002) or in the case of developing preparedness and response plans for health-care facilities to deal with epidemic outbreaks (Ammon et al., 2007; Ippolito et al., 2006; Rebmann et al., 2007; Savoia et al., 2009; Webby and Webster, 2003). While resource allocation models and contingency plans provide a strong insight towards epidemics control, they often overlook some critical aspects: allocation of resources cannot be accomplished unless the availability of these resources is assured at the right time, right place and right quantity. In addition, contingency plans often overlook critical logistical parameters like patient flow logistics and the availability of workforce and, therefore, several decision variables related to possible bottlenecks or workforce shortages are omitted. Results of many full-scale exercises have shown that logistics poses a real challenge when controlling an epidemic outbreak (Aaby et al., 2006). Logistical barriers could also be apparent even when establishing a simple quarantine program in terms of transferring supplies across quarantine lines, recruiting qualified medical personnel etc. (Barbera et al., 2001).

The aforementioned gap in the literature concerning epidemics logistics operations and their management has been our main driver for conducting this review paper. Our scope is to shed light into the general context of emergency supply chain management in the case of epidemics containment. Thus the objectives of the paper may be summarized as follows:

- To define and inter-correlate the logistics operations taking place during the containment of an epidemic.
- To find to what extent literature has produced a critical mass of scientific work in terms of methodologies applied and research techniques utilized regarding the issues of epidemics control logistics.
- To determine whether the methodologies applied in business logistics problems could be utilized in the context of epidemics control logistics (e.g. Operational Research methods utilization etc.).
- To develop a more robust definition of the epidemics control supply chain and enhance its understanding.
- To look for trends in epidemics control supply chain management academic research and to propose areas for further investigation.

The remainder of the paper is structured as follows: in Section 2 some key concepts of emergency and humanitarian supply chain management are outlined. Section 3 provides an overview of the research methodology utilized for the purposes of the review and the boundaries of our research. In Section 4 an inventory of the logistics operations taking place during the control of an epidemic is developed. Section 5 deals with the analysis and classification of the selected literature regarding epidemics logistics operations. In Section 6 the main findings of the review are discussed. Finally, the paper ends with some concluding remarks and suggestions for future research directions.

2. Epidemics control and emergency supply chain management

The control of infectious diseases may be based on measures adopted at international, national, provincial or even community level. Reducing the rate by which susceptibles become infected, reducing the mortality rate for those already infected and increasing the immunization capacity of the population comprise the main objectives of any containment effort. Such control measures demand the launching of vaccination or quarantine programs over certain geographic regions. They also call for interventions that will ensure the provision of medical supplies like antiretroviral drugs, antibiotics, clean water/adequate sanitation and better nutrition conditions in order that the multiplication of the infectious agent be reduced. Control measures could be adopted with the aim either to prevent the spread after the initiation of an infectious disease (as pre-event measures) or to control a confirmed outbreak (post-event measures). In the first case, a certain level of medical supplies should be kept in order to be utilized immediately at the initiation of an epidemic. In the second case the deployment of all the available resources should rapidly take place providing either treatment to those already infected or prophylaxis to those susceptible to the agent triggering the outbreak.