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EVALUATING STATIC AND ADAPTIVE SAFETY STOCK POLICIES FOR ROBUST PHARMACEUTICAL SUPPLY CHAINS

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ABSTRACT

Over the past decade, there has been an epidemic of drug shortages plaguing the U.S. While efforts have been made to address the robustness of pharmaceutical supply chains, shortages persist. Two common drivers of drug shortages are (1) supply disruptions and (2) responses by decision makers throughout the supply chain as they react to these disruptions. To understand and characterize the relationship between these drivers, a systems dynamics model has been developed. Results indicate that, for various decision makers, the best inventory policies, based on Data Envelopment Analysis (DEA), evolve with the type of disruption.

1 INTRODUCTION

In recent years, drug shortages have been increasingly common within the United States. While some put the blame for these shortages on a lack of incentives for manufacturers to produce drugs with low profits, others claim that poor manufacturing facilities are the leading cause of these shortages. Even though drug shortages are widespread, there is a poor understanding of the supply chain features and the disruptions within operations leading to these shortages; furthermore, these factors are historically difficult to recover from. Part of the challenge in addressing the drug shortage problem is that shortages are driven by a number of different causes, each having its unique features. For example, possible causes include (i) manufacturing challenges, (ii) sudden changes to supply and demand, (iii) other supply chain disruptions, (iv) regulatory actions, and (v) the discontinuation of products.

Despite efforts to increase the robustness of pharmaceutical supply chains, these remain vulnerable to supply disruptions. Designing a system which is robust to handle these disruptions is complex and requires an adaptive decision process that dynamically changes over time. In addition, the complex interdependencies among different members of the pharmaceutical supply chain can cause an amplification of disruptions throughout this complex system. This situation becomes aggravated when multiple disruptions occur in the supply chain, even if each of them may be minor in nature; the structure of the supply chain is such that the aggregation of individual events can lead to major problems. Dealing with supply chain disruptions and mitigating their effects have been studied in the literature of supply chain management. Most of the suggested strategies involve (i) building additional manufacturing capacity, (ii) using multiple sources for suppliers, and (iii) restructuring the supply chain. However, while these solutions may be effective, they are often not practical for real world implementation. These proposals involve significant financial investment and may require a lengthy amount of time to put into practice. Correspondingly, another approach is needed to prevent shortages for life-critical products with low profit margins as these experience frequent shortages.

2 METHODOLOGY

In the present study, a different approach is examined to address drug shortages that does not require large fixed-cost investments. Specifically, how changes to inventory policies, without the requirement of changing manufacturing capacity, is explored. These can alleviate shortages caused by supply disruptions at multiple parts of the supply chain.

The assumption for this model is that all actors in the supply chain, at the various echelons, make ordering and purchasing decisions using a periodic review policy, such that they seek to order enough to meet a predetermined level, the order-up-to-level. This level is chosen with the purpose of limiting unmet demand while minimizing inventory costs. To account for these dual goals of minimizing costs and unmet demand, an appropriate safety stock level is chosen. The optimal safety stock level is expected to vary based on (i) the type and location of disruptions in the supply chain, (ii) the responsiveness of the supply chain members to change safety stock levels after disruptions, and (iii) the relative preference for the two goals.

A system dynamics simulation model is created to capture the complexities of a pharmaceutical supply chain. Utilizing this model, the effects of different inventory strategies, including both static and adaptive safety stock levels, are examined. The use of the system dynamics model allows for a better analysis of the effects of a disruption in each level (echelon) of the supply chain and how these effects spread throughout the system to different echelons. With the developed system dynamics model, the total cost for varying safety stock levels and disruption profiles is calculated. Correspondingly, a Data Envelopment Analysis (DEA) is employed to define the optimal safety stock for varying relative costs of shortages and inventory holding costs.

Disruptions are characterized by multiple features. The optimal inventory policy, as defined by a fixed safety stock level, varies significantly based on the features of the disruptions. These include: the length of the disruptions, the length of the time between events, the number of events, and the type/location of the disruption. Initial results show that an inventory policy optimizing one disruption profile may lead to poor results if an alternate disruption profile occurs. Therefore, understanding the features of the disruption pattern is essential in deciding how to alleviate an ongoing shortage.