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ANALYSING SUPPLY CHAIN FACTORS AFFECTING ANTIBIOTICS SHORTAGE WITH SYSTEM DYNAMICS SIMULATION

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ABSTRACT

Antibiotics supply is continuously facing disruptions and markets are suffering from shortages at a global level. The antibiotics supply chain (SC) is a dynamically complex system. A number of issues are affecting the availability of these essential drugs. Upstream issues are prevailingly influencing the production and downstream issues are influencing decision makers from a business profitability perspective. Inter-organization cooperation and transparency are also affecting antibiotics supply. Looking into the Swedish market, this study aims at mapping the factors causing antibiotics insufficiency from the entire system's viewpoint. A causal loop diagram model is used to map the causal relationships among these factors and with the core issue of shortage, then a system dynamics (SD) simulation will quantitatively assess their degree of influence. Starting from both theoretical and empirical lenses, this work is directed from analyzing the dynamic supply issue towards proving support to decision and policy makers for optimizing the supply of antibiotics.

1 EXTENDED ABSTRACT

In the supply of antibiotics, scarcity, shortages and stock outs occur because the global antibiotics market doesn't work well (Cantrell 2018). A number of impediments discourage firms from developing new antibiotics. Projects are evaluated according to development costs, likelihood of regulatory approval and selling costs (Bax and Green 2015). The prevailing business model for any industry is to have access to a large market in order to generate greater profits while the antibiotics market aims at narrowing down due to resistance development, thus reducing business interests for manufacturers and developers (Whewell 2009). In addition, the pharmaceutical sector is heavily regulated often from several national and international regulatory bodies and drug development must comply (ibid). Looking at today's global business, the emerging market structure is a network of tightly integrated organizations that cooperate together to form a SC entity (Christopher 2016). A number of scholars has defined SC as a network of connected and interdependent organizations working together on activities to ultimately produce value in the form of products and services for the consumer. These interconnections and links between organizations engender interactions and influences. Organizations make tradeoffs where one entity will lose and the other will benefit to favor the entire SC (Ibid). Interconnectivity between networks promotes cooperation by means of organizational complexity and enhanced reciprocity (Wang et al. 2016).

This work studies the impact of the previously mentioned issues on antibiotics availability. Many scholars have approached the issue of antibiotics shortage by simulating issues related to a single problem in the system namely the production process, the upstream supply, downstream, or the demand profitability and others. However the system's view of the supply structure and how to use simulation to tackle pharmaceutical drugs shortage from the whole system's perspective seems to be poor. In SC management, the performance of one component directly affects the overall performance of the system. It is therefore

important to explore the area of SD of the SC in antibiotics. This study aims at mapping the factors causing antibiotics insufficiency from the entire system's viewpoint and analyzing the dynamics into this system. By looking into how the factors affect each other and affect the availability of the end product, this work aims at providing an analysis on the important issues that decision makers should look at. The issues in antibiotics supply constitute the dynamics of the system, and these are mapped, analyzed then quantitatively and qualitatively modelled.

To help understand the causal relationships between the factors and the core problem, a causal loop diagram (CLD) has been used. The function of the causal loop diagram is to map out the structure and the feedbacks of a system in order to understand its feedback mechanisms. The CLD is used to understand how a behavior has been manifesting itself in the antibiotics SC system so we can develop strategies to work with, or counteract the behavior (Haraldsson 2004). It helps understanding the effect of the identified factors on the shortage of antibiotics and thus guide decision makers on how to mitigate them and prioritize based on their influence. CLD will be the base for building a simulation model. In this study, the causal loop provides whether one factor has a positive or negative impact and the SD model is built on this causal loop to quantify how much these factors influence negatively and positively on the core issue. SD simulation has been chosen for this study because the model analyses the dynamic behavior of the system and it can be used for identifying causal structures and for simulating the qualitative and quantitative output of a system in various what-if scenarios with different initial values.

The causal loop model developed in this study illustrates all feedback mechanisms that are in play in the case study of the antibiotics SC system with respect to the core issue: the antibiotics shortage. When a causal link demonstrates a reciprocal relationship, a feedback loop was created. Each feedback loop was evaluated with regards to its polarity. A positive polarity refers to a reinforcing relationship, meaning that this factor is increasing the antibiotics shortage and a negative polarity refers to hindering relationship, meaning that the factor is decreasing the shortage (or increasing the availability, which we want). Our use of this SD model enabled us to identify the complex interplay of factors that affect antibiotics availability on the market and explain why the case study of antibiotics SC no longer supported this shortage. The lack of transparency and inter organizational coordination among the different actors in addition to the current competitive structure of the antibiotics system form an adverse feedback loop or a vicious cycle that enhances the antibiotics shortage on the market. This study demonstrates the critical importance of leveraging policies that encourage information sharing between organizations when stockouts occur involving all actors in the antibiotics SC system.

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