Coupling discrete-event simulation and multi-objective optimization of a pharmaceutical supply chain

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Introduction

A pharmaceutical supply chain (PSC) is a demand-driven system, that provides medicines covering every activity from new product development to delivery to the hospital, retail pharmacy or patient. Its key features distinguish it from other supply chains:

- Most drugs involve primary active ingredient (AI) production generally with multi-stage chemical synthesis and secondary (formulation) production. Both stages are characterized by low manufacturing velocities and require the need for quality assurance.
- Drugs are considered a strategic commodity. As a product linked to the health of the population, any disruption in its supply chain can cause a severe crisis.
- Supplying and distributing medicines in the right amount, at right time and in the right place are among the most significant considerations when managing this supply chain (Goodarzian 2020). This is a very sensitive supply chain where anything less than a 100% customer service
- level (CSL) is unacceptable because of the direct impact on health and safety.

In this supply chain inventory management and distribution constitute a crucial issue since unsuitable management strategies for health care industries may lead to large financial losses and a significant impact on patients (Uthayakumar 2013). The scientific objective of this work is to propose a methodological framework to model and optimize a PSC targeting inventory optimization.

Methodology

The methodology is based on a two-tier approach involving:

1. Discrete-event simulation as a modeling approach widely used in decision support tools for logistics and supply chain management: it has been selected here to model the dynamic behavior of the PSC given the versatility and effectiveness of the method demonstrated in several issues, in particular to address the dependencies of the different building blocks of the network and to analyze supply chain performance (Cigolini 2014).
2. Genetic algorithms (GA) as an outer optimization loop used in combination with discrete-event simulation. This kind of algorithm has demonstrated its efficiency in a broad range of engineering complex problems where the use of mathematical programming approaches has reached its limits. GAs have been successfully implemented to define the optimal inventory policy in stochastic multi-product inventory systems (Jackson2018), among others.

The approach has been implemented in the SIMIO Simulation Modeling framework based on Intelligent Objects. This object-based modelling environment is both process and event-oriented, and allows modelling both discrete and continuous systems. The choice was also motivated by the integration of optimization applications such as OptQuest, which includes a library of genetic algorithms.

The support of the methodological framework is a generic yet fictitious supply chain determined from an investigation carried out by the FusionOps group (Allen, 2016) through big data analysis.

The methodology of this study is as follows:

1. Interpretation of data and statistics for inventory modeling, procurement, demand, transportation lead time, etc.
2. Based on the interpretation of the data modeling by means of the SIMIO software for each link of the supply chain, modelling of the PSC.
3. Use of the OptQuest tool to optimize the supply chain and maximize the level of demand fulfillment while minimizing inventory metrics.
4. Analysis and comparison of results.

Figure 1 represents the average PSC and its echelons from inventories, quality processes, manufacturing processes and transportation. The model is formulated as a bi-objective approach in which the objective functions are the maximization of the service level while and the minimization of the inventory levels.

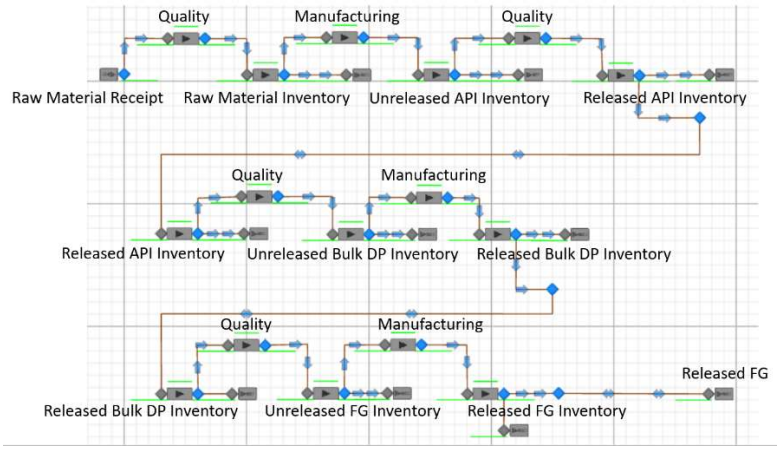

Figure 1 Supply chain diagram modeled in SIMIO

Conclusions

This study aims to study the operation of a pharmaceutical supply chain through an approach combining modelling and optimization. The use of these tools can be an effective aid to scenario development and system resilience. The design of this type of supply chain considering uncertainty is a logical extension of this work.

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