Stockout Risk of Production-Inventory Systems with Compound Poisson Demands

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Production-inventory systems with continuous production or continuous manufacturing have been implemented in a variety of manufacturing contexts. Most recently, the Commissioner of the FDA has called on drug and biological product manufacturers to begin switching from batch manufacturing processes to continuous production. Motivated by prevailing applications and the emerging and promising landscape in the healthcare and pharmaceutical industries, this paper studies a continuous-review production-inventory system with a constant production rate and compound Poisson demands, in which the cost of the system is assessed via inventory holding, stockout penalty and production costs. For any initial inventory, we derive a closed-form expression for the expected discounted cost function until stockout occurrence. We systemically quantify the stockout risk on four different dimensions (i.e., *time, volume, frequency* and *percentage*) and derive explicit expressions for each type of risk metric. The objective is to derive the production rate that minimizes the expected discounted system cost subject to a given risk tolerance level on stockouts. With the aid of the derived explicit forms of stockout risk and the cost function, we develop a computationally-efficient algorithm for the optimal solution. Extensive numerical studies are conducted to illustrate our results with rich insights. Numerically, we show that it is outrageously costly to reduce stockout risk, especially when this risk is relatively low; the value of risk is more sensitive to the stockout risk level if the demand distribution has a higher volatility.

Key words: Pharmaceutical manufacturing, drug shortage, production-inventory systems, continuous manufacturing, stockout risk, risk metrics.
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1. Introduction

Production-inventory systems with continuous production or continuous manufacturing have been commonly implemented in a variety of manufacturing contexts, such as oil refining, metal smelting, natural gas processing, steel refining, chemical production, carpet and textile manufacturing, and many others; cf. BioProcess Online, 2016. In the context of pharmaceutics, many pharmaceutical manufacturers are already converting their processes to adopt continuous production, e.g., continuous production of cell-free proteins, nanostructured particles and exosomes; cf. Membrane Separation Technology News (1997), van Ommen *et al*. (2015) and Whitford *et al*. (2015). Most recently, the Commissioner of the FDA has called on drugs and biological product manufacturers to begin switching from batch manufacturing processes to continuous production; cf. Brennan (2015). The development and implementation of such manufacturing technology based on continuous production can overcome many chronic limitations (e.g., lowering cost and improving quality). Accordingly, *Integrated Continuous Manufacturing* (ICM) will be the ultimate goal for this industry.