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Achieving sharp deliveries in supply chains through variance pool allocation

D. Garg [a], Y. Narahari [a,*], N. Viswanadham [b]

[a] *Electronic Enterprises Laboratory, Computer Science and Automation, Indian Institute of Science, Bangalore 560 012, India*
[b] *The Logistics Institute Asia Pacific, National University of Singapore, Singapore 119 260, Singapore*

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Abstract

Variability reduction and business process synchronization are acknowledged as key to achieving sharp and timely deliveries in supply chain networks. In this paper, we develop an approach that facilitates variability reduction and business process synchronization for supply chains in a cost effective way. The approach developed is founded on an analogy between mechanical design tolerancing and supply chain lead time compression. We first present a motivating example to describe this analogy. Next, we define, using process capability indices, a new index of delivery performance called *delivery sharpness* which, when used with the classical performance index *delivery probability*, measures the accuracy as well as the precision with which products are delivered to the customers. Following this, we solve the following specific problem: how do we compute the allowable variability in lead time for individual stages of the supply chain so that specified levels of delivery sharpness and delivery probability are achieved in a cost-effective way? We call this the variance pool allocation (VPA) problem. We suggest an efficient heuristic approach for solving the VPA problem and also show that a variety of important supply chain design problems can be posed as instances of the VPA problem. One such problem, which is addressed in this paper, is the supply chain partner selection problem. We formulate and solve the VPA problem for a plastics industry supply chain and demonstrate how the solution can be used to choose the best mix of supply chain partners.

Keywords: Supply chain management; Lead time reduction; Variability reduction; Process capability indices; Statistical tolerancing; Variance pool allocation (VPA)

* Corresponding author. Tel.: +91 80 2293 2773; fax: +91 80 2360 2911.
E-mail addresses: dgarg@csa.iisc.ernet.in (D. Garg), hari@csa.iisc.ernet.in (Y. Narahari), mpenv@nus.edu.sg (N. Viswanadham).

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1. Introduction

Businesses today operate in a very tough environment that is constantly in flux [1,2]. Customers have become increasingly demanding looking for better and innovative goods and services that are specifically customized to meet their unique needs. There is also an implicit requirement on the accuracy, timeliness, convenience, responsiveness, quality and reliability of the service offered to them. And all of this is desired at ever-lower prices. Simultaneously, the rapid pace of innovation has resulted in shorter product and technology cycles, leading to uncertainties in supply and demand. Variability is thus a major issue and variability reduction and business process synchronization are therefore acknowledged as key to achieving superior levels of performance in supply chain networks. This paper proposes an approach inspired by statistical design tolerancing for achieving cycle time compression in supply chains through variability reduction.

One of the key issues in supply chain design, facing companies today is the strategic selection of partners for each stage of their outsourced value chain, in the face of uncertainties of various kinds [3,4]. This selection needs to take into account the synchronization of schedules for suppliers, manufacturers, and logistics providers in order to streamline processes throughout the supply chain. The variability reduction approach presented in this paper focuses on this important problem in supply chain design.

1.1. Contributions

The main contribution of this paper is in suggesting a way of formulating design optimization problems in supply chains by exploiting the connections with statistical design tolerancing. This opens up the use of statistical design tolerancing techniques and tools to be used in supply chain design and optimization. The specific contributions of this paper can be summarized as follows:

1. We first present a motivating example to develop an analogy between mechanical assemblies and supply chain networks. The example shows that the variation in end-to-end lead time of a supply chain can be viewed as the variation in the dimension of the parts produced by a machining process.
2. The above example motivates us to investigate the use of standard design tolerancing techniques (based on process capability indices), that are popularly used for quantifying and reducing the defective assemblies produced by a machining process, for the purpose of quantifying the delivery performance of the supply chain. Using supply chain process capability indices, we describe the delivery performance of a supply chain in terms of two metrics. The first is a traditional metric, *delivery probability* (DP), which is the probability that a typical customer order is delivered during a customer-specified window. The second metric is a new one that we propose, which we refer to as *delivery sharpness* (DS), which is a measure of how close to the target (most desired) delivery date a customer order is actually delivered.
3. The setup above prepares the ground for formulating the following generic design optimization problem for supply chains:

> Given a supply chain and the mean and standard deviation of the end-to-end lead time for a certain product mix, how do we optimally distribute the pool of variance among individual business processes so as to minimize the cost and achieve six sigma delivery performance?

We call this problem as the variance pool allocation (VPA) problem. We come up with a five stage approach for solving the VPA problem. We then look at linear or pipelined supply chains and solve the VPA problem through the Lagrange multiplier method.

4. Finally, we show that a rich variety of supply chain design problems, in particular, the supply chain partner selection problem, can be cast as a VPA problem. We show that the optimal variance of each stage