Decision Support Systems 54 (2013) 1076–1084

Contents lists available at SciVerse ScienceDirect

Decision Support Systems

journal homepage: www.elsevier.com/locate/dss

Managing supplier delivery reliability risk under limited information: Foundations for a human-in-the-loop DSS

Roberto Pinto [a,*], Tobias Mettler [b], Marco Taisch [c]

[a] CELS, Department of Engineering, University of Bergamo, Viale Marconi 5, 24044 Dalmine (BG), Italy
[b] Institute of Information Management, University of St. Gallen, Müller-Friedberg-Strasse 8, CH-9000 St. Gallen, Switzerland
[c] Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Viale Lambruschini 4/b, 20156 Milano, Italy

ARTICLE INFO

Article history:
Received 23 November 2011
Received in revised form 26 July 2012
Accepted 21 October 2012
Available online 1 November 2012

Keywords:
Delivery reliability
Distribution-free
Human-in-the-loop DSS
Supply risk mitigation
Limited information

ABSTRACT

The potential impact of suppliers' delivery reliability issues in many industries requires a proper decision support system (DSS) that allows decision makers to analyze and reduce the delay's detrimental effects. Despite the relevance of the topic, companies are often confronted with the lack of historical, quantitative data and knowledge about a supplier's performance (i.e., when selecting a new supplier). In this paper, we address the problem of the scarcity of quantitative data by considering and extending the human-in-the-loop DSS concept, which accounts for an expert's knowledge and experience. In our concept, a human expert is involved in making and revising data provided by a computational model, with the aim of supporting companies in making decisions when dealing with unreliable suppliers, in order to minimize the costs related to external discontinuities. To deal with scant quantitative data, we developed a distribution-free model. Our findings positively support the distribution-free approach as an effective tool to be used when only a limited and perhaps unstructured base of data is available. The presented computational model aims at creating a solid foundation for developing a comprehensive human-in-the-loop decision support system.

1. Introduction

Recently, *delivery reliability* has shifted from an order winner to an order qualifier factor in many manufacturing and service industries [11], thanks to the wide diffusion and consolidation of operations paradigms, such as just-in-time and quick response distribution [7,26]. In extended, complex, and highly collaborative supply chains, suppliers' delivery reliability – a specifically operational performance measure – is strongly affected by strategic and tactical decisions, such as selecting the “right” suppliers for conjoint design, development, manufacturing, and distribution. In fact, seeking the timeliness of all operations since the network design stage is of paramount importance when a large part of the production is outsourced. In this respect, suppliers are often perceived as a source of delay risk, affecting the company's delivery reliability either directly or indirectly [9,27].

The potential impact of the suppliers' delivery reliability problems in many production industries requires a proper decision support system (DSS) to help in analyzing and reducing the delay's detrimental effects. Such a support system must be able to deal with highly complex environments, where both qualitative and quantitative elements play a substantial role.

Nonetheless, considering the quantitative perspective, companies are often confronted with the lack of historical, quantifiable data and information about a supplier's previous performance; thus, in today's volatile business environment decisions usually have to be based on incomplete or even non-existent information. Focusing on the delivery reliability dimension, for example, distributional information on the earlier delivery performance of a supplier may be limited or missing (i.e., in the case of a new supplier). Sometimes, such a lack of numerical data is compensated for by an educated guess of the mean and the variance of the data distribution. According to Moon and Yun [18], under these conditions the tendency is to use normal distribution in the computational models, even though such an assumption does not provide the best decision in cases when other probability distributions with the same mean and variance occur.

Furthermore, although DSS can assist decision makers in acquiring data, information, and knowledge regarding products, services, suppliers, and customers, not all of the possible factors behind an optimal decision can be algorithmically implemented, due to the complexity or the nature of the factors themselves. This aspect emphasizes the role and contribution of a human expert in integrating qualitative knowledge into the decision process.

Considering the relevance of the supplier's delivery reliability dimension and the scarcity of contributions to this topic, the purpose of this paper is to investigate the feasibility of an architecture for a DSS that supports decision makers in dealing with delivery delay risks when the available information about a supplier's performance

* Corresponding author. Tel.: +39 035 205 2044.
E-mail addresses: roberto.pinto@unibg.it (R. Pinto), tobias.mettler@unisg.ch (T. Mettler), marco.taisch@polimi.it (M. Taisch).

0167-9236/$ – see front matter
http://dx.doi.org/10.1016/j.dss.2012.10.033

is limited to the mean and the standard deviation (or their educated guess).

Specifically, we strive to address the following research questions:

- How is it possible to mitigate the delay risk? How may computational models support the decision maker when no historical knowledge of the supplier's performance is available?
- How can the computational model developed for delay risk mitigation be implemented within a DSS and integrated with qualitative information?

We see our contribution as a possible foundation for developing a *human-in-the-loop decision support system* (HIL-DSS), allowing quantitative data to be complemented with qualitative information provided by a human expert. In order to answer the proposed research questions, the remainder of the paper is organized in five sections: the next section explores the role of buffers in reducing delivery delays in manufacturing sectors. Then, we delineate the scenario in which we developed and tested the computational model. The computational results are discussed in the following section, along with an outline of the integration of qualitative information. Finally, we present our conclusions and recommendations for future research.

2. Background

The on-time delivery of products and services is still recognized as a key success factor for competition in many manufacturing and service firms [2,6,23]. Make-to-order (MTO) companies, in particular, are highly sensitive to potential problems that might influence delivery reliability performance, as discussed in the next section.

2.1. The delivery delay domino effect

Delivery reliability issues might originate from internal problems, both in the production stage (i.e., machine breakdown, lack of human resources, workforce absenteeism, missing materials) and in the planning process (i.e., errors in planning and scheduling decisions, selection of an unreliable supplier), leading to shortages of the final products and the impossibility of fulfilling customer demand. Nonetheless, it is important to highlight that a company's delivery reliability is not an exclusively internally determined performance. In fact, in a multi-tiered supply chain, the performance of an actor almost inevitably impacts the performance of the following ones; for example, a delay in delivery from supplier A to company X might jeopardize the delivery reliability of X with respect to its customer E and, eventually, to its end customer F (Fig. 1). According to this "domino effect," one's performance should contemplate his/her suppliers' performance.

According to Nieuwenhuysea and Vandaele [19], "it is desirable from the buyer's point of view that the arrival of the ordered material can be predicted as accurately as possible, such that the start times of the production runs can be planned with a high level of certainty, and rescheduling efforts (due to material arriving too early or too late) can be restricted to a minimum." Such an aspiration is hardly achievable if delivery delays are not controlled from the beginning: in fact, if delivery reliability problems propagate through the supply chain without control, a short delay in the first tier might result in a dramatic delay to the final customers, leading to a kind of "reversed" bullwhip effect [14] from the upper links of the chain downstream to the final links.

According to the scenario depicted in Fig. 1 and described above, in the rest of this paper we assume the perspective of company X, whose objective is to mitigate the effects of supplier delay.

2.2. Managing delivery delay risk: the role of buffers

Due to the potential impact of suppliers' delivery reliability problems, different countermeasures, such as process and product flexibility, and redundancy and supplier collaboration, for example, can conceivably halt the propagation of delivery delays and reduce the consequent detrimental effects. In our research, we focus on the use of redundancy based on buffers, since they represent one of the most common backup solutions adopted by companies aiming at reducing the impact of delays in the inbound flows. Indeed, the "variability in a production system can be buffered by some combination of inventory, capacity, and time" [12]; such a *variability buffer law* is considered one of the pillars of risk management and, thus, adopted here. Moreover, buffers generally do not affect the inter-organizational supplier–buyer relationship (the supplier might not even know about the presence and the entity of the buffer at the customer's site); instead, they are meant to have a direct effect on the demand side, providing continuity of operations.

Perhaps one of the most intuitive forms of buffering is represented by inventory, but it is also possible to buffer the effect of delays by using time and capacity buffers, in order to ensure the continuation of the business and on-time delivery to customers [1,8,24,28].

Buffers represent a cost that must be carefully managed. Building a buffer generally involves an upfront payment for resources that might or might not be used in the future. Therefore, the entity (i.e., size) of the buffer must be consciously defined, balancing the benefits and drawbacks of buffers that are too large or too small.

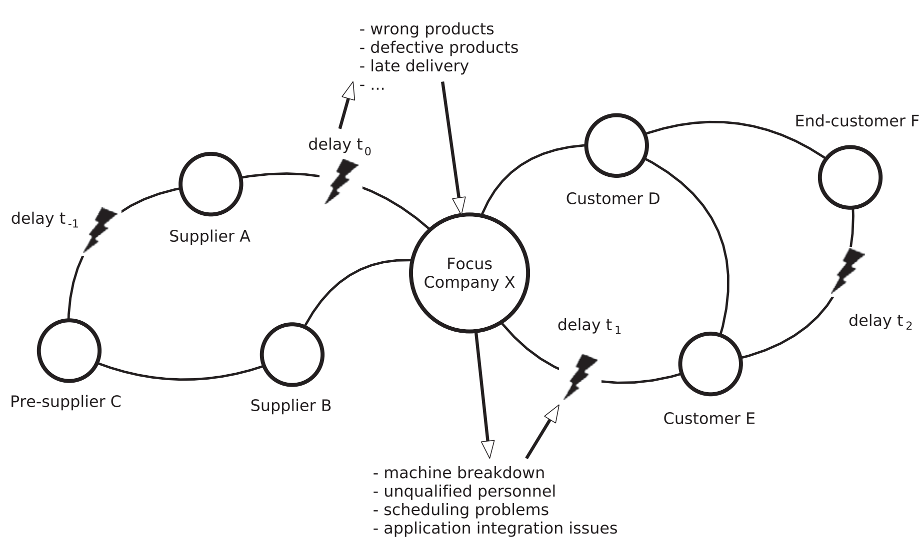

Fig. 1. Domino effect due to deliver reliability problems.