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Application of a Fuzzy Feasibility Bayesian Probabilistic Estimation of supply chain backorder aging, unfilled backorders, and customer wait time using stochastic simulation with Markov blankets

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ABSTRACT

Because supply chains are complex systems prone to uncertainty, statistical analysis is a useful tool for capturing their dynamics. Using data on acquisition history and data from case study reports, we used regression analysis to predict backorder aging using National Item Identification Numbers (NIINs) as unique identifiers. More than 56,000 NIINs were identified and used in the analysis. Bayesian analysis was then used to further investigate the NIIN component variables. The results indicated that it is statistically feasible to predict whether an individual NIIN has the propensity to become a backordered item. This paper describes the structure of a Bayesian network from a real-world supply chain data set and then determines a posterior probability distribution for backorders using a stochastic simulation based on Markov blankets. Fuzzy clustering was used to produce a funnel diagram that demonstrates that the Acquisition Advice Code, Acquisition Method Suffix Code, Acquisition Method Code, and Controlled Inventory Item Code backorder performance metric of a trigger group dimension may change dramatically with variations in administrative lead time, production lead time, unit price, quantity ordered, and stock. Triggers must be updated regularly and smoothly to keep up with the changing state of the supply chain backorder trigger clusters of market sensitiveness, collaborative process integration, information drivers, and flexibility.

1. Introduction

The importance of supply chain management in today's military cannot be overemphasized. The Defense Logistics Agency (DLA) seeks to resolve a continually growing list of problem parts for the war effort and military readiness. It requires a streamlined and proactive approach to resolving problems with needed parts to reduce the long-term costs of maintaining the readiness of DLA-supported weapons systems. This paper presents an empirical study of the determinants of backorder aging for the Battlefield Breakout Backorder Initiative (B3I), a DLA supply chain system. We discuss the effects of the flow of material, information, and finance through the main supply chain agents of supplier, manufacturer, assembler, distributor, retailer, and customer.

DLA uses a multi-echelon supply system to make items available to the operational community. When this supply system is unable to satisfy demand, a backorder is created, indefinitely extending the customer wait time for that item. Backorder aging is affected by many factors associated with the item's demand and procurement history and by past support funding and the economics of suppliers. To improve the responsiveness of its supply system, DLA is seeking innovative, nontraditional ways of more quickly resolving backorders (and thus reducing customer wait time). DLA has created the B3I to research, develop, test, and evaluate policies, procedures, processes, tools, and methodologies to reduce the backorder aging problem for critical war-fighter supply items.

In addition, DLA is seeking ways to analyze supply chains as well as the factors that affect supply and demand to predict and address potential backorder problems before they occur. As part

Abbreviations: AAC, Acquisition Advice Code; ALT, administrative lead time; AMC, Acquisition Method Code; AMSC, Acquisition Method Suffix Code; B3I, Battlefield Breakout Backorder Initiative; BLS, birth to last shipment; CIIC, Controlled Inventory Item Code; COTS, Commercial Off The Shelf; DLA, Defense Logistics Agency; NIIN, National Item Identification Number; NP, Non-deterministic Polynomial-time; NSN, National Stock Number; PHDM, Procurement History Data Mart; PLT, production lead time; RHDM, Requisition History Data Mart; SCBORT, supply chain backorder trigger.

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of this initiative, we developed a mechanism that can be embedded in the requisition process to identify items with a potential to become backordered, even before orders are placed. With this type of predictive tool available to them, DLA personnel are able to more efficiently and effectively address the problem of backorder creation, thus freeing up critical items for military personnel.

DLA supports the armed services by supplying a wide range of food items, medical items, construction and industrial materials, fuels and lubricants, clothing and textile items, and repair parts for weapons systems and associated equipment. When a military organization needs items, it requests (requisitions) them from DLA. DLA supports such requests by procuring and storing items in defense depots (stocking) and then shipping the items from the depots (issuing) to the organization requesting them or letting contracts with vendors who, when instructed by DLA, ship directly to the organization requesting the item. DLA thus manages more than 5.2 million items. Each day DLA responds to more than 54,000 requisitions, lets more than 8200 contracts, and performs contract actions such as delivery orders and modifications (Defense Logistics Agency, 2012).

To manage the procurement, stocking, and issuance of these 5.2 million items, DLA employs 21,000 people and uses an information technology system known as its Business System Modernization system. This system handles the full range of DLA business functions from procurement, to inventory management, to finance. DLA is not able to stock all items, and those items it does stock (or the items for which it sets up contracts for direct delivery) may not be fully stocked at levels that will satisfy all requisitions at any given time. This may be because of funding constraints or an inability to accurately forecast the demand for items. When DLA experiences stock outages (i.e., when a customer requisitions items but DLA is unable to fulfill all or even part of the requisition), that requisition is labeled as being "on backorder," which increases customer wait time. The total time necessary to procure and ship items can be broken down into two component times: the time needed to procure the item (administrative lead time [ALT]) and the time required to produce and deliver the item (production lead time [PLT]). Accurately predicting the total lead time (the sum of ALT and PLT) is as important to successfully maintaining inventory as predicting demand, particularly for replenishment items. The number of backorders is one key metric used by DLA to measure the performance of the order fulfillment aspect of its system and is monitored by the highest levels of management. Backorder reduction is thus a continued focus of attention from DLA management.

In this paper, we use real-world data to determine the structure of a Bayesian network. We then use stochastic simulation based on Markov blankets to determine the distribution of backorders. Fuzzy logic is used to produce a funnel diagram that demonstrates that the Acquisition Advice Code (AAC), Acquisition Method Suffix Code (AMSC), Acquisition Method Code (AMC), and Controlled Inventory Item Code (CIIC) backorder performance metric of a trigger group dimension may change dramatically with variations in ALT, PLT, unit price, quantity ordered, and stock. Triggers must be updated regularly and smoothly to keep up with the changing state of the supply chain backorder risk trigger (SCBORT) supply chain clusters of market sensitiveness, process integration, information drivers, and flexibility. The rest of the paper is organized as follows. In Section 2, we present the theoretical background and previous research on supply chain management. In Section 3, we describe the theoretical framework and hypotheses. In Section 4, we introduce the research design, data collection, and operationalization. In Section 5, we provide the results of the experiments. In Section 6, we conclude the paper with a summary and directions for future work.

2. Theoretical background and previous research on supply chain management

2.1. Research method and supply chain management

2.1.1. Research methodology

Backorder risk trigger evaluation of a supply chain is a complex task and research on this topic is still in its infancy. The significance of our research is that we are attempting to quantify the benefits of a Fuzzy Feasibility Bayesian Probabilistic Estimation model. This research method was the first to develop Fuzzy clustering to produce a funnel diagram that demonstrates that the Acquisition Advice Code, Acquisition Method Suffix Code, Acquisition Method Code, and Controlled Inventory Item Code backorder performance metric of a trigger group dimension may change dramatically. Because the choice of methodology is the most important factor necessary to identify the correct solution to a particular research problem, the collection and analysis of empirical data is being used in this research. Empirical data analysis will be beneficial to understand the role of the five trigger probability metric performance dimension groupings that include engineering issues, obsolescence issues, disruption of demand planning issues, NSN-specific unique sustainment problems, and cataloging issues in performance of the supply chain and the identification of backorder risk triggers. Our research methodology is employed to demonstrate that basic backorder information, such as the performance metric of a trigger group dimension, may change dramatically with variations in ALT, PLT, unit price, quantity ordered, and stock. Triggers must be updated regularly and smoothly to keep up with the changing state of the supply chain backorder risk trigger (SCBORT) supply chain clusters of market sensitiveness, process integration, information drivers, and flexibility. For this purpose, we have chosen to investigate 56,000 items from the Aerospace Industry. Our research method describes the structure of a Bayesian network from a real-world supply chain data set and then determines a posterior probability distribution for backorders using a stochastic simulation based on Markov blankets. Fuzzy clustering is used to produce a funnel diagram. To initialize the Bayesian network process, the basic mathematical approach used is outlined in Section 3.2.

A discussion of our contribution compared to the current relevant literature will be endeavored by making an explicitly clear list what is new in this study which has not been done by previous studies. Moreover, this list will make a direct connection between ESWA and our paper by clearly discussing the research contributions to ESWA-related works.

Our first contribution extends the work of Lee, Park, and Shin (2009) in which they used a Bayesian belief network to investigate risk in a large engineering project. Our paper extended the understanding of risk management by introducing trigger risk dimensions that may change dramatically and must be updated regularly and smoothly to keep up with the changing state of the supply chain.

A second contribution is introduced by a comparison with the study of Hanafizadeh and Sherkat (2009). Their fuzzy-genetic learner model allowed for the adaptation of plans to real conditions for decision making. Our paper extends this concept by introducing a fuzzy clustering algorithm that was used to produce a funnel diagram that demonstrates that the Acquisition Advice Code, Acquisition Method Suffix Code, Acquisition Method Code, and Controlled Inventory Item Code backorder performance metric of a trigger group dimension may change dramatically with variations in administrative lead time, production lead time, unit price, quantity ordered, and stock.