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Transportation Research Procedia 18 (2016) 164 – 171

Transportation Research Procedia

www.elsevier.com/locate/procedia

XII Conference on Transport Engineering, CIT 2016, 7-9 June 2016, Valencia, Spain

Intelligent Approach to Inventory Control in Logistics under Uncertainty Conditions

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Abstract

The article presents a proposal for a combined application of fuzzy logic and genetic algorithms to control the procurement process in the enterprise. The approach presented in this paper draws particular attention to the impact of external random factors in the form of demand and lead time uncertainty. The model uses time-variable membership function parameters in a dynamic fashion to describe the modelled output fuzzy (sets) values. An additional element is the use of genetic algorithms for optimisation of fuzzy rule base in the proposed method. The approach presented in this paper was verified according to four criteria based on a computer simulation performed on the basis of the actual data from an enterprise.

Peer-review under responsibility of the organizing committee of CIT 2016
Keywords: inventory control; artificial intelligence, optimisation methods, logistics systems

1. Overview of inventory management issues

As a result of the on-going globalisation and mass consumption, the demand on the goods market is characterised by intense dynamics and a certain level of uncertainty, especially in large agglomerations and urban areas. The logistical processes that occur there as part of supply networks focus primarily on the flow of the streams

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Peer-review under responsibility of the organizing committee of CIT 2016
doi:10.1016/j.trpro.2016.12.023

of material goods, but also take into account the flows of necessary information and financial resources. The volatility of these processes and certain level of uncertainty cause all sorts of inventory to amass at various levels of the logistic network in order to ensure the continuity of production and the uninterrupted availability of the finished products to customers. Due to the impact of random factors on the nodal elements of the supply network (manufacturing plants, distribution centres, warehouses, etc.) through the volatility of demand for semi-finished products or finished products, lead time changeability, vendors' limited capabilities, etc., the optimal policy for the supply and inventory control logistics is of utmost importance to the effectiveness of the entire logistic network.

As a result of the above-mentioned factors and the ever-increasing competition among entities, logistics companies are often forced to keep a high inventory level in order to maintain the desired service level. This behaviour makes it possible to dynamically respond to unexpected changes in the demand or other external factors but it generates increased costs at the same time. These are, in particular, associated with the carrying the inventory, leasing additional storage space and freezing the limited financial resources in the inventory. On the other hand, the inventory level that is too low in relation to the stock-keeping units characterised by an unusual demand pattern which are essential for the enterprise can lead to the occurrence of external costs caused by lost resources. They can be expressed as cash but also as a customer loss, lowering the reputation of the enterprise or a loss of its competitiveness. This situation is also conducive to the formation of additional transport costs associated with the implementation of unplanned deliveries.

2. Overview of inventory control solutions

Due to the impact of the aforementioned factors, the optimal inventory control is a complex decision-making process that requires analysis of multiple criteria and parameters, which in practice are usually non-deterministic in nature. The result is that the basic decisions about how much merchandise should be purchased and at what point in time in order to minimise the stocking and stock-carrying costs and meet the established level of customer service are made in conditions of uncertainty. The subject literature, both domestic and international, provides numerous rich sources on the topic of inventory management. The most popular classical methods for determining inventory levels include, first and foremost, the Economic Order Quantity (EOQ) model, the Re-Order Point (ROP) models and Re-Order Cycle (ROC) models (Krzyżaniak, Cyplik, 2007). However, the applicability of these methods is quite limited as it often requires the adoption of limitations on the stationarity of demand or the known and fixed lead time. The extensions of these methods take into account certain variability with regard to the demand or the lead time by introducing an additional parameter in the form of a safety stock, which aims to cover the unexpected changes in the demand (Grzybowska, 2010), (Niziński, Żurek, 2011), (Krawczyk, 2011). In addition to the above-mentioned methods, one may also encounter other control models, such as: the reorder point model using fixed reorder cycles or the combined re-order point and fixed re-order cycle model (Wolski, 2010). Few papers indicate the problem of inventory control in the conditions of demand discontinuity. When dealing with this issue, authors often present methods created by Wagner-Within and Silver-Meal. Compared to the domestic literature, the list of international publications on the subject of inventory control is definitely more extensive and takes into account a greater number of determinants and characteristics of the task being considered (Axaster, 2006), (Lang, 2009), (Nahmias 2010). An important element raised in foreign publications is the simultaneous inclusion of several products in the control models, which is much closer to the reality (Frank, 2009), (Li, Cheng, Wang, 2007), (Maity, 2007), (Maity, 2009). Due to the difficulty of simultaneously taking into account many parameter variables in the analytical models, more and more papers suggest identifying uncertainty through the introduction of a fuzzy environment. Some articles (Mandal, Roy, 2006), (Roy, 2007), (Taleizadeh, 2009), (Hsieh, 2002), (Maiti, 2006), present an approach that assumes that demand, lead time, stock-carrying costs, customer service, etc. are fuzzy values. Due to the great complexity and elaborateness of the problem, researchers have been increasingly proposing the use of genetic algorithms to find optimal solutions to the issue (Taleizadeh, 2013), (Khanlarpour, 2013), (Gupta