Inventory Control in Logistic and Production Networks

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Summary. The implementation of appropriate inventory control rules delivers the logistics operations of organizations a competitive advantage on the market place. This is also true for special types of networked manufacturing supply chains such as production networks which have complex topologies and increased complexity due to their logistic and production processes, information delays and the globalized markets. The paper builds the case of a production network and determines which inventory control policies applied in practice, order points and periodic-reviews, suit most the functions of the production network. Basically the production net consists of four manufacturing units that proceed to the joint development of products. In order to produce the four different items, the manufacturer orders from the other units as well as from the external supplier according to the exogenous customer demand. Although the case portrays a simplified instance of a production net, yet it already exhibits complex non linear dynamics inherent to such systems. The model is simulated with the system dynamics method which demonstrates the aptitude to describe distributed environments as long as product aggregation is permitted. The simulation results derived from the application of the inventory control rules on the production net will allow a detailed assessment of the suitability of each of the policies, in terms of the inventory costs criterion. A discussion on when to implement which inventory rule in respect to the functionalities of the production net will be pursued.

1 Inventory Control

Inventories generate costs whether they are physical inventories like warehouses or virtual ones such as trucks or trains that transport containers for example. It is important to keep these costs low otherwise production will be less profitable. Inventory control is about the minimization of the average cost per time unit while satisfying the incoming demand to the production system. This field started at the beginning of last century boosted by the growth of manufacturers' activities. Inventory control rules are described in the literature [1, 2, 3]. Modern inventory control saw the contributions of tools such as material requirements planning (MRP), its successor manufacturing resources planning (MRP II) and subsequently enterprise

resources planning (ERP), as well as Kanban cards to name a few. Recently RFID yields real time traceability and identification of products. Under this trend novel research examines autonomy in logistic processes [4].

In a production network manufacturers integrate and coordinate the general net production plan to their individual production planning to satisfy customer demand. When the internal complex dynamics of the network, such as production specifications and logistic processes, favour external disturbances, inventory oscillations will gain in intensity. A production network is a form of cooperation between manufacturers and the challenge consists in the integration of the various production plans. Former studies proposed the application of (a) load-oriented or order release control methods and (b) decentralized control loops [5]. These methods follow a black box solution approach.

In this paper the utilization of the inventory control rules is complemented by the modelling of the holistic network and its feedback structures through the continuous system dynamics methodology. Because it considers the entire network, the identification of leverage points where improvement is possible becomes an easier task. Continuous and periodic inventory control rules are applied to the system dynamics model of the logistic and production network in order to find a policy that reduces inventory costs. Costs are occasioned by products on hold and the backlogs of items ordered and not yet available. The latter is charged double the former as a penalty for the risk of customer loss. Under the continuous policies is meant an uninterrupted supervision of the inventory performed by the policies of (a) order point - order quantity (s, Q) and (b) order point - order up to level (s, S). On the contrary periodic review policies take into account constant order intervals. The ones investigated are (a) review period - order quantity (r, Q), (b) review period - order up to level (r, S), (c) review period - order point - order up to level (r, s, S), and (d) order inventory rule. In (d) the order O (1) is a function of the constant reacquisition time L (time between the order is placed and the supply is made), the safety factor z, the average demand d_{avg} (2) as well as its standard deviation during reacquisition d_{std} (3). The demand d_i is assumed to follow a normal distribution with σ_d the standard deviation. P is the length of a static period (one minute in this case).

$$O = (L \cdot d_{avg}) + (z \cdot d_{std} \cdot \sqrt{L}) \tag{1}$$

$$d_{avg} = \frac{d_i + \ldots + d_{i+(L-1)}}{L}, \quad \text{where } i = 1{,}2{,}3 \ldots \tag{2}$$

$$d_{std} = \sigma_d \cdot \sqrt{\frac{L}{P}} \tag{3}$$

2 Production Network

The case (1) describes a production network with four manufacturers, M_i, $i = 1 \ldots 4$, who jointly produce items. The manufacturer has four parallel production lines L_{ij}, $j = 1 \ldots 4$ and each of them produces one dedicated item P_{ij}. The product P_{ij} denotes product j manufactured by M_i. Each line is externally coupled with the production system of the other manufacturers. There is also internal coupling within a manufacturing unit (line L_{12} and L_{14}). A production line has a work-in-process