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DISCRETE-EVENT SIMULATION OF PRODUCTION AND SALES PROCESSES IN A COMPANY

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Abstract

A company, facing growing backorders, repeated failures, complaints and other problems in performance, losses profits and time. Therefore, mangers need to put and solve complex strategic alignment issues concerning how business processes can be improved as well as what results would be achieved by such strategies. Present paper uses customer order decoupling point and inventory control policy as primary managerial tasks for the alignment of production and sales processes. The solution of these tasks ensures production line balance, supports reliable and efficient customer relationships, and, in particular, orders fulfilment. To verify the solutions' ability to shorten costs and sales loss, computer-aided discrete-event simulation is chosen as scenario analysis tool. In the paper, Arena simulation models represent manufacturing system in make-to-stock manner according to customer order decoupling point and implement periodic inventory management policies with backordering and loss of sales, such as line balancing and basic stock, checking threshold, and combination thereof. The models are managerial tool for decision-making, providing verification of business strategies by parametrical study of non-stationary customer demand.

Keywords: Discrete-Event Simulation, Production, Sales, Inventory Management, Problem Solving

INTRODUCTION

Companies have to handle with a variety of challenges in their production and sales processes in fast-changing business environment (Kulkarni and Prashanth, 2012). Managers look for many events and external factors to identify risks and managerial problems. Generally speaking, problems are seen as failures or breakdowns, economic lags, backlogs of orders, gaps between planned and actual values of performance indicators, collection of criteria and alternatives, separated knowledge, and different constructions and perceptions of "real world", etc. (Hicks, 2004). During control of economic facilities managers declare often that a problem has arisen at a situation, when they regard facility's state as abnormal, unacceptable or undesirable, and see that indicators of efficacy, effectiveness and efficiency are below the necessary or expected level. This type of problems might be called as "negative problem". If system saves its good or normal state that was previously defined so that it caused mainly unreasonable rising of the objectives of system's activity, then agents deal with the type of "positive problem". The first type of problems usually leads to losses of profit due to expenses for elimination of mismatches, while the second type may cause losses owing to large expenses for conformance to excessive objectives. The lack of sophisticated problem-solving approaches, techniques and tools restrains company's ability to tackle crucial issues and tasks at the right time and the lowest cost under rapidly changing customer demand.Many researchers consider computer simulation is one of the well-known efficacious tools for problem solving.

Understanding of complex problems, their roots and effects on performance and ready deliveries requires "what-if" scenarios that can be supported by simulation techniques (Robinson, 1994). It is important to synchronize business processes and align corresponding strategies of marketing, production, sales and logistics. First of all, managers have to consider company's production and sales processes from push/pull views of logistics and Customer Order Decoupling Point, CODP, and types of production system (van der Vorst, Beulens and van Beek, 2005). Also they need to choose or modify inventory policies, e.g. (R,Q), (s,Q), (s,S), (R,S), (R,s,S) etc., and set parameters for them that would lead to balancing production line and inventory and decreasing costs, and meeting customer demand (Axsäter, 2007; Estelles-Miguel et al; Rabta and Aissani, 2005; Rosetti et al, 2008; Wisner et al, 2008). Simulation techniques can help to overcome such challenges due to selective or combined applying of a wide variety of business approaches, policies and strategies and keeping other specifics of production and sales processes in dynamic non-stationary environment.

So, it's important to find out, which inventory management policies should be selected for the manufacturing system under varying customer order flow at planning period. Because of non-stationary order flow and unstable operations mode, the policies cannot contain constant values of parameters, which indicate when and how much to produce goods to fulfil new orders, backorders, and replenish stock.

Thus, this study is devoted to verification of system capacity and selective or combined inventory management policy responsible for alignment of production and sales processes, ensuring line balance, lowest inventory costs and loss of sales. The paper proposes utilizing simulation techniques and tools for scenario analysis.

Therefore, study’s objectives are to develop discrete-event simulation models of production and sales processes for make-to-stock manufacturing system, based on the principles of basic stock and threshold checking, incorporating sales patterns.

METHODOLOGY

Computer-aided discrete-event simulation belongs to the main techniques for problem understanding and solving as well as decision support at strategic and operational level under complexity and uncertainty (Kleijnen, 2005). It possesses events, workflows and performance measures and so it has a broad application, for example (Robinson, 1994):

- System configuration (allocation of business units) that makes possible a validation of structure and workflow control strategy.
- Process improvement and optimization of facilities in order to assess decisions in accordance with aspects of reliability, effectiveness, efficiency and quality.
- Working out measures for business process management to solve problems and make decisions under different events (scenarios) and external impacts.
- Synchronization of material flows and removal of bottlenecks.
- Operational control and scheduling through assignment and visualization of jobs, resources allocation and covering of resource shortages.
- Staff training by the creation and using of learning stands.

This method is used to analyse order fulfilment and inventory replenishment in the context of efficient customer demand meeting. For example, Badri's (1999) simulation model represents periodic review policy and reorder point for inventory replenishment in conditions of unstable demand. Levels, such as backlog of orders and inventory of goods, are presented as variables and counted by running simulation model (Lee at al., 2002).Kristianto, Helo and Takalo (2010) used discrete-event simulation to analyse safety stock and throughput for manufacturing process design, grounded on customer order decoupling points. Computer-aided simulation of production/inventory system in «Arena» software was presented by Altiok and Melamed (2010). Inventory policy in their model prescribes that if stock level up-crosses target level, then production stops, and if stock level is less than or equal to reorder point, then production starts.

RESULTS

Line balancing and basic stock

Managers choose inventory management strategies and coordinate with the structure of business processes. First alternative strategy is more similar to basic stock method or ($\mathrm{R,S}$) policy, which is characterized by replenishment cycle R and order up to level S (Estelles-Miguel, 2013; Wisner, 2008), without backordering (only loss sales). The simulation model uses time intervals $\tau r(t)$ between initiations of production and planned volumes of output VPR_t,excluding request queue OQ_t (backorders). This is the background for discrete-event model of production and sales processes with periodic review policy for line balancing– DEM.1.

When request for product output comes at time ts, it gets into the first state $i1$ (Request has been generated). Further it passes through the states $i2$ (Request is in progress) and $i3$ (Request has been executed): $i(t) \in i1 \vee i2 \vee i3$.One more prescribed time interval in the model is manufacturing lead time $TP(t)$, which can be either constant or variation. When a manufacturing request gets into third state ($i \in i3$), it induces further updating of stock and right after that nulling of production volume. Similarly, customer order gets into the states $j1$ (Order has been arrived), $j2$ (Order is in progress) and $j3$ (Order has been fulfilled): $j(t) \in j1 \vee j2 \vee j3$. Time intervals between two sequential order arrivals $\tau o(t)$ and a batch of orders bo_t specify the flow of customer orders, and quantity VO_t^j ($j \in j1$) is not fixed and assigned to each order.

Decision about accepting or refusal of customer order, as it's formulated in(1), depends on whether there is sufficient reserve of merchandise or not. The checking of this condition takes a sum of quantity of product in a new customer order $OF_t^{j \in j1}$ and quantity of product, dedicated to execution of previously accepted orders $OF_t^{j \in j2}$, but unfilled yet.

$$DSOA = \begin{cases} \text{yes} \;\; if \;\; I_t \geq OF_t^{j \in j1} + \sum_{j \in j2} OF_t^{\,j}, \\ \text{no, else.} \end{cases} \qquad (1)$$

If there is a shortage of product ($DSOA = \text{"no"}$), a new order leaves the system, and company counts up lost orders (LO). Otherwise, this order is accepted and its volume is recorded to database and sent for production control (variable $OF_t^{j \in j2}$).When customer order j is at the end of execution that means its state transition from $j2$ to $j3$ and stock's decrease by $OF_t^{j \in j2}$, value of variable $OF_t^{j \in j2}$ is recorded for $OF_t^{j \in j3}$ and after it becomes zero.

DEM.1 may assist with the problem of performance coordination for the avoidance of merchandise shortage. It determines such performance indicators, as expected sales, volume of lost orders, and dynamics of stock level, production and sales systems utilization, costs and lost revenue. Advanced variant of the model allows both backorders and lost sales (DEM.1A). More modifications of these models are concerned with priorities of orders, queue disciplines, the order book and other attributes of the customer service, production and logistics processes.

Checking threshold

The second version of discrete-event model of production and sales processes DEM.2 unlike DEM.1 realizes (s,Q) or (s,S) inventory policy, but also corresponds to loss system type. Signal y_t to start produce in VPS_t amount is generated in (2), if inspection of stock level I_t indicates that it is equal or less a threshold level $P(t)$.

There are regular or irregular ways of inspections with intervals $\tau c(t)$:

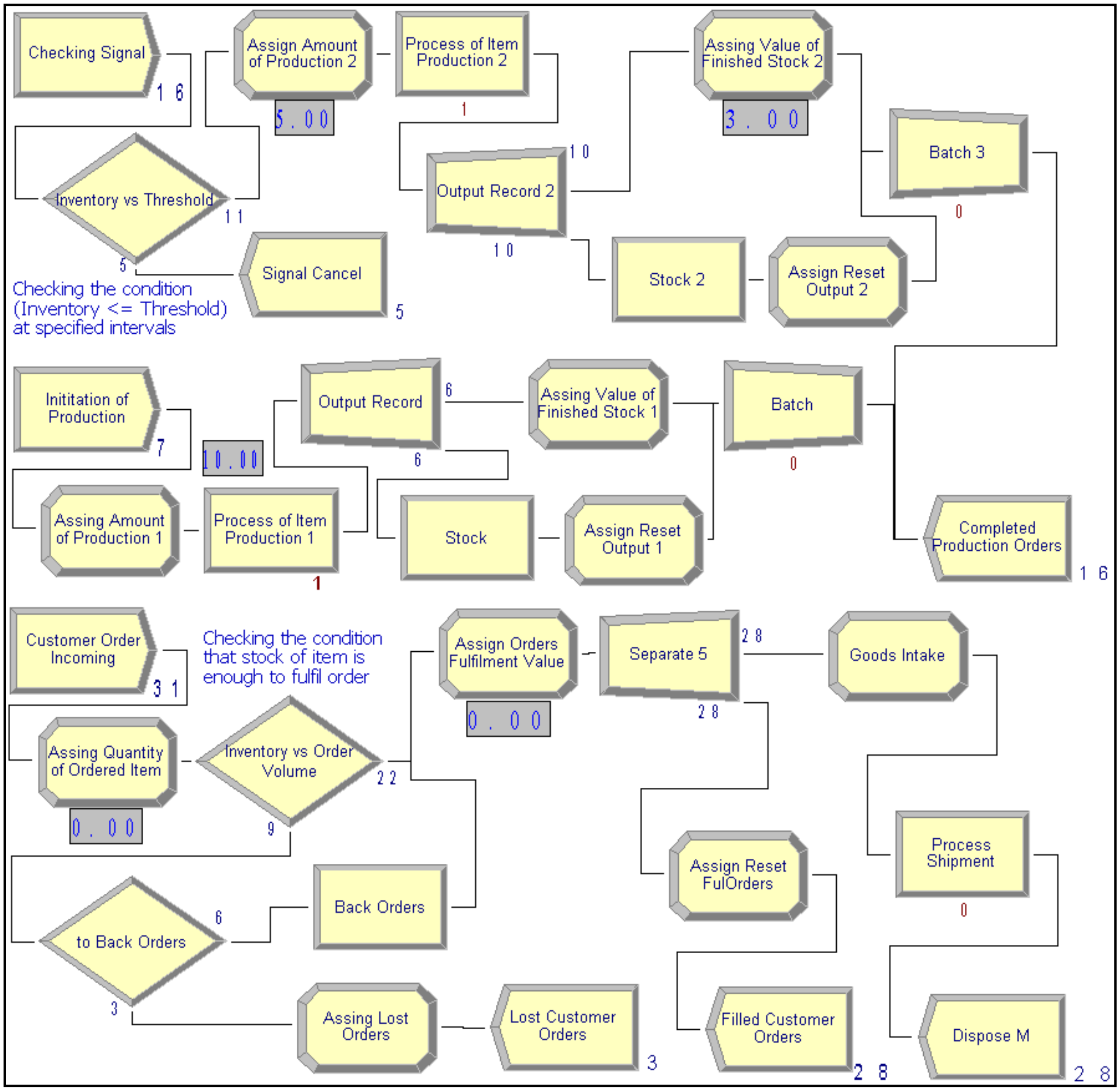
$$y_t = \begin{cases} 1 & \text{if} \quad I_t \le P(t) \\ 0 & \text{else} \end{cases} \quad \forall t_k = t_{k-1} + \tau c(t) \quad . \qquad (2)$$

Concerning variants of the model, there is flowchart of the single location inventory control activities, applied by Rosseti and Tee (2001) as a basis for their Arena simulation model, which admits backorders accumulation.

Combined strategies

There is the diagram of discrete-event model of production and sales processes (DEM.3) in Figure 1, built in «Arena». The model is grounded on «Make-to-Stock» manufacturing system, a principle of which is production line balance and lowest loss of sales.

Figure 1: The Discrete-event model of production and sales processes (DEM.3) in «Arena»



The strategy of finished stock replenishment combines basic stock and (R,s,Q)-policy, given backorders and lost sales, in order to provide line balance and meet demand. Generally, (R,s,Q) policy means monitoring the stock level every R units of time and if it is less than or equal to s an order in the amount of Q is placed to raise it over s and till $s+Q$ (Janssen et al, 1998). Besides the mentioned policy the model allows considering of (R,s,nQ) policy, which concludes producing of nQ (Wisner et al, 2008), and (R,s,Q,c) inventory replenishment policy (Cerdaramirez, 1997).

In the model the production volume VP_t at the time t is the sum of output VPR_t at specified intervals $\tau c(t)$ and the quantity of product VPS_t that is manufactured when the finished stock (inventory I_t) falls to or below a threshold level $P(t)$, similarly to (2):

$$VP_t^i = VPR_t^l + VPS_t^m \cdot y_t(\tau c) \ \forall i = l + m \quad (3)$$

Variable $Inventory$ (I_t)from equation (4) below expresses the size of finished stock for the entire time horizon. If we look at Arena's diagram, we can see that three modules quantify this variable, namely, “Assign Value of Finished Stock 1”, “Assign Value of Finished Stock 2” and “Goods Intake”:

$$I_t = I_{t-1} + VP_t^i - \sum_j OF_t^j \quad \forall i \in i3, j \in j2 \quad (4)$$

The volume of all customer orders VO_t that should be performed at current period of time t is the sum of backorders BO_{t-1} from the previous period of time $(t-1)$ and the volume of new orders OI_t, which arrive currently:

$$VO_t = BO_{t-1} + OI_t. \quad (5)$$

The volume of accepted orders AO_t is taken into calculation of backorders:

$$BO_t = \max\left(0, AO_t + BO_{t-1} - I_t\right). \quad (6)$$

And it equals to difference between total incoming orders rate OI_t and the volume of lost orders LO_t due to customers' refusals to expect:

$$AO_t = OI_t - LO_t, \quad (7)$$

$$0 \le LO_t \le AO_t \text{ when } VO_t > I_t. \quad (8)$$

The following Arena's modules «Assign» determine dynamics of VO_t $(VolumeCOrders)$:

"Assign Quantity of Ordered Item" – the module assigns new order quantity OI_t and also summarizes it with backorders volume (BO_{t-1}) thereby determining the volume of orders VO_t;

"Assign Lost Orders" – if finished inventory are not enough to fulfil order and customers refuse to expect, then the module sets the volume of lost orders (LO_t) as follows:

$$LO_t = VO_t - I_t; \qquad (9)$$

"Assign Orders Fulfilment Value" – it assigns the product quantity to fulfil accepted orders OF_t and resets lost orders;

"Assign Reset FulOrders" – reduces the volume of accepted orders by size of fulfilled orders.

Figure 2 shows dynamics of total production output VP_t (curve "Output"), that according to equation (3) consists of production VPR_t at specified intervals (the case of "Regular Output") and production VPS_t according to periodic review of finished stock and placing an order in case of falling to or below threshold level ("Output on Threshold").

Figure 2: Results of DEM.3 simulation: production dynamics

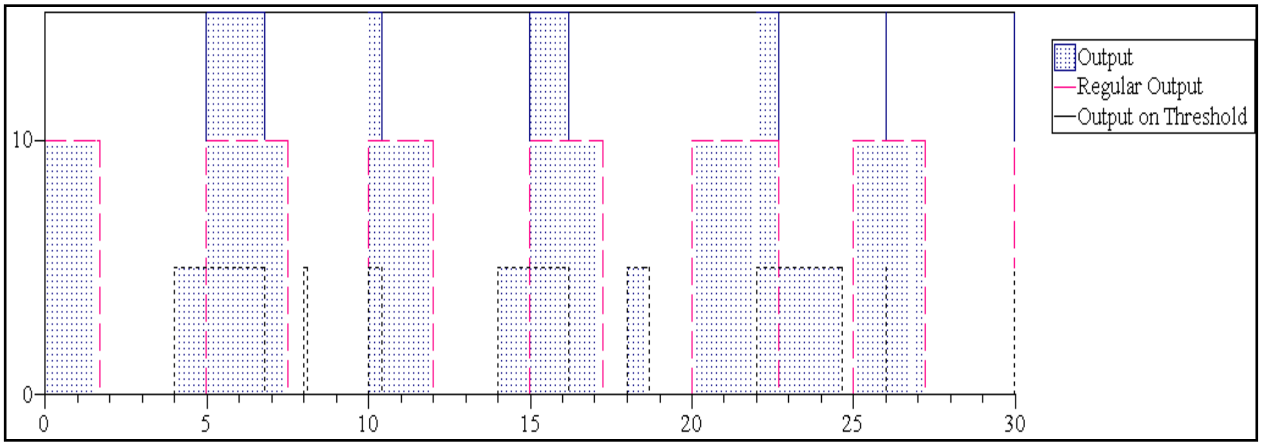
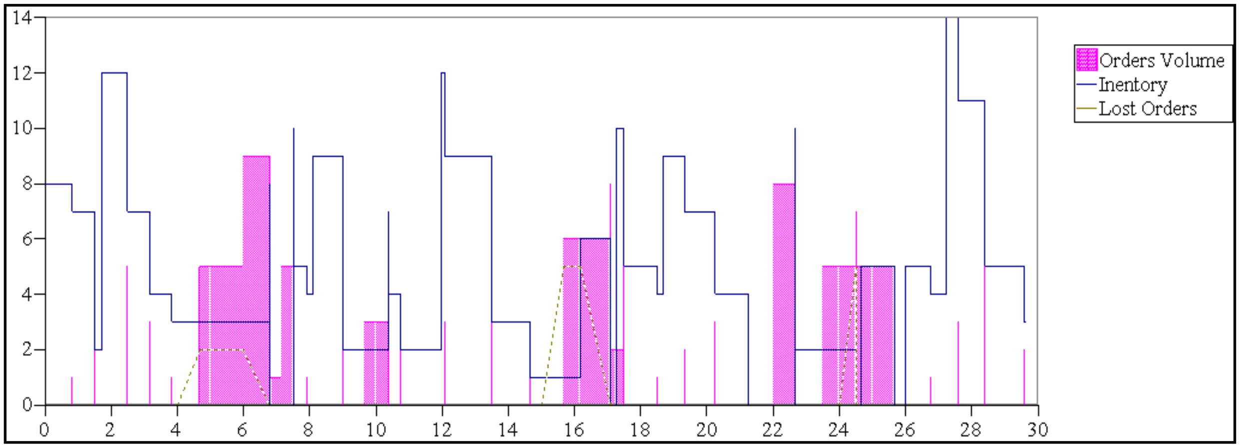


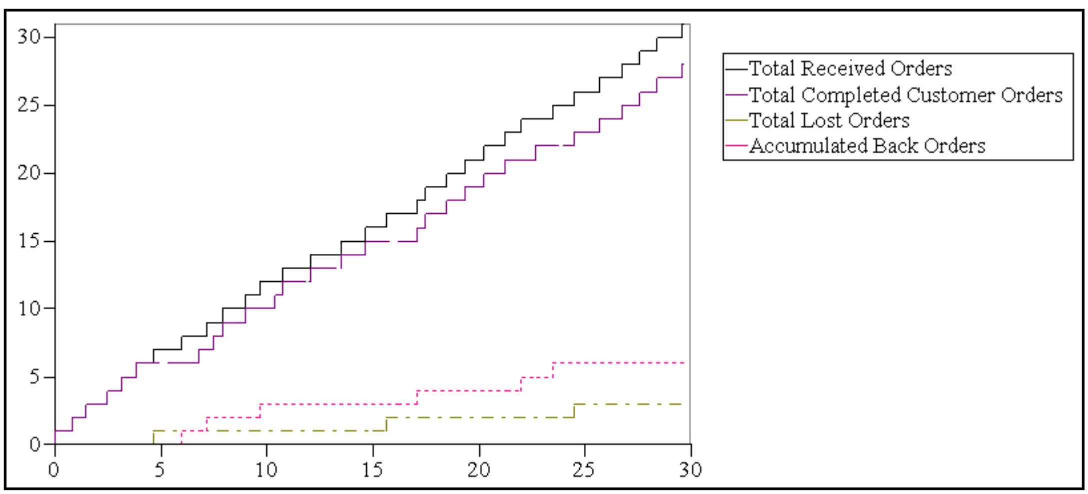
Figure 3 depicts curves for the variables: volume of orders in the system ("Orders Volume" that is VO_t), lost orders ("Lost Orders", LO_t) and finished stock ("Inventory", I_t).

Figure 3: Results of DEM.3 simulation: incoming orders, lost sales and finished stock



Moreover there are accumulated values of the variables for the whole planning period or portion thereof in the model (Figure 4). This helps evaluating process effectiveness and performance efficiency.

Figure 4: Accumulated values of the variables in DEM.3



DISCUSSION

A set of discrete-event models may support the push/pull view on logistics system and different type of manufacturing system according to Customer Order Decupling Point (CODP). Besides Make-To-Stock there are such types, as Deliver from stock, Make-To-Order, Assembly-To-Order and Engineer-To-Order. They are connected with inventory management policies, which have to answer when and how much goods must be produced. Indeed, managers modify the structure of production and sales processes, trying to synchronize them to efficiently meet customer demands, and choose a best set of inventory policies for planning horizon. Production and storage capacity are not constrained in DEM, so one way to modify the models is about constrained production and storage capacity. Therefore other modifications may take into account technological patterns of manufacturing and logistics systems, attributes of orders, specifics of sales strategy and customer relationships and so on.

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