Financial Risk Control in a Discrete Event Supply Chain

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Abstract

In this work, a discrete event supply chain is modeled from the point of view of one of the members. The model takes into account uncertainty and it determines an optimal ordering policy so that profit is maximized and financial risk is controlled. Two cases are considered. In one case, uncertain the behavior of the other members of the chain is known while in the other they are not.

1. Introduction

A Supply Chain Management (SCM) problem by means of discrete-event simulation is studied in this paper. The paper is an extension to discrete event modeling of the models presented by Perea-López et al. (2001). We add uncertainty in the form of two-stage modeling and financial risk management (Barbaro and Bagajewicz, 2002a,b). This paper is organized as follows: The SC dynamic modeling is first described. In the following sections, the deterministic and the stochastic models are described. Next, the risk concept utilized is explained. Finally, some conclusions and ideas for future work are exposed.

2. Modeling the Supply Chain

It has been consider a supply chain (SC) with all entities acting as independent agents, each of these being represented by a collection of states and transitions (Figure 1). The model has been constructed using two toolboxes of *Matlab*: *Stateflow* and *Simulink*, and it considers the SC as a decentralized system where there is no global coordinator and every entity in it makes decisions locally. The demand has been modeled as a set of events distributed over the time horizon of the study, each of them having an associated amount of material and time of occurrence. The inter-arrival intervals are uniform but the associated amounts are distributed according to a normal distribution.
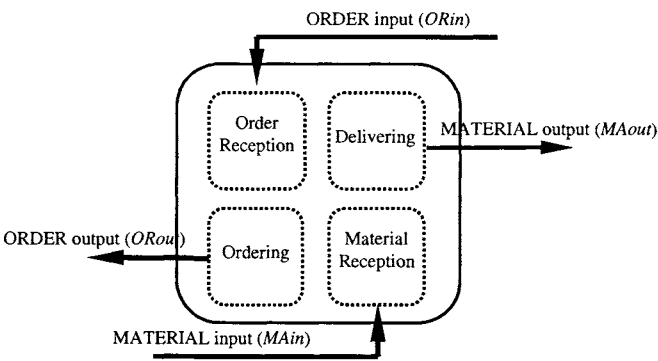
Figure 1. Generic unit scheme.

The inventory policy aims at determining when should a replenishment order be placed and how large should this order be at each time. At every time R, the inventory position I is checked. All the members of the supply chain, except the one in consideration, behave like follows: If I is below the reorder threshold s, a replenishment quantity is ordered according to a known law. One example of such law is the proportional one used by Perea-Lopez et al. (2001): If the inventory is above a threshold s, nothing is done until the next review, otherwise an order u is done according to the proportional law, $u = k \ (s - I)$. Total profit is used as performance index. It considers sales, purchasing costs and storage costs for materials and orders over the simulation time horizon.

3. Deterministic Model

Six generic units have been connected as Figure 2 shows. The material flow moves from the entity *SIP* to the customers and the ordering flow moves in the opposite direction. The inventory control policy beforehand described has been applied in all the entities belonging to the model, except in the *DIB*.
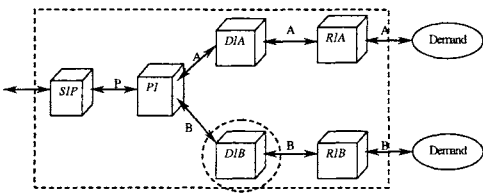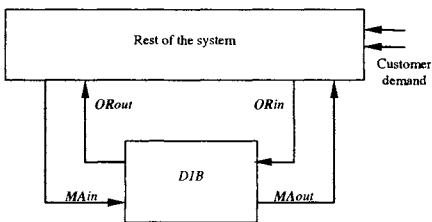

Figure 2. Supply Chain Scheme.

Figure 3. Relation between the SC and one entity.

The case posed considers that a given plant wishes to make decisions in order to maximize its own profit. The manager of this plant knows the modus operandi of all the chain by means of a simulation model, and has information about the future demand. In

our case study, the distribution center DIB receives orders that the system places ($ORin$). It can either respond by delivering materials ($MAout$) or save the order if it has not enough material. On the other hand, the system sends materials to DIB ($MAin$), and if it is necessary, DIB places orders ($ORout$) to the system. The variable that has to be manipulated to modify the profit of DIB is $Orout$. The question to answer is what is the quantity of material that should be ordered in time τ_0, τ'_1, τ'_2 and τ'_3 in order to maximize DIB's profit. Thus, there exist three possible discrete values at each of the four time instants. One of the permitted values is chosen at each time τ_0, τ'_1, τ'_2 and τ'_3, and one simulation of the system is executed. For each simulation, the profit is calculated and the one with largest profit is kept.
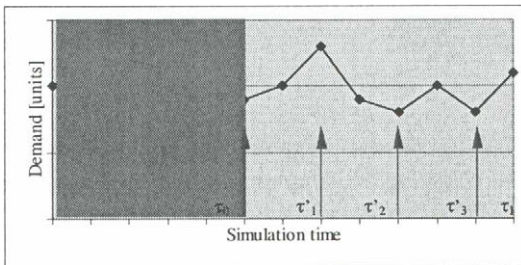

Figure 4. Demand and Time instants in which orders have to be placed.

4. Stochastic Model

The demand is modeled using normal distributions and sampling scenarios. The amount ordered in time τ_0 is considered as a first-stage variable, that is, a decision made before the uncertainty is revealed, whereas the amounts of materials ordered in the next periods, τ'_1, τ'_2 and τ'_3, are considered second-stage variables, decisions made after the uncertainty materialization.

5. Financial Risk

This work applies the financial risk concept defined in Barbaro and Bagajewicz (2002a). Financial risk is the probability of a certain design x of not meeting a certain target profit level Ω. Figure 5 represents a typical curve that describes the risk as a function of different profit targets. The objective is to reduce the risk for certain aspiration levels.

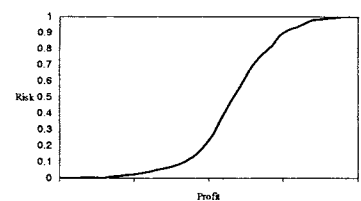$$Risk(x,\Omega) = \sum_{s \in S} P(profit_s(x) < \Omega) \tag{1}$$

Figure 5. Typical risk curve.

6. Results

Since the size of the orders that has to be request is chosen between three values, and, in addition, there are four time instants in which an order has to be placed, there are 81 possible combinations for simulating in each scenario. For each one of these configurations, taking into account each scenario, the expected values of the profit (*E(profit)*) has been calculated and the one with the largest expected profit is picked. In the deterministic case the values for the demand have been chosen in 7 units of product A each five simulations steps and 3 units of B with the same frequency. Moreover, the value for the safety inventory level has been set in 50 units for all the entities except in *S1P* and *P1* where the selected value has been 100 units. In the first case below described, a variance of 3 and 2 has been added to both deterministic values of the demand size. In the second case, a variance of 30 has been added to the deterministic value of the safety inventory level.

6.1. First case. Uncertain demand

In this case, it has been considered that uncertainty is only in the demands. The model used 100 scenarios and three discrete values at each time. Three curves of maximum profit has been generated (Figure 6). Decisions can be taken by observing the chart and by comparing the expected profit *E(Profit)* and risk values for each alternative (Table 1). It is important to notice that these curves represent the maximum *E(Profit)* achieved for each value of τ_0. The negative profit values correspond to scenarios in which the sales are minor to the purchases or storage costs in the simulation. For example, if a customer asks for materials and the inventory level is not high enough, the orders are accumulated, then, *D1B* incurs in a penalization cost.
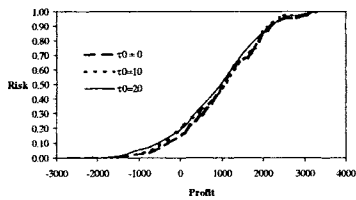

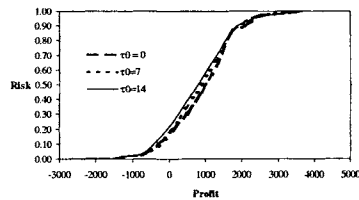*Figure 6. Risk curves for the stochastic first case*

Figure 7. Risk curves for the stochastic second case.

Table 1. Results for the stochastic first case.

Order size at τ_0	E(Profit) [€]	Risk($\Omega = 1000$) [%]	Risk($\Omega = 2000$) [%]
0	1043	46	86
10	952	45	88
20	897	50	87

6.2. Second case. Uncertain ordering policy in third parties

In this case, it has been considered that uncertainty is in one of the parameters of the ordering policy of the entity *R1B*. It has been supposed that the uncertain parameter is the reorder point *s* of the inventory control policy of *R1B*, and the values for this parameter belongs to a normal distribution with a given mean value and variance. The same procedure than in the first case has been applied. Results can be seen in Figure 7 and Table 2.

Table 2. Results for the stochastic second case.

Order size at τ_0	E(Profit) [€]	Risk($\Omega = 1000$) [%]	Risk($\Omega = 2000$) [%]
0	940	47	89
7	857	52	92
14	780	56	92

6.3. Risk management

In both cases above, as the profit is maximized for each option of the first stage variable (size of the order at τ_0) the risk also increases. Given the simulation-based approach used, solutions with smaller risk are found by inspection. Consider case one (uncertainty in demands) and an aspiration level of $\Omega = 500$. The risk at this level was computed for all the simulations and the smaller was chosen. The curves corresponding to maximum profit and reduced risk are shown in Figure 9. The size of the order picked for the reduced risk case is now $\tau_0 = 10$, as opposed to zero for the maximum profit case. The expected profit reduces from 1043 to 940. The risk at an aspiration level of 500 is reduced from 34 % to 28 %, which is significant. For an aspiration level of 0, that is, the risk of loosing money is reduced for this solution from 19 % to 14 %, again a significant reduction. The value of the downside risk at an aspiration level of 0, that is, the integral of the financial curve from $-\infty$ to 0 (Barbaro and Bagajewicz, 2002a), also decrease from 40 to 30.
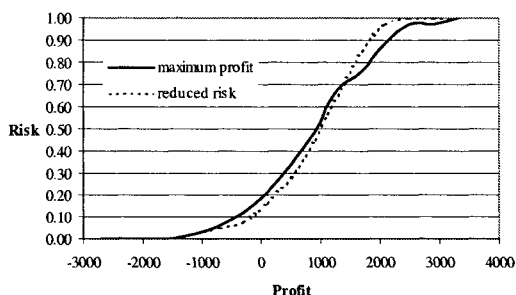
Figure 9. *Maximum Profit and Reduced Risk curves.*

7. Conclusions

A SC is modeled in this paper, determining the optimal ordering policy of one of the members in conditions in which the behavior of the other members is perfectly known and the demands are uncertain. A second case was considered where the demands are certain and the parameters of the order policy models of the other members are uncertain. It has been shown how financial risk can be managed. Extensions to the consideration of more uncertain parameters as well as decentralized control with sharing of information or centralized control are work in progress.

8. References

Applequist, G.E., Pekny, J.F. and Reklaitis, G.V., 2000, Risk and uncertainty in managing chemical manufacturing supply chains, Comp. Chem. Eng., 24.

Barbaro, A.F. and Bagajewicz, M., 2002a, Managing Financial Risk in Planning under Uncertainty, Part I: Theory, AIChE Journal, Submitted.

Barbaro, A.F. and Bagajewicz, M., 2002b, Managing Financial Risk in Planning under Uncertainty, Part II: Applications. AIChE Journal, Submitted.

Law, A.M. and Kelton, W.D., 1991, Simulation Modeling & Analysis, McGraw-Hill International Editions.

Perea-López, E., Grossmann, I.E., Ydstie, B.E. and Tahmassebi, T., 2001, Dynamic Modeling and Decentralized Control of Supply Chains. Ind.Eng.Chem.Res., 40.

9. Acknowledgements