

A hierarchical approach for robust planning in supply chains

Carles Sitompul and El-Houssaine Aghezzaf

Department of Industrial Management, Ghent University
Technologiepark 903, 9052 Zwijnaarde- Belgium
Email: elhoussaine.aghezzaf@ugent.be

Abstract:

Supply chains are subject to various types of uncertainty. According to Geary et al. (2002), these types of uncertainty can be classified in four categories: demand, process, supply, and control uncertainty. In this presentation, we propose and discuss an integrated hierarchical planning approach for supply chains that generates plans which are robust to two particular types of uncertainty, namely demand and process uncertainty. These two types of uncertainty are typical in any supply chain and often lead to deteriorations in service levels. We aim at modeling the problem, in a supply chain, of meeting the uncertain demand when failure-prone machinery is used. The conditions affecting a supply chain are naturally complex and make the analysis of the supply chain more difficult. Using a hierarchical approach makes it possible to reduce the size and possibly the complexity of a problem by decomposing it into simpler and manageable sub-problems at the strategic, tactical and operational levels. Although there exists a vast literature addressing uncertainty in supply chains, most of the papers discusses the issue only at one specific level. We propose an integrated model, which addresses the uncertainty within a hierarchical process at all planning levels in a supply chain.

At the strategic level, we extend the safety stock placement model of Graves and Willems (2000) taking into account capacity limitations. The problem is to determine not only the optimal location but also the proper size of safety stock in the supply chain in order to maintain a prescribed service level. We use a two-step approach to solve safety stock placement problem in the capacitated case. The first step is simulating the effect of capacity for a single stage supply chain. The result, that is the correction factor of safety stock, is generalized for a multi stage serial supply chain. The problem is then solved using a shortest path algorithm (see also Sitompul, et al., 2008). At the tactical level, each stage in the supply chain must generate its own aggregate plan in order to balance supply and demand. Assume that periodic demands $d(t)$ are stochastic following normal distributions with average $\mu(t)$ and standard deviation $\sigma(t)$. If we decide to produce in a period u to cover all demands in period $u, u+1$ until period v , then production plus the initial inventory must exceed the total demand from u to v . Since we are working at the tactical level, production planning is basically a capacity reservation for product families. This capacity must be large enough to produce finished products covering all realizations of demands from u to v . We called this strategy as capacity cushion levels. The resulted formulation is in fact deterministic which brings about a reasonable computational time (Aghezzaf, et al. 2010).

At the operational level, we need to allocate the capacity reserved at the tactical level for the production of finished products. At this level, we encounter problems due to the fact that machines may break down leading to a reduction in available capacity level.

To address this issue, we propose an integrated model for production and maintenance planning. There are two types of maintenance: preventive and corrective maintenance. We decided that preventive maintenance should be integrated at the tactical level while machine breakdown (which requires corrective maintenance) must be dealt with at the operational level. Assume that the failure rate of a machine follows a Weibull distribution with shape parameter α_m and scale parameter β_m . The problem is to determine which periods are optimal to hold preventive maintenance action. If we decide that a preventive maintenance is executed in period v then we can calculate the expected maintenance duration (hence expected capacity) of period v , $v+1$, and so forth. If period w equals to v then the expected maintenance duration is a total of preventive maintenance duration plus the expected number of failures times the duration of corrective maintenance. If w is larger than v (as we are moving away from the last preventive maintenance), then the expected number of failures is becoming large. The expected capacity in a period is then defined as capacity minus the expected capacity loss in that period due to maintenance actions (see Figure 1).

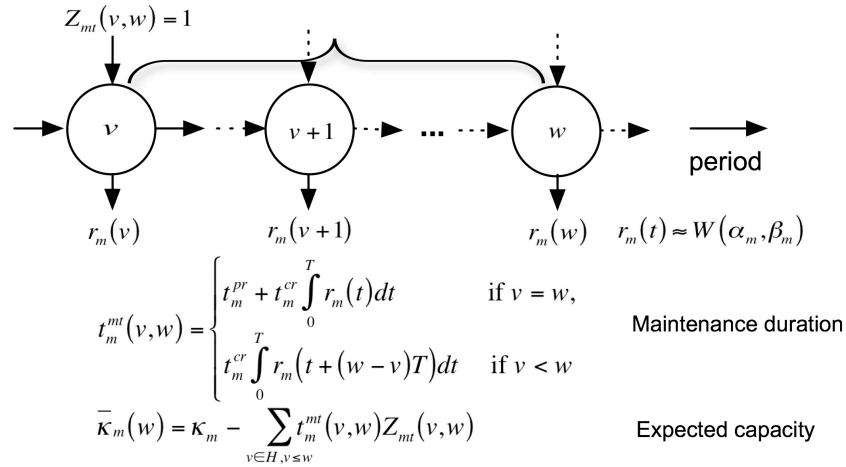


Figure 1. Preventive maintenance actions for machine uncertainty

The tactical level planning gives results in planned production for finished products and in preventive maintenance planning. These results are then used at the operational level in order to disaggregate families into their finished products taking into account machine breakdowns. A scenario-based optimization is therefore proposed to minimize the expected runout deviations and unmet production.

References:

1. Aghezzaf, E.H., Sitompul, C., Najid, N., 2010. Models for robust tactical planning in multi stage production systems with uncertain demands. *Computers and Operations Research* 37 (5), 880-889.
2. Geary, S., Childerhouse, P., Towill, D., 2002. Uncertainty and the seamless supply chain. *Supply chain Management Review* 6 (4), 52-60.
3. Graves, S.C., Willems, S.P., 2000. Optimizing strategic safety stock placement in supply chains. *Manufacturing and Service Operations Management* 2 (1), 68-83.
4. Sitompul, C., Aghezzaf, E.H., Van Landeghem, H., Dullaert, W., 2008. Safety stock placement problems in capacitated supply chains. *International Journal of Production Research* 46, 4709-4727.