

## Chapter 7.10

# Supporting Demand Supply Network Optimization with Petri Nets

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### ABSTRACT

The present study implements a generic methodology for describing and analyzing demand supply networks, that is, networks from a company's suppliers to its customers. There can be many possible demand supply networks with different logistics costs for a product. Therefore, we introduce a Petri Net-based formalism, and a reachability analysis based algorithm that finds the optimum demand supply network for a user-specified product structure. The method has been implemented and is currently in production use inside all Nokia business groups. It is used in demand supply planning of both network elements and handsets. An example of the method's application to a concrete Nokia product is included.

### INTRODUCTION

*Logistics* refers to the flow of materials, information, and money between the suppliers and customers. A *demand supply network* refers to the manner in which components flow from suppliers to the manufacturer's plants, and finally to the end customers. The logistics cost associated with a demand supply network include such costs as freight, warehousing, interest rate, duties, and taxes.

A typical problem that logistics professionals face in a global corporation is finding the cheapest and most reliable way of producing a product and delivering it to customers. Often, the product structures and supplier bases vary considerably during a product design phase. The logistics manager must decide the most economical component suppliers and the best-positioned assembly facto-

ries over the product's lifecycle. Typically there are hundreds or thousands of different demand supply network setup options for a given product. Therefore, manual analysis of demand supply networks is practically impossible.

Companies have considerable incentives to optimize their end-to-end demand supply chains. Firms approach this problem in two fronts: optimization of manufacturing functions on one hand and the demand supply chains on the other. As such, several methods for demand supply network analysis have been introduced in the literature. Most solutions use operations research paradigm—mixed integer programming—or discrete simulation to analyze demand supply networks (Bramel & Simchi-Levi, 1997; Simchi-Levi et al., 2003).

Recently, the industry has seen several examples of disasters brought up by broken demand supply networks (Norrman & Jansson, 2004). A logistics manager must know all the demand supply network options available to reduce possible risks. This enumeration requires reachability analysis where each path (i.e., a possible demand supply network setup) is explored. Mathematical optimization may give the optimal setup quickly via analytic or heuristic methods. However, these techniques converge to the optimum, rather than enumerating the entire state space (including the costlier network possibilities). Discrete simulation, on the other hand, is excellent in dynamic analysis of a single demand supply network. Yet, it lacks the “helicopter view” of all demand supply network options which are possible to obtain using reachability analysis. Moreover, simulation and optimization software are costly in an environment with 200 potential users. It was realized that a reachability analysis-based solution, which solves small to medium size optimization problems in reasonable time, could be created in-house. The previous demand supply network analysis methods inside Nokia had relied on spreadsheets where each demand supply network setup was manually analyzed. In wake

of increasing competition, the logistics team was looking for a powerful, yet cost efficient solution. Thus, I as a member of logistics team, started to consider the following research question:

*How to apply reachability analysis in demand supply network analysis?*

The result was a generic Petri Net model for describing arbitrary demand supply network options, and a reachability analysis algorithm that computes the network setups and costs from the Petri Net model. A Web-based analysis tool based on the methodology was constructed during 2004 and has been in production use since February, 2005.

The rest of the article is organized as follows: the remainder of the introduction reviews the current approaches to demand supply network analysis. The second section gives the generic Petri Net model for demand supply networks through example and formal definitions. The third section presents the reachability analysis algorithm for the model. The fourth section presents a concrete Nokia case for the tool use. The fifth section concludes with discussion and future work.

## **Literature Review**

analyzing demand supply networks. Next, I describe operations research methods (Fandel & Stammen, 2004; Thomas & Griffin, 1996; Vidal & Goetschalckx, 2001; Zeng & Rossetti, 2003), analytic hierarchy processes (Dotoli et al., 2005; Wang, Huang, & Dismukes, 2004), control theoretical methods (Ortega & Lin, 2004), discrete simulation methods (Persson & Olhager, 2002), and workflow net related methods (van der Aalst, 1998a; van der Aalst, 1998b; van der Aalst & ter Hofstede, 2005; Desel & Erwin, 2000). Each of these methods fits into one of four categories: deterministic analytical, stochastic analytical, economic, or simulation (Beamon, 1998). The five methods are briefly described along with their position in Beamon's categorization.

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