Virtual Plant-Wide Management and Optimisation of Responsive Manufacturing Networks (VIP-NET): An EC Collaborative Research Project

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Abstract
This work describes some of the research and technological developments achieved in the course of VIP-NET, a large EC funded project in the area of manufacturing. A comprehensive strategy and several computer-aided tools have been developed for the optimal management of both complex manufacturing networks and their individual components taking into account a multitude of objectives. Particular emphasis in placed on the description of real life case studies provided by the industrial partners of the consortium.

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1. Introduction

During the last decade, political and financial decisions have been taken towards the strengthening of economic cooperation and coordination among different countries. In Europe, the most important step towards this goal is the European Monetary Union initiative. These changes simplify the process of investing and expanding to new markets and open new opportunities for the industry. Today, the competitive drivers are time and service (responsiveness and flexibility) and concepts such as agile manufacturing, time-based competition and supply chain management have begun to significantly impact the way manufacturing compete (Thomas and Griffin, 1996; Cohen and Lee, 1988). It has now been accepted that current planning and scheduling models/tools cannot address the global manufacturing problem well including supply chain and distribution network management. Planning and scheduling without visibility of the entire supply chain and extended enterprises is sub-optimal and will soon become unacceptable. If manufacturers plan to compete successfully in the global marketplace, they must provide responsiveness and flexibility not only to their customers but to their entire supply chain (Backx et al., 1998; Vidal and Goetschalckx, 1997).

Modern industrial enterprises are typically multi-product, multi-purpose and multi-site facilities operating in different regions and countries and dealing with a global-wide international clientele. In such virtual enterprise networks, the issues of global enterprise planning, coordination, cooperation and robust responsiveness to customers demands in the best possible way at the global as well as the local level, are critical for ensuring effectiveness, competitiveness and business sustainability and growth. In this context, it has long been recognised that there is a need for an integrated approach that considers various levels of enterprise management, plant-wide coordination and plant operation, in a systematic way, in order to reduce capital and operating costs, increase supply chain productivity, improve business responsiveness and environmental planning and decrease energy consumption. In that way, industries could better cope with more competitive and sustainable production patterns allowing for tighter operating, product quality and variability constraints thus achieving shorter product life-cycles (Towill, 1991).

This work presents a few of the activities of VIP-NET EC funded project comprising 14 partners from 9 European countries. A major innovation of this project is the development of an integrated set of methodologies, mathematical models, efficient solution techniques and computer-aided tools for:

- infrastructure network design (product portfolio planning, plant location, capacity selection) and forecasting approaches;
- operation of the entire supply chain, including multi-echelon production and distribution systems, multi-enterprise supply chain, and integration of financial and production aspects within supply chains;
detailed scheduling and production planning at plant level. Novel mathematical programming approaches for batch, continuous and discrete operating modes have been investigated; and

incorporation of environmental impact considerations, robust performance criteria and uncertainty issues.

The above methodologies, algorithms and tools have been applied to several industrial problems provided by the industrial partners of the consortium. A few selected industrial case studies are presented in the following sections.

2. Optimisation and Design of the MORRIS Distribution Network

*MORRIS S.A.* is a manufacturer of electrical equipment appliances in Greece (dishwashers, cookers, etc). The enterprise comprises two production sites in Greece with unlimited warehousing capacity which supply directly to customers or to secondary distribution centres. The management of the company wants to examine the options of establishing one or more distribution centres in one European country (Germany) to serve its local customer basis. There are two specific problems that *MORRIS* wants to solve through this case study: (i) the selection of the best position for a new distribution centre in Germany to serve the local market and (ii) the development of a mathematical model, which will optimise the production and distribution decisions. There are several candidate distribution centres allocated in different geographically distributed areas to serve six customer zones. Production is happening at two sites without any additional information on the production capacity except the ability of the plant to produce certain products. There is an interaction between the plants but the information provided does not allow for further exploitation of this relationship. There are two types of storage for the finished products: major warehouse which are located next to each plant and Minor warehousing sites described as distribution centres. Transportation in our system occurs between the following stages (i) production plants to warehouses (ii) warehouses and distribution centres and (iii) distribution centre and customers. The mathematical representation of the problem has the exact form of the supply chain formulation proposed by Tsiakis *et. al.* (2001) with some minor modifications. The mathematical formulation was solved using XPRESS from Dash Optimisation Ltd. Two established warehouses are used to serve the new distribution centre in Germany which is designed to serve five major customer points. The location selected purely based on financial objectives and is illustrated in Figure 1. The selection of Magdeburg as the location of the new distribution centre is explained by both its geographical location as well as the associated costs for establishing and operating the site. It is located evenly between the customer points and has the lowest operating and infrastructure costs. The cost of operating the supply chain consists of production costs for the final products, transportation costs between the different stock points and the infrastructure costs for establishing the new distribution centre. It is important to mention that all product demands are satisfied based on the data reported. The same problem has been extended by considering uncertainty in product demands for a more realistic representation of the dynamic market conditions.
3. Development and Application of Forecasting Techniques

Forecasting is a precursor to planning that is often neglected in the process industries. Forecasts in most process companies are still based on manual interpretation of history. This leads to the emergence of multiple forecasting functions across different areas, as each area interprets history based on local information. Forecasting plays a particularly important role in the Supply Chain Management. It has been long recognised that if supply chain management begins with a forecast that is substantially in error in terms of timing or quantity, the ramifications will be felt throughout the entire process (Helms et al., 2000). In the context of VIP-NET project all industrial partners considered the application of new forecasting techniques as an important step towards better management of their manufacturing networks. To this end a new quantitative forecasting methodology was developed by UPC based on the following steps (i) a preliminary analysis to identify patterns in the series of historical data available along with special aggregation and disaggregation techniques for better data analysis, (ii) employment and assessment of several statistical-based fitting models and selection of the best one taking into account its predictive power. Here exponential smoothing, ARIMA methods, non-linear regression, decomposition-based techniques have been investigated, (iii) new forecasts based on the selected model and prediction of confidence intervals and error measurement constitute key steps and (iv) continuous forecasts and monitoring. On the basis of the accuracy of the results, the selected model may be updated or a new model may be decided. The details of these steps are documented in several technical reports of the project and have been automated based on a UML implementation. It is important to emphasise that new quantitative methods have been investigated relying on the following assumptions: (i) information about the past quantified in the form of numerical data is available and (ii) some aspects of the past pattern will continue into the future (assumption of continuity). The overall approach has been applied in several real life data provided by the industrial partners of
the consortium. For illustrative purposes, a case study from TAJCO (a Danish manufacturer of car accessories and automotive parts) is presented here. Demand information for a special product group was provided by the company for the period of January 1997 until October 2001. Results are shown in Figure 2 where $F_{t+m}$ represent the forecast value for each time period, $P_{low}$ and $P_{upp}$ represent the bounds of the predicting intervals, calculated as an uncertainty measure. The developed methodology and tool now provides an effective mean for making reliable product forecasts not only at TAJCO but also at all the other industrial partners of the consortium.

![Figure 2. Forecasts for one Product Demand at TAJCO](image)

### 4. Production Scheduling

Several industrial case studies regarding applications of new mathematical techniques for optimising productions schedules have been considered. In this section we focus on the real life problem of UPM one of the largest paper converting industries in all over the word. The Walki Wisa Pietarsaari factory of UPM has six laminators (combined with slitting machines), six printing machines for producing different types of wrappings, two separate slitting machines plus some additional special slitters. It produces about 700 different types of products. The number of orders to schedule every day or reschedule may vary from 80 to 100 depending on the current order situation. It is a very complex process with several common resources and tight operating constraints. In close collaboration with the academic partners of the consortium Walki Wisa has implemented theoretical algorithms and methodologies developed during VIP-NET in user friendly environments to derive daily production schedules. A typical schedule for multiple machines is shown in Figure 3. The company now fully exploits the potential offered by using techniques developed by the academic partners (especially by Abo Academy in Finland) for deriving nearly optimal schedules under a dynamic market environment.
5. Conclusions

This work summarises some of the developments achieved in the course of the European VIP-NET project. An important realisation has been that industrial companies are willing to explore the potential offered by modern Computer-Aided techniques in order to reduce total costs, improve response to dynamic market changes and increase efficiency of their manufacturing networks and supply chains. However, a closer collaboration between academic institutions, industry and SMEs is required to remove existing barriers between theoretical research on one hand, and real industrial needs on the other. It is strongly believed that VIP-NET was a contribution towards this direction.

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