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A web-based approach for exceptions management in the supply chain ☆

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ABSTRACT

This research aims at developing collaborative planning and scheduling in complex and dynamic supply chains by providing a software architecture and a methodology to define cooperation in a distributed environment. The study contributes to gain the competitive advantage at the extended enterprise, since it analyzes the implications of changes occurred at a certain point of the supply chain for other nodes. This way, the different production schedules of the supply chain are coordinated in order to find a best global solution, thus leading to more realistic plans, better due date fulfilment and less inventory levels in the supply chain as a whole. The general framework of the project using a decentralized approach can be defined by means of three subsystems of communication based on agents: (i) a communication subsystem inside the plants, which will manage the unforeseen events that may lead to a rescheduling of part or the entire production plan, (ii) an inter-plants communication subsystem, which will manage the events produced in a plant that may affect other plants and (iii) a supply chain communication subsystem, which will manage events occurred in a plant that can affect suppliers and/or customers. Next steps will include full development and systematic tests of the prototype that will check the suitability of the architecture and algorithms selected. This research is being funded by Grant PI2008-08 from the Basque Government in Spain.

1. Introduction

The objective of Supply Chain Management is ‘‘managing the entire flow of information, materials and services from raw materials suppliers through factories and warehouses to the end customer’’ [1]. A supply chain is composed of several agents, such as vendors, wholesalers, manufacturers, retailers and customers. In most cases, unless the supply chain is vertically integrated, different companies must share information and coordinate physical execution of their operations to ensure a smooth flow of goods, services, information and cash through the pipeline. Collaboration among entities in the supply chain can have a positive impact on the system performance. This research proposes to incorporate collaborative capabilities to real-time production scheduling in order to reduce inventory levels and improve customer service in the supply chain as a whole.

Unplanned demand oscillation may cause distortions in the supply chain when the different nodes do not interchange information. These distortions are commonly known as the ‘‘bullwhip effect’’ [2]. This effect used to be considered unavoidable but today is a key issue of many scientific publications due to the negative implications it has in terms of excess of inventory, shipping cost increase and quality problems. There is a common agreement that information sharing is a crucial factor in order to obtain global benefits in the supply chain level. Therefore, a fluent flow of information throughout the supply chain is necessary.

Since research started to grow, different models have appeared to represent the way a supply chain has to be managed. The most important ones are the following:

- The CPFR model [3] offers a general framework by which a buyer and a seller can use collaborative planning, forecasting and replenishing processes in order to meet customer demand. Buyers and sellers are involved in four collaboration activities: Strategy and planning, Demand and Supply Management, Execution and Analysis.
- The Supply Chain Operations Reference Model, commonly known as SCOR [4] is a diagnostic tool for the Supply Chain Management that spans all customer interactions, including order entry to payment, products transactions and market interactions.

These two models have been used by several institutions as a reference to create different ways to represent a supply chain.

Furthermore, the so-called CO-OPERATE project [5] aims at improving the overall goal of the supply chain by creating a communication infrastructure between companies. This

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infrastructure enables a collaborative production planning, multi sourcing coordination, process visibility and exception handling reducing the "bullwhip" effect thanks to information sharing.

But some authors [6] showed, that in order to enjoy the full benefits of collaboration, practitioners should focus more on synchronization than just on information visibility. Therefore, the SCOR and CPFR models provide suitable tools to reduce the bullwhip effect and best meet customer demand. Besides, the CO-OPERATE project enables collaborative production planning and exception handling by means of creating a common information infrastructure in the supply chain. Despite all contributions in this research area, there is a lack of studies that focus on synchronizing local scheduling solutions in real time in order to attain a global optimal solution. This means that improved tools are required to handle anomalies that optimize globally rather than locally over the extended enterprise.

2. Problem definition

The problem we are going to tackle with is related to a manufacturing supply chain composed of several plants and companies.

The system works with the following assumptions:

- Information is exchanged with immediate suppliers and customers in order to facilitate production synchronization between different levels of the supply chain. On their part, the affected suppliers and customers could also inform the next level in order to reduce safety stock and shorten the total lead time.
- The company has several plants that are independent in the sense that they are not connected through assembly operations. Besides, they can have alternate resources that can be used in case a certain resource is not available at a plant.
- The manufacturing context is related to demand patterns that are relatively stable, so that inventory will not be much affected.
- The selected approach makes use of distributed control, where decisions are made at each node but taking into consideration the information exchanged with other nodes. This means that each plant will be autonomous as regards decision making in terms of production management but, at the same time, will take advantage of information coming from other nodes in order to allow a dynamic collaboration and a better global solution.

2.1. Performance indicators

Performance indicators can be classified into three categories: production efficiency, customer service and replanning quality. In Table 1 a list of the performance indicators used is displayed.

As far as production efficiency is concerned, the following indicators can be considered:

- *Makespan*, that minimizes the amount of time it takes to complete the set of jobs included in the schedule.
- *Machines utilization*: Machines are expensive resources. Therefore, it is important to occupy them as much as possible, thus reducing the machines idle times.

In the second category, i.e. customer service, the following indicators can be included:

- *Tardiness*: Work orders must be finished on time. This way it will be possible not only to offer confidence and reliance to customers but also to allow them delivering their own orders punctually to the next echelon of the supply chain.

Table 1
List of performance indicators.

Types	Indicators
Production efficiency	• Makespan • Machines utilization
Customer service	• Too late delivery • Too early delivery
Replanning quality	• Number of pending operations • Similarity with the original plan

- *Earliness*. In case the Just In Time (JIT) philosophy is preferred, a too early delivery will involve increasing holding costs. If we do this, the customer will probably penalize us, or what is even worse, could prevent us from making the delivery, thus increasing the costs of the company.

In the third category, the so-called replanning quality, the following indicators will be included:

- *Number of pending operations*: It refers to the operations that remain undone due to an exception that makes the currently active schedule unfeasible.
- *Similarity with the original plan*. If no disruption occurs, the active schedule will be carried out. However if a replanning process is necessary, then the resulting plan might be different from the original one. This indicator measures the differences between both plans by considering the list of jobs allocated to each resource, the sequence of the list or the starting and finishing times of the jobs.

3. Exceptions

This research aims to provide a proactive tool for exceptions management that operates in real-time and accounts for the integration of different nodes of the supply chain. This means that an in-depth analysis is carried out for each exception in order to ascertain the implications of changes occurred at a certain point of the supply chain for other nodes. Exceptions can be classified into two groups: internal and external (see Fig. 1). The former are related to events that occur at a particular plant, the latter are those coming from either suppliers or customers.

3.1. Internal exceptions

Main internal exceptions are related to the availability of machines, operators and auxiliary resources, as well as quality related events. If an exception occurs at a shop floor, the affected operations at the current production schedule will be identified and the feasibility of the solution will be verified. Nevertheless these internal exceptions can generate external exceptions if they affect either suppliers or customers. These exceptions will contribute to synchronize and optimize the entire supply chain.

At this point a case study related to the management of an internal disruption at a plant is described. The event that is going to be examined is the so-called "repeat parts" event (see Fig. 2). Handling this event implies repeating from the very beginning of the process plan some defective parts that have been detected during the manufacturing stages.

When some defective parts are found, the plant manager has to stop the affected work order to prevent it from being manufactured. Furthermore, he/she has to enter a repeat parts event