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Information Exchange and Synchronized Scheduling in the Supply Chain

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1. Introduction

A supply chain encompasses several agents, such as vendors, wholesalers, manufacturers, retailers and customers. These companies must share information and coordinate physical execution 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. In this context, the incorporation of collaborative capabilities to manufacturing systems planning and scheduling is an important part of any enterprise integration effort. Integrated scheduling systems describe procedures to review and coordinate production scheduling in supply chain management. The ability to develop effective collaborative scheduling procedures in the extended enterprise is expected to become a key to success in the market.

In order to do this effectively it is necessary to optimize both delivery times and inventory levels, as these are translated into costs for the company. A smooth communication between players who are part of it is essential. Information must be exchanged between nodes and new methodologies for collaborative planning and scheduling must be developed. This will contribute to synchronize different production schedules, gaining a valuable competitive advantage over other supply chains. This collaboration is difficult to implement since it involves breaking cultural, organizational, information and technology barriers.

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2. Research objectives

The main goal of this research is to develop an integrated approach for collaborative planning and scheduling in the supply chain that will result in a better performance of extended manufacturing networks. This project will apply to a supply chain where inventory and production is distributed into several shop floors. A key objective will be to develop rational approaches that optimize the production flow over the entire value chain. Furthermore, it is important to identify the information that the different agents will exchange in answer to possible disturbances during the production stage. There is a common agreement that sharing demand information with other members of the supply will reduce inventory levels but it is also important to exchange real-time information that could affect the initial schedules that are being executed at each shop floor. Unplanned demand can affect not only the directly involved node but also other nodes related to customers and suppliers. On the one hand, it is necessary to collaborate with suppliers in order to guarantee the availability of raw materials. On the other hand, it is important to early warn customers about any problems that could affect order fulfillment.

Finally, typical disturbances must be classified in order to provide a timely solution. Disturbances can come from three different sources: (i) internal exceptions, (ii) supply side exceptions and (iii) demand side exceptions.

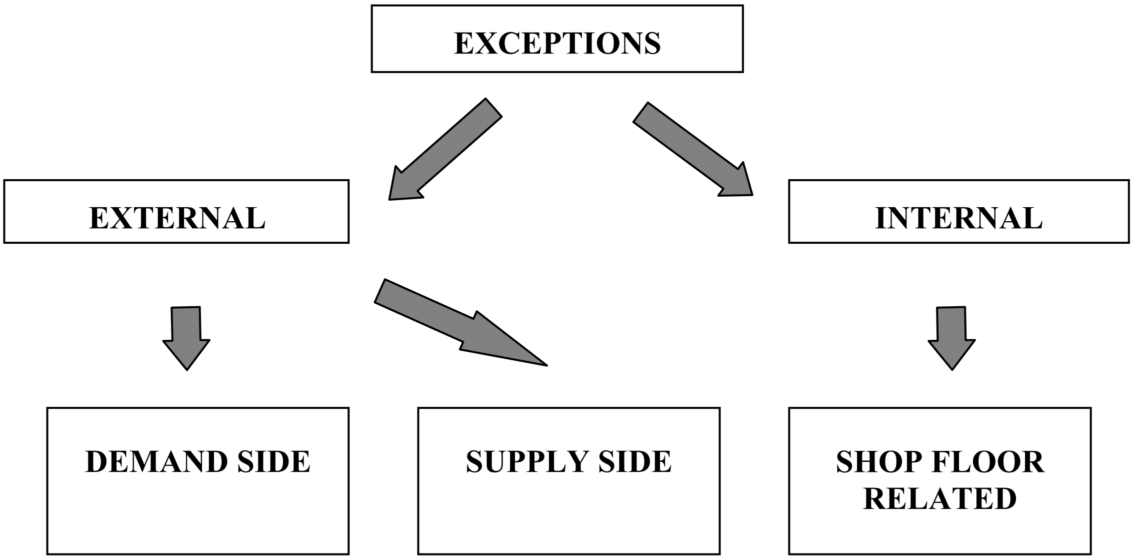

Figure 1: Supply chain exceptions.

Internal exceptions comprise the following anomalies: machine failure, machine recovery, unexpected absence of operator, presence of operator, lack of auxiliary resource and auxiliary resource recovery.

Supply side exceptions include the following events: material rejection, partial delivery, late delivery and cancelled delivery.

Demand side exceptions include: due date change, new urgent order, order quantity increase or decrease and order cancellation.

3. Literature review

There is a common agreement that information sharing is a key fact in order to obtain global benefits in the supply chain. Therefore, a fluent flow of information throughout the supply chain is necessary.

Unplanned demand oscillation may cause distortions on the supply chain if no information is exchanged between the different nodes. This distortion is known as the “bullwhip effect” (Donovan, 2002). This effect was considered normal in the past but now it has captured the attention of the scientific community since it causes important negative effects in business such as excess of inventory, shipping cost increase and quality problems.

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

- The CPFR model (CPFR web, 2008) 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 (SCOR web, 2008) is a diagnostic tool for the Supply Chain Management that spans all customer

interactions, including order entry to payment, all products transactions and all market interactions.

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

But some authors (Viswanatha et al, 2007) showed, that in order to enjoy the full benefits of collaboration, practitioners should focus more on synchronization than just on information visibility. In this sense, the so-called CO-OPERATE project (Azevedo et al, 2005) aims at improving the overall goal of the supply chain by creating a communication infrastructure between companies. This infrastructure enables a collaborative production planning, multi sourcing coordination, process visibility and exception handling reducing the “bullwhip” effect thanks to information sharing.

According to (Jodbauer, 2005), the relationship between utilization, optimum time and work in progress plays a very important role in the design of a supply chain and a manufacturing system. This research shows that inventory or work load variability cause capacity waste, low machine utilization rates and long optimum time.

Some authors have explored the possibility of integrating different stages of the value chain that have traditionally been solved separately. The approach in (Kanyalkar and Adil, 2005) investigates production planning in a multi-plant company where each plant can serve different customers, so when a new order arrives, a decision must be made as regards plant allocation. The authors developed the model based on a linear programming algorithm in order to obtain the aggregated plan and the detailed plan simultaneously. Thanks to it, it is possible to beat the hierarchical methods’ limitations that cannot usually find a possible solution or a sufficiently optimized one. Another approach (Park, 2005) states that companies have tried to optimize production and distribution systems separately. Therefore, it presents a solution for the integration of production planning and distribution, to improve their productivity by incorporating a multi-stage, multi-use, multi-item and multi-period plant. The main goal is to maximize the total net profit. The study shows that the integrated approach substantially outperforms the approach that considers both stages of planning and distribution separately. In order to do this, the author uses a heuristic in the solution of production planning and distribution in an integrated manner. However, this model is not computationally feasible when the number of plants, customers, consumer product and periods is high.

Other research studies have taken advantage of creating schedules with auctions that fit naturally into a distributed architecture. In (Dewan and Joshi, 2002) an auction-based solution is presented where jobs are planned in a distributed way. The resulting problem contains a variable number of operations and different process times. Each task has to be done following a set of operations where each one requires a specific machine with contiguous time slots. This type of solution is not often used because it is impossible to obtain an exact solution and the generated planning is not real. In (Siwamogsatham and Saygin, 2004) an algorithm based on bids for the sequencing of real-time flexible manufacturing systems with alternative routes is presented. The effectiveness of the proposed framework is verified by comparing it with a number of priority rules using simulation. The analysis of the results showed that the approach based on auction outperformed the rules of priority in almost all measures of performance. Nevertheless, the auction-based method is not well accepted in industry because of the unpredictability of the system performance, poor quality of schedules generated, and no theoretical basis for computing the bids and bid evaluation.

In (Surana et al, 2004) an interesting model is presented, which reacts before unexpected events that might appear by continuously revising both planning and scheduling. Other authors (Huang et al, 2005) propose a new algorithm (NEG) based on negotiation in order to solve the distributed projects problem. This algorithm allows all nodes in the supply chain to make decisions independently but it also makes the most of shared information to improve the quality and effectiveness of the supply chain. A study shows that NEG works better than a heuristic centralized algorithm and can obtain solutions in a short period of time.

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 a 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.

4. General Framework

This research aims at developing suitable solutions to support collaborative planning and scheduling in complex and dynamic supply chains by providing software architecture and a methodology to define cooperation in a distributed environment.

The project 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 fulfillment and less inventory levels in the supply chain as a whole.

The context of the research considers a supply chain composed of different plants having initial production schedules that are dispatched to the shop floors. Each one will have its capacity model in order to check the feasibility of new production orders or added capacity demand coming from internal exceptions in the factory. Besides, it will communicate with suppliers so as to ensure the availability of raw materials before new demand requirements.

The general framework of the project using a decentralized approach can be defined by means of three subsystems of communication based in 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.

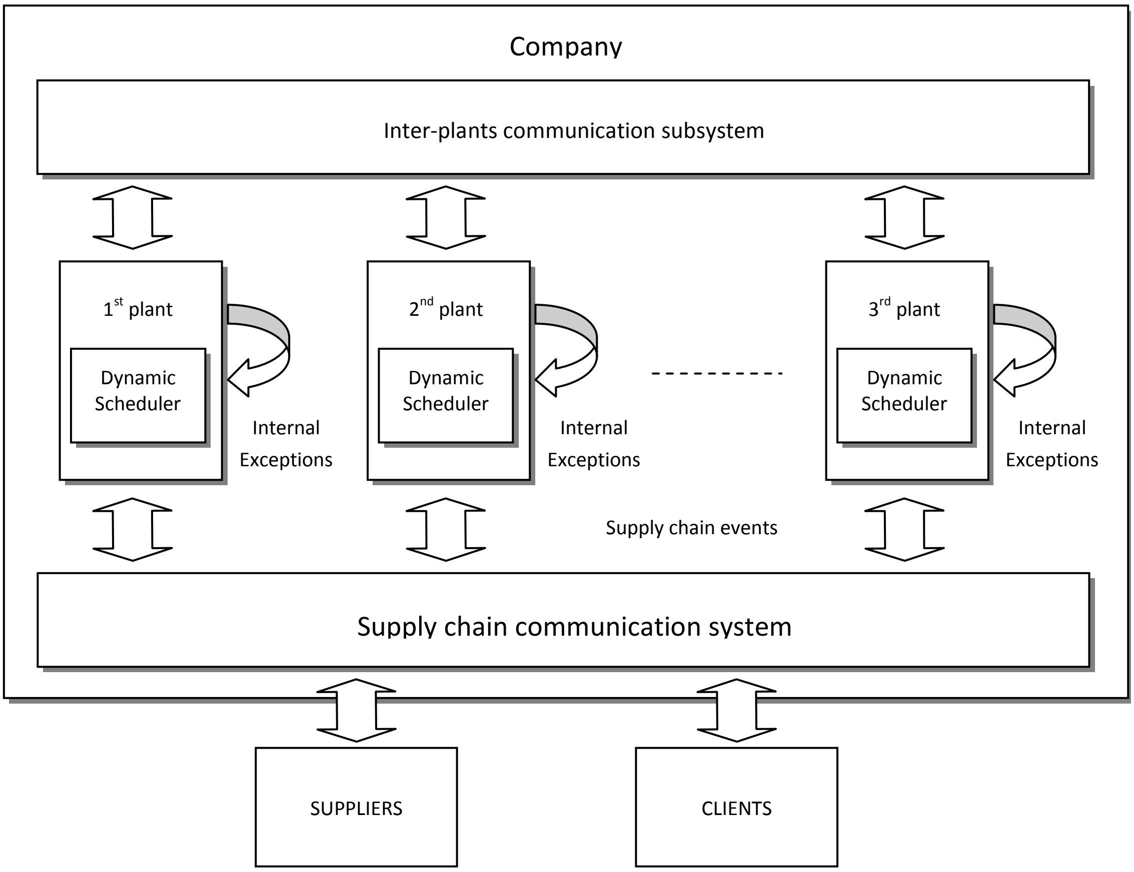

Figure 2: General framework of the system.

This means that a fluent communication system is necessary to ensure information visibility between different links of the supply chain but this information must be successfully managed in order to synchronize different production schedules and gain a global competitive advantage.

A multi-agent architecture will be used, where each agent represents a node of the supply chain. Each plant will optimize its own production independently. Nevertheless, when exceptions occur, other nodes will be informed or involved in the decisions, e.g. when new orders require an availability check of raw materials outside the company.

When an anomaly occurs, the affected node will reschedule the necessary operations taking into account the capacity available at the active production plan and will also check the feasibility of the solution externally. If a new urgent order arrives at a shop floor and there are not enough materials at its warehouse, the affected node will send a materials order to one or several suppliers, which could have to communicate with their own suppliers. The solution, taking into account the cumulative lead time, will be transmitted to the customer that originally sent the order.

There are two main approaches to rescheduling, namely total rescheduling or partial rescheduling. The second one is considered as more interesting since it brings a solution within a short time and preserves the original schedule as much as possible.

Furthermore, it is necessary to define when a rescheduling process should be accomplished at each shop floor in order to face possible anomalies occurred at execution time. If just small changes between planned start and end times for each job happen it is not advisable to let a rescheduling process start since this will unnecessary increase the nervousness of the system and will not significantly improve results. In fact, the system should not react to small deviations since this will mean instability and distance from the original schedules which will negatively affect costs. One important performance measure in order to evaluate the quality of schedules should be the distance between schedules.

With exceptions management two main advantages can be obtained: cost reduction and better service of the supply chain; this is particularly important in order to achieve the competitive advantage at a globalised market.

5. Conclusions

This research aims at developing a synchronized scheduling solution which operates in real time by monitoring possible disturbances and processing them on a wide basis, thus considering their impact on the overall supply chain. In this way, the different production schedules of the supply chain will be synchronized, thus leading to better global solutions.

Literature review showed that although SCOR and CPFR are successful models to reduce the bullwhip effect and best meet customer demand, it is not enough to share demand information but to synchronize the processes in the supply chain.

Some expected benefits of the system are the following: a better information visibility, a fast notification of disturbances throughout the supply chain and a synchronized production scheduling. These benefits will involve important cost savings and a competitiveness increase for the supply chain as a whole, which is very important in order to survive at the new global business market.

Next steps will include a prototype development and systematic tests that will check the suitability of the architecture and algorithms selected.

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