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From process control to supply chain management: An overview of integrated decision making strategies

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ABSTRACT

Optimal decision-making in a process industry is fundamental in order to guarantee optimality of operations and increase profits and performance of a company. Decision-making occurs at different levels, from process control to supply chain management. Traditionally, these decisions have been considered individually, with little or no interaction between each other. However, an integrated decision-making framework can guarantee solutions closer to optimality. Such integration usually results in complex and large scale problems that are difficult to solve. We provide an overview of integrated decision-making strategies and review recent advances in the area, highlighting promising works as well as the main challenges that have yet to be overcome.

1. Introduction

The process manufacturing industry has a tremendous significance to the US economy. It accounted for 12.1% of gross domestic product income (GDP) in the economy in 2015, and it is directly responsible for 12.3 million jobs in the US, according to the Bureau of Economic Analysis. However, this segment faces numerous challenges such as the constantly growing world-wide competition, increasing complexity of production process, fluctuating customer demand and expansion of supply chains, as well as huge structural cost disadvantages when compared to its major competitors, according to the Manufacturing Institute ("The Structural Cost of Manufacturing in the United States," 2011). In the field of operations research and process systems engineering, the main strategy to combat these emerging challenges and improve the efficiency of process industry is the pursue of optimal operation conditions through an enterprise-wide optimization.

Enterprise-wide optimization proposes to optimize the decision making process amongst the various levels that comprise the supply chain of a company. The decision making in the process industry ranges across different scales, from process control to supply chain management as shown in Fig. 1. The decisions taken at these levels vary in terms of time horizon, complexity and objectives. On one end of the spectrum, strategic decisions determine the configuration of the supply chain network and usually have time horizons of years. On the other end, process control decisions have time horizons of seconds and focus on transition periods when processes are subject to disturbances.

Traditionally, the decision making problems have been considered individually and solved in a sequential way. An upper level problem is often solved with few or none information from lower levels. Its result is then transmitted to the lower levels, which must be optimized given the conditions already set by upper level problems. Consequently, sequential approaches may result in sub-optimal and infeasible solutions that can be avoided by an appropriate integration of different decision layers. Driven by this possibility, many researchers have explored the problems of integrating two or more decision making process, and techniques to solve the complex resulting problems have been developed.

This paper provides an overview of state-of-the-art methods for integrating different levels of the decision making process. In particular, the problems of supply chain management, the integration of planning and scheduling and the integration of scheduling and control are addressed. An ideal framework capable of integrating all the decision levels, considering the complexities and dimensions of a real world enterprise has yet to be developed. The ultimate goal of an enterprise wide optimization will require efforts from both academia and industry communities. However, considerable advances in the past few years can be found in the literature. We review such advances, highlighting promising works as well as the main challenges that have yet to be overcome.

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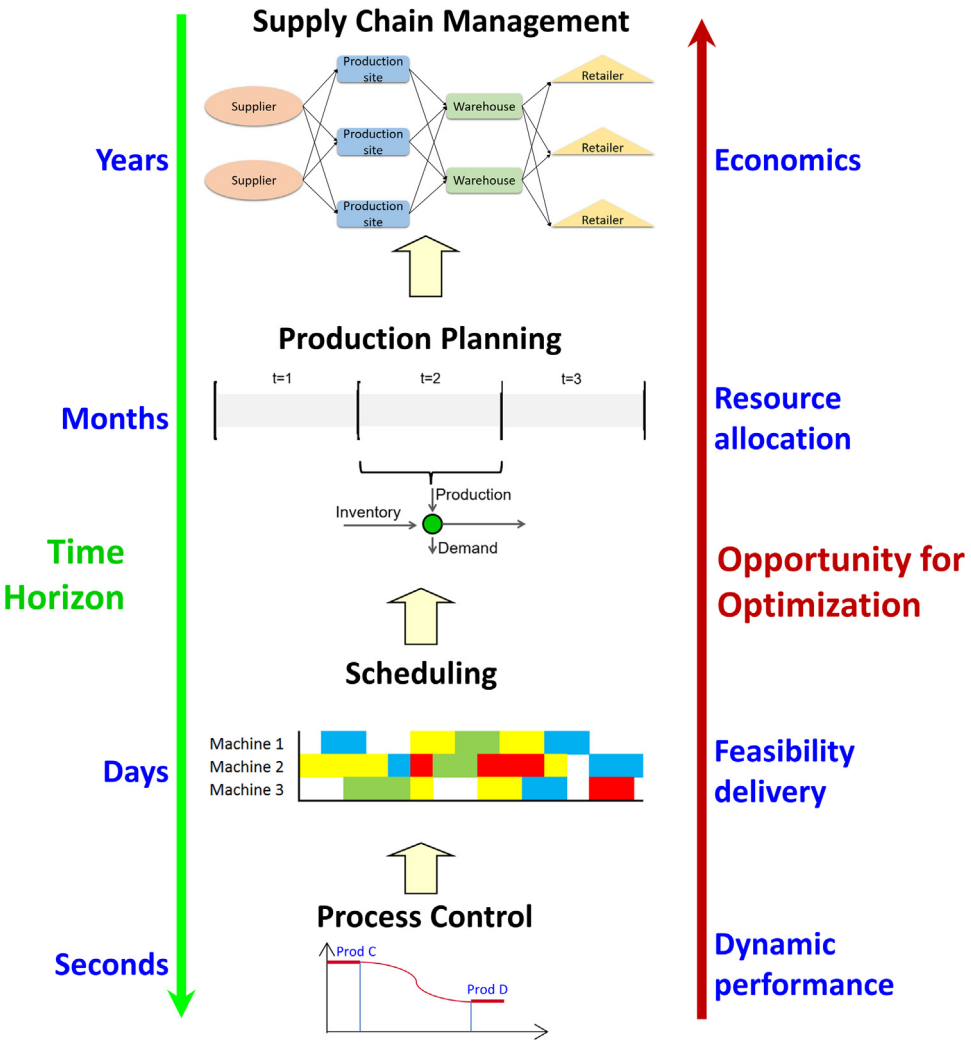

Fig. 1. Enterprise-wide decision making.

2. Supply chain management

A supply chain may be defined as an integrated process in which a group of various business entities, such as supplier, producers, distributors and retailers, work together in an effort to acquire raw materials, convert these raw materials into specified final products, and deliver these final products to retailers (Beamon, 1998). A supply chain schematic is shown in Fig. 2. Stadtler (2005) defines supply chain management as: '*the task of integrating organizational units along a supply chain and coordinating materials, information and financial flows in order to fulfil customer demands with the aim of improving competitiveness of the supply chain as a whole.*'

The planning tasks that support the decisions about material flows across a supply chain can be considered at different levels of aggregation and planning intervals ranging from "aggregated long term" to "detailed short term" planning (Fig. 3). At the strategic level (long-term), decisions related to number, capacities and location of manufacturing sites, warehouses and distributions centers are taken. Therefore, at this level, the design of the supply chain is defined. A comprehensive review focusing on methods to optimally design supply chains, as well as opportunities and challenges in this area has been recently published by Garcia and You (2015). At a tactical level (mid-term decisions), we look at problems which aim to define the most efficient way to fulfil demand forecasts over a medium-term planning interval. Tactical planning aims to balance demand forecasts with available capacities, and assign demands to production sites.

Traditionally, decision at strategic and tactical levels of a supply chain have been made individually by each entity in a network, based on their individual goals and objectives. However, greater efficiency and reduced costs can be achieved through proper coordination amongst the entities in terms of material, financial and information flow, which provides the motivation behind developing an integrated model for the whole supply chain. Due to increasing globalization of companies, integrated models must consider complex, large size global networks with different laws, taxes regimes, exchange rates and policies intrinsic to each country belonging to the supply chain. Hence, the first challenge in supply chain optimization is related to the modeling and accurate representation of detailed, complex interactions between global entities. A second challenge rises from the fact that strategic and tactical decisions usually involve a high level of uncertainty, such as uncertainties in demand, supply, process, resources availability and product returns. Such uncertainties must be dealt within the optimization frameworks, and risk management must be incorporated in solution strategies (Barbosa-Povoa, 2012, 2014). Additionally, the traditional supply chain paradigm where the goal was the maximization of profit while guaranteeing customer satisfaction is now changing, and aspects related to environmental and social concerns should be considered, leading to sustainable supply chains.

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