Supply chain production planning of a manufacturing project system 4.0: case study: Shipbuilding

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Abstract: Projects characterized by high difficulty in terms of planning and administrative control, require the strategies facilitated by Manufacturing Project Systems (MPS). Among them is an adequate management of the Supply Chain used as a competitive strategy. It could be said that in the case of shipbuilding, the Supply Chain is much more complicated due to the number of intervening parties and many shipyards have opted to include Concurrent Engineering with the implication of considering all the elements that make up the product life cycle. The objective of this article is based on the study of the existing applications for the integration of the companies' management as well as the technological contributions that can collaborate to the integration of the Supply Chain production planning. Getting to identify the seven key technologies of Industry 4.0 that most contribute to the sustainability of shipbuilding.

Keywords: Production planning, Supply chain, Shipbuilding, Industry 4.0.

1. Introduction

Manufacturing Project Systems (MPS) consist of a series of phases in which there is a sequence of operations that contribute to the final objective of the project. Projects that are characterized by high cost and difficulty in planning and administrative control [1]. It is therefore that among the MPS strategies there is an adequate management of the supply chain, as well as models to follow. At the same time, an adequate supply chain management affects all the strategic levels of the company. It affects the corporate strategy, both in the sector and in the market in which the company will compete, it affects the competitive strategy and the functional strategy within each of the areas of which the company is composed. Therefore, the Supply Chain is considered as a strategic concept in the business models of the companies [2].

One of the most complex projects would be those associated with shipbuilding, where a project involves different manufacturing plants that may or may not be located in the same shipyard, as well as different suppliers and other secondary agents, enhancing the strategic concept of the Supply Chain with the intention of improving the great impact it has on the profitability of the project. To achieve this impact on the profitability, supply chain management must be excellent and must be the objective of the company itself, since competition no longer takes place between companies but between Supply Chains [3].

Within this competition between Supply Chains and in the search for competitive strategies, one of the existing proposals that many companies, as well as some shipyards, are opting for is Concurrent Engineering. Concurrent Engineering is defined as a systematic effort for an integrated design of the
product, its manufacturing process and its service. This effort on the part of the managers, implies to take into account all the elements of the Product Life Cycle [4].

This Concurrent Engineering approach, as opposed to traditional approaches, requires cross-functional integration and concurrent development of the product and its associated processes as shown in figure 1. It is a philosophy that is implemented by several methodologies and requires different tools and technologies. Of course, good communication among all team members, which represents a cultural change in the company [5]. The purpose of this article therefore, is to analyse both the technologies that may be necessary for its implementation among the enablers of Industry 4.0, as well as tools and techniques that may be useful to the production planning of the supply chain of a manufacturing 4.0 project system applied to the case of shipbuilding.

![Figure 1. Concurrent Engineering approach to SC. Adapted from [6].](image)

2. Methodology

In order to achieve higher flexibility and quicker response to market changes as well as better internal communication, the strategic perspective of including Concurrent Engineering in the integration process of research and development, product design, process planning and manufacturing is valued. This creates the need to manage in a coordinated way the design processes with the production and Supply Chain processes through the solutions provided by enabling technologies of the Industry 4.0 and integrating it with those that the company already has for its management, such as the Enterprise Resource Planning (ERP) systems, in order to leave aside the traditional structures that promote the individual efficiency of each department. The introduction of technologies that facilitate functional integration does not guarantee the success of such integration among all the agents, but also requires important changes in the way processes are conceived, which are usually not well received by the participants.

In order to carry out the study, it will start with an overview of the applications for integrated enterprise management and then study the technological contributions that enhance the integration of the supply chain in production planning. The study will take into account those in which sustainability is a transversal axis through which the development and implementation of good practices are promoted both in the company itself and in the collaboration with suppliers and customers.

For integrated enterprise management, there are several solutions that have been implemented thanks to information and communication technologies. Each of these technologies covers the different elements of the product life cycle under the umbrella of Concurrent Engineering as shown in figure 2. Among them are the Manufacturing Execution Systems (MES) guaranteeing quality and efficiency of
the manufacturing process. They are capable of concentrating different plants and information related to the production of the different suppliers and of easy integration with the different equipment used and the different applications within the company. It can be said that MES provides visibility, control and optimization of processes and products throughout the company in real time [7].

Following there are Enterprise Resource Planning (ERP) systems that cover production, distribution and even human resources operations, allowing the automation of company processes, providing information on the same platform and integrating different databases in a single program [8]. In order to know what we must manufacture, when and how much must be supplied, the concept of Material Requirement Planning (MRP) and its evolution MRP II arise, which takes into account the entire business organization, in this evolution the resources available to carry out this planning are contemplated [9]. In order to provide fast, accurate and real time information about what is happening on the production line, Point of Production (POP) systems are born, allowing to collect, analyse and consult all these data, the production result, stocks, work in progress, inventory, quality, equipment performance and problems according to the production plan and order [10].

In addition, the combination of various technologies such as Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) and Computer Aided Engineering (CAE) give rise to Computerized Manufacturing Systems (CIM) increasing the speed of manufacturing processes through the use of sensors facilitating the control of processes in real time [11].

Advanced Planning & Scheduling (APS) is based on the ERP and analyses all production and sales variables. It makes relative decisions on the optimal quantity to produce, in which plant it is convenient to carry out the production and at what time it is convenient to do it [12].

Additionally, there are software applications for Supply Chain Management (SCM) providing real-time analysis of the entire flow of products and information throughout the entire Supply Chain network. Also, for Supplier Relationship Management (SRM) and Customer Relationship Management (CRM). Summarizing, it could be said that there are solutions to control the processes of most business management, to name some more: Sales & Service Management (SSM); Business Process Management System (BPMS); Product Data Management (PDM); Quality Management System (QMS); Warehouse Management System (WMS).

Figure 2. Solutions for Integrated Enterprise Management.

3. Technological Contributions
Having analysed the enabling technologies of Industry 4.0, it is possible to say which may be the ones that most directly influence Supply Chain production planning. Starting with the Internet of Things it
could be said that it has quite a lot of application on Supply Chain process control, it allows feedback automatically and in real time. This information allows to know the deviations that could be detected along the chain, allowing to establish corrective measures to solve these deviations. This exchange of information and data is very valuable for production planning, reducing preparation and delivery times [13,14]. It facilitates the management of verification actions and identity of the machines in use [15]. In the shipbuilding sector, there are examples of these solutions [16] as well as a pipeline construction project, where the identification and traceability of the pipelines is carried out by means of sensors [16].

All these data collected through the Internet of Things can be subsequently analysed through the use of Simulation [17], thus providing a very useful tool both before the possible implementation or inclusion of any new element, whether machine, supplier, destination, etc, as well as for a possible analysis after the detection of failures in the search for solutions. Simulation also helps to predict the effects of part assembly [18] as well as a control tool for supply chain decision making [19] to solve complicated problems [20] and to identify critical points in the logistics flow [21]. Specifically, in the shipbuilding sector, there is evidence of its use as a tool for both supply chain decision making [22] and as a training tool for the development of ship design [23].

Similarly, the data collected provides advantages if used in remanufacturing practices through the use of Big Data Analytics [24]. Big Data Analytics is also used to support Supply Chain decision making by supporting dynamic production [25]. In the shipbuilding sector, it is interesting to note how the use of Big Data focuses on reducing emissions [26,27] as well as optimizing ship safety efficiency and maximizing health and safety efficiency [28].

A new dimension of the relationship between financing and production appears with the use of Artificial Intelligence [29]. It facilitates the execution of negotiations based on the design of mechanisms [30]. It solves problems in SC management by allowing to track, communicate, analyse and ensure the overall sustainability of the system [31]. Artificial Intelligence offers adaptive resource management based on multi-agent technology [32] and allows producing parts more affordable, faster and with less weight [33]. In shipbuilding, there is evidence of its use in plant scheduling [34] and production control architectures focused on CO2 emission reduction [35].

Another technology that is part of the study and stands out in how it affects supply chain production planning is Cybersecurity performing the function of threat deterrence and mitigation [36] and providing mechanisms to identify generic and manufacturing-specific vulnerabilities [37]. Other options found are based on deriving the behaviour of programs with hidden malicious operations and supporting workforce productivity [38] in addition to providing operational certainty of supply chain systems [39]. In shipbuilding, there is evidence of improvement in economic, energy and environmental aspects [40] through the use of Cybersecurity and Cloud Computing. In addition, Cloud Computing provides unlimited processing to Supply Chain Management [41] and enables the collection, provision and analysis of relevant data across all companies that make up the Supply Chain [14,42].

Another technology that supports Supply Chain sustainability is Additive Manufacturing through material recycling [43] and through remanufacturing of high-value parts in the reverse logistics supply chain [44]. Additive Manufacturing used during the supply phase, modifies complex subassemblies into a single integrated structure [45] In shipbuilding allowing design flexibility, reducing waste and integrating subassemblies [46] however increases lead time, shipping cost, inventory requirements and transportation vulnerability [47].

Finally, it is worth mentioning Blockchain technology, this technology ensures traceability by certifying the agents involved in the Supply Chain [48,49], provides reliability in the creation of shared process protocols, business logic and financial ledgers [50]. It also ensures the security, transparency and visibility of the network from the origin of the Supply Chain and reengineering processes to improve security. There is evidence in shipbuilding of security enhancement in collaborative process development processes improving the integrity and traceability of Supply Chain data [51]. Figure 3 show a summary of enabling technologies studied.
4. Conclusions
Through the study carried out, we have been able to analyse how the concurrent engineering philosophy provides a series of advantages such as efficiency in the production of high quality with the creation of optimized designs in which there is a feedback in each of the phases that compose it.

To implement this type of philosophy, we have seen how there are different applications on the market that allow to establish in an agile way and in real time, the interconnection between all the phases as well as the identification and solution of the problems that allow to reach the production objectives.

Subsequently, an analysis was made of the Industry 4.0 enabling technologies that add the most value to the characteristics described above while supporting sustainability.

In this sense, the Internet of Things stands out above the rest, providing a series of real-time data that will serve as the basis for the subsequent study through Big Data Analytics, as well as Simulation. For the Shipbuilding sector, the contributions of Simulation technology are of great interest. Cybersecurity is postulated as essential in this sector especially in military projects and as a guarantor of all Blockchain operations closes the circle of the most outstanding.

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