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International Manufacturing Networks Supply Strategy Design Aided by Simulation Tools: An Empirical Study in the Wind Sector

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1. Introduction

In the last decades, many manufacturing companies are suffering a trend toward multisite location and greater fragmentation of theirs productive and logistic processes. This fact out lights that the open of boundaries in Eastern Europe and the irruptions of countries in the global trade economy, have forced to develop value added activities such as engineering, purchasing, manufacturing and assembly in different places, even in different countries. According to Ferdows (2006) and Farrell (1997), there are four main reasons that explain this phenomenon:

Off shoring: access to low cost production in developing countries through owned or partly owned (joint venture) facilities.

Entering new markets: Companies enter new countries to expand demand where new facility is needed because there is a trade barrier or transport/logistic lead time that avoid supplying this market from the headquarters.

Disaggregating value chain and reengineering value chain: design and produce the different engineering, purchasing and production activities of the value chain in the most suitable location in terms of cost, quality and service.

Creating new product and market: identifying new markets with new product/process far beyond the traditional activities carried out in the company.

Complementary reasons to begin the internationalisation process are: *diversification of risk* to compensate for temporary losses in some regions with the gains in others (Thompson and Strickland (2004), Jarillo and Martínez, 1991); g*etting economies of scale* in their production activities, R+D, distribution and procurement, among others, this allows a reduction in costs (Deresky, 2000); *capitalizing major investments* and compensating the reduced cycle life of products with the relative homogeneity of markets (Jarillo and Martínez, 1991, Yip and Bink, 2007); a*cquiring prestige* and carrying on growing globally and gaining competitiveness (Jarillo and Martínez, 1991).

Thus, the internationalisation of manufacturing networks implies carrying out disaggregated value chain activities (i.e. engineering, purchasing, manufacturing and distribution) beyond its traditional market, which require a greater coordination to get acceptable levels of quality, flexibility and cost. The new manufacturing and supply configuration, when facing a internationalisation process to enter new markets with new facilities implementation abroad, is a topic which is becoming relevant in the operations management science (Johansson and Vahlne, 1977, Ferdows, 1997, Errasti, 2011).

Nevertheless, the process of designing these manufacturing networks and how to accomplish the integration of the multisite and fragmented production system has not been studied in depth.

Thus, this paper after showing the literature of the relevant issues in Global Operations strategy when designing a new manufacturing network, explores the supply strategy and how simulation techniques could aid designing the supply strategy. To demonstrate the effectiveness of the proposed techniques, the researchers have been involved in a case research of a wind power sector company.

2. Literature Review

2.1 Business Strategy and the Ramp up of the Operations in an Internationalisation Process

Some authors (Moneska et al., 2009) state that Business strategy should be linked with Operations strategy. In this context, the production and logistic system strategy or Operations strategy conditions the decisions and reengineering projects to be accomplished in the medium and short term in a company to improve the competitive advantage of the supply chain. The Operations strategy has to gain more effectiveness and efficiency of operations resources through defining and implementing the suitable operations strategy decisions, managing the tangible resources, developing operations capabilities to reach the performance objectives of the market requirements.

The decisions to be accomplished in a new manufacturing network configuration in an internationalisation process are: manufacturing facilities location, supply strategy, productive and logistic operations activities design, integration or fragmentation of productive and logistic operations, facility strategy role in the global network design, suppliers and distribution network design.

The ramp up concept describes the period characterized by product and process experimentation and improvements (Terwisch and Strickland, 2004), which strictly speaking starts with the first unit produced and ends when the planned production volume is reached (T-Systems, 2009). Nevertheless, in order to manage such a ramp up with a high degree of precision, first of all a planning period phase is necessary, starting with the design of the product, the process and the supply chain network (Kurtila et al, 2009; Sheffi, 2006).

2.2 Supply strategy in a multisite and fragmented production system

Among relevant Operations strategies, the Quick Response Supply Chain strategy consists of reducing the lead time of the supply chain and allows a synchronized and demand driven production system, integrating manufacturers and suppliers. The production capacities of all echelons are balanced and there is a tangible takt time trying to optimize the materials flow in terms of quantity, response time, stock and equipment efficiency (Simiche et al., 2000)

Nevertheless, in a multisite and fragmented production system, where the suppliers network is composed by local or domestic suppliers and offshore suppliers and manufacturing facilities, these offshore suppliers and facilities need the coordination of quality control and long delivery times. Here is the problem; due to the fact that Quick Response Supply Chain and Just in Time principles are not applicable in depth, and the gap between customer delivery time and supply chain lead time needs forecast driven manufacturing, supplying and purchasing decisions. Besides, multiple Decoupling Points and the Order Penetration Point have to be fixed to assure the supply strategy.

According to the strategy to respond the demand, it could be to differentiate two concepts: Order Decoupling Point (ODC) and Order Penetration Point (OPP). The lead time gap between the production lead time, i.e. how long it takes to plan, source, manufacture and deliver a product (P) and the delivery time, i.e. how long customers are willing to wait for the order to be completed (D) is key element of the supply chain (Sheffi, 2006). Based on comparing P and D, a firm has several basic strategic order fulfilment options: *Engineer to Order (ETO) – (D>>P), Make to Order (MTO) – (D>P), Assemble to Order (ATO) – (D<P) and Make to Stock (MTS) or Build to Forecast (BTF) – (D=0).* The OPP is defined as the point in the manufacturing Value Chain for a product, where the product is linked to a specific customer order. Sometimes the OPP is called the Customer Order Decoupling Point (CODP) to highlight the involvement of a customer order. Nevertheless is not the same, because in a fragmented international material flow there could be various ODCs, but the OPP is one. Thereby, the OPP is one of the strategic decisions because of its impact in the supply chain performance in terms of service and cost.

The Global Operations tendency arises multiple configurations. Meixel e Gargeya (Meixall and Gargeya, 2005) state that the raw materials, components, manufacturing and assemblies stages could be locally or globally configured. As a result, the internal functions such as engineering, purchasing, manufacturing, and external suppliers have to coordinate the decision points and the action points to ensure the smooth functioning of the manufacturing system. Thus, the coordination between agents of the supply chain and the supply strategy response to a highly dynamic and volatile environment when entering a new market could cause ramp up delays in time and volume, production losses, especially when new factors are introduced (Abele et al., 2008).

2.3 Digital Factory and simulation techniques: DGRAI and Discrete Event modelling simulation

To accomplish the production process and network development, the Digital Factory concept and tools related such as simulation techniques could be appropriate to plan and test the different configurations in order to reduce time to market (Spath and Potinecke, 2005).

Simulation techniques have been used in industry for many years, but the increase in the power of computers has expanded the scope of simulation tools, as well as facilitating their use in smaller companies. One definition of computer simulation is the following: “The practice of building models to represent existing systems, or hypothetical future systems, and of experimenting with these models to explain system behaviour, improve performance, or design new systems with desirable performances" (Khoshnevis, 1994). Computer Simulation is a technique that uses the computer to model a real-world system, especially when those systems are too complex to model with direct mathematical equations without disturbing or interfering with the real system (Banks et al., 2010). The main advantages of simulation arise from the better understanding of interactions and identification of potential difficulties that simulation offers, allowing the evaluation of different alternatives and therefore, reducing the number of changes in the final system. There are several simulation techniques; however, Discrete Event Simulation is the most commonly used (Jahangirian et al., 2010).

Among simulation tools, the DGRAI tool could be useful to plan and test the decision centres of the operational planning and scheduling system. This system contains the decision of plan, source, make and/or deliver of different agents in the supply chain and the impact in customer delivery and the coordination problems of the simulated supply strategy (Poler, Lario and Doumeingts, 2001). This simulation allows coordinating the decision points and action points to ensure the adequate functionality of the manufacturing and supply system (Errasti, 2008).

3. Research Methodology

Our examination of the literature revealed that simulation techniques could aid configuring the supply strategy in an international manufacturing network design. Therefore, in order to test this proposition, a two phase research design based on the principles of Action Research (AR) was devised, i.e. a theory building and a theory testing phase.

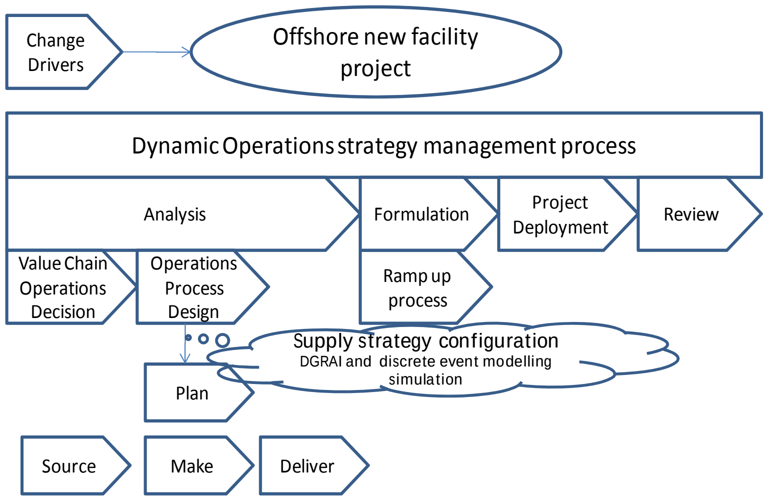
The objective of the theory building phase was to define a methodology/guide that could be used by practitioners in real organizations to implement the supply strategy configuration aided by simulation tools.

In the theory testing phase, the approach used is experimented and the results of the implementation process are shown. AR is a variation of Case Studies, where both researcher and client are actively engaged in solving a client-initiated project dealing with a certain business problem (Schein, 2006).

3.1. Theory building: Globope Framework

The Globope Model is a framework for the design of operations in manufacturing networks (Errasti, 2008). The methodology/guide takes into account the position of the Business unit in the Value Chain and sets the stages which should help value creation. An analysis stage is used to analyze the factors and choose the content of the strategy. In the analysis stage, the operations process is revised and when studying the supply strategy, DGRAI and Discrete Event modelling simulations techniques are used. The analysis contributes to a definition or formulation of the new facility ramp up process and then, a deployment stage of the formulated design is set. The deployment is a project-oriented task, where a process of monitoring and reviewing to facilitate the alignment of the organization to the Operations strategy is set. The full framework is illustrated in Fig. 1.

Figure 1 Schematic representation of the Globope framework



3.2. Case Research

The case company is a wind generator company which supplies these generators for the Eolic Wind sector. The company has a facility in the north of Spain, but due to the formulation of a global Business strategy to enter new markets, specially the North American market, there is a need of implementing a new facility in the USA. For the ramp up process, the defined Operations configuration is that the first stage of the generators are manufactured in Spain and the second stage (balanced and assembly) are made to order in the USA facility.

This supply strategy proposes that generators are assembled to order in the USA facility and there is a need of strategic inventory of subassemblies in the USA, which are replenished based on forecast by the Spanish facility. Thus, the OPP of the system is the inventory of subassemblies.

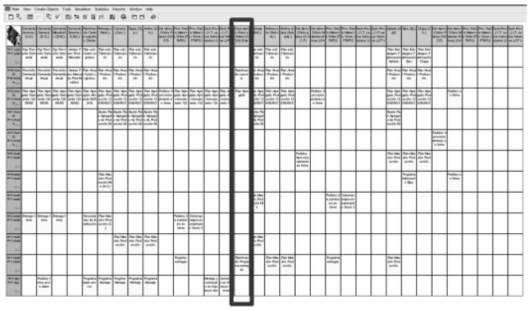
The Spanish facility has to settle down also strategic inventory of critical parts, which are replenished based on forecast. Thus, there is an ODC of the company in the critical parts storage to assure the manufacturing of first stage of the generator when needed.

Thus, the gap between customer delivery time and supply chain lead time needs forecast driven manufacturing, supplying and purchasing decisions and multiple decoupling points and the OPP implementation along the supply chain.

Besides, the coordination needed in the production planning and scheduling between agents of the system has high complexity and the strategic inventory quantity of subassemblies and parts have to be fixed depending of the demand pattern and procurement and supply uncertainty.

The researchers monitor de Decision system of the production planning and scheduling through DGRAI to highlight the problems related to the decision coordination from a dynamic point of view (Fig.2)

Figure 2 Production planning and scheduling simulations with DGRAI



Secondly, the possible demand patterns and the supply uncertainty are simulated with Discrete Event Simulation through the software AnyLogic 6.5.0 (Fig.3) to fix the strategic inventories of subassemblies in USA and critical parts in Spain. For this purpose, the company managers set four different scenes: regular demand and certain supply, variable demand and certain supply, regular demand and uncertain supply and finally variable demand and uncertain supply.

Figure 3 Discrete Event Simulation with Anylogic 6.5.0

These simulations let us to choose the obtained Service level to customer and the subassemblies and critical parts stock needed, aiding to fix the right Service Policy. The Discrete Event simulation aids defining the Inventory Policy (s, S) of subassemblies and critical parts, the security stocks, the reorder points and the replenishment quantities taking into account different demand patterns and supply uncertainty due to maritime transport of subassemblies.

4. Conclusions

The analysis of the supply strategy to guarantee the service policy becomes more complex due to longer lead times and the management of different stocks and ODPs, in a multisite and fragmented international production system.

The simulation techniques used with a structured approach could aid to increase effectiveness when configuring the supply strategy.

Thereby, in the initial Operations design should consider the following properties on a network level: adaptability to product demand changes, flexibility to product demand variety and contingency operability.

Firstly, the adaptability let them handle a variety of requirements that could change such as product volumes. Thus, the proposed design would have the ability to be scalable and adjustable at reasonable costs to future needs coordinating decisions of different agents of the supply chain. Secondly, the flexibility let them handle the product mix, so the proposed design would have the capacity to accomplish constraints due to the increase of information and material flow complexity related to product mix increase. Finally, the possible contingency plans need to cover supply uncertainty. It will allow confronting the unforeseen events due to their high impact even if the probability of occurrence of these events is not high.

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