Framework for Improving the Design and Configuration Process of an International Manufacturing Network: An Empirical Study

Sandra Martínez, Ander Errasti

Framework for Improving the Design and Configuration Process of an International Manufacturing Network: An Empirical Study

Sandra Martínez[1], Ander Errasti

[1] Engineering School, Tecnun, University of Navarra, San Sebastián, Spain,
{smartinez, aerrasti}@tecnun.es

Abstract. As competition becomes global and the environment in which companies operate is becoming more complex, the design and managing of international manufacturing networks has become crucial. Therefore, it is important to do an analysis of the necessary decisions any company must make, such as facilities location, supply strategy, facility strategy role, etc., in order to accomplish the internationalisation process with more reliability and success. The authors of this paper present the GlobOpe framework, which is a model to be used by managers to design and configure a new manufacturing network aided by various techniques. This paper also presents a case study in order to demonstrate the effectiveness of this model when reconfiguring an international manufacturing network for a wind generator manufacturer.

Keywords: Internationalization, framework, ramp up process, operations strategy

1 Introduction

In the last decades, in addition to the multinational companies (MNEs) already in the market, more and more small and medium size companies (SMEs) are also engaging in international production. Specifically, both MNEs and SMEs are experiencing a trend toward multisite location and greater fragmentation of their productive and logistic processes. This fact highlights that the opening of borders in Eastern Europe and the eruption of countries such as China, Brazil and India into the global trade economy have forced companies to develop value added activities such as engineering, purchasing, manufacturing and assembly in different places, even in different countries. Due to the long-term impact on the competitiveness of companies, offshoring decisions are key aspects of strategic enterprise positioning [1-2], and they also play a crucial role in the competitiveness and the labour market of the regional and national economy [3].

According to Ferdows [1] and Farrell [4], there are four main reasons that explain the internationalisation phenomenon: offshoring, entering new markets, disaggregating the value chain and reengineering the value chain and creating a new product and market.

adfa, p. 1, 2011.

Thus, the internationalisation of manufacturing networks means carrying out disaggregated value chain activities (i.e. engineering, purchasing, manufacturing and distribution) beyond a company's traditional market, which requires greater coordination in order to get acceptable levels of quality, flexibility and cost. Therefore, it is important to take into account that increased commitment abroad does not only promise opportunities, but it is also fraught with risk. For this reason, the relocation of production as well as auxiliary activities calls for a careful balancing of risks and benefits [5].

New manufacturing and supply configurations, which companies who are undergoing the internationalisation process in order to enter new markets must face when installing new facilities abroad, is a topic which is becoming relevant in the science of operations management [1], [6]. Additionally, the coordination between agents involved the supply network 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, especially when new factors are introduced, which then leads to production losses [7].

Finding the best network for manufacturing and supply facilities adapted to new marketplaces is not a problem that is exclusive to MNEs, which operate in a worldwide context; it is now just as relevant for both SMEs or "late movers" who are undergoing an internationalisation process and companies that are reconfiguring their multiple site networks [8].

Operations strategy has to gain more effectiveness and efficiency over operations resources through defining and implementing suitable Operations strategy decisions, managing tangible resources, and developing operations capabilities in order to reach the performance objectives of the market requirements.

The decisions that need to be made regarding a new manufacturing network configuration in the internationalisation process are:

- Manufacturing facilities location decisions.
- Role of facilities strategy in the global network design.
- Integration or fragmentation of productive and logistic operations.
- Supply strategy.
- Suppliers and distribution network design.

Furthermore, the Global Operations trend gives rise to multiple configurations. Meixell and Gargeya [9] state that the raw materials, components, manufacturing and assembly stages could be locally or globally configured. As a result, internal functions such as engineering, purchasing, manufacturing, and external suppliers have to coordinate with the decision points and the action points to ensure the smooth functioning of the manufacturing system.

Practical experience has shown that strategy-specific checklists are needed, which might raise awareness of the real success factors of the pursued goal. Such checklists could serve managers as experience-based guidelines to identify the most important criteria and thus avoid unpleasant surprises [10]. Vereecke and Van Dierdonck [11] as well as Shi [12] state that Operations and Supply Chain management researchers should pay attention to providing understandable models or frameworks of international manufacturing systems that help managers to design and manage their networks. Moreover, our examination of the literature revealed that simulation techniques could aid in configuring the supply strategy in an international manufacturing network design [13].

The Framework presented in this paper is intended to fill a gap left by Production systems (i.e. Toyota PS, Volvo PS, Bosch Siemens PS, etc.) and the lean manufacturing programs both of which lead the way to excellence when implemented in a facility in a stable environment but which are difficult to take advantage of in a dynamic market environment and in the new contexts of new offshore facilities implementation and the reconfiguration of an existing network [14].

Hence, this paper, after showing the literature of the relevant issues in Global Operations strategy, presents how a framework and associated techniques could aid when designing and configuring a new manufacturing network. To demonstrate the effectiveness of the proposed techniques, the researchers have been involved in a case study of a wind power sector company.

2 Literature Review

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

Some authors [15] 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 carried out in a company in the medium and short term to improve the competitive advantage of the supply chain. Operations strategy has to gain more effectiveness and efficiency over operations resources through defining and implementing suitable operations strategy decisions, managing the tangible resources, and developing operations capabilities in order to reach the performance objectives of the market requirements.

When assessing production locations abroad, companies tend to underestimate the necessary ramp up times for securing process reliability, quality and productivity. The ramp up concept describes the period characterized by product and process experimentation and improvements [16], which strictly speaking starts with the first unit produced and ends when the planned production volume is reached [17]. Nevertheless, in order to manage such a ramp up with a high degree of precision, first a planning period phase is necessary, starting with the design of the product, the process and the supply chain network [18-19].

A study carried out in 39 internationally active German companies show that not only the small firms but also the larger companies tend to heavily underestimate ramp up times and coordination costs for foreign production sites. Specifically, on average, ramp up times are 2.5 times longer than originally planned. The absolute time required for the ramp up of foreign production sites until smoothly running production processes have been established ranges in almost all the cases from 2-3 years. Ramp up times do not only entail higher coordination costs, they can also considerably affect the calculated amortisation time, which for many companies is the decisive criterion tipping the scale for or against an offshoring engagement [10].

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 which tries to optimize the materials flow in terms of quantity, response time, stock, and equipment efficiency [20].

Nevertheless, in a multisite and fragmented production system, where the supplier network is composed of local or domestic suppliers and offshore suppliers and manufacturing facilities, these offshore suppliers and facilities need the coordination of quality control and the supply network with different delivery times and procurement reliability. The gap between customer delivery time and supply chain lead time needs forecast driven manufacturing, supplying and purchasing decisions. 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. In addition, multiple Decoupling Points and the Order Penetration Point have to be fixed to assure the supply strategy.

According to the strategy for responding to demand, two concepts should be differentiated: 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 [20]. Comparing P and D, a company 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)* [21].

Given the inherent differences in these manufacturing strategies; MTO firms are characterized by low volume, customization, process flexibility, higher work-in-process inventory, lower finished goods inventories, and longer lead-times; and MTS firms are characterized by high volume, standardization, dedicated equipment, lower work-in process and higher finished goods inventories, and shorter lead-times [22].

Nevertheless, the implementation of the right supply strategy in global and fragmented production systems becomes more difficult because there is a need of settling down more than a decoupling point. Multiple Decoupling Points and the Order Penetration Point (OPP) have to be fixed to assure the supply strategy. The OPP divides the manufacturing stages that are forecast-driven (upstream of the OPP) from those that are customer-order-driven (the OPP and downstream). The OPP is defined as the point in the manufacturing Value Chain where a 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, it is not the same because in a fragmented international material flow there could be various CODPs, but there is only one OPP. Thereby, the OPP is one of the strategic decisions because of its impact on the supply chain performance in terms of service and cost.

The Global Operations phenomenon proposes multiple designs for the different stages of the production system. These stages could be locally or globally configured [9]. Effective coordination between the agents of the supply chain and the supply strategy response in the Global network is really important for trying to avoid ramp up delays in time and volume.

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

To carry out the production process and network development, the Digital Factory concept and the related tools like simulation techniques could be appropriate for planning and testing the different configurations in order to reduce the time to market [13].

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" [23]. 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 [24]. The main advantages of simulation arise from the better understanding of interactions and the identification of potential difficulties, 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 [25].

Among simulation tools, the DGRAI tool is useful for planning and testing the decision centres of the operational planning and scheduling system. This system contains the plan, source, make and/or deliver decisions of different agents in the supply chain, as well as the impact on customer delivery and the coordination problems of the simulated supply strategy [26]. This simulation allows the coordination of the decision points and action points in order to ensure the adequate functionality of the manufacturing and supply system [6].

3 Research Methodology

The methodological framework used for this study was based on Constructive research theory. The Constructive research is an approach that aims to produce solutions to explicit problems and is closely related to the concept of innovative constructivism [27]. This approach produces an innovative solution, which is theoretically grounded, to a relevant practical problem. An essential component of constructive research is the generation of new learning and knowledge in the process of constructing the solution [28].

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 organisations to design and configure a new manufacturing network, aided by different purpose-tailored techniques.

In the theory-testing phase, the approach used was tested and the results of the implementation process are shown. AR is a variation of the Case Study, where both researcher and client are actively engaged in solving a client-initiated project dealing with a certain business problem [29].

3.1 Theory building: GlobOpe Framework

The GlobOpe (**Glob**al **Ope**rations) Model is a framework for the design of operations in facilities which are key nodes of the manufacturing networks but also the supply networks [6]. Thus, this Model aids facilities design or redesign process within a network.

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. Moreover, the analysis contributes to a definition or formulation of the new facility and associated network 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 Operation strategy is established [30].

This Framework consists of new facility decision drivers, Operations Management principles, Operations strategy key decisions and potential methods and techniques for aiding the decision process (see Fig.1).

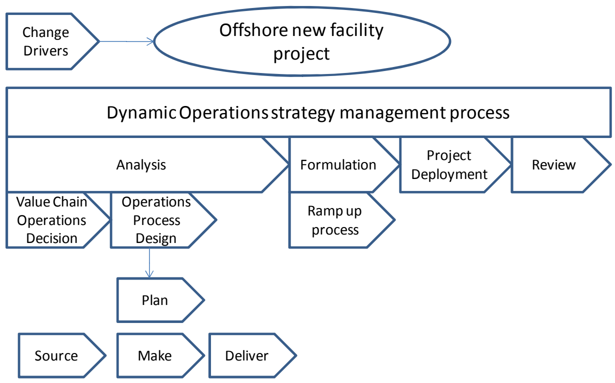

Fig. 1. Schematic representation of the GlobOpe Framework

The principles of Operations Management are those paradigms to be taken into account in Global Operations. The scope of the Operations strategy key decisions are the strategic issues that managers have to decide on before starting with the physical and organisational design of operations involved in the plan, source, make and deliver process [31]. Moreover, the method also describes the implementation processes of the principles and the tools.

3.2 Case Research

The case company is a wind generator company that supplies generators for the wind energy 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 and give a quick response to strategic customers, especially the North American market, there is a need to implement a new facility in the USA.

To grow in sales and reduce business risk of investment in the new facility, the company proposes to fragment the current production process. The production processes header (stacking and winding) are held in Spain and the final processes (balancing and assembly) are implemented in the new location making a sequential industrialization in the generators range until the whole generators is manufactured in the American facility.

The researchers have responded to the five Operations strategy key decisions to engage in an internationalisation process aided by the GlobOpe Framework and the associated principles and tools. The key decisions, the principles and tools will be briefly shown:

- **Location:** The facility location was decided considering the 13 factors identified by MacCarthy and Atthirawong [2]. Firstly, the area was chosen, which was North America; secondly, the country was chosen, in this case the USA, and finally the region was chosen, specifically, Wisconsin.
- **Role:** The strategy role of the plant was selected from among the different roles proposed by Ferdows [1]. The facility in the USA is a server, that is to say, the factory supplies specific national or regional markets. It typically provides a way to overcome tariff barriers and to reduce taxes, logistics costs, or exposure to foreign-exchange fluctuations.
- **Integration/fragmentation of productive and logistic operations:** The fragmentation of the ramp up process was selected from among four different alternatives [7] to achieve the maximum market impact in a short time at a minimal operations cost. The chosen strategy is to introduce the products and the manufacturing process sequentially in order to reduce the complexity of the individual steps. In addition, gaps in employee training can be filled successfully.
- **Supply strategy:** Simulation techniques were used to decide from among different order fulfilment options and configurations (Engineer to Order, Build to Order, Assemble to Order and Make to Stock) and to choose strategic inventory positioning in the fragmented manufacturing system. It is decided that the American facility

assembles the generators upon request, for that reason there must be a strategic inventory of subassemblies in the U.S.A, which are replenished based on forecasts by the Spanish facility. Then, the OPP of the system is the subassemblies inventory. Moreover, the Spanish plant also has to establish a strategic inventory previous to the manufacturing based on forecast; but in this case, this inventory is of critical parts (copper and sheet steal). On this occasion, there is an ODP in the critical parts storage to ensure the first phase of generator manufacturing whenever it is necessary. Thus, with the intention of cover the difference between the customer delivery time and the supply chain time is needed a MTO strategy, decision making at purchase and supply level, and the implementation of multiple ODP and OPP along of the supply chain. Therefore, in order to solve the previous problems, on the one hand, the Discrete Event simulation through the software AnyLogic 6.5.0 aids in defining the decoupling points positioning, 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. On the other hand, DGRAI allows the monitoring of the Decision system of production planning and scheduling to highlight the problems related to the decision coordination from a dynamic point of view.

- **Suppliers and distribution network design:** Firstly, aided by Krajlic's [32] supply market matrix, the most appropriate purchase policies were mapped and defined. This approach takes into account the importance of purchasing and the complexity of supply market. The strategic importance of purchasing in terms of the value added by product line, the percentage of raw materials in total costs and their impact on profitability and the complexity of supply market in terms of supply scarcity, pace of technology and/or materials substitution, entry barriers, logistic costs, complexity, and monopoly or oligopoly conditions. By assessing the company´s situation in terms of these variables the supply strategy was determined trying to exploit purchasing potential and diminish risks. Secondly, aided by Meixall and Gargeya's [9] alternatives, the local and global supply chain configurations were designed.

4 Conclusions

The case study discussed in this paper provides several key conclusions:

- The researchers conclude from the learning process of the implementation that 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, adaptability lets companies 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 to future needs at reasonable costs by coordinating the decisions of different agents in the supply chain.

- Secondly, flexibility lets them handle the product mix, so the proposed design would have the capacity to accomplish constraints due to the increase in information and material flow complexity related to product mix increases.
- Finally, the possible contingency plans need to cover supply uncertainty. They will allow companies to confront unforeseen events due to their high impact, even if the probability of occurrence of these events is not high.

- The analysis of the supply strategy to guarantee the service policy is becoming more complex due to longer lead times and the management of different stocks and order decoupling points (ODPs) in a multisite and fragmented international production system.
- Simulation techniques used with a structured approach could aid in increasing effectiveness when the design and the supply network of the manufacturing facilities are configured. Furthermore, these techniques help to increase the effectiveness of the supply chain configuration by increasing strategic customers' sales due to the reduction of ramp up time.
  - DGRAI technique allowed to highlight certain coordination problems between departments, check the staff saturation and distribute tasks.
  - AnyLogic simulation facilitated the visualization of the different scenarios proposed by the heads of the company and helped to ratify the decisions made.
- The multidisciplinary team involved in the research project considerer the GlobOpe Framework and simulation tools useful for decreasing ramp up delays and managing this process with a high degree of precision. Thus, it could be a management tool for a Steering Committee that is responsible for the effectiveness and efficiency of Global Operations.
- Until that moment, the researchers only thought to develop a framework in order to facilitate the ramp up process for the new facilities implementation abroad, but with this case is thought that it is necessary to expand the GlobOpe Model because there are also a lack of methods and techniques to accomplish the design and configuration process of a global production and logistic network.

5 References

1. Ferdows, K.: Making the Most of Foreign Factories. Harvard Business Review, March-April, pp.73-88 (1997)
2. MacCarthy, B.L., Atthirawong, W.: Factors affecting location decisions in international operations – a Delphi study, International Journal of Operations & Production Management, vol. 23 Iss: 7, pp.794-818 (2003)
3. Porter, M.E.: Clusters and the new economies of competition. Harvard Business Review 6, pp. 3-16 (1998)
4. Farrell, D.: Offshoring. Understanding the Emerging Global Labor Market. Mckinsey Global Institute, Harvard Business School Press (2006)
5. Lewin, A.Y, Peeters, C., 2006. Offshoring work: business hype or the onset of fundamental transformation? Long Range Planning 39, 221-239

6. Errasti, A.:International Manufacturing Networks: Global Operations Design and Management. Servicio Central de Publicaciones del Gobierno Vasco, San Sebastian, Spain (2011)
7. Abele, E., Meyer, T., Näher, U., Strube, G., Sykes, R.: Global production: a handbook for strategy and implementation. Springer. Heidelberg, Germany (2008)
8. Rudberg, M., Olhager, J.: Manufacturing networks and supply chains: an operating strategy perspective, Omega, vol. 31, pp. 29-39 (2003)
9. Meixall, M., Gargeya, V.: Global Supply Chain Design: A literature Review and A Critique. Transportation Research Part E., vol.41, pp. 531 (2005)
10. Kinkel, S.; Maloca, S.: Drivers and antecedents of manufacturing offshoring and backshoring. A German Perspective. Journal of Purchasing & Suppply Management, vol. 15, pp. 154-165, (2009)
11. Vereecke, A., Van Dierdonck, R.: The strategic role of the plant: testing Ferdow´s model, International Journal of Operations and Production management, vol. 22, pp. 492-514 (2002)
12. Shi, Y.: Internationalization and evolution of manufacturing systems: classic process models, new industrial issues, and academic challenges Integrated, Manufacturing Systems, vol. 14, pp. 385-96 (2003)
13. Spath, D., Potinecke, T.: Virtual product development – Digital Factory based methodology for SMEs. CIRP Journal of Manufacturing Systems, vol. 34(6), pp. 539-548 (2005)
14. Mediavilla, M., Errasti, A.: Framework for assessing the current strategic plant role and deploying a roadmap for its upgrading. An empirical study within a global operations network, APMS, Cuomo, Italy (2010)
15. Monczka, R.M., Handfield, R.B., Guinipero, L.C., Patterson, J.L.: Purchasing and Supply Chain Management, 4th edn. South-Western Cengage Learning, USA (2009)
16. Terwisch, C., Bohn, R.: Learning and process improvement during production ramp up. International Journal of Production Economics, vol. 70 (2001)
17. T-Systems : White paper ramp up management. Accomplishing full production volume in-time, in-quality and in-cost (2010)
18. Kurtila, P., Shaw, M., Helo, P.: Model Factory concept-Enabler for quick manufacturing capacity ramp up (2010)
19. Sheffi, Y.: La empresa robusta, Lidl, Madrid (2006)
20. Simchi Levi, D., Kaminsky, P., Simchi Levi, E.: Designing and Managing the Supply Chain: Concepts, Strategies, and Cases. Mac Graw Hill, USA (2000)
21. Khoshnevis, B.: Discrete Systems Simulation. Singapore: McGraw-Hill Inc, pp. 337 (1994)
22. Wikner, J., Rudberg, M.: Integrating production and engineering perspectives on the customer order decoupling point, International journal of operations and production management, vol. 25(7), pp. 623-64, (2005)
23. Birou, L., Germain, R.N., Christensen, W.J.: Applied logistics knowledge impact on financial performance, International Journal of Operations & Production Management, vol. 31(8), (2011)
24. Khoshnevis, B.: Discrete Systems Simulation. Singapore: McGraw-Hill Inc, (1994)
25. Banks, J., Carson, J.S., Nelson, B.L.: Discrete-Event System Simulation. 5th edition. United States: Prentice Hall, pp. 640 (2010)
26. Jahangirian, M., Eldabi, T., Naseer, A., et al.: Simulation in manufacturing and business: A review. European Journal of Operational Research EJOP, vol. 203 pp.1-13 (2010)
27. Poler, R., Lario, F.C., Doumeingts, G.: DMDS Computers in Industry, vol. 49, pp. 175-193 (2002)

28. Meredith, J.: Theory building through conceptual methods, International Journal of Operations and Production Management, vol. 13(5), pp. 3-11(1993)
29. Mendibil, K., Macbryde, J.C.: Designing effective team-based performance measurement systems: an integrated approach, International Journal of Production Planning and Control, vol. 16(2), pp. 208-225 (2005)
30. Schein, E.H.: Process Consultation Revisited, Building the Helping Relationship. Addison-Wesley, Reading, MA (1999)
31. Feurer, R., Chaharbaghi, K., Wargin, J.: Analysis of strategy formulation and implementation at Hewlet Packard Management Decision, vol. 33(10), pp.4-16 (1995)
32. Huan, S.M., Sheoran, S.H., Wang, G.A.: Review and analysis of supply chain operations reference (SCOR) model, Supply Chain Management: An International Journal, vol. 9 Iss: 1, pp.23 - 29 (2004)
33. Krajlic, P.: Purchasing must become supply management, Harvard business review (1983)