Global Manufacturing Virtual Networks in the Aeronautical Industry

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Abstract

Global Manufacturing Virtual Networks (GMVNs), include all kinds of enterprises and production centres and establish a new type of horizontal collaboration and relations between independent companies or even competitors who establish occasional collaborations on projects they could not take on individually. This paper analyses the causes behind the formation of such networks, their strategy, structure, dynamics and evolution, taking into account areas such as strategic intercompany alliances, synchronization of their value and supply chains, their information systems, the cultural aspects of the organizations in question and, finally, their convergence with another of the more relevant future trends in production: mass customization. The proposed model shall be applied to the aeronautical industry which is one of the industries which has developed the GMVN concept. This will demonstrate its effectiveness by clarifying and putting these organizations in perspective and analysing their evolution over the next few years.

Keywords: Global Manufacturing Virtual Network, manufacturing strategies, mass customization, aeronautical industry

1. Introduction

Today, the concept of plant or production centre is becoming increasingly more ambiguous. In many industries, there is growing collaboration between production centres and manufacturing networks that seek to respond to market demands more efficiently and obtain competitive advantages in an increasingly globalized environment. In some industries, such as the aeronautical industry (Chen et al., 2003), the electronics industry (Shi et al., 2003) or the car industry, there is mention of Global Manufacturing Virtual Networks (GMVNs) based on a new manufacturing architecture model with a high development potential to satisfy an increasingly demanding and fragmented market (Shi et al., 2001). In short, these networks represent a compendium of the new tendencies within the production organization, such as global manufacture, strategic alliances, flexible production and mass customization.

The environment in which enterprises currently work with increasingly globalized markets, company consolidation and strategic alliances is forcing companies to find new forms of collaboration to improve the integration and synchronisation of the various functions and stages of their product value chain (Zhao et al., 2001). Global Manufacturing Virtual Networks allow companies to focus on their core competences, maintaining their participation in the design and manufacture of complex integrated systems. These networks can be considered as extended manufacturing systems where various companies can co-operate on a specific project whose result is the manufacture of a product or the provision of a service and where each company is expert in one or more of the areas that give the product its value (Elmuti et al., 2001).

Although there are hardly any theoretical models or studies on how these networks function, they are known to develop on a large scale and involve a complex number of participants that include enterprises, organizations and institutions covering several countries or even continents. The implications in the various manufacturing fields are manifold and knowing how they are structured, how they coordinate and plan their needs and implement their supply chain management, what their specific competences are and how the different members of the network communicate shall be some of the features this paper seeks to clarify. In addition, market demands for increasingly customized products and services lead to the implementation of new manufacturing techniques such as mass customization, where the complexity of the implementation, the information flow or the planning of resources complicate the management of this type of network even further. Figure 1 gives a simple example of the structure of this type of network, together with the relations between the nodes.

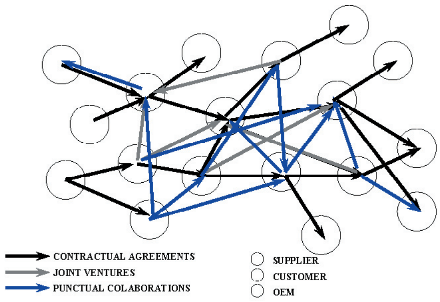

Figure 1. Structure Of Global Manufacturing Virtual Networks

2. Development of the Conceptual Framework

To study this new phenomenon of collaboration between production centres and understand the nature of Global Manufacturing Virtual Networks in more detail, a conceptual framework is proposed in accordance with the diagram shown in figure 2, based on Ayers's customer-centric model (2002) and the proposal put forward by Johansen et al. (2005); the said framework is to be used as a platform for analysing this type of network. This diagram enables the sequential analysis of all the factors that affect the design of a Global Manufacturing Virtual Network, such as its strategy, structure, communication systems and network culture. Following this proposed model, the network strategy and structure will be developed below for a practical case in the aeronautical industry, i.e. the global network of the engine manufacturer Rolls-Royce (RR).

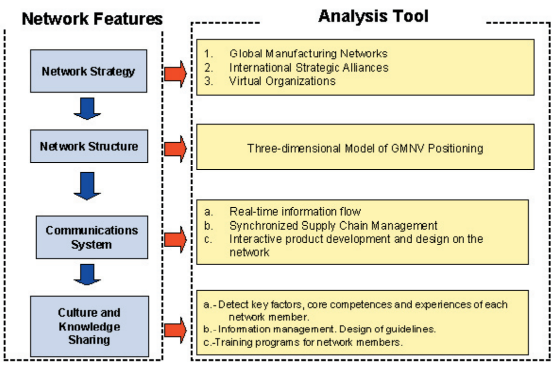

Figure 2. Evaluation Model Of Global Manufacturing Virtual Networks

3. Global Manufacturing Virtual Networks in the Aeronautical Industry

Aeronautical industry appeared at the beginning of the 20th century and, in a short period of time, has adopted various production strategies and organization methods ranging from the craft processes of its beginnings to the Global Manufacturing Virtual Networks that constitute the way in which commercial aircraft are manufactured today, including the mass production systems that were implemented during the Second World War, technological innovations and the future mass customization systems that will constitute the trend of this century (figure 3). It is a compendium of the ideal way in which production has evolved and can be used to apply the conceptual model described above.

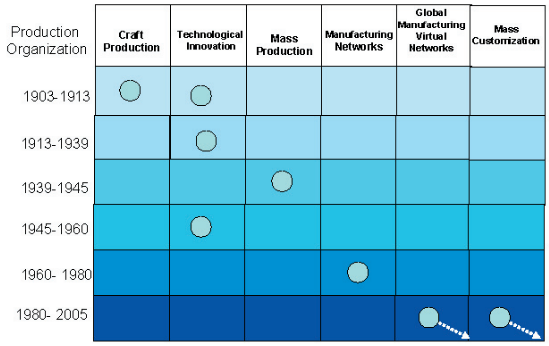

Figure 3. Production Organization Evolution Within The Aeronautical Industry

Rolls-Royce is currently one of the world leaders in the manufacture of engines for the civil and military aeronautical industry. The structure of the Rolls-Royce manufacturing centre network in the world is organized in such a way that each centre specializes in one or more engine components, which enables greater technical specialisation and larger economies of scale. As a result, today, unlike the organization it had in the 1960s and 70s, no single centre is capable of manufacturing an entire engine.

To see how the network is structured, it must be understood that for each engine model or project, there will be a different supply chain on the network itself in accordance with a set of basic premises. Each manufacturing network will use the internal and external resources it requires, such as research centres, technology or component suppliers, own manufacturing centres, as well as horizontal collaborations with companies that manufacture engines. Figure 4 shows a simplified diagram of an aircraft engine to give an example of how its components might be manufactured at the various manufacturing centres on the network, the result of the collaboration between GE and RR on a new engine.

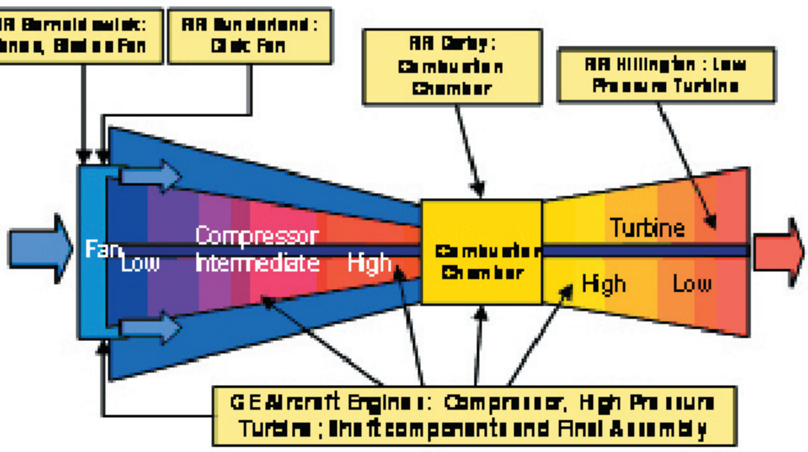

Figure 4. Example Of A New Engine Manufacturing Diagram In A GE-RR Collaboration

3.1. Global Manufacturing Virtual Network Strategy and Structure

At present, companies need to focus strategically on their main competences to offer greater value added in the supply chain. Accordingly, a growing trend today is the subcontracting of the manufacturing process to external collaborators or suppliers. The traditional relations between vertically integrated manufacturers, component suppliers and distributors are currently under reconsideration and being compared with horizontal business collaborations between OEMs (Original Equipment Manufacturers), highly specialized technology companies, component suppliers and distributors that form dynamically changing collaboration networks depending on each product, client and moment in time. In these Global Manufacturing Virtual Networks, the main company does not need to maintain internal manufacturing resources to cope with unpredictable variations in demand (Li et al., 2000). Rather they are based on relations with the various components of a virtual network that enables the company to design a specific supply chain in accordance with each client or specific contract. Therefore, this type of network is not based on the possession of certain resources that condition what can be produced, when, and how much, but rather on managing and sharing the network resources.

Today, the formation of GMVNs follows four strategic focuses: (1) operative excellence; (2) access to new markets - geographical, product, client segments and compensation strategies (Williams et al., 2001); (3) diversification of financial risks; and (4) access to new technologies.

One of the most significant trends in the changes occurring to today's manufacturing systems, especially in the aforementioned industrial sectors, is the substitution of vertical integrations or relations with horizontal relations between competitors or enterprises specialising in very specific technologies to allow companies to focus on their main competences (Colotla et al., 2002). Paradoxically, this type of collaboration, which leads to a Global Manufacturing Virtual Network, will allow them to provide their clients with highly flexible global solutions depending on market demands at any given time. When designing a Global Manufacturing Virtual Network, consideration must be given to the strategy of the preferred manufacturing system. Accordingly, four basic factors are taken into account:

1. *Internationalization of the manufacturing process:* the manufacturing process is no longer considered as one single production centre, but rather has to include expansion or dispersion plants in accordance with the company's current strategy.

2. *Supply and value chain:* the various tasks involved in the manufacturing systems and carried out on the network must be defined throughout the product value chain, and both the stage of the chain during which the tasks are to be carried out and the party by whom they are to be controlled must be specified. In addition, this comprehensive view of the process will enable optimization through the selection of internal and external activities, collaborators and the types of controls established, slightly increasing process efficiency and obtaining more competitive advantages.

3. *Strategic alliances:* a very broad range of possible forms of intercompany collaboration must be assessed, ranging from specific collaborations on certain projects to long-term joint ventures or strategic alliances.

4. *Integration process:* the three factors described above cannot be considered separately, but rather as part of an integrated manufacturing system in line with a preferred strategy.

3.1. Global Manufacturing Virtual Network Positioning of Rolls Royce

These three dimensions, on which the design of the virtual network manufacturing system will be based, are described in figure 5 (Shi et al., 2005) and their result will define the positioning of the Global Manufacturing Virtual Network in which Rolls-Royce has changed its production strategy over time.

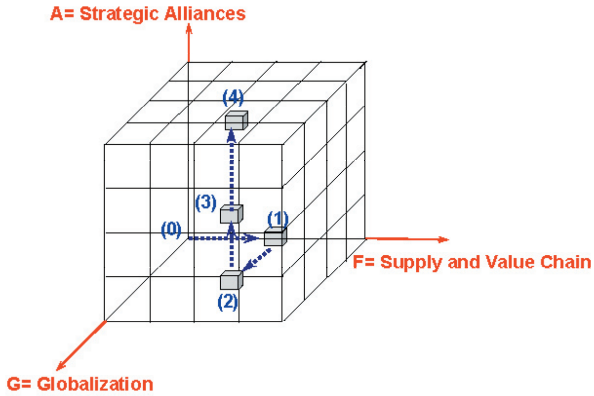

Figure 5. Strategic Positioning Of Rolls Royce Global Manufacturing Virtual Network

G represents the degree of globalization or internationalization of the manufacturing system.

F represents the creation of value obtained from the integration of the various supply and value chains formed by the companies that take part in the network, determined by the synergies and value added resulting from the integration of the various production centres.

A represents the level of collaboration between the various companies that define the strategic alliances on the network. Strong strategic alliances will allow for closer, long-term collaborations whereas more occasional collaborations will furnish the network with greater flexibility.

The vector resulting from the three dimensional variables provides a qualitative idea of the type of Global Manufacturing Virtual Network in question.

It is interesting to note that in the design of traditional manufacturing systems, the dimensions of internationalization (G) or collaboration (A) are rarely given consideration and only the impact of the manufacturing process on the product value chain (F) is considered. The current studies carried out on manufacturing systems are usually limited to two dimensions: on the one hand, the companies that consider only the GxF plane, where consideration is given to internationalization and the product supply and value chains, but collaboration with external companies is ignored; and, on the other, the GxA plane, which studies the internationalization of production processes and strategic alliances without considering the value added that could be obtained through the integration of the corresponding value chains. The overall view of the three dimensions has been the subject of little study and, therefore, the true potential of Global Manufacturing Virtual Networks has not been analysed.

Point (0) of figure 5 refers to Rolls-Royce's beginnings in 1953, when it started up its aircraft engine manufacturing activity with a model called Dart, manufactured entirely at one of its plants in the United Kingdom. Point (1) shows the decentralization of the manufacturing processes begun by RR after it was privatized in 1987. Point (2) indicates the company's internationalization after privatization; however, this process did not include any significant collaboration with other companies. Point (3) shows the current situation, which presents a highly globalized company with manufacturing centres distributed all over the world (each centre specialising in one or more engine subunits), integrated supply chains that add value and a high level of participation in international projects in collaboration with other companies to form an authentic virtual network.

The aim of this network is to satisfy a number of requirements that previously limited its expansion policy, such as the possibility of incorporating technological innovations into its engines, reducing financial risks with regard to new engine projects, reducing its own manufacturing resources by subcontracting subunits to collaborating companies, with each centre specialising in one type of engine technology, and achieving economies of scale by the production process of each manufacturing centre on the network specialising in one or more engine components or subunits. In addition, by reducing its manufacturing resources, Rolls-Royce has become more flexible with regard to reacting to changes in market demand, maintaining the main competences of its organization, which, within the scope of the manufacturing process, include the design and development of the engines and the assembly and final testing stages.

Rolls-Royce's strategy on the network is to change the supply chain in accordance with the project or engine type in question. In the case of its Trent engine family, there is very little horizontal collaboration, since it has a highly consolidated position on the market and has been manufactured for many years. The manufacturing process is carried out at Rolls-Royce manufacturing centres or companies in which the company has significant holdings in the share capital. Each centre makes one or more engine components that are finally assembled and tested at its facilities in Derby in the United Kingdom. However, in the case of the new F136 engine, the supply chain is based on horizontal collaboration with manufacturers, in some cases, direct competitors (e.g. GE), to form an authentic virtual network whose external participants work together on the specific manufacture of the engine. The benefits of this type of collaboration are beyond question since they allow an approach to high-financial-risk projects, resulting in greater technical specialization of the components and a highly flexible production.

Point (4) in figure 5 indicates the company's trend for the coming years, where external collaboration will be used more and more to the point where the company's own resources shall be decapitalized. The future of this type of network is not based on the internal maintenance of manufacturing resources to satisfy unpredictable variations in demand. Rather it is based on relations with the various components of a virtual network that allow the company to design a specific supply chain in accordance with each engine type or client. Therefore, this type of network is not based on the possession of certain own resources that condition what can be produced, when it can be produced and how much, but rather on managing and sharing the network resources.

Figure 6 is based on the three-dimensional figure shown before and can also be used as a very interesting analysis tool (Shi et al., 2005). It shows the range of possibilities for positioning a network between virtual organizations (VO) and international strategic alliances (ISA). Global Manufacturing Virtual Networks can be positioned within this spectrum in accordance with their strategy and based on the flexibility afforded by virtual organizations to attract new business opportunities or enter new markets and the ability of strategic alliances to increase levels of capacity and improve relations in the long term. This positioning should not be considered as an immovable, hierarchical concept, but rather as a dynamic positioning that can be modified in time in accordance with the market situation as it changes.

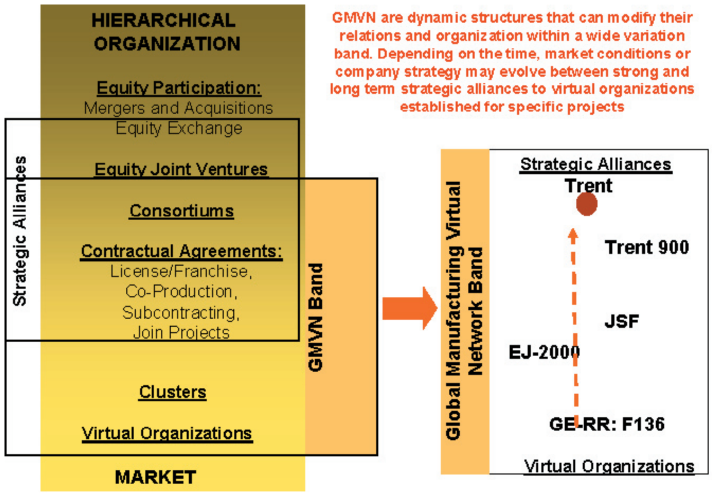

Figure 6. GMVN Band

Figure 6 also shows some of the engines and projects in which Rolls-Royce takes part. The more stable projects appear at the top of the table, with more lasting relations between the members of the network in the form of strategic alliances, as is the case with the Trent engine family and the company's long-term relations with enterprises such as ITP. For projects at earlier stages, where the risk is higher, such as the F136 engine, specific horizontal relations are established. Between the two, there are projects such as the new Trent 900 engine for the Airbus A380, based on collaboration with external companies, albeit true that the project is still clearly led by Rolls-Royce.

4. Future Evolution of Global Manufacturing Virtual Networks in the Aeronautical Industry: Mass Customization and "Network Virtualization"

The challenge now is to forecast what the next step will be, how the manufacturing systems will evolve in the coming years with regard to these Global Manufacturing Virtual Networks and what the determining factors behind the development of this industry will be. Basically, there are two clear trends in the production strategies of these networks in the aeronautical industry: (1) the convergence between this type of network and mass customization systems; and (2) a greater "virtualization" of the networks leading to the decapitalization of a large part of the companies' manufacturing resources in favour of a greater specialization in one or more aircraft engine components.

4.1. Mass Customization in the GMVN of the Aeronautical Industry

According to McClellan (2003), Mass customization is a growing market demand that will require manufacturing networks to implement production systems that address the said demand for customized services and products at prices similar to those that are mass produced. In addition, the Society of Manufacturing Engineers (Christman, 2003) has also referred to mass customization and to the collaboration of manufacturing networks as two of the most important trends in production strategies for the 21st century. Finally, Meixell et al., (2004) and Kamrani, (2004) have also mentioned the importance of mass customization in the context of global manufacturing networks, highlighting the importance and difficulty of supply chain management in these environments.

Although it is not at all simple to consider all the possibilities of this convergence, it is possible to estimate the feasibility of the process and the profits that would be obtained. Global Manufacturing

Virtual Networks are based on a dispersed manufacturing process which, in most cases, implies the manufacturing of the product by modules or independent subunits or in completely separate stages of the product chain. As a result, the application of mass customization techniques, such as the modularization of products (Ulrich, 1995) or the customization during the latter stages of production is possible.

According to Bugos (2001), customization in this industry began with the introduction in 1970 of the Boeing 747. When this plane was supplied to the airlines of each country, it was discovered that each one had slightly different requirements, which forced Boeing, McDonnell Douglas and Airbus to implement new mass customization methods through the application of small final adaptations in their mass production processes, such as that implemented by Boeing in its wing production process. However, mass customization will be implemented on a large scale in the aeronautical industry as a natural process resulting from Global Manufacturing Virtual Networks and the varied requirements of an increasingly demanding market that seeks differentiation through customized aircraft that satisfy the particularities of clients or their strategic positioning on the market without increases in the price of the aircraft in question.

Within Global Manufacturing Virtual Networks, mass customization becomes a feasible model that was almost unthinkable in the past. The dispersion of the manufacturing process requires greater specialization in one or more specific components in comparison with the all-round solutions that were supplied previously. As a result, in this context, mass customization systems will be based on two fundamental trends: product modularity and superficial changes in the final stages of the value chain.

1. **Product modularity:** this will be one of the fundamental factors behind the effective implementation of mass customization in the aeronautical industry. Product modularity refers to a design of the product that allows for the combination of different components or subunits in such a way that the client can choose from several options for each module. This feature can be implemented seamlessly in Global Manufacturing Virtual Networks, since the network involves the dispersion of manufacturing processes and, for the said processes to be efficient, some kind of product modularity is necessary so that its manufacture can be broken down into similar subunits for later assembly. The example of the manufacture of the Airbus A380 is a very good one, since each country taking part in the consortium is responsible for one of the structural subsystems of the aircraft (fuselage, wing, cabin or tail), which are manufactured separately with their own supplier networks, subunit suppliers and collaborators until the manufacture of the subsystem is completed and sent to Toulouse (France) for the final assembly stage. In other words, by dispersing the manufacturing processes over a network, the modularity of the product design is almost a fundamental requirement for the efficiency of the supply chains. Therefore, when implementing mass customization systems based on modular designs, half the work has already been done.

2. **'Superficial' changes:** mass customization through changes in the final stages of the value chain will be one of the most effective techniques to be implemented in the aeronautical industry. Many manufacturers have uncovered the market's need for changes to the variety and specifications of the aircraft and at structural subsystem level (wings, engines, fuselage, cabin, etc.); however, at the same time, they have found that the existing processes can satisfy these changes in the demand. In other words, new market requirements focus on 'superficial' changes to the aircraft which, in most cases, do not require substantial changes to either the manufacturing networks or the internal production processes. The new Airbus A380 has already implemented this option by offering various internal configurations of

the inhabitable area of the aircraft and, in the coming years, the concept will be applied to other subunits with no substantial effect on the manufacturing processes. The origin of this trend lies in the requirements of a market that is becoming more and more demanding and versatile and seeks to provide its clients with a differentiated service.

4.1. "Virtualization" of the Network in the Aeronautical Industry

Another trend that will gain in significance in the production strategy of these networks in the aeronautical industry is the increase in virtual collaborations between external companies for specific projects. The benefits of this type of collaboration will mean that companies will not need to maintain internal manufacturing resources, since they will be able to use the network resources and assume greater flexibility to satisfy unpredictable variations to the demand. The manufacturing systems of the future will be based on relations with the various components of a virtual network that enable the company to design a specific supply chain in accordance with each engine type or client. In short, this type of network will not be based on the possession of specific resources, but on managing and sharing the resources available on the network.

Consequently, as with other manufacturing companies, Rolls-Royce shall tend more towards specialization. Participation in every stage of an engine's value chain will no longer be profitable and companies will have to specialise in a number of main competences, such as design or a specific structural subunit (e.g. a compressor), leaving the responsibility for other structural subunits or specific technologies to other companies on the network.

5. Conclusions

Global Manufacturing Virtual Networks are based on three basic vectors: the globalization of internal manufacturing processes; the supply and value chains of all the centres involved; and strategic alliances with companies outside the organization. Although this type of intercompany collaboration is becoming more and more common, especially in the aeronautical industry, the car industry and the electronics sector, there are currently no models that describe how the networks operate or how they should be managed or designed. Their future growth potential is huge, since, on the one hand, they are more efficient at meeting the requirements of a market that is becoming increasingly varied and variable in its search for customized solutions at very competitive prices and, on the other, they allow manufacturers to reduce their financial risk by disinvesting heavy internal manufacturing resources, access new markets and seamlessly incorporate technological improvements to their products. In addition, the future evolution of this type of network will be based on a greater "virtualization" of the network and a convergence with mass customization systems.

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