VIRTUAL ENTERPRISE BROKERAGE: A STRUCTURE DRIVEN STRATEGY TO ACHIEVE BUILD TO ORDER SUPPLY CHAINS

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Abstract: This paper proposes the concept of the Virtual Enterprise Broker as an innovative model to design and create Build to Order supply chains. The Build to Order supply chain responds to the demands of new global manufacturing economy offering high level of customization, high customer driven design, volume flexibility, short cycle time, none inventory costs, minimal total cost and dynamic supply chain integration. A review of different manufacturing production models is presented to set the context for the requirements of Build to Order operations. The review includes the following models: Make to Stock, Make to Order, Assemble to Order, Engineer to Order and Configure to Order. A structure driven strategy named Virtual Enterprise Broker is proposed to support the implementation of Build to Order supply chains. The Virtual Enterprise Broker strategy is described in terms of core products, processes and competencies. The demonstration of how the Virtual Enterprise Broker structure has been implemented in an industrial case related to the supply of maintenance tooling for the aerospace industry.

Keywords: mass customization, strategy, virtual enterprise, supply chain management, manufacturing strategy

1. Introduction

Current market dynamics and changes have led manufacturers to face different threats which must be overcome by the execution of key strategies. However, which strategy would lead to a successful outcome? To a significant extent, this will depend on the specific market that the company decides to operate in. As a consequence, the characterization of the market requirements must drive the strategy of the company which enables the alignment of core processes and competences to become an outstanding performer. The achievement of the concept of mass customization is becoming key for the manufacturing firms to face new market realities such as reduced product life cycles, time to market restrictions, unpredictable customer requirements, and the search for individualism in customers [Pine 1993, Gilmore and Pine 1997].

Supply chain management seems to be an answer to respond to these new realities of dynamic markets, specially Build to Order (BTO) requirements [New, 1997]. The main principle is to keep the core processes and competences within the firm and subcontract the reminder of production resources required to produce specific products from the best available suppliers. However, this is an inherently risky taking and the company must carefully analyze how to pursue this strategy. The concept of Virtual Enterprise seems to fit very well the requirements of Build to Order operational models. This paper introduces the concept of Virtual Enterprise Brokerage to design and create Virtual Enterprises to respond to the Build to Order demands. This
paper has been organized in the following manner. Section 2 of the paper summarizes different manufacturing production models including Make to Stock (MTS), Make to Order (MTO), Assemble to Order (ATO), Engineer to Order (ETO) and Configure to Order (CTO). The literature review sets a perspective to discuss nowadays manufacturing dynamism and the need to create a new model i.e. Build to Order (BTO). In section 3 the BTO model is presented from different perspectives and compared against traditional operation models to point out its relevant characteristics: level of customization, customer driven design, volume flexibility, cycle time, inventory, production costs, and level of supply chain integration. The conceptualization of Virtual Enterprise is introduced in section 4 to explain how it could be used to deal with the demands of BTO operations. A framework to design, create and operate Virtual Enterprises is then introduced based on two concepts: Virtual Industry Clusters and Virtual Enterprise Brokers. These two concepts are explained in terms of their core products, processes and competences. A detail explanation of how the structure driven strategy of the Virtual Enterprise Broker fulfils the requirements of the BTO model is depicted in section 5. Finally, a demonstration of these novel ideas are illustrated in a case study of a brokerage company that satisfies the aeronautical industry for designing and manufacturing tooling for airplane maintenance.

2. Operational Models in Manufacturing Systems

A proposed characterization of each manufacturing production models are presented in table 1 [Molina et al, 1999]. These classification is based on approaches followed by McCarthy (1995) and Amaro et al (1999). A more detail review of the different operational models are presented in following sections.
Table 1. Proposed characterization of manufacturing production models

<table>
<thead>
<tr>
<th></th>
<th>MTS</th>
<th>MTO</th>
<th>ATO</th>
<th>ETO</th>
<th>CTO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customer</strong></td>
<td>Immediate availability, high standardized and high traceability.</td>
<td>High customization (One of a kind / catalog) and High quality</td>
<td>High customization, short delivery time and low cost of inventory</td>
<td>High customization, long delivery time, none repetitive product and one of a kind product.</td>
<td>High customization, short delivery time and low cost of inventory</td>
</tr>
<tr>
<td><strong>Product</strong></td>
<td>Standard, low cost and high volume</td>
<td>Tailored/nong customization, high cost, high variety and produced only when an order is placed.</td>
<td>Standardized customization, high cost, produced only when and order is placed, high risk of obsolescence in inventory (sub assemblies) and Assemble as result of an order.</td>
<td>Pure customized, high difficulty (added value), high cost, produced only when an order is placed and no cost of inventory</td>
<td>Standardized customized (many configuration per product), high cost, produced only when an order is placed and high risk of obsolescence in inventory</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>Mass production process, shorts cycle time, high repetitively, high automate and forecasting bases planning</td>
<td>Job shop or process, configuration, low automate and high flexibility.</td>
<td>Job shop/line production process, medium automate, medium repetitive and high in process inventory (sub-assemblies).</td>
<td>Project production process, low/medium automate and no repetitive.</td>
<td>Job shop/line production process, high automate, high use of IT and high repetitive.</td>
</tr>
<tr>
<td><strong>Suppliers</strong></td>
<td>Few suppliers per part, Push system and high inventory levels.</td>
<td>Many suppliers per part, push system and low purchasing power with the suppliers</td>
<td>Many suppliers per part, push system and the supplier keeps the inventory</td>
<td>Few suppliers per part, pull system and no supplier chain management</td>
<td>High inventory levels, high use of information technologies, high supplier chain and management and integration.</td>
</tr>
</tbody>
</table>

2.1 Make to Stock - MTS

Make to Stock is an operational model where the production and operations are scheduled according to the forecast of customer demand, and customer demand is met from finished product stock. Some details definitions can be found in [Sen et al, 2000], [Rajagopalan, 2002], [Bertsimas and Paschalidis, 2001]. A summary of this model characteristic is the following:

- High standard parts ratio
- Demand can be forecast with necessary accuracy, demand quantity is large
- Production Planning is based on forecast, planned well in advance and adjusted if necessary.
- Delivery time is short
- Stock out and stock cost are main reasons of causing risks
- Manufacturing trigger is stock level
- The sources of competition power are cheap prices and fast delivery
- Low customization extent

Although, this model is widely implemented, is sustainable for very stable markets such as commodities: food, beverage and cement. This model is based on forecasting customer requirements however with changes
on demand every day, the anticipation of customer consumption is becoming more difficult to predict. Traditional Make to Stock (MTS) industries are evolving to other manufacturing operational models which allows them to reduce inventories cost and product obsolescence such as Make to Order and Assemble to Order.

2.2 Make to Order - MTO

Traditional MTO assumes that engineering and design process are completed and manufacturing process is proven. Manufacturers use this operational model when demand is unpredictable and when customer lead-time permits the production process to start upon receiving an order [Rehg and Kraeber, 2001]. However, new approaches to MTO systems, suggest that the company must develop some activities in the design, purchasing and specification process. [Yhe, 2000], [Sen, 2000], [Hendry, 2002], [Ketzenberg, 2002], [Hendry et al, 1998]. Key characteristics are:

- Low standard parts ratio
- Demand quantity is small and difficult to forecast
- Production planning is based on order and cannot be planned in advance
- Delivery time is much longer, leading to greater risks
- Customization extent is high, a key source of competition power
- Manufacturing and other operations are triggered by customer orders

In most of cases, customization is the winning order criteria for MTO operational model [Shaladdin and Hendry, 2003]. The levels of customization in MTO model are usually tailored customized (based on manufacturing process capabilities) or none customized. An example of tailored customization is changes in size or quantity of the products. These changes do not imply change in the design of the product but imply a great flexibility in the shop floor. On the other hand non customization is focused in the delivery time and quantity flexibility. An example of this model is the automotive part suppliers and its complete supply chain, from OEM (Original Equipment Manufacturer) to nTier supplier. These companies do not have any interaction in the design, but their customization is orientated to the quantity, delivery time and the capability to adapt their process to the customer requirements. [Muda and Hendry, 2002].

Another example of this operational model are the companies that sells their products based on variations of a predefined range or catalogue, where the customer has to fit his requirements in what is available in the catalog, and afterward the product is manufactured. [Porter et al, 1999]

Taking into consideration that some made to order products are manufactured on a unique basis in order to meet customer’s requirements (non customized), winning criterion are based on how quickly the product can be delivered to the customer from the time it is order [Handfield, 1994].

MTO model must be accomplished by efficient production planning, setup time control and flexibility. Process flexibility has two important features; range, a typical machine can perform number of different operations without requiring a prohibitive amount of switching time, and mobility, time required to switch from one product mix to another is high. [D’Souza and Williams, 1999]. Therefore, some manufacturing practices based on agile management systems must be combined with this manufacturing model in order to achieve flexibility, cost, lead times, efficiency, business volume and profitability requested by the market. [Babu, 1999].

2.3 Assembly to Order - ATO

ATO is an operational model in which standard parts and subassemblies are acquired or manufactured according to forecasts, while schedules for remaining components, subassemblies, and the final assembly are
not executed until detailed products specifications have been derived from booked customer orders. The typical example is the manufacturing electronic subcontractors. Main characteristics are listed below [Sen, 2000], [Song et al, 1999], [Wemmerlöv, 1984]:

- Medium standard parts ratio
- Demand quantity is medium and can be forecasted
- Production planning is based on forecast and order, planned well in advance and adjusted to order
- Stock cost and delivery time are the reasons of causing risk
- Customization extend is medium
- The sources of competition power are cheap prices, relatively fast delivery and better customization
- Production is triggered by stock and order.

ATO is a hybrid system between MTS and MTO, because the sub-assembly production is forecasting while the final product is assembled when the customer set an order. Usually when using this model a company makes and stocks only the modules and other major components [Song, et. all, 1999]. Therefore, the modularity concept is introduced, allowing customers to configure some features of the product. Product modularity permits a fast lead time and consequently this is the order winning criterion [Andel 2002], [Song, 2000], [Song, 1999], [Glasserman, 1998]. In order to achieve this criterion the company modularizes the design in such a way that the customer is free to choose some of the important features of the product but the functionality will be conserved [Desking and Mark, 2003].

This model tries to minimize the risk on inventory from MTS and tries to reach customization from MTO introducing modules. However, the modules inventory is costly than a single component inventory and, the customer frames its requirements in a set of predefined product characteristics.

2.4 Engineering to Order - ETO

Accordingly with Amaro et al, (1999) ETO model is related to products that are manufactured to meet a specific customers needs requiring unique engineering design or significant customization. Thus, each order results in a unique set of part numbers, bill of material and routing. [Hicks et al, 2001], [Hics et al, 2000], [McGobern et al, 1999]. The customization offered by ETO companies is purely customization, in which a product is developed from scratch for each customer. The main characteristics in this model are:

- High customization
- Long delivery time
- No inventory level
- High product complexity
- The source of competition is based on differentiation and technology
- High quantity restrictive (one of kind products are common in these systems)

ETO fulfills customer requirements in terms of design and customization; however requirements in terms of quantity, time and costs are not easy to achieve.
2.5 Configure to Order - CTO

CTO was introduced by companies such as Dell, among others, where they took advantage of the information technologies and changed the way to do business [Kraemer et al. 2000]. In the same way than ATO, CTO provides standard customization, where the customer is obtaining certain variations that can result in a differentiate product and the manufacturing process is completed when an order is placed. However, the term Configure to Order appears to be an evolutionary concept from Assembly to Order. The important difference between these two production models is that, ATO, as previously explained, combines forecasting and holds inventory of parts, subassemblies and make to order finished products. However, CTO no longer forecasts or holds inventory. Under the CTO concept companies buy components and assemble the final product after the receipt of an order, in such a way that the inventory is held by the supply chain and not by the company. This is not an efficient system because the problem is not solved; inventory levels and forecasting are part of the supply chain [Carbone, 2001a].

The key issue is to define the right number of alternatives that will satisfy the customer demand. Once an offer is designed, more complexity can be avoided by ensuring that the product is designed with common parts and modular subassemblies [Terrence, 1998]. This model is effective in products that have few components like in the computer industry where is possible to manage 15-50 components per computer. In large components industry, such as automotive industry, this approach will be very difficult to implement, unless a major redesign can be achieved in the main automobile systems [Agrawal et al, 2001]

3. Mass customization in manufacturing – the need for the Build to Order paradigm

Each of the traditional operational models described above do not satisfy entirely customer requirements in mass customization environments. In terms of customer satisfaction, a manufacturing system should be able to have the following distinctiveness:

- High level of customization
- High customer driven design
- Not quantity restrictive
- Short cycle time
- None inventory costs
- Minimal total cost
- High supply integration

High level of customization and high customer driven design are criteria that are constantly taking more importance as a competitive advantage in hypercompetitive markets. Customer is expecting to have a differentiated product, and the idea of having a unique product is less unreal today.

Mass production companies are becoming less relevant in the market due to the standardization in their products. However, mass customization seemed to be the way out for these kinds of companies, providing strategic flexibility together with quick responsiveness [Radder and Louw, 2000]. Although mass customization is an improvement over mass production, customers are still restricted in terms of pre-selected components and integration capability (standard customization). As an example is Dell.com allows customers to configure their own computer. However this example is limited to a company in which combinations are no
greater than 100,000. In products in which the numbers of possible choices are bigger, this customization is not longer achievable by the mass customization concepts.

Industry requires an achievable change, with less risk, providing better responses to customer demands. This change is not related with quality, cost reduction or deliveries, in the sense that, these criteria are not longer added value criteria; according to Svensson (2000) these are an entry level to compete. In order to be competitive it will be necessary to customize products in short time considering cost balance. Customer satisfaction is the basic concept; the customer is who decide what features the product must comply with.

Manufacturing models can fall into two categories: those in which the manufacturing process starts with the receipt of a customer order and those which depend on forecasts. MTO, CTO and ETO are part of the first type of systems, while MTS and ATO comprise the second. However, none of these categories is solving the issue: “How to produce exactly what customer’s want when they want it” [Holweg and Pil, 2001]. In forecasted based systems there are two destructive cycles. First, the company must rely on larger economies of scale to compensate the use of push-based selling. Second, the company losses sight of real customer requirements because it is selling too many products from stock; the most undesirable effect of this cycle is not focusing on customer requirements.

The Build to Order model tries to fill in the gaps that are presented between each model (see table 2). Next paragraphs elaborates on these issues.

<table>
<thead>
<tr>
<th></th>
<th>ETO</th>
<th>MTO</th>
<th>MTS</th>
<th>ATO</th>
<th>CTO</th>
<th>BTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of customization</td>
<td>High</td>
<td>Tailored</td>
<td>None</td>
<td>Standard</td>
<td>Standard</td>
<td>High</td>
</tr>
<tr>
<td>Customer Driven Design</td>
<td>High</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Quantity restriction</td>
<td>High (Low Volume)</td>
<td>Medium</td>
<td>High (High Volume)</td>
<td>High (High volume)</td>
<td>Medium</td>
<td>Low-High (High Value)</td>
</tr>
<tr>
<td>Cycle Time</td>
<td>Large</td>
<td>Large</td>
<td>Immediately availability</td>
<td>Short</td>
<td>Short</td>
<td>Short</td>
</tr>
<tr>
<td>Inventory</td>
<td>None</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>None</td>
</tr>
<tr>
<td>Total Cost</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Supply Chain Integration</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 2 Gaps of Manufacturing models filled by BTO strategy.

An ETO firm for instance, in providing what customers expect as a final product, is not dealing with inventory costs and is reactive facing new demand. However, the long lead time and high costs; make this model inapplicable for great number of products. Indeed, it is only applicable for products in which the customer is willing to wait. Capital goods and equipments fall into this category. Nevertheless, the goal for ETO companies is to improve their delivery times and reduce manufacturing costs. Once these are achieved, the company will have competitive advantage and remain in the market.

On the other hand, MTO strategy is used by companies that either produce using an approved design or sell catalogue products. These companies usually offer less degree of customization but improve the delivery time. [Andel, 2002]. However, if customer needs must accommodate to a catalogue, then satisfaction is not achieved. Also when the customer provides the design, the delivery time is affected. In other words, there is a gap between ETO and MTO that distorts customer needs and expectations.

Similarity, CTO strategy begins the process with the receipt of an order, it is assumed that the customer is obtaining a differentiated product. However, this product is the result of a configuration of components within a catalogue previously designed to anticipate the number of variations of the product. In this way, customer is not completely satisfied. Additionally, although CTO companies do not have inventory in the factory, the
supply inventory level is significantly high. Therefore, in the long term, this model is not sustainable [Carbone, 2001b]. Build to Order aims to satisfy customer requirements within the time, price and quantity required. BTO must be implemented by companies which either have technological capabilities and information technologies to adequate their process and production planning for the flexibility required within the extended enterprise concept [Browne and Zhang, 1999]. Next section introduce the Virtual Enterprise concept as an alternative to achieve the challenge of the Build to Order paradigm

4. Virtual Enterprise - An unique concept to achieve dynamic organizations

Several authors have work in the topic of Virtual Enterprises (VE) and have defined this term. According to Davidow and Malone (1993) Virtual Enterprises can be defined as a way of organizing business activities, where different and independent partners exploit a specific business opportunity by establishing an enterprise co-operation. The virtuality is then the ability to offer customers a complete product or service, where the enterprise itself just owns some of its competences. Other required competences are achieved through co-operation. In fact the idea of virtual enterprises is nothing new and has been used in some business sectors for many years. The changes in the society as a whole as well as new information and communication technologies are making them strategically and economically feasible for a wider range of enterprises [Eversheim et al., 1998].

Three main aspects can characterize a Virtual Enterprise according to Goldman (1995):

- Uniqueness - a virtual enterprise exists to explore one single business opportunity at a time,
- Competence Orientation - a virtual enterprise aims to join the best competences in order to fulfill the opportunity, independently of their location, and
- Modern information infrastructure - the use of modern and efficient information and communication technologies (information infrastructure) allows the formation and management of dynamic co-operation among different and also global partners.

According to Camarinha-Matos and Afsarmanesh (1999) a Virtual Enterprise is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose cooperation in supported by computer networks.

A Virtual Enterprise is a particular case of a Virtual Organization. A Virtual Organization is a concept similar to a Virtual Enterprise, comprising a set of (legally) independent organizations that share resources and skills to achieve its mission / goal, but not only limited to an alliance of profit enterprises [Camarinha-Matos and Afsarmanesh, 1999].

Virtual Organizations can be supported by long term networks that provide the environment where they are created. These kinds of networks are known a Virtual Organization Breeding Environments (VBE). Virtual Organization Breeding Environments represents an association (also known as a cluster) or pool of organizations and their related supporting institutions that have the potential and the will to cooperate with each other through the establishment of a “base” long-term cooperation agreement and interoperable infrastructure. When a business opportunity (profit driven) is identified by one member (acting as a broker), a subset of these organization can be selected and thus form a Virtual Enterprise [Camarinha-Matos and Afsarmanesh, 2003]. It is important to mention that a European project named ECOLEAD – European Collaborative Networked Organization Leadership Initiative (www.ecolead.org) has been initiated to create the necessary foundations and mechanisms for establishing an advanced collaborative and network-based industry society in Europe. ECOLEAD addresses three most fundamental and inter-related focus areas as the basis for dynamic and sustainable networked organizations: Virtual Breeding Environments, Virtual Organizations, and Professional Virtual Communities.
In order to understand how Virtual Enterprises could be conceived to exploit new opportunities in global markets, a framework for Global Virtual Business was worked by COSME network in 1998. COSME was a network created by the European ALFA Project constituted by 4 European and 2 Latin American universities. European Universities: Technical University of Aachen (Germany), Universitat Ca’Foscari di Venezia (Italy), University of Newcastle Upon Tyne (England) and University of St. Gallen (Switzerland). Latin American Universities: ITESM Campus Monterrey (Mexico) and Universidade de São Paulo - Escola de Engenharia de São Carlos (Brazil). The framework is based on three business entities: Virtual Industry Clusters, Virtual Enterprise Broker and Virtual Enterprises.

These entities are particular cases of Virtual Organizations and Virtual Breeding Environments, its definition is as follows:

1. Virtual Industry Cluster (VIC), are aggregation of companies from diverse industries, with well defined and focused competences, with the purpose of gaining access to new markets and business opportunities by leveraging their resources and therefore there competences. The companies can be geographically distributed or not. Virtual Industry Clusters are particular cases of Virtual Breeding Environments.

2. Virtual Enterprise Broker (Broker), who is responsible for searching business opportunities and enabling the creation of Virtual Enterprises. The Virtual Enterprise Broker performs the processes of partner search and partner selection, and configures suitable infrastructures for Virtual Enterprise formation/commitment i.e. physical, legal, social/cultural, information. To achieve its goal the Virtual Enterprise Broker is supported by the services provided by the Virtual Industry Clusters. The Virtual Enterprise Broker is an especial actor in the Virtual Breeding Environment; certainly a Broker can be also a member of the Virtual Industry Cluster, and, by definition, a member of a Virtual Breeding Environment. But since the Broker is an important actor, is analyzed separately.

3. Virtual Enterprises (VE), which are temporary networks of independent companies, linked by information technology, that share competences, infrastructure and business processes, with the purpose to fulfill a specific market requirement. Virtual Enterprises are particular cases of Virtual Organizations.

In order to facilitate the reading, the terms Virtual Industry Cluster and Virtual Enterprise will be mentioned in the article by its acronyms: VIC and VE; and Virtual Enterprise Broker will be denoted as “Broker”. Table 3 summarizes the description of these three entities in terms of their core products, core processes and core competences. Table 3 provides the description of all the human and technological resources and process that can be offered by the cluster. The commercial success of VIC depends on how well defined and focused the cluster is. Hence the information regarding the technological resources, processes and human capital has to be structured in a way that can be used by Brokers to search and select partners for VE. Furthermore, this information should be used to support strategic decision making in managing the VIC’s core competences.

VIC has three main core processes: definition and design, creation and core competences management. The first two processes are related to the organization, formation and marketing of the VIC, which includes searching, selecting and qualifying enterprises. The latter involves identification, building, deployment and protection of the VIC’s core competences.

VIC success relies on the effective management of its own core competences and the marketing of the competence aggregation of the members. The VIC’s core competences are the aggregation of the competences of its members, the ability and flexibility to integrate and deploy resources and capabilities, and the cost management. This aggregation should have a focus and therefore should represent the competence of the VIC.

The competences of the VIC are the capacity of the cluster to make certain types of products, offer a group of
business process or provide specific technological capabilities. The results of research related to the design, creation and implementation of Virtual Industry Clusters can be found in Flores and Molina (2000).

Table 3 Core products, core process and core competences of VIC, VE and Broker [based on Molina and Flores 1999]

<table>
<thead>
<tr>
<th>Core Products</th>
<th>Core Process</th>
<th>Core competences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Industry Clusters (VIC)</td>
<td>Technological processes (manufacturing, logistics, information services), Technological resources (manufacturing equipment and technologies) and knowledge and experience ok human capital</td>
<td>Cluster definition and design, cluster creation and cluster core competences management</td>
</tr>
<tr>
<td>Virtual Enterprise Broker (Broker)</td>
<td>Build to order services, integration of services, supply chain management services and enterprises (Joint Ventures, Long term collaborations)</td>
<td>Search/selected business opportunities, project planning, project execution and customer follow-up</td>
</tr>
<tr>
<td>Virtual Enterprises (VE)</td>
<td>End products and end services</td>
<td>Global integrated product development, build to order supply chain management execution, global project execution and coordination and dissolution.</td>
</tr>
</tbody>
</table>

The Broker is the driving force for the formation of the Virtual Enterprise, acting as initiator, coordinator through defining the business arrangements and assignments of the VE memberships, and moderator during the executions/operation of the VE by resolving conflicts between VE members [Kanet et al, 1999]. However the experience has shown that the market is not very familiar with Virtual Enterprises and many brokers are working as an intermediary entity just finding contacts to the cluster members. Nevertheless it is feasible to conceptualize the Broker as an independent entity from the others entities shown in the framework. As a result, a broker can be managed as a company that is constantly looking for new business opportunities. This model set the foundations to create two demonstration cases: Brazilian Case (Bremer et al 1999) and Mexican Industry (Molina and Flores 1999). These two cases were similar to the concept of Virtuelle Fabrik developed by the EUREKA-project that was started in 1995 under the supervision of the Institute for Technology Management in Switzerland (Schuh 1997 and Katzy 1999). More than 30 manufacturing companies of the Bodensee region were taking part on this project. They setup a stable, regional cooperation network, in which the main challenge is to build trust. "Ground rules for collaboration" were agreed, a standard contract for setting up virtual factories was drafted and the required infrastructure developed.

5. Virtual Enterprise Brokerage responding to Build to Order demands

Based on the three experiences related above, the Virtual Enterprise Brokerage (“Broker”) model has evolved to become a structure driven strategy to achieve Build to Order supply chains. The Broker model reaches the BTO strategy through the aggregation of core products, processes and core competences of an enterprise network (Virtual Industry Cluster). This aggregation of capabilities together with the core process of the
Broker as an entity reaches the BTO flexibility required, and makes an adaptable model that can be applied to different kinds of companies and industries. The operational model of the Broker is illustrated in figure 1.

*Figure 1 Virtual Enterprise Broker operational model  [Adapted from Molina et. al., 2006].*

The broker uses the processes and competence of the companies in the Virtual Industry Clusters in order to design and create Virtual Enterprises. This Virtual Enterprises must satisfy the customer mass customization demands. This framework demonstrates how the Broker reaches the BTO Model. Integration is the main concept in Broker Model. Supply chain integration not only means to know the suppliers well, but also know their capabilities and restrictions; in this sense all goals of BTO can be achieved by the Broker. The Broker has to assess the development of the suppliers throughout the results of project execution and the measurement of their performance. Suppliers’ development is a complementary activity that supports the Broker for selecting the best competences for the network. It is also important to mention that the integration of the supply chain means that no excess inventories will be carried for any partner. Also, all costs and inventories will be distributed equally so the entire level will be reduced. All those characteristics described above support the relationship between BTO operational model, and the Operative Framework of the Virtual Enterprise Broker. In figure 2, it can be appreciated how the characteristics of the BTO Business Model can be achieved by the Virtual Enterprise, through the integration of the Virtual Enterprise Broker and the Virtual Industry Cluster. The activities of the broker include searching and selecting business opportunities and partners, developing products, and being responsible for the final product. While on the other hand, the activities of the cluster are related to the manufacturing capabilities necessary for the manufacturing of the final product. Accordingly with this framework this integration results in a new entity called Virtual Enterprise.
5.1 High level of customization, through the integration of partners’ competencies

The level of customization is understood in terms of quantities, flexibility to change and design options. Taking into account that the Broker model works in a collaborative way with the customer, the customization will be measured as the capacity to respond to customer requests.

In the Broker model, the major limitation is the capability of the partners involved, but in real terms, this limitation is easily overcome by searching new suppliers that can fulfill processes needs. The key activity is how to integrate the capabilities of each partner, and how to manage the project in order for it to be successful in terms of time and resources required.

As a consequence, in the market requirements stage, the benefits of high level customization discussed in the BTO strategy are reached by Broker. The level of customization offered by a Broker exceeds the level of customization of a company working under a traditional model restricted by the flexibility of their machines. BTO companies must: satisfy customer requirements, be flexible in the design and reactive to the demand. The Broker makes sure that the companies selected as partners will comply with these requirements. There is no restriction in terms of requirements in such a way that the Broker can disintegrate the production process into machines or operations, and split them in terms of the capabilities provided by each partner.
### 5.2 No quantity restrictions, due to network configurations and collaborative work

The Broker working under a BTO strategy is not restricted in terms of quantities. Since process begins with the receipt of an order, the manufacturing process must be able to satisfy one of a kind production or mass production. Broker companies achieve this goal when, instead of configuring machines or work centers (that has capabilities restrictions on a shop floor), companies are configured in a network and processes are integrated in such a way that their capabilities are maximized through the collaborative work.

As an example, one business opportunity is the reduction of production costs using labor resources from developing countries. However the first constraint faced by the customer is the quantity level that the supplier is able to readily handle. Medium and small companies can often offer significant cost reductions, but they have small investment capacity and in many cases they can not handle the whole project. As an alternative, the customer can contract multiple suppliers but the operational cost of handling a great number of suppliers may exceed the cost reduction expectation. The customer can, by the contrary, look for high-tech suppliers, but these could be unable to offer the cost reduction desired.

The Broker offers the integration of technological capabilities of small and medium companies that can offer significant cost reductions. Also, the Broker supports the whole project investment. In this case the customization of quantities can be reached as the customer is dealing with only one supplier that offer the volumes desired through its network configuration.

### 5.3 Inventory costs reduction, achieved through Business Plan configuration.

The Broker Business Plan guarantees to the customer the integration of capabilities needed to fulfill the requirements. The Broker Business Plan specifies in which proportion each partner will contribute to the development of the project, how the contract will be generated and under which conditions this contract will be enforced. Complementary services such as logistics and delivery can be included, depending on customer requirements. The Broker can offer more integrated services than an isolated company. This is a competitive advantage that will offer the customer savings in inventory and operational costs.

### 5.4 Cost reductions by using networks of SMEs (small and Medium Enterprises)

BTO model reduces costs due to the inventory savings gained throughout the supply chain integration. Under the concept of collaborative work, the Broker model reduces manufacturing costs due to the contract of medium a small companies. This reduction is guaranteed by the quality assurance process. The Broker acts as the customer voice, controlling the production process in each company.

However, cycle time is one of the main restrictions when a project is executed by the Broker. The capability to manage the network of companies must guarantee an efficient outcome. Broker management entails the collaborative work among partners in the Virtual Enterprise aimed to cover time requirements. Collaborative work and disintegration of product into processes can guarantee cycle time reduction, and consequently cost reduction, in a way that the diverse activities can be done simultaneously and there will not be queues during the production process. Several activities during the production process can involve non added value time due to the machine capability or floor shop capacity; in a network integrated production process, such activities can be developed in advance avoiding delays in cycle time.

### 5.5. Information technology to support the Broker operations

Information technologies will help to the Broker to assure the traceability during the execution of the project. As an example, the companies involved in the manufacturing process, can update the production status of
every part in a HUB of integrated e-services. The performance of the Broker can be improves if information technology in terms of e-services support the different core processes of the broker. Some of the e-services that support the operations are [Mejia and Molina 2002]:

- e-Marketing to support the development of intelligent webportals for promotion of products and services
- e-Brokerage integrates software to enable the selection, evaluation and configuration of SMEs (Small and Medium Enterprises) to exploit a business opportunities.
- e-Engineering is a collaborative environment to support integrated product development and product transfer to the SMEs.
- e-Supply integrates services related to e-factory, e-logistics for importing/exporting materials and products, ERPs, supply chain management and manufacturing execution systems.
- e-Productivity integrates technologies for the diagnosis, planning, evaluation and monitoring of SMEs.

Although each individual e-service contributes significantly to the development of core competences in the Broker, these technologies must be integrated. An European project was developed to implement the concept of an e-HUB to offer a set of services for collaborative engineering [Mejia et al, 2002] and a current project is being develop to support the integration of a HUB of e-services to support the operation of the broker and its supply chain of SMEs [Molina et al, 2006].

5.6. Defining strategies for Virtual Enterprise Brokerage

In order to maintain competitive advantage, the Broker, as any other type of company, must define its strategy. Therefore it is important to take into account the following concepts [Molina 2003]:

- External Drivers: all the issues that drive the environment and that will affect the decision maker in conceiving the business definition. This might include: Global Economy, Industry Context and Technology evolution, Market Attractiveness, Customers and Suppliers relations, and Government Influence.
- Internal Enablers: key aspects that might affect the realization of the concept, and which are internal to the company and have to be understood: Product/Service Life Cycle, Core Processes and Core Competences (i.e. Human Capital, Technological Capital and Organizational Culture).

In a brokerage services company, those concepts must be understood in terms of customer requirements and target market. The external drivers should guide the development of technologies that allow the Brokerage service company to follow up the development of each project, at the same time; these technologies must allow the customer to track the entire process.

On the other hand, for a Brokerage Service Company internal enablers are constantly changing. The definition of the New 7S's [D’aveni, 1995] can be helpful in this process due to the dynamics that these strategies involve. In a Brokerage Service Company core processes and competences are combined with the BTO Strategy, resulting in a company that must react to the demand, be flexible and fulfill customer requirements in prices, quantities and time required. Porter Analysis [Porter, 1985] or static strategy analysis must be consistently applied. However, the competitive advantage in a company with BTO strategy must be reached by the supply chain management. In this particular case, the management of the allies or companies members of Virtual Industry Clusters is a key issue in this process.
6. From concepts to reality: the operation of the Virtual Enterprise Broker in the aerospace’s supplier industry.

IECOS S.A de C.V, is a brokerage company, created by CIDYT (Center of Design in Innovation and Technology) at ITESM University, with the objective to demonstrate how a Broker company composed of SMEs could be designed, developed and operated. In 2000, IECOS initiated operations and worked as a broker, searching for business opportunities and selecting several Mexican SMEs in order to comply with certain customer requirement. However, at this time, IECOS worked more as an integrator than as a broker. An integrator integrates the companies in order to satisfy business requirements, while a broker operation involves more activities such as being responsible for the whole process (design, manufacturing, quality check, packaging and delivery).

It was until 2001 that IECOS found the opportunity to operate as a broker offering its services to a customer in the aerospace industry. The customer had the need to reduce manufacturing costs and its strategy was to find partners in Mexico in order to take advantage of low manufacturing labor cost and the proximity of the US target market.

However, when this aerospace company tried to do business directly with small and medium enterprises, it found that the prices were competitive, but it was necessary to establish a department responsible for the product transfer of the product, suppliers’ development and quality process in order to make sure that customers’ requirements were met. On the other hand, options like subcontracting large companies were not feasible due to the fact that the prices were similar to those in the United States.

IECOS propose a solution to this problem using its Brokerage model. The Broker operational model allowed IECOS to met customer requirements within the time and quality required.

The activities that IECOS performed in order to fulfill the first customer order were:

- **Core competence selection development and protection:** Once IECOS understood customer requirements; it had to make sure that those requirements would be met by the partners involved in the project. So in the first stage, IECOS defined which capabilities were going to be needed and pre-selected some partners from the VIC network, in accordance with the capabilities and core competences of each partner.

- **Search and select partners:** Based on technological capabilities and the analysis previously made about the potential partners, IECOS was able to make the selection of the core competence of each partner and invited them to participate during the development of the project. However, the capability analysis was combined with the financial analysis in which IECOS determined project feasibility.

- **Quotation, Negotiation and Contract:** After a positive financial evaluation, IECOS evaluated each one of the proposals presented by the partners and integrated them in one proposal in order to present the best option for the customer. By this stage, the customer was already saving operational costs due to the negotiation and contract of a collaborative network in order to supply an integrated product. However, IECOS performed and optimized these operational activities due to the close relationship with the partners involved.

- **Integrated process of product, process and facility development:** In this case, IECOS was responsible for the product since the receipt of the order. IECOS received the design from the customer and transferred it to the partners. Afterwards, IECOS designed the process chart in the same way that a manufacturing company would do it on the shop floor; but the main difference is that IECOS was configuring companies’ networks rather than machines.
• Project coordination management and control: The coordination of the project involved activities such as: coordination the arrival of raw materials in the case that these were brought from foreign countries, coordination of partners’ manufacturing activities, coordination of intra-partner activities, and finally, coordination of the final assembly and shipment. Management activities are related to all decisions that need to be taken during project execution, such as a change in the product design or in a raw material. With the configuration of its suppliers’ network, IECOS had the flexibility to respond rapidly to a change in the characteristics of the product or quantity demanded.

• Quality assurance: IECOS as an integrator needed to make sure that the quality standards required by the customer were achieved. Indeed IECOS transferred all the knowledge necessary to comply with the standards required. Thought VICs suppliers’ development process, IECOS continuously improves quality performance of its partners.

In this case the BTO was achieved by the application of the Broker operational model, in such a way that the time response for deliver the part was optimum configuring a Virtual Enterprise (network of suppliers) with the partners that had the desired competencies.

When purchasing a part, there are several activities that do not add value to the company, such as: analyze proposals, emit purchase orders, and solve questions about product design, among others. Figure 3 shows a list of these activities, that usually an OEM (Original Equipment Manufacturer) performs with each supplier. The Broker adds value through the integration of partners in Virtual Enterprises, offering a complete service to its customer performing these customer-non-value-added activities.

![Figure 3. Non value OEM's activities vs BTO integration.](image)

Added to the advantages of having just one supplier for each part and saved operational cost in non-added value activities, the Broker provides individual solutions for each one of the projects requested by the customer.
The aerospace industry is a particular case, since it is characterized by low volume and high accuracy; this makes difficult the participation of SMEs in its supply chain due to the technological knowledge and flexibility required. In the case analyzed, the required parts were maintenance tooling with a volume variability that could go from 1 of a kind product to 40 parts per year. Consequently, two types of projects can be undertaken:

- Maintenance tooling - “made to order”
- Maintenance tooling - “projects”

The characteristics of each group are described in the table 7, and will be detailed in following sections.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Quotation time</th>
<th>Activities</th>
<th>Lead time</th>
<th>Quantity</th>
<th>Input requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance parts, “made to order”</td>
<td>1 days</td>
<td>Manufacturing, quality check, shipment</td>
<td>3-4 weeks</td>
<td>1 parts per order per year</td>
<td>External material and components</td>
</tr>
<tr>
<td>Maintenance parts “projects”</td>
<td>2-3 weeks</td>
<td>Re-design, manufacturing, quality check, shipment</td>
<td>2-3 months</td>
<td>40 parts per order per year</td>
<td>Redesign of the part</td>
</tr>
</tbody>
</table>

6.1 Tool Maintenance parts - “made to order”

In this case Made to Order means that the design of the part was already made, the orders are usually one of a kind product and the process begins with the manufacturing of the part. The volume was low and the variability of the parts was high.

Within this scenario the customer requested parts with some manufacturing difficulty, as for example, assembly parts, tool kits, hand tools, among others. These maintenance parts did not have a stable demand over the year, so the customer kept them in stock and whenever the part was requested, a purchase order was then emitted. However, one of a kind product is not a representative volume for the supplier, so in many cases, the supplier was not willing to spend time and resources in the manufacturing process.

Although the operational excellence of the suppliers existed in their core processes, some challenges were faces, such as the lack of technical knowledge necessary to transfer the customer design to the shop floor. Resultantly many costs were added to the product without adding value. Then the Broker offered a solution sparing the product into processes, taking advantage of the operational excellence of the partners in the VIC. This is the capability to perform Broker core process, and combine it with the technical knowledge in product transfer and logistics necessary to integrate organizations in Virtual Enterprises.

In this way the supplier did not have to invest in new technologies or resources, using only what was idle and available and the customer does not have a disintegrated product process involving a high operational cost. The Broker assumed the responsibility of the whole project, saving cost for the entire network.

In order to produce one of kind products, there are some characteristics that the network must comply with and are related to the core competences of the entities involved in the process. Figure 4 shows the configuration of the entities in order to comply with this type of customer/market requirements; core competences, processes and BTO characterization according to this type of requirements are indicated in gray color.
To fulfill one of a kind product requirement, the VIC contributes with the operational excellence and the availability of the capabilities and capacities of its allies. This core competency reaches the BTO strategic model fulfilling the requested flexibility in terms of quantity and customization and at the same time this core competences are supported by entities’ core process, such as, the searching and selecting partners and the core competence selection development and protection.

In the case of the one day quotation, the VIC contributes with the knowledge for competences integration and deployment, necessary to react rapidly to the customer requirements. These core competences are related to the BTO strategic model in terms of the low cost and high supplier integration involved in the execution of the project. However, the BTO characteristics are supported by some Broker’s processes such as, core competence deployment in which the Broker is taking advantage of the capacity availability of its partners, and the negotiation and contract in which the Broker is formalizing the relationship between partners.

In the case of the external material and components, the VIC contributes with the aggregation of core process, products and technologies necessary to integrate each partner into the network and the flexibility of the supply chain that allows the VIC to react easily to a customer requirement. These core competences fulfill BTO requirements in terms of not carrying inventory and are supported by VE core processes of distribute supply management and global coordination.

Figure 4 Application of the Operative Model of Virtual Enterprise Broker to one of a kind product market requirement.
6.2 Maintenance tooling - “projects”

Project parts in this case refers to the developments required by the customer in order to standardize their parts according to the local standards in such a way that the material and components cost could be reduced. In this type of project, the customer requires a redesign of the parts, prototype and/or manufacturing process. Figure 5, shows how the Broker is relating its core competences and process in order to satisfy customer requirements and fulfill BTO strategy in re-engineering of parts; core competences, processes and BTO characterization according to this type of requirements are indicated in gray color.

The Broker is able to redesign the product according to the local standards, due to the technological knowledge and experience in product development. However, this activity involves the validation of the part not only in terms of measurements and material but also in functionality and performance.

Again each entity contributes in certain parts to the customer requirements. The Broker takes advantage of the knowledge of product and technologic transfer necessary to transmit this knowledge to the network, the knowledge of project management, necessary to coordinate the whole process. This core processes fulfills BTO requirements in terms of high level of customization supported by Broker core process of selection of partners, high customer driven design supported by the Broker core process of integrate process for products and high supply chain integration supported by Broker process of project coordination and control.

Consequently, the Broker is able to redesign customer parts and customize them in accordance with the local availability and VICs integration.

![Diagram](image)

Figure 5 Application of the operative model of Virtual Enterprise Broker to re-engineering of parts.
7. Conclusions

The Build to Order production model can achieve mass customization ideals, in such a way that the customer will have a customized product within the time and quality required. However, this strategy proposes several challenges and requires a novel approach that can be easily applicable to a significant number of companies or industries. The proposed approach in this contribution is the Virtual Enterprise Brokerage a structure driven strategy based on the concept of Virtual Enterprises. A Virtual Enterprise is designed and created by combining core competences and core process of companies organized in Virtual Industry Clusters (VIC), a type of Virtual Breeding Environment as defined in the ECOLEAD project. The VIC contributes with the management of core competences and core products of its allies, the Broker with the capability to search and select partners in order to comply with customer requirements, and the design and creation of a Virtual Enterprise that must meet customer demands.

The advantages of the model, are that the broker integrates the core processes of each partner, responds easily to new demands by integrating more partners to the network, and satisfies customer requirements in such a way that each process adds value to the final product. Additionally, the Broker has been validated by the implementation of several projects related to the manufacturing of maintenance tooling for the aerospace industry. The case study demonstrates how BTO characteristics (level of customization, customer driven design, volume flexibility, cycle time, inventory, production costs, and level of supply chain integration) can be accomplished in a structured manner and following a clear brokerage strategy. Nevertheless, there are some cultural barriers that have to be overcome. This is the case of the lack of trust among partners, many companies where not able to share a project with a competitor. As a consequence, the Broker needs to work on the relationship between the partners in order to avoid future problems. It is also the case of the mental barriers from the customer point of view. It has been difficult to explain the model to potential customers without falling into the category of a distribution company. The general belief is that as long as more companies are involved in a specific process, the more expensive the final product is. However, this is not the case of the Broker model, because the network adds value instead of being a barrier in the supply chain.

The Virtual Enterprise Broker is a new structure driven strategy to achieve Build to Order supply chains based on small and medium enterprises that are willing to share their core competences and processes.

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13 Biographies

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