Article **ECORFAN Journal-Mexico**
OPTIMIZATION December 2015 Vol.6 No.15 1254-1279

Modular technological capabilities in the furniture industry

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Received January 9, 2015; Accepted April 30, 2015

Abstract

This paper presents an analysis of modular technological capabilities in furniture industry, in particular case of two companies producing wood residential furniture, BV and SGS. These companies operate in two different areas of furniture industry, the first is characterized by producing classical European style furniture. The second detonated SGS at time known Mexican rustic furniture design. Both companies have offered their products nationally and internationally, which led them not only to establish the quality within its objectives, but also needed management strategies productive and technological capabilities and design to stay competitive in their market. This document focuses on the technological effort of firms and analyzes the modular capabilities have developed in different areas such as production, product and marketing.

Marketing, furniture industry, technology, production, market.

Citation: Gonzáles-Vega, Norma Alejandra. Modular technological capabilities in the furniture industry. ECORFAN Journal-Mexico 2015, 6-15: 1254-1279

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Introduction

Introduction the work of Baldwin & Clark (2000), focus on design as a key activity in the innovation process, being the design establishes the architecture of artifacts and their interactions. They analyze the modularity as a mechanism that enhances innovation given the standardization of interfaces with other appliances.

Modularity is the process of dividing a large design in consistent units "modules" that can work together as an integrated whole. By definition, the modules are indivisible units of the activity of design within a larger, divisible and hierarchical system. A module is defined as a set of parts that are interrelated structurally interlinked to form a unit which is integrated into a larger system, in which interacts with other modules through functional links (Baldwin and Clark 2002, 6).

A modular system is composed of modules that are designed independently, designers get modularity partitioning information in visible rules of design and hidden design parameters, enabling the functioning together as a whole. The modularity is beneficial only if the partition is accurate, complete, and non-ambiguous.

Modularity, is the response that has been built to address the complexity, presents a breakdown of complex products in simple and independent modules through a standardization of interfaces.

This production strategy has been adopted by various industries that handle a high level of technological complexity, and seek to reduce the diversity of components reaching a productive synchrony and high levels of standardization of components inside and outside your company or industry.

This document presents in the first place the tool used to perform this analysis, then presents the main elements that determine the modular capabilities, as the third point arises the economics of the furniture industry context, followed by the definition of the two analyzed cases and its analysis, in a fifth section presents the results and finally the conclusions of the analysis are presented.

Methodology

First of all put this research into the methodology of case study, for which followed the methodology proposed by (Yin, 1994), we define this study as multiple holistic, in which there are two cases and an object of study.

For the analysis of the modular capabilities, Gonzalez (2014), proposes an array of modular capabilities that allows you to locate the State of the modular capabilities of enterprises or industries, this matrix is that we use to perform this analysis to furniture companies. This matrix identifies the types of modular capacity that can be found in the Organization, to then assess the level of these first, i.e., allows us to recognize the modularity and the level in which the analyzed organization is located, but also allows us to establish a management strategy of these capabilities according to the production environment of the company It will advance the capabilities to improve its competitive position.

Firstly the technological capabilities of both companies were analyzed, then focused the modular capabilities study, determining the type and the level in which are, describes these capabilities in terms of their productive activity. Table 1 presents this tool used to assess the status of these capabilities in both companies.

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Types / Levels	Modularity in the configuration	Modularity in production	Modularity in the use	Modularity in transportation
1. Null Capabilities				
2. Basic capabilities				
3. Intermediate capabilities				
4. Advanced capabilities				

Table 1 Matrix of modular capabilities (outline)

This matrix is divided into four types of modularity and in three levels of the same, also offers a reference point of zero state of modularity, a reference in a premodular state, which serves as reference to determine, case of a company or organization that may be at a point prior to a state of modular capability. The matrix here proposed, allows an internal and external analysis of the productive organization, as well as it allows in the same way, analyzing an object in relation to its architecture and design rules, as well as its interconnectivity with other systems or subsystems.

The principles and foundations of the modularity

Design Rules

Modular design rules established strict partitions of knowledge and effort in the realization of a design that supported the structure of efficient and flexible processes, whose parts are worked independently and in parallel with each other. The application of those rules extends the possibilities of design and thus opportunities for more innovations in the modular design. In a modular configuration options in the design are multiplied because changes in one module become independent from changes in other modules.

They are also decentralized because as designers adhere to the design rules, you have the freedom to configure (apply modular operators) without reference to the original architecture or any central Configurator of design (Baldwin & Clark, 2000).

According to Taboada (2005), these rules of visible design fall into three categories, architecture, interfaces and standards.

- An architecture that specifies which modules will be part of the system and what are their functions.
- A series of interfaces that describe in detail how the modules will interact, including how it is that they will work, will be connected and communicate together.
- Standards to prove that a module compliance in accordance with the design rules.

That is, architecture is the plan of basic design of the product, which is to divide it into different parts by assigning them different roles and deciding how they are connected. It may be, Integral: one whose components have a high degree of interdependence. Or Modular: design that is based on the use of components and interfaces, allowing customization (customization) of the product by mixing and setting (mix and match) them (Taboada, 2005).

The formalization of a modular architecture enables the independence of structure and function integration[1].

1 Modular architecture began to be developed in the computer industry from the e. U. A. between 1960 and 1970 and resulted in the emergence of clusters of firms and markets around successful computer systems modular (Taboada, 2005).

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The interface as well as the bond of communion of the components must denote the language indicative, to establish formal features of the component, that denote the operation, assembly, clamping and any other indication to the user for optimal operation (González, 2014).

Principles

Following Ethiraj & Levinthal (2004), when the strategy is not modular, a small change/problem can affect the entire system. Modular systems are more stable and predictable, and it establishes seven positions on the modularity.

- Modularity relates positively with speed of imitation of the design product, and therefore negatively the durability of the advantages of product performance.

- The heterogeneity of the product negatively moderates the relationship between modularity and imitation.

- Modularity will be positively related with the speed of the increase of improvement and performance of the product.
- The modularity is positively related to the reliability of incremental improvements to the performance of the product.

- The modularity is positively related to the likelihood of radical innovation in the component and subsystem level.

- The advantages of radical innovation, gained through modular design are positively related to durability of modular performance of the advantages of the organization.

- The experience in the use of the modular design principle, positively moderates the relationship between innovation and modularity.

Lara, A (2000), points out that the modular architecture has at least three objectives i) standardization and decrease of variability; (ii) increase in the variety; and (iii) flexible manufacturing processes.

Standardization and decrease of variability

The modular product is built with a series of units or modules, where all the product variants can be created from those modules. The modules are linked together through interfaces. In this way, is built the product with a minimum of parts reducing its variability and expanding the flexibility of designs and creating a structure open to change.

Increase in the variability

The modular architecture allows the interior of each module to improve the designs and produce variations that explore new forms.

The variety in the product is created with different versions of each component in the final product. So any combination of components can be assembled in different versions of the same product, or even in different products, with slight modifications.

Flexible manufacturing processes

The units or modules are common components of all variants. The variants are defined by design rules that respect the assembly and interconnection interfaces.

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Modularity levels

Modular system designers must design and specify visible design rules, needed to make the modules work as a system, the modularity in the development of new products may occur at four different levels (Hsuan, 2000):

- Components: parts standardized, well defined and accepted as industry standards. They are useful for many industries.

- Module. Combination of different parts of the component level.

- Subsystem: formed by the combination of modules, under specifications for each subsystem.

- System: Composed of subsystems with clear boundaries and defined interfaces.

These four levels can be or not present in products, this depending on the modular complexity of the object, to more complex higher level, less complexity less modular level.

The complexity is not given by the number of components, if not for the combinations in the modular arrangement (González, 2014). The degree of modularity in the development of new products is highly dependent of the number of standardized components, the composition of components, the interfaces between components, modules and subsystems, as well as the degree of substitution of components.

As more components are created at each level, modularization implies greater restriction on the system level, increase in the degree of customization (Hsuan, 2000).

Modularity typologies

It is possible to define the modular design from different perspectives: product and technology process, reconfiguration of the spatial distribution of components and subsystems; degree of connectivity and no-connectivity of the elements of the system, etc. (Lara A., 2000).

According to Gonzalez N., (2014), we find various kinds of modularity of agreement to different authors, she brings these proposals into four types: 1) modularity in the configuration, 2) modularity in the production, 3) modularity in use and finally, 4) modularity in transport.

- Modularity in the configuration: it is "hierarchy of the product", i.e., "architecture of the product" which defines the plan's basic design, which is to divide it into different parts, assigning different functions, like wise defines the interfaces between components.

Is designated when the components are closely interrelated within units, and there is among them a task interdependence and parameters, and these, in turn, are independent units (Baldwin and Clark, 2000;) Fujimoto and Akira, 2001).

- Modular production: consists of the "hierarchical structure of the product and its production process", i.e. the modularity provided by the variety of components of the product and the variability among them.

She completely specify all parts of the product and their interactions, are standardized under the strict parameters and can be manufactured or made at different times and each component or process in different place. (Baldwin and Clark, 2000 ;) Fujimoto and Akira, 2001).

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- Modularity in use: it is defined in terms of the interrelationship between the "function of the product" and the "hierarchical structure of the product", i.e., the function of the product is governed by the architecture of the product. I.e. the provision provided by the appliance the user to configure or reconfigure the product according to your needs. (Baldwin and Clark, 2000 ;) Fujimoto and Akira, 2001).

- Modularity in transport: is the modularity sued by channels, means and costs of the action of moving from one place to another component, module, sub-system or system, whether by the modularity intra-firm, inter-firm or for marketing.

I.e. it can be defined by components or modules that move within the firm or by modules that are delivered by suppliers external to the company, these modules are assembled in finished products in sub-systems on the main line of the contractor, in a process of outsourcing. Or it can be defined by the need to distribute the product to a lower volume and cost. (Baldwin and Clark, 2000 ;) Fujimoto and Akira, 2001; Gonzalez N, 2014).

The furniture industry

In sectors of economies of scale as the automobile industry, the volume factor - distance that determines the economic density of the product, has not been relevant element to trigger another kind of modularity. However in areas of low economic density products as they can be certain industries such as the furniture, since transportation costs are a crucial factor in the competitiveness of the product, required a fourth type of modularity the modularity in the transportation.

This modularity is determined by the capacity of modules or subsystems of recovering ones from others, reducing its volume in transportation given an outsourcing or in the marketing of the product to the end user (González, 2014).

The wooden furniture industry, is considered an industry that uses mature technology, with low technological income and high international broadcasting. It is classified as dominated by the supplier, however, even when this activity is classified in this way, there are companies that do not strictly conform to this classification, which is analyzed in this research (González Vega, 2005).

The furniture of wood, for many years industry has been a family business, formed by companies that initially were small workshops with little machinery and poor workmanship. The product of this industry is a good of consumer durables which are placed in the third phase of the life cycle of the product. The technological application of furniture products, grows in importance in the global production. Wood furniture manufacturing, linked resources from the primary sector, including providers of economic infrastructure; the secondary sector, suppliers of inputs and services and; of the tertiary sector, including infrastructure and transport.

The wooden furniture industry, internationally turned towards the use of new materials and increasing integration between companies. Traditional production processes are being overwhelmed by technology transfer, courses, trainings, technical manuals and experimental productions, manifesting itself as one of the great features of the international industry of furniture (Torres and Muñoz, 2002). Among the most relevant factors that characterizes the new type of industry (Domínguez, R., 2002: 105)

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- Consolidation of companies to obtain advantages of scale in the purchase of raw materials and distribution of products.

- Greater horizontal integration for the manufacture of new products.

- Specialization of small companies in the manufacture of components, such as suppliers of large enterprises.

- A growing integration of small businesses to form distributors to export markets.

- Technological innovations seeking simpler, less expensive and more automated processes.

- Less use of tropical timber and greater use of the temperate.

- Increase in the use of MDF (Medium Density Fiberboard) and fiberboard, instead of solid wood (furniture for kitchen 90%) and 80% in furniture for the home and office.

- A change in the industry towards manufacture ready-to-assemble (RTA) furniture.

- More training in norms, standards and quality control required in export markets.

According to Gonzalez, N. (2005)

- The use of new tools and design methods as CAD-CAM, Virtual and 3D furniture design, have transformed the technological profile and how to conceive and produce companies.

- The increasingly greater use of information technologies, as the Internet and intranet, as well as the use of communicator radios for the exchange of information.

- The creation of databases of the company, where the information is organized to be consulted by the different departments.

In general, this industry, moves along by technological advances and the development of substitutes for wood, as well as by the development of new finishes.

Globally, the industry is segmented by product type, where the home furnishings are the most significant.

Mexico has a moderately developed, the furniture industry where important stages of the production process are still made with traditional methods. So the national furniture industry can be classified as intensive in hand work and low volume. In Mexico are three types of companies: automated, fairly automated and handmade[2] (Bancomex).

The wooden furniture industry mainly produces furniture for the home, followed by office furniture and furniture for institutions, hotels, shops etc. Costs represent 60% in raw materials, 30% labor and 10% in other expenses such as transportation, marketing and other areas. In terms of sales, for the year 2000, the total sales of wooden furniture, the 58.1% corresponds to the micro and small enterprise, 31.4% to medium and 10.5% to the large (Torres and Muñoz, 2002).

2 The companies that are discussed in this research are defined one in fairly automated and other craft.

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This industry, controlled mainly by national companies, is an important foundation of manufacturing for domestic consumption.

The national furniture industry, is composed of about 44000 companies[3], as he already explained are mostly micro and small. 54% of the companies are located in Mexico City, Jalisco, Mexico State, Michoacán, Oaxaca, Puebla, and Veracruz.

General characteristics	
Size of the company	Many micro and small companies with an average of 6/7 company workers.
Style	Traditional and craft with little own design
Product line	Different lines of products, with great variety of models.
Machinery and equipment	It has little specialized machinery and Semi-industrial equipment.
Type of Industry	Semi-developed, with idle production capacity, low volumes of production

Table 2 Characteristics of the wood in Mexico furniture industry

The economic concentration of this industry is minimal, presents one less than 0.1 CR4, this means the four largest wooden furniture-producing companies have no more than 0.1% of the market.

The economic concentration in this industry does not exist, since more than 90% of the establishments are micro and small industries, and over time, this divergence is greater, in 1981 the number of microfinance institutions and small was only 79%, for 1999 the percentage rises to 99%, i.e. the concentration of the market disappeared, there is no power market in this sector (INEGI). As mentioned above, this is explained by the number of establishments engaged in the repair, and in addition the technological ease that represents access to a mature industry.

3 15th Industrial Census. 1999 INEGI

Of the total exports by customs of furniture, the 15.8 percent wooden furniture (Bancomex, 2001).

The world market of wood furniture is increasingly more open, it is estimated that world demand for this product is increased by 3% (Canacintra). Emerging new players such as India, Viet Nam and Romania, while China stands as a main player in the market.

Although Italy continues to be the main exporter of furniture in the world together with Canada, Germany, China and Poland.

The largest importers are the United States, United Kingdom, France and Japan. Mexico is not in any of these two groups but is expected in 2004 continued on an upward trajectory as producer and exporter, mainly to the United States.

One of the factors that make small the competitiveness of Mexican modern enterprises, are the high costs of operation, as it would be the case of the electrical energy that is 60% more expensive compared with foreign competitors, such as China (Canacintra).

The Mexican companies have indicated a growth from trade liberalization, especially since the implementation of the free trade agreement with the United States and Canada, this growth has been explosive and provided investment opportunities for the manufacturing and marketing of furniture, which have had as main target the domestic market followed by the United States market. After this, Europe represents one of the main markets of the Mexican furniture.

The Cases

This section is a summary of the history of companies, information on their origin and evolution.

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Describes a set of background, characteristics and information about production and the market, to place the object of study in one company.

VB Company

The VB furniture company, was founded in 1934, is located in the industrial zone of Naucalpan, Mexico State, manufactured in a home, English style furniture, which were exact copy these designs and some European classics of the 15th and 16th century. These furniture were made in 100% solid wood, i.e. industrialized wood (plywood or chipboard) was not used.

It focused on a classified as upper middle class market, which could acquire this type of furniture, which are characterized by a large size and high price. Currently the company is dedicated to the manufacture and distribution of wooden furniture for the home in the following lines; canteens, bedrooms, tables, bookshelves, especially using derivatives of wood.

Its main models which follows the line that characterizes them: Orleans, Sheraton and Chippendale.

Some of these models are maintained today, but also has emerged a classic line that is developed by this company.

Its main clients are; Liverpool, Dico furniture, Hermanos Vázquez, Sears. It is also present in the interior of Republic in the major cities, such as: Guadalajara, Monterrey, Tamaulipas, Morelia, Queretaro, and Hidalgo. The Interior of the Mexican Republic, furniture are distributed by large local retail chains. And in some of these States distributes its furniture through its main clients.

Its furniture is targeting a particular sector of the market, characterized as upper middle class; being large, ample spaces for furniture. In addition to having a higher price to similar styles that are available in the market, because of its prestige and quality.

The company has its furniture to South America mainly exported to Central America, its main customer was in the country of Guatemala.

Production process

The company is currently divided into two plants, the main plant, which manufactures dinners (except chairs), bedrooms, booksellers and Center tables. It is located in the industrial zone of Naucalpan, and the plant Lerma, which manufactures chairs for dinners, located in the industrial area of Lerma, both in Mexico City.

Both plants are divided in the same areas of production, but different dimensions. The main plant, has a ship to one or two areas, while the Lerma plant has only one ship divided into two, for all areas of chairs production:

- Storage area: is in charge of reception, selection and distribution of wood, sheets, chipboard and MDF to the different productive areas.

- Shred: in this area it was held the yarn, cut planks, molding parts, as well as the training and integration of (strips of glued timber) boards and cutting of sheets of plywood for the manufacture of covers or modules that will be calibrated to leave them to the exact measurement.

- Veneer: this area is responsible for enabling the sheets of veneer (root of Elm, cherry, mahogany, etc.) for the veneer of modules and covers.

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- Machining: this area is responsible for drilling, molding head, cut and shape the veneer pieces, strips and wood boards, for the dimensioning of parts, according to the models of the product.

- Polishing: this area deletes the roughness that arise in machined parts, to give them the required texture.

- Pre finished: this area will ink some parts by immersion, as well as the application of the catalyst to covers of tables, commodes, and bureaus.

- Finishing: this area has a single recent acquisition machine, it consists of a finishing process U.V, which is characterized by being more resistant to solvents and scratches. This finish is applied to flat pieces such as, the surfaces of tables, panels, shelves, drawer among other fronts.
- Assembly and final assembly: in this area is the assembly of each of the components that make up the furniture.

- Upholstery: the upholstery of the chairs that arrive from the Lerma plant is done in this area.

- Finished product (store): in this last area is saved the finished product carefully identified and accommodated in racks that are arranged according to the order of production, to be distributed.

Plant Lerma which only produces chairs has similar areas of storage area, shred, veneer, machining, polishing, pre finishing and final assembly. But unlike the main plant, at Lerma the product is assembled before entering to pre finishing. Table 6 shows the process of production of the furniture company, in its plant Naucalpan.

By reversing the order in the process of Assembly and finishing, plant in Lerma is in reverse.

SGS Company[4]

It is a company specialized in the manufacture of rustic furniture artisan characteristics in industrial volumes.

It is located in the town of Chipilo, Puebla 140 kilometers from the city of Mexico. The plant of the integrated company[5] - is installed in an area of approximately 60 000 m2, divided into several sections[6], associated workshops and integrated micro-enterprises[7] are also located in the same community, creating an important source of employment in the region.

It started operations in 1987 exporting that same year 50% of its products to the United States. That first year, the company had an area of 150 M2 and had 20 employees. In 1989 three workshops for the production of furniture in white were integrated. That same year they started exports to Europe and its markets showed very high growth, which led them to integrate new associated workshops.

External workshops, mostly started by internal workshops, i.e. integrated companies born of the own company.

4 The company as such disappeared at the beginning of this century, but continued with other social reason PN, which operates under a similar system although on a lesser scale. Retains the same designs and produces new, lighter, more standardized under the same concept of furniture rustic.

5 Companies of specialized services that individuals and companies, associated preferably small scale and medium (SECOFI, integrators).

6 Subcontracted workshops dedicated to machined furniture in white (unfinished)

7 Companies subcontracted by the company Integrator (SECOFI, integrators).

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The capital of finance for the creation of these new workshops, is issued by the same company, is encouraged them to lending them money so they start producing, coming at a time of self-financing.

Products

Each of the furniture comes from a piece of old furniture, from the 14th to the 19th century, whose reproduction have been studied and careful details

They are made with a combination of new pine wood and authentic ancient woods moth-eaten, whose whimsical beauty and appearance has been created by nature.

They handle white furniture to then give the finish the customer wants, such as pewter inlay, quarry, marble or talavera customers and suppliers.

Clients and Providers

As initial export policy, it was decided to open a store in California, United States, in order to reach customers directly, without intermediaries as they had been doing. However they faced the problem that was not easy access to that market since only 33 small businesses who were not buying volume, that they had no awareness of open market (Villa, M. 1997) could be contacted.

The company decided to focus on distributors, being the first contact in the United States. The U.S. market grew in such a way that it became their first source of demand, followed by the European market.

Production process

The production process in the company is done in two phases, functions of the workshops depend on the production process of integrating.

Functions of the associated workshops:

- Shred: This is the initial step, which involves cutting wood in longitudinal dimension tables, in order to take advantage of only that portion of wood.
- Cleaning: Refers to get square faces in wood, i.e. without imperfections and to the specified thickness.
- Dimensioning: It consists of giving the final dimensions of length, width and thickness to the tables.
- Assemblies: It is the work in wood which gives resistance to the assembly and therefore to the furniture.
- Assembly: furniture using galvanized nails are armed and it is made by subsystems. After this process gets a piece of furniture in white, which is as associated workshops delivered it to the company that this proceed with finishing steps.
- The furniture is designed by the company, which is delivered to the sizes, through the design of given parts and planes of the design prototype.
- Finished: the company controls this area internally through internal workshops specialized in sand, wax, metal fittings, sealed, moth control and repair of damage.
- Packing & crating: several types of gasket, which depend on the distributor are used. Among them is the paper carton, sealed air, corners, plastic film or boxes.
- Boarding: filled containers and trailer for the transport box.

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The company is responsible for going to the workshop to pick up furniture in white, which are carried to the furniture store area blank or product in process. It is here where the quality of the furniture as well as your stock is verified.

The design activity is generated from the company; the department of engineering of the product, performs the prototypes that will be delivered to the integrated micro and associated workshops.

Design prototypes are carried out under rules of standardization of given parts, which will be manufactured by the company and delivered to the associated workshops.

Analysis of modular technological capabilities

This section presents the description and analysis of technological capabilities in modular that they generated the two companies studied. The aim of this section is to present the level of capabilities that enterprises have achieved throughout his technology career.

The obtained information rests on analysis of interviews with companies, as well as the review of studies that have been done on them. From the evidence presented, it was possible to identify the set of capabilities.

We return to the definition of technological capabilities that exposes Richardson (1972), as "the skills, experience and knowledge that the company possess" capabilities that Kim (1997), requires "the ability to make effective use of technological knowledge, to assimilate, use, adapt, and change existing technologies, as well as the ability to create new technologies and to develop new products and processes in response to changes in the economic environment"

And connection to the modular ability, offers us a fertile framework for exploring and exploiting the design process, as a possibility for promotion and development of innovation process - product. Modularity has enabled different industries handle the increase in technological complexity. Result of a technological search of advancement through modifications in the production process, in the architecture of the product and in the management of relations between companies.

Breaking an enormous flexibility, different companies can take responsibility in modules or separate subsystems and fully trust that the product formed from the joint efforts will work properly (Takeishi & Fujimoto, 2001; Lara & Constantine, 2000; Taboada, 2005).

The following table is the matrix used for the analysis of the productive capacities of the cases.

Kind capacity	Settings	Production	Use	Commercialization
NULL	Design rules are determined	No replacement and sharing of components	The company defines the use and configuration of the product.	Final product integrated into a single unit not reconfigurable
	No need for interface design, but assemblies or specific joints for each component		The user has no option to modify the function which was established to the product by the production company	Product components are packed
			The target language is between specific components of the production process	It provides stacking for transport and packaging
BASIC	Integrated Architecture	Prior enabled components	Some components are assembled by the user	Reduction of dead space in storage and transport

	Standardization and minimum segmentation (reducing components)	Classification of raw materials and planned supply (vandalize and enabled parts)	Components to be assembled in specific position	
	Higher variability components and less variety of products	mproved production processes and services: segmenting, standardizing them, adapting	Easy replacement of components	Regulated by regional standards
	Least degree of substitution of components	Search product homogeneity	Contemplate the design rules, you can add a module, you can exclude a module	
	Intra-company communication	They arrive at the production line, raw materials and intermediate goods	Indications and assemblies joints between various components, is set in the production process	
		Governed by local or regional standards		
MEDIUM	Transition to modular architecture	Productive supply line component and module level	Components and user modules are assembled	It is packed by modules and components
	Less coordination between modules, greater coordination at a central module	Pre enabled components and modules	Components and versatility modules assembled in different positions	Some older user components will be assembled for ease of packaging. storage and distribution
	Flexible designs in its configuration and reconfiguration	Parts and modules arrive at the production line	Facilitates replacement of components and modules	Final package dimensions are reduced
	Incremental innovation	Definition of common subsystems intra company. Reduces Variability of components and increase the variety of designs	The user has the option to award some other functions to preset by the producer	Packaging for each product or modules
	Coordination between components allows for replacement or exchange of modules	Allows use some design rules can add a module. you can exclude a module, you can replace a module or can invest in a module position	Begin interaction with products of the same brand	Increases transportation capacity
	Reduced variability of components, as variety of products	Regulated by national standards	Begin use with limited customization of product variants (product family)	Reduce marketing operations and transportation costs
	Communicati on inside the company and between companies		Coupling previous delimitation of space with other products of other companies. Allows use some design rules can add a module, you can exclude a module, you can replace a module or can invest in a module position	Respond to national standards
			Indicative language component module, and user modules	
ADVANCED	Modular architecture (the parts can change position to change the function or use of the product)	Pre enabled modules and subsystems	Modules and subsystems user are assembled	It is packed modules and subsystems
	Greater coordination between modules and independence of a central module	Material and shared components for different products	It offers great flexibility for the user to configure the product according to your need	The modules and subsystems user will be assembled for ease of packaging, storage and distribution

	Reconfigurable designs	Independent modules that allow reconfiguration of subsystems	Full customization product	Packaging coupling between subsystems, increasing transportation capacity
	Development of design rules within and between companies	Interfaces defined and shared between companies (established rules of design)	Coupling established interfaces with other products of other companies	Reduce marketing operations and transportation costs
	Resists technological obsolescence	Definition of common subsystems between companies	Modules and subsystems with versatility assembled in different positions	Product assembly by the user
	Constant innovation	Providing coordinated among enterprises, network production	The user can assign a variety of functions preset by the producer	Reduce the volume of packaging
	Less variability in components, greater variety in products	Modules and subsystems come directly to the production line	Apply more design rules can add a module or subsystem, you can exclude a module or subsystem can replace a module or subsystem or can invest a module or subsystem position, can split and swap modules or subsystems with those produced	Maximum speed communication between companies for marketing
	High degree of substitution or exchange of modules and their-systems	Technology developed adapted to existing interfaces		Extensive communication between certain distribution networks
			Apply more design rules can add a module or subsystem, you can exclude a module or subsystem can replace a module or subsystem or can invest a module or subsystem	Regulated by international standards
				Extensive communication

Table 3 Modular capabilities matrix

This matrix allows an internal and external analysis of the productive organization, as well as it allows in the same way, analyzing an object in relation to its architecture and design rules, as well as its interconnectivity with other systems or subsystems.

It is divided into its ranks in four levels, the first of them are established features of a product that lacks of modularity (zero level).

The next level includes the minimum characteristics that may have a product that will denote how modular (basic level).

The two remaining (medium and advanced levels), establish modular products, only the difference between one and the other is by degree of interconnectivity in terms of design, with other products of the company in the case of the middle level and other companies in the case of the Advanced (González, 2014).

Below we present the analysis of the cases in the light of this instrument.

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VB Company

Modularity in the configuration

Basic Capabilities

- The design department develops parts of furniture, from the commercial dimensions of the wood, from the acquired technology and new processes of furniture finished. This is the result of an analysis of the problems of machining parts, and the resulting changes of acquiring new machinery and adopt new furniture finishes.

- Developed a multidisciplinary team of generation of new products, which gave it the ability to produce a new model in just 4 weeks. I & D area in the furniture design generated a process of standardization that had an impact in the Organization and in the process of production of furniture, providing the ability to produce more quickly. Also developed the ability to produce new models of versatile form through the exchange of parts and incremental changes in way to standardized parts.

The company had the ability to generate new models from established models, because as mentioned it has developed a process of standardization, which allows you to combine parts from different models which makes small modifications of shape or size, thus generating new designs.

Modularity in the production

Basic Capabilities

- Acquired an American in 1996 origin-numerically controlled machine, first numerically controlled machine that acquires the company and used for machining parts enabled and another, of German origin, acquired at the end of the 90's, which produced what produced 10 machines in just one hour a day. The acquisition of these CNC machines it was decided after doing a study of the production process and detect bottlenecks. This determined the need for the standardization of components.

- Because of a change in the process of finishing technology; pass a train of varnish to a train of U.V (ultra violet), the production process was substantially modified and redesigned interfaces between components and modules. The design of the furniture underwent changes, was redesigned the sequence of Assembly and Assembly form.

The Organization of the production process are rearranged, the finish area is put to the area of Assembly - layout - and followed by final quality changes.

More stringent measures regarding were taken to quality, grinding, the quality and tone of the pieces had to be uniform, so they jump not differences when assembling furniture, the interfaces between components should be more accurate, since with this new finish, misalignments not could be just hidden with varnish.

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- The design department had at other times its own area for development of prototypes, samples, scale 1:1 (area), this area was developed: from 1991 to 1992, a new line of designs; in 1993, it redesigns a new system of Assembly that provides greater resistance and quality; 1994 to 1995 amending the Assembly process and tested different types for different parts, also in this period that is the standardization of the furniture, which leads to a restructuring of the Organization of production, making it more efficient and; new materials are implemented as the MDF, which replaces the wood moldings and is implemented in the manufacture of doors at first, and then to different parts of the furniture.

- From that the design department was a process of standardization of parts of the furniture, the company implemented a parts enabled area. This area allowed them to have parts that can be used in different designs or as a stock of prefabricated parts that serve as rear mind in almost all designs, it is the case of the legs of the chairs.

- Only parts authorized area is located in Lerma plant, to the process of production of the chairs. The process allowed the company to have an area of authorized parts for replacement and stock for the production.

The company produces a number of models of chairs with a variability of only twelve components.

Modularity in the use

Null capabilities

- The company defines the use and configuration of the product.

- The user has the option of modifying the function which was established to the product by the production company.

- The indicative language occurs between specific components to the production process.

Modularity in the transportation

Null capabilities

- Final product integrated into a single unit not reconfigurable, without the possibility of reducing its volume or weight at the time of move inside and outside the company.

Levels	Configuration	Production	Use	Transportation
Null			The company defines the use and configuration of the product The user does not have the option of modifying the function which was established to the product by the production company.	A single unit not reconfigurable, components and the final product are no versatility, they are transported as complete elements, which cannot stacked, folded down, rearm, folded or compacted.
Basic	Minimum segmentation (reduction of components) and standardization Greater variability in components and less variety of products * low degree of substitution of components	Pre enabled components. Planned supply and classification of raw materials (given the Nuke and parts enabled). Improvement of production processes and		

	Communication inflow	services, segmenting them, standardizing them, adapting them. Commodity raw material and intermediate use goods arrive at the production line.		
Medium				
Advanced				

Table 4 Technological capabilities level modular reached by VB

The VB Company, reaches in the configuration modularity basic capabilities, at the time of the enabled pieces regarding the commercial dimensions of the wood. At the beginning of the standardization process of components, a process of standardization which enabled him to produce new models of versatile form through the exchange of incremental changes to standardized parts and components.

In the production modularity, achieves basic capabilities by purchasing CNC machines that also demanded the need of standardization of components.

The acquisition of UV finishes unit determined the redesigned the sequence of Assembly and Assembly of furniture form; the Organization of the production process are rearranged, the finish area is put to the area of Assembly - layout - and followed by final quality changes; the interfaces between components should be more precise, the production process was substantially modified and redesigned interfaces between components and modules. At the time of the implement of a parts enabled area.

This area allowed him to have parts that can be used in different designs or as a stock of prefabricated parts that serve as rear mind in almost all designs of chairs. The company produces a number of models of chairs with a variability of only twelve components.

In the use modularity and transport modularity not present any kind of modularity since the company defines the use and configuration of the product, the user does not have the option of modifying the function which was established to the product by the production company. The final product is integrated into a single unit not reconfigurable, without the possibility of reducing its volume in the transfers within the company or its marketing.

SGS Company

Configuration Modularity

Basic capabilities

- Enabled area represents a key role in the process and organization of production. It is here where begins the process of production of furniture that continues in the associated workshops.

Enabled area was possible given the process of study of the designs and the standardization of dimensions and some components of the furniture.

From its establishment, production, quality and design of the Cabinet could be controlled by the company.

The area enables the maquiladora wood workshops, absorbing 50% of the production of the final piece of furniture.

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Intermediate Capabilities

- Designed an assembly that allowed to establish constructive standards of the product, reducing the process of production of parts of subsystems as well as the process and Assembly time. The standardization of furniture and design of an Assembly that enables the company to enable parts that are generalized in design and dimensions, allowing the versatility of new models and increase the volume of production.

- The Department of engineering of the product in which the design center, is told with an area of research and development (ID) for the creation of prototypes.

This allowed the company to supply the market and consolidate its leadership in its market segment, at the time of enabling the evaluation of product and improvement of components.

Advanced Capabilities

- I & D area in the furniture design generated given because the process of standardization of parts, generating subsystems through the use of standardized components sides, doors, drawers, funds among others.

This systematization gave the company the ability to design versatile new products, be able to use for example, doors as sides, covers or drawer fronts. At a higher level, using sub-systems consist of these standardized components for user in different models, variations in subsystems, they generated new proposals of designs. Same sub-systems on various models.

Modularity in the production

Basic capabilities

- Before having a design department, associated workshops determining the dimensions and the production process of the piece of furniture that they manufacture. From the generation of the Department, models is shipping and have standardized versatile pieces, thus controlling the homogenization of the furniture.

- In 1995 the engineering department of the product, enables a molder of 7 heads which the company had acquired, which was on the floor of enabled.

Working directly in the redesign of parts, proposing alternatives, and a specific usage, the molder manages to increase the production process. This machine requires the standardization of components.

- The plant depends on the distribution of the given parts for the production, standardized parts: moldings, panels, backs, posts, doors and drawer fronts, in large volumes, which reduce production times and the workload of the manufacture workshops[8], reporting a higher utilization of the wood of pine and moth-eaten wood.

8 The manufacture workshops are those who work the moth-eaten wood and pine wood furniture. Refers to them as well to differentiate them from the workshops of forging, casting, fabric, finishes and wood carving. But all fall into the category of partners.

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Intermediate Capabilities

- The modularity of the furniture comes from face problems of production and use of furniture. Standardization aimed to develop a subsystem that would allow having different products, equal application and identical procedures and materials, parts and components like.

Facilitating the use of tools and replacement of parts, providing the Organization of simultaneous processes and production continuity.

Advanced capabilities

- Furnish was divided into different subsystems, their interfaces and their dimensions were redesigned.

- First worked in the saving of materials, on the basis of the commercial dimensions of the materials and studying the operations that apply to parts, moved a modulation and arrangement of parts that would be consistent with these dimensions.

- Second worked on the approval of production processes, which seeks that in essence production processes must be of the same nature, so that operators work under the same guidance, regardless of the model. Thus develops the standardized construction of parts for Assembly.

- Third is defining building standards, through a normalization of dimensions of the subsystems (drawers, doors, sides, shelves, seats and backs, legs and bases, etc.). Previously each workshop producing furniture according to their criterion of savings and use of material.

- Finally, they worked on the possibility of the versatility offered by these changes, for the development and design of new models, through the exchange of standardized parts and subsystems.

Modularity in the use

Basic capabilities

- Some components are assembled by the user, which in this company are the workshops, we will call them first users.

- Components to be assembled in a specific position, given the specifications of the company.

- Facilitates the replacement of components, the workshops have the ability to produce some of the components under specifications of the company, which to be standardized to facilitate their production and replacement.

- Language indicative of the production process, i.e. the company must set language clear and direct in the furniture processed semi production specifications, to prevent productive imbalances between it and the workshops.

Modularity in Transportation

Basic capabilities

- Components of the product are packed and transported to the workshops, which are the first users in this process.

- It includes stack for their transport and packaging for transport intra-company.

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- Reduction of dead storage and transportation space
- Regulated by the company quality standards.

Levels	Configuration	Production	Use	Transportation
Null				
Basic		Pre enabled components.		
			Some components are assembled by the user, which in this case are the workshops.	
		Planned supply and classification of raw materials (given the Nuke and parts enabled).		
			Assembled in position-specific components.	
	Minimum segmentation (reduction of components) and standarization	Improvement of production processes and services, segmenting them, standardizing them, adapting them.		The components of the product are packed and transported to the workshops, which are the first users in this process.
			Facilitates the replacement of components.	
	Greater variability in components and less variety of products	Search homogeneity of the product.		View stack for their transport and packaging for transport inflow.
	Low degree of substitution of components	Commodity raw material and intermediate use goods arrive at the production line.		Reduction of dead storage and transportation space.
			The indicative language is established between different components in the production process.	
	Communication inflow	Regulated by local or regional standards.		Regulated by standards of quality of the company.
Medium				
		Supply of the production line at the level component and module.		
		Pre enabled for components and modules.		
	Transition to modular architecture.			
	Flexible configuration and reconfiguration designs.			
		Parts and modules arrive at production line.		
	Incremental innovation.			

		Definition of common subsystems intra company. It reduces the variability of constituents and increase the variety of designs.		
	Coordination between components enables the replacement or exchange of modules.			
		Makes it possible to use some rules of design can add a module, you can exclude a module, you can replace a module or it can reverse a module position.		
	Lower variability of components.			
		Regulated by national and international standards.		
	Intra and inter business communication			
	Modular architecture, (parts may change position to change the function, the position of the product).			

Advanced	Greater coordination between modules, and independence of a central module.			
	Designs reconfigurable.	Pre enabled modules and subsystems		
	Less variability in components, greater variety of products.			
		Materials and components shared, for different products.		
	High degree of substitution or exchange of modules and sub-systems.			
		Independent modules enabling the reconfiguration of subsystems.		

Table 5 Technological capabilities level modular reached by SGS

The company SGS, accomplished in the modularity in the configuration basic capabilities: the area of enabled is where begins the process of production of furniture which continues in the associated workshops.

Before the standardization of furniture, the company developed the ability to perform incremental design their products, can be designed from an already accepted model, new incremental models with variations in its components which can be considered new models.

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In intermediate capabilities, designed an Assembly that allowed to establish constructive standards of the product, reducing the process of production of parts of subsystems as well as the process and Assembly time. Capabilities advanced, does them at the time that I & D area in the furniture design generated because already the process of standardization of parts and design an own ensemble, generate subsystems through the use of standardized components sides, doors, drawers, funds, among others.

Use formed by these components standardized subsystems to be user in different models, variations in subsystems, generated new proposals of designs. Same sub-systems on various models.

About modularity in the production, manages basic capabilities, from the generation of the department enabled, models shipping and have standardized versatile pieces, thus controlling the homogenization of the furniture. To enable a molder of 7 heads, this machine requires the standardization of components. The plant depends on the distribution of given parts for the production, standardized parts: moldings, panels, backs, posts, doors and drawer fronts, in large volumes, which reduce production times and the workload of the maquiladora workshops. Intermediate, furniture modularization capabilities emerges from face problems of production and use of furniture.

Modularization aimed to develop a subsystem that would allow having different products, equal application and identical procedures and materials, parts and components like.

Advanced capabilities are achieved to the moment in which we worked on the possibility of the versatility offered by these changes, for the development and design of new models. The furniture was divided into different subsystems, their interfaces and their dimensions were redesigned.

Develops the standardized construction of parts for Assembly. It is defining building standards, through a normalization of dimensions of the subsystems (drawers, doors, sides, shelves, seats and backs, legs and bases, etc.). He worked on the possibility of the versatility offered by these changes, for the development and design of new models, through the exchange of standardized parts and subsystems.

In the modularity in use reaches basic capabilities, some components are assembled by the user, which in this company are the workshops. The components will be assembled in a specific position, given the specifications of the company. Facilitating substitution of components by workshops, which have the capacity to produce some of the components, which to be standardized to facilitate their production and replacement.

The modularity in the transportation, reaches basic capabilities, since the components of the product are packed and transported to the workshops, which are the first users in this process. It includes stack for their transport and packaging for transport inflow. Seeks the reduction of spaces dead in storage and transport.

Conclution

The VB company your higher level modular capacity presented in the modularity in the production, where the process of standardization leads to generate a versatility in the design and production of furniture.

The standardization of parts of furniture allows the creation of a stock of standard parts that are used for the replacement of damaged parts and the production process is not delayed.

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It reduces the production of the furniture before standardization but also has allowed to establish a production plant that is dedicated only to the production of chairs, which given a modular architecture and a clear definition of the interfaces you has allows to design a variety of chairs with only a little variability of components. The company has strived to offer new products to the market, initially design pushing the Department of sales, currently sales pushes the design Department - now is the market to decide.

For which the company has developed throughout his career, a capacity of design, which allows you to develop a piece of furniture together with the development of new products and customers team in a period of 4 weeks and have it in production by a total of 6 weeks. Modularity in use and transport have not been served or sued by the company, although it is on a quest for export in addition to its domestic demand, has not established any strategy to attack the economic low density of your furniture.

The company SGS, reaches its highest level of modular capabilities through a standardization of components that has carried out a process of modularity in the production and in the configuration modularity, what you been allowing the exchange of parts for the production of new models, providing versatility and variety of the same.

He worked on the possibility of the versatility that they offered the changes of working components, modules for the development and design of new models, through the exchange of subsystems and standardized parts between them, increasing its capacity and production volume.

It also allowed him to create a storage area of pre modules enabled a large number of models, enabling the company, which operates under a model of enterprise integration, make 50% of the production and workshops the other 50%. Workshops may specialize in the manufacturing of in a type of furniture or can adapt to the demand for new models, given that large amount of pre-enabled modules. A flexible workshops and integrative enterprise production.

Level of modular capabilities accomplished by company VB

Levels	Configuration	Production	Use	Transportation
Null			The company defines the use and configuration of the product.	A single unit not reconfigurable.
Basic	Standardization and minimal segmentation (reduction of components)	Pre enabled components.		
Medium	Lower variability of components, equal variety of products.	Supply the production line at the level component and module.		
Advanced				

Modular capabilities level attained by the company SGS

Nivel	Configuration	Production	Use	Transportation
Null				
Basic	Estandarization	Pre enabled components.	Some components are assembled by the user, workshops.	The components of the product are packed and transported to the workshops.
Medium	Transition to modular architecture.	Supply of the production line at the level component and module.		

Advanced	High degree of substitution or exchange of modules and sub-systems.	Independent modules enabling the reconfiguration of subsystems.		

Table 6 Overview of modular capabilities achieved by both companies

The productive contexts of both company have led them to the modularity as a response to the productive pressures of their environment.
Both companies have taken the standardization as a means to decrease the variability between the components of the product. Likewise of quality costs to replace components and modules quickly and efficiently.

The redesign of interfaces for these companies allowed that these are common among modules or components, enabling the construction of the product with the minimum of parts.

Both companies chose to standardization, modularization and only one reached the level of subsystems as a strategy to reduce the complexity of managing a wide variety of designs and components.

Both companies found the need of the redesign of interfaces to component level or module, to first coordinate the variability of marriages, second for the reduction of external components that increase the number of components. Reducing the costs of coordination in Tin variability systems.

Companies found in the modularity an innovative passive resistance, they manage through the redesign, generate incremental innovations in short term costs and low efforts.

It increases the flexibility of designs, production, reduces the activity of manufacturing and the replacement cost, and improves coordination inflow, in both cases, either with another production plant or in the scheme of enterprise integration, with integrated workshops.

However the companies have not seen in Modularization response to a series of problems of cost, market or productive. The modularity in the present transportation is basic, however that the furniture industry produces goods of low economic density, not so, these companies cannot find products stackable, folding, buildable or reconfigurable by the end user. This modularity would be a key factor in the national and international marketing.

For both companies, having an area of I & D, appeared to be effective but expensive, although it was the origin of many production problems, both companies did not maintain these departments for research, design and development. It was a fairly expensive activity, since it implies a comprehensive creation, experimentation and testing of the different modules.

The development of modular architecture is more complicated than the of whole-grain products, in traditional or mature industries, as in the case of furniture. Since the pressure of the context has not sued make an effort not be glimpsed as a priority. Get modularity requires a thorough understanding of the functionality of the product and the distribution and interaction of its components and their interfaces. Coupled with their form of production has not filed a high degree of subcontracting or production network.

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However, in this same industry we see companies that have managed to obtain a higher penetration of market under the scheme of products "build it yourself" RTA, products that are packaged to be unarmed, in order to take up less space in the transportation. And once they reach the user or distributor, are reconfigured by manuals that relate the interfaces between components or modules, it is the case of the Ikea company, which sells its products globally. We also see increasingly more products that can be configured by the end user, of a series of options preset by the manufacturer, it is the case for companies that sell via virtual. And a series of products, collapsible, folding or reconfigurable by user, who see the modularity the added value of use and transport or storage.

The modularity in the production is the kind of modularity that most have implemented various manufacturing companies over the years, which has enabled them to divide the manufacturing processes and standardize components.

In case studies of VB and SGS, its modular behavior has allowed: i) standardization of parts of furniture allows the creation of a stock of components, ii) reduction of the time of production, iii) specializing in the production, iv) the exchange of parts for the production of different products and models, v) development of modules pre enabled a large number of model (vi) decrease of product components, vii) speed and innovativeness of designs, viii) reduced complexity of its processes and ix) greater coordination and production domain.

This matrix has allowed us to make a diagnosis on the level of complexity in the productive organization, and establishes specific measures, if among other things aims to reduce processes, control the order and the variability of the process, increase the variety of products and reduce the variability between components, reduce the cost of quality control, increase the flexibility of Assembly and manufacturing processes more flexible increase incremental innovation and radical innovation, encourage modular or architectural level.

If the modularity is the answer who have built companies such as in the automotive and electronic sector to confront the technological and organizational complexity. It is possible that then these knowledges of modularity are adopted by industries of various productive areas to cope with the accelerated changes of product and technology process of reconfiguration of the global production of components and subsystems, the demand for industry and innovation of the user, of the need for interconnection between products of different industries among others.

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