Technogical capabilities: Construction and evaluation of the Delphi case in Tamaulipas (México).

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TECHNOGICAL CAPABILITIES: CONSTRUCTION AND EVALUATION OF THE DELPHI CASE IN TAMAULIPAS (MÉXICO).

Resumen

El objetivo del trabajo es describir y valorar el proceso de construcción de capacidades tecnológicas de cuatro plantas maquiladoras de la División Arquitectura Eléctrica/Electrónica pertenecientes a la multinacional Delphi en Tamaulipas, cuyo único producto es la maquila de arneses. Se utilizó una metodología cualitativa, a través de una estrategia de investigación de estudio de caso tipo descriptivo. Los resultados reflejaron que las cuatro plantas estudiadas han construido capacidades innovadoras básicas en aquellas actividades de producción, desarrollando habilidades orientadas a la aplicación de nuevos modelos organizacionales. En cambio, dos de ellas, además de las actividades de producción, también avanzaron gradualmente en la función de soporte, que implicó mayor vinculación al interior de Delphi y al exterior con los agentes locales como las instituciones educativas.

Palabras clave: Capacidades Tecnológicas, Matriz de Capacidades tecnológicas, Subsector de Autopartes.

Abstract

The aim of this study is to describe and assess the technological capacity construction process of Delphi in Tamaulipas, whose only product is the assembly of harnesses. It focuses on the case of a group of four maquiladora plants belonging to the Electrical/Electronics Architecture Division of such multinational. Using a case study methodology, the study shows that the four researched plants have developed basic innovative capabilities in those activities related to production, placing emphasis on the development of skills oriented to the application of new organizational models. In contrast, two of the plants, in addition to the production activities, also gradually made progress on the support function. It is argued that such progress was due to their internal liaison work within Delphi as well as their external networking work with local agents such as educational institutions.

Keywords: Technological Capabilities, Technological Capabilities Matrix, Autoparts Subsector.

1. Introduction

The development of the maquiladora industry in Mexico has been given a great deal of attention from the social sciences since the 90s. This has been reflected in the abundant literature addressing this topic from different perspectives. (Carrillo and Hualde, 1996; Dutrénit and Vera-Cruz, 2002; Hualde, 2003; Carrillo, 2004; Dutrénit, Vera-Cruz, Arias, Sampedro and Urióstegui et al., 2006). This article analyzes the ways in which transnational maquiladoras, particularly those that participate in the Export Manufacturing Industry Program (EMI[1]) in Mexico build technological capability. To do so, it focuses on the case of an enterprise with potential to generate innovation, just as Lara's (2005) case study of the multinational Delphi in Chihuahua.

Since the 60's, as a result of the support provided by the Mexican government and the proximity of the United States to Mexico, the automobile assemblers located in the United States started an accelerated expansion process towards the Mexican economy (Gasca, 2006). They adopted a maquiladora investment model due to their assembling technical functions which are common to all the industry. In the 60's and 70's a new stage of the sector's development began with the 1962 and 1977 Presidential decrees which require manufacturers to include national components in their products. As part of the decrees, enterprises were given considerable incentives to import automotor parts (Miranda, 2007; Sosa Barajas, 2005; Juárez Nuñez, et. al. 2005). Such incentives attracted the establishment of enterprises committed to the assembly of parts for an overprotected domestic market and oriented almost exclusively to meeting the national market. This way various plants such as Volkswagen (assembly plant, State of México, 1964), Ford (two new assembly plants, State of México, 1964), General Motors (Engine and foundry plant, State of México, 1965), Chrysler (Engine plant, Toluca, 1964), and Nissan Mexicana (Cd. Industrial del Valle de Cuernavaca, 1961) started to establish themselves. The establishment of all these enterprises helped to increase the national production to nearly 600, 000 units in 1981 (Juárez Nuñez, et. al. 2005).

The main focus of this article is the autoparts sub-sector of the automobile sector. This sub-sector has been gaining a great deal of importance recently. For example, it generated 6.20% of the manufacturing's Gross Domestic Product (GDP) in 2009, and nearly 1.94% of the total GDP. In 2008, it had 126,362 employees, which represented 67.08% of the total employment rate in the Transportation Equipment Manufacturing subsector (INEGI, 2011).

[1] The maquiladora export industry performs service-related productive activities under the temporary import scheme in which most of the production is allocated to the external market. Even though the maquila establishments are not the original manufacturers, they are characterized by the fact that they undertake some stage of the production process of goods or services.

The global economy has been subject of different changes; Mexico is not an exception although the state has exercised little intervention in them. Perhaps one of the most important changes has been the attraction of Direct Foreign Investment (DFI) to the country. This has been carried out by reducing the restrictions to this type of investment. These changes were based on the argument that foreign enterprises' the productive activity would generate capabilities or learning in domestic enterprises. This would in turn allow the knowledge gained to be disseminated towards the economy in general (Dominguez and Brown, 2004).

For this reason, the aim of this study is to describe and discuss the technological capacity construction process of a group of subsidiaries of the Delphi's Electrical/Electronics Division in Tamaulipas.

This research made use of a case study methodology in order to take advantage of the richness of its contents and to describe the real context in which the object of research takes place (Eisenhardt and Martin, 2000). All these considerations serve to corroborate the appropriacy of the case study methodology used for this research. In this context, the underlying assumptions of this research are related to the how and why the organizational and learning process of technological change emerges and develops in enterprises. That is to say, the main concern is to explain the complex technological and organizational situation that has taken place or is being produced in organizations under study. It is argued that this research addresses a contemporary phenomenon as the development of accumulation of technological capabilities is being produced these days, or has been produced in the past, but its participants are still able to provide information about it.

It has an exploratory, descriptive and explanatory nature regarding the building of technological capacity as the object of research. To do so, the fundamental aim of this research is to validate the studies undertaken by Dutrénit et al. (2002), following Yin's (1989) argument that one of the aims of the case study methodology is precisely to validate other studies.

The unit of analysis for this research is the Electrical/Electronics Division of multinational Delphi in Tamaulipas, which is made up of four plants: two of them are located in Nuevo Laredo and two in Cd. Victoria. A theoretical sample was used in order to choose a case which could provide a greater learning opportunity (Stake, 1994).

Based on data collected through interviews with managers and heads of engineering, development and quality departments, questionnaires administered to technicians and engineers, and observations conducted during three visits to the subsidiaries, the technological capabilities profile of the four plants was developed following Dutrénit's et al. (2002)

Technological Capabilities Matrix of the EMI. A description of the activities grouped according to their (two) stages of technological development is provided in such Matrix. This facilitates the understanding of their technological construction process, placing a strong emphasis on those that have managed to accumulate capabilities, which are complemented by the assessment of the technological capabilities index and level.

The article is organized into four sections: (1) introduction, (2) DFI reference framework, the technological capabilities construction processes and indices; (3) results, and (4) main conclusions drawn mainly oriented towards building basic technological capabilities in the production and support function.

2. Direct Foreign Investment, Technological Capabilities and their Levels and Indices: Reference Framework

2.1. Direct Foreign Investment

The contribution of multinationals to the technological development in emergent economies has been a controversial phenomenon. The assessment of such contribution has been always dependent on the affiliation of the scholars to either school of economic thinking. Regardless of that, multinational enterprises and their fundamental instrument, their direct foreign investment, have been important vehicles for technology transfer and capability generation in developing countries since World War II.

In one of his first research projects into the effects of foreign investment, Hymer (1976) argued that direct foreign investments are not only a capital transfer, but also a source of the combination of capital, enterprise organization and new technology for the receiving countries. Similarly, DFI is also considered as one of the mechanisms through which technology is disseminated. The rapid growth in level of importance of the DFI and its widely international presence reflect the growing geographical diversification of economic activities and by sector of enterprises. Multinationals are the traditional participants with heaviest weight in this type of transborder transactions. This evolution has coincided with the tendency of transnationals to participate in foreign trade activities. Over the last few years, the small amd medium sized enterprises (SME) have also increased their level of participation in DFI.

2.2. Technological Capabilities

Regarding technological capabilities, various scholars have contributed to the development of an analytic framework of the concept. They have also contributed to the understanding of the processes involved in the building of technological capabilities by enterprises in developing countries (Dutrénit, Vera-cruz and Arias, 2003).

Westhpal, Kim and Dahlman (1985) define technological capability as the ability to make use of technological knowledge. Such capability does not lie in the knowledge possessed, but in the use of knowledge and the capability of utilizing it in production, investment, and innovation issues (cited in Torres, 2006). Bell and Pavitt (1995) make reference to technological capabilities such as "...the very capabilities of generating and managing change in technologies used for production purposes; these capabilities are widely based on especialized resources."

Kim (1997) defines technological capabilities as the ability to make an effective use of technological knowledge to assimilate, use, adapt and change the existing technologies. It also allows the creation of new technologies and the development of new products and processes in response to the changing economic environment. Enterprises learn over time, acumulate technologcal knowledge, may progressively engege in new activities. By doing so, they become more skilful in developing new capabilities.

Capabilities are abilities and technological capabilities reflect the dominance of technological activities (Bell and Pavitt, 1995) and (Kim, 1997). Based on empirical pieces of work at the enterprise level, taxonomies that describe the acumulation of technological capabilities have been developed. Examples of such taxonomies are those developed by Dahlman and Westphal (1982), Lall (1992) and Bell and Pavitt (1995), which range from a basic level of knowledge stage through to an advanced innovation capabilities stage (Dutrénit y Arias, 2003).

2.3. Technological Capabilities Matrix of the EMI

Over the last few years, technological capabilities matrices specially designed for the Mexican context, in particular for the EMI based on the model proposed by Bell and Pavitt (1995), have been under construction.

In order to understand the role played by the processes of describing the activities aimed at building technological capabilities, their analysis using the model adapted to the EMI context developed by Dutrénit et al. (2002) is proposed. According to these authors, the development of this taxonomy was based on the analytical framework proposed by Bell and Pavitt (1995) and the subsequent adaptations made by Dutrénit, Vera-Cruz and Arias (2003), Ariffin and Figueiredo (2003) and Figueiredo (2001).

Of particular relevance is the contribution of these scholars to explaining the processes involved in the construction of technological capabilities. Such proposed matrix reflects the characteristics of the technological capabilities construction process according to the activities in which multinational enterprises participate (Urióstegui et al., 2007). The three technical support functions (internal links, external links and equipment modification) were kept. The main changes took place in the production and support functions. The investment function remained unchanged.

In the Technological Capabilities Matrix for the EMI proposed by Dutrénit et al. (2002) (Table 1), a description of the activities performed in each technical functions (Investment, Production, Support). On the row axis, the four levels of technological capabilities are presented from lowest to highest innovativeness. Level 1 represents the most basic innovativeness, or basic operative capabilities. These are capabilities which Dutrénit et al. (2002) describe as routine capabilities "to use and operate the existing technology." Next, two intermediate levels, with a greater innovation degree (basic innovative capabilities and intermediate innovative capabilities) and where capabilities to manage technical change already exist. Exactly in the superior level or that of the highest degree of innovativeness: advanced innovative capabilities. Unlike the previous innovative capabilities, the contribution of the technological capabilities to change is more important and significant.

Level capabilities	Investment technical function		Production technical function		Support technical function		
	Decision making and control	Project preparation and execution	Focus on the process and production organization	Focus on the product	External liaison work	Internal liaison work	Equipment modification
Basic operational capabilities	.Expenditure estimation	.Planning protocol .Preparation Protocol .Land preparation .Basic civil engineering construction	. Process specifications replica .Routine operation of basic or more complex assembly process .Workstations improvements based on monitoring or quality assurance system .Basic engineering process	.Product specifications replica .Quality control in quality assurance process	.Suppliers, customers and institutions relationship trough headquarters	.Relationship with headquarters to receive authorization about inputs, technical specifications of products and process and investment projects.	.Routine maintenance of components and equipment (including replacement of original parts) .Replica of plant specifications and single parts of equipment . Basic maintenance without schedule.
Basic innovative capabilities	.Active monitoring and control of feasibility studies -Technology selection /suppliers -Activities planning	.Feasibility studies .Standard equipment search .Basic engineering	.Minor adaptations to assembly process based on studies of time and movement - Shaining methodology - Implementation of Poka-yokes in critical seasons. .Working groups formation . *improvement of Layout (design)* ,Productive programming, total productive maintenance .Escalation of the assembly process and/or final assembly of diverse sizes parts	.Less adjustments to the product according to needs Progressive improvement on product quality	.Costumers relation trough product specifications .Research and bargaining with indirect material suppliers .Search for liaison with local institutions for training staff	.Establishment of working groups to liaison between plants, design center, deviations and headquarter.	.Less copy and adaptations of specifications of exiting equipment test .Reconstrucción de equipos pequeños sin asistencia técnica . Scheduled basic maintenance
Intermediate innovative capabilities	.Search, evaluation, and technology selection/ /suppliers .Negotiation with suppliers .Full project management	Detailed engineering .Equipment acquisition .Environmental studies .Project management and monitoring .Working group designation. Training and recruitment .Putting into operation	.Design and/or redesign of parts in the final assembly process .Process validation according with the product .Increased production capability based on the rolling line .Final assembly, quality systems and ongoing improvement.	Progressive product design	.Technologic transfer to local suppliers for increase efficiency, quality and local sourcing . Attracting direct material suppliers to the region .Joint project with universities for professional training	. Headquarters' delegation of decisions related to designs, customers, suppliers and institutions.	.Big equipment adaptations .Reverse engineering . Engineering and construction of test equipment .Preventive maintain
Advanced innovative capabilities	.New systems production and components development.	.Process design and development of D+R related	.Process and activities innovation of D+R related	.Basic characteristics design of new products .Product innovation and activities of D+R related	.Liaison with universities focusing on D+R for technological developments .Collaboration with suppliers, customers and partners in technological development activities	.Autonomy in decision making about production, Direct and Indirect supply, new products.	.Equipment construction and design .Associated R+D

Table 1. Technological capabilities matrix for the export manufacturing industry.

Source: (Dutrénit et al. 2002).

2.4. Technological capabilities index

The original matrix developed by (Bell and Pavitt, 1995) and the revised version proposed by Dutrénit et al. (2002) classify the technological capabilities into two levels: basic operative capabilities and innovative capabilities (basic, intermediate and advanced). However, they have been modified taking into consideration the specific characteristics of the Mexican subsidiaries, but maintaining the original proposal's main idea.

Such modification consisted of integrating the three innovative capabilities into one single innovative capability which was labeled basic innovative capabilities. This decision was made as the other two innovative capabilities were absent due to the little progress on knowledge generation and more complex innovation processes made by the researched subsidiaries.

The basic operative capabilities are minimum capabilities which enterprises need to meet if they are to remain in the market Urióstegui et al. (2007). The basic innovative capabilities are those which enterprises acquire through socialization processes within the multinational, generating differential revenue from the market. They are classified as basic, excluding the existence of other types of more complex innovative capabilities which may require some regular process, in order to make them more stable so as to obtain innovation-based revenue.

In this context, different scholars have proposed indices to measure the changes and progress made by maquiladoras in the management of incorporated technologies (Urióstegui et al., 2007). The index reflects the level of cumulative technological capabilities in a certain period of time. It is designed in such a way that one level of the index by every assessment of the technological capabilities matrix in different periods of time can be obtained.

A comparison of the technological capabilities indices in different periods of time enables enterprises to observe the evolution of their technological capabilities. Table 2 shows the values assigned to each technical function in each of its cumulative levels.

Level capabilities	Investment technical function		Production technical function		Support technical function			
Total accumulation level	Decision making and control	Project preparation and execution	Focus on the process and production organization	Focus on the product	Internal links	External links	Equipment modification	
Stage 1: Basic operational capabilities	0.15	0.15	0.20	0.20	0.10	0.10	0.10	1
Stage 2: Basic innovative capabilities	0.30	0.30	0.40	0.40	0.20	0.20	0.20	2

Table 2. Indexes for the assessment of EMI technological capabilities.

Source: Adapted from Dutrénit et al. (2002).

The numerical values were assigned by (Dutrénit et al., 2002), according to the levels of accumulation in the investment, production and support technical functions.

A description of the Delphi case is provided in the next section. Such description includes a detailed discussion of aspects related to its enterprises and maquiladoras located in Mexico.

3. The case of Delphi

The study of the Delphi case is relevant for different reasons. First, the sector to which it belongs has been highly regarded. The autoparts sub-sector in particular, and the automobile sector in general, hás been well valued due to its high export activity since the North American Foreign Trade Agreement (NAFTA) came into effect. It is also highly valued because of its use of complex technology and its close relatiosnhip with national suppliers, both of which enable it to have the capability of promoting technological development. The enterprise is a good example of how an enterprise combines these two circumstances. Second, Delphi is aimed at meeting the world market needs. Its operations are performed using state-of-the-art technology. It also has a long process of capabilities accumulation, which is combined with its close relationship with national enterprises to strenghthen its links with them, with its own maquiladoras and local agents (research centers, higher education institutions, other enterprises, customers, suppliers, local industry) being its first targets. Finally, Delphi has been considered the world leader of the autoparts sector (Global Automotive Financial Review, 2006).

In this section, the case of four subsidiaries of the multinational Delphi of the Electrical/Electronics architecture division, located in the state of Tamaulipas (Nuevo Laredo and cd. Victoria). All of them have US capital and participate in the maquiladora program of the automobile sub-sector whose purpose is to meet the autoparts supply needs of the automotive assembly plants in the United States of America.

Delphi is a good example of a globally integrated production process. Over the last 30 years, the Delphi main office in the United States has been moving all its branches towards Mexico. Today, almost 100% of all its assembly activities (including diverse products) are carried out in maquiladores concentrated in 8 Mexican states (Chihuahua, Sinaloa, Guanajuato, Querétaro, Tlaxcala, Nuevo León, Coahuila and Tamaulipas). Only central activities such as research and development remain in the USA, except for an important part of applied engineering activities which were transferred to Mexico.

12 subsidiaries of Delphi are located in Tamaulipas, with more than 14,000 employees. All these employees are organized into two divisions: Delco Electronics Division (8) and Electrical/Electronics Architecture (4), whose operational center is located in Nuevo Laredo, Tamaulipas. Of these, four were selected for this study. They belong to the Electrical/Electronics Architecture Division, which is devoted to harness assembly. Two of them are located in Cd. Victoria and the other two in Nuevo Laredo. The four subsidiaries employ approximately 4225 workers in 2009.

Following Yin's (1989) methodology, the description of the technological capabilities construction profile of maquiladoras I and II (located in Cd. Victoria) is presented first, followed by that of maquiladoras III and IV of Nuevo Laredo. Such description is based on data collected through interviews and questionnaires administered to technicians and engineers of the four maquiladoras.

A) Technological capabilities construction profile of maquiladoras I and II in Ciudad Victoria Tamaulipas.

The manufacturing of harnesses in Cd. Victoria, Tamaulipas belongs to the Electrical/Electronics Architecture Division and is located in two subsidiaries (I and II) due to the need to meet the growing demand for harnesses from its main client: General Motors. Data were collected from interviews (6) with managers, heads of departments, and questionnaires (18) administered to technicians and engineers of the subsidiaries.

The **first stage** has been labeled as "Basic Harness Assembly," and is comprised of the period of time between 1990 and 1997. This first stage is characterized by the basic harness assembly processes to be shipped to the United States of America. The operation of the maquiladora I in Cd. Victoria started as a strategy as Cd. Victoria was located near the Delphi's headquarters. However, decision-making and the centralized control at this stage take place in Monterrey, Nuevo Leon, where the multinational's administrative offices are located. These administrative offices are in charge of coordinating all the efforts of the Division's local maquiladoras.

It is important to mention that all the managers were from Monterrey, Nuevo León and Nuevo Laredo, Tamaulipas during the opening of subsidiary. However, local managers were gradually incorporated into management activities at a later stage. Due to its high volume of harnesses that the subsidiary was required to supply to the same client, the operation of subsidiary II took place.

Subsidiaries I and II started their harnesses assembly activities without the capability of cutting cable in the required measures. To overcome that difficulty, the Electrical/Electronics Architecture Division made the arrangement to obtain support from some suppliers and other subsidiaries which provided them with the material needed. This stage is characterized by a minimum level of proficiency in operative technological activities, which becomes evident by the basic operations for harness assembly, without sophisticated equipment and with art craft features.

In this stage, once the harnesses have been assembled in maquiladoras I and II in Cd. Victoria, they are shipped to the United States of America, where the manufacturing of the vehicle takes place using the components previously assembled in such maquiladoras.

In the **second stage**, which is called "basic assembly of harnesses and productive improvements" (1998 and on), the necessary capabilities to remain in the market have been developed by these subsidiaries, but more complex technological activities such as design or R&D activities that could enable them to consolidate themselves in other markets have not been conducted.

Regarding organizational models, the Data Management System (DMS) is now in operation. This system refers to an adaptation made to the production system of Toyota for the transformation and ongoing improvement of the support activities based on customers' needs, Lean Manufacturing, the use of the Gold Standard Website, Best practices and Learning lessons.

In this stage, the subsidiaries tested various models aimed at improving organizational processes. One has been labeled as "supermarket" which refers to the practice of having containers in the maquiladores for the deposit of inventories, storing materials available for suppliers free of charge until they are actually used. Another is called Kan Ban whose purpose is to control and avoid incurring in additional costs associated with the materials inventory.

In this stage, as evidence of their high standards, the ISO 14000 and ISO TS 16 949 certifications were achieved. The engineers and technicians gained sufficient experience and are capable of introducing innovations such as equipment redesign and certain processes aimed at raising productivity levels and the quality of the products line.

Few liaison activities have been performed, mainly with some local high schools and higher education institutions. In this second stage, the evidence reveals that these two maquiladoras achieved a significant progress on the technical function of production, achieving a basic level of innovation technological capability of 1.2 (See Table 3). These activities are closely related to the ongoing improvement, which is based on the permanent work done by the engineers of the technical area to overcome all the difficulties experienced by the production lines and the finished products. Continuous improvement is the fundamental source for the increasing generation of innovations in an enterprise. In the case of the researched plants, they have been involved in recent improvements related to their fuel module kits. Such improvements have produced a new fuel module electrical connector, which resists wiring and connector overheating; an improved fuel level sensor, which is resistant to sulfur contamination and contact finger wear; the development of a new vehicle body harness splice kit, etc.

Perhaps the most interesting progress made has to do with the organizational models. Maquiladoras plants I and II in Cd. Victoria have been successful in developing capabilities related to the introduction of new organizational processes.

	Índex C T	Technical function	investment	Technical production function		Technical support function		
Stage		Decision making and control	Project execution and preparation	Focus on the process and production organization	Focus on the product	External liaison	Internal liaison	Equipment modification
Stage 1	1	Basics operational	Basics operational	Basics operational	Basics operational	Basics operational	Basics operational	Basics operational
Stage 2	1.2	Basics operational	Basics operational	**Basics Innovative**	Basics operational	Basics operational	Basics operational	Basics operational

Table 3: Assessment of the technological capabilities of maquiladoras I and II in Cd. Victoria

Source: Derived from interviews and Tables 1 and 2.

B) Technological capabilities construction profile of maquiladoras III and IV in Nuevo Laredo, Tamaulipas.

The harness maquila in Nuevo Laredo, Tamaulipas is carried out by the Electrical/electronics Architecture Division and is located in two maquiladoras (III and IV). These maquiladoras manufacture harnesses for the FORD enterprise. The analysis of data gathered through interviews with managers and heads of departments (5), and questionnaires administered to technicians and engineers (25) reveals that the evolution of these two subsidiaries has been mainly centered on two stages from their beginning. An examination of their technological history and their structure allows us to uncover that:

The **first stage is** labeled as "Basic assembly of harnesses." This stage includes the period between 1987 and 1994 and is characterized by basic processes of harness assembly to be shipped to the United States of America. On March 1990, the maquiladora III in Nuevo Laredo started its activities to provide its service to Ford.

At the beginning, this maquiladora was settled in Cd. Juárez, Chihuahua and was focused on Ford trucks. However, as it was attracting more and more customers and as a strategy to be geographically located closely to the automobile assembly plants in the United States, it was moved to Nuevo Laredo Tamaulipas. Its operations started with managerial staff from Cd. Juarez, with decision-making and a centralized control exercised from Cd. Juarez, Chihuahua.

Due to the high volume of harnesses that they had to supply to the same customer, the operation of the maquiladora IV started to take place on June that year. Both subsidiaries (III and IV) also started their harnesses assembly activities without the capability of cutting cable in the required measures. To overcome that difficulty, the Electrical/Electronics Architecture Division made the arrangements to obtain support from some suppliers and other subsidiaries which provided them with the material needed. Similarly, they had a minimum level of control over the maquiladora's activities; the processes were not systematically documented. The harness assembly operations were basic, without the use of sophisticated equipment and with a tendency to use art craft techniques.

Once the harnesses have been assembled in maquiladoras III and IV in Nuevo Laredo, they are shipped to the United States of America, where the manufacturing of the vehicle takes place using the components previously assembled in such maquiladoras.

Due to Ford's high demand for harnesses and the expansion strategy of the company, the fourth maquiladora was created. The administrative offices were also constructed in order to coordinate not only the activities of this new maquiladora but also those of maquiladoras I and II in Cd. Victoria, Tamaulipas.

In the **second stage**, which is called "basic assembly of harnesses and productive improvements" (1995 and on), the maquiladoras have developed the necessary capabilities to remain in the market over this time, but have not conducted more complex technological activities such as design or R&D activities which could enable them to consolidate themselves in other markets. In Mexico, capabilities are rather limited, mainly because the tendency is to maintain the R&D activities near the United States of America (Carrillo and Hinojosa, 2001). The Lean manufacturing was consolidated in order to maximize resources as the need to incur in new practices was evident due to the critical situation that the enterprise has been facing at world level since 2007.

Today, some progress has been made, particularly on the product design, but without the resources necessary to carry out more complex innovations. With respect to organizational models, the Data Management System (DMS) is now in operation. This system refers to an adaptation made to the production sytem of Toyota for the transformation and ongoing improvement of the support activities based on customers' needs, Lean Manufacturing, the use of the Gold Standard Website, Best practices and Learning lessons.

The enterprise has implemented an organizational model called "the supermarket," which refers to the practice of having containers in the maquiladores for the deposit of inventories, storing materials available for suppliers free of charge until they are actually used. For the implementation of such organizational model, different teams made up of staff members who participate actively in continuous training activities. Regarding equipment and machinery, different maintenance control measures have been implemented.

In relation to the ongoing improvement measures that Toyota has been implementing for the last few years, they have had a significant impact on the production and organization capabilities of the organization. Therefore, Delphi has adopted the DMS[2], as a strategy to increase its organizational capabilities, and as a way to lower production costs.

Delphi has been awarded the ISO 14000, the Ford Q1 certification, and ISO TS 16 949 harness certifications for Ford. Such certifications have worldwide recognition, which means that the enterprise meets high quality international standards. The engineers and technicians have gained sufficient experience and are capable of introducing redesign innovations applying ongoing improvement through organizational models.

From 1995, a cutting machine developed by the Warren Technical Center, Ohio for the Electrical/Electronics Architecture Division has been in operation. This machine has been distributed to the member maquiladoras, and Delphi has been in charge of its use and maintenance since then.

The evidence presented reveals that these two maquiladoras (III and IV) have achieved a significant progress on the production technical function during the second stage. This progress can be explained by the implementation of organizational models which currently serve as instruments for the transfer of organizational practices and forms aimed at improving the organizational processes.

Moreover, the evidence also shows a significant progress made on support technical function(liaison with local agents), which can be explained by the agreements signed with junior and senior high schools and higher education institutions in order to promote social service, professional practice and internship activities among the students. Those students who

[2] Delphi Manufacturing System

receive training at the subsidiaries III and IV can be incorporated into the staff within them at a later stage.

The most outstanding aspect of the progress made by these subsidiaries has to do with the organizational models of the support and production functions (internal and external liaison). This is accounted for the transition made from basic operative activities to basic innovative ones, with a technological capabilities index of 1.4 (See Table 4).

Stage	Índex C T	Investment technical function		Production technical function		Support technical function		
		Decision making and control	Project preparation and execution	Focus on the process and production organization	Focus on the product	External liaison	Internal liaison	Equipment modification
Stage 1	1	Basic operative	Basic operative	Basic operative	Basic operative	Basic operative	Basic operative	Basic operative
Stage 2	1.4	Basic operative	Basic operative	**Basic Innovative**	Basic operativel	**Basic Innovative**	**Basic Innovative**	Basic operative

Table 4: Indexes and levels of the technological capabilities construction process of maquiladoras III and IV in Nuevo Laredo.

Source: Authors.

	Primary activities				Support activities	
	Investment		Production			
	User decision making	Project preparation and implementation	Focus on the process	Focus on the product	Liaison development	Capital assets development
Stage I. N. Laredo (1987) Victoria (1990)	Centralized on the administrative direction of the architecture division E/E in Tamaulipas (Nuevo Laredo)	Centralized on the administrative direction of the architecture division E/E in Tamaulipas (Nuevo Laredo)	Training by Juarez city, Chihuahua workers			Preventive maintenance to the machinery and equipment Change of single parts of machinery and equipment. External cutting cable
Stage II. N. Laredo (1995) Victoria (1998)	Centralized on the administrative direction of the architecture division E/E in Tamaulipas (Nuevo Laredo)	Centralized on the administrative direction of the architecture division E/E in Tamaulipas (Nuevo Laredo)	DMS, Lean Ongoing improvement, Kan cards ban3, Dummies4, Shaining, gold standard, best practices Learning lesson Supermarket	Product improvement: Victoria case "Fuel tank door"	School-enterprise agreement Chambers: Traffic problems Tamaulipas Institute for Adult Education (ITEA) "United Fund"	Cable cutting machine – and the fixing of clinch bolt in maquiladoras

Table 5. Cumulative technological capabilities matrix Delphi E/E Arquitecture Division in Tamaulipas.

Source: Adapted from Dutrénit et al. (2002), and based on interviews and observations in the four researched maquiladoras.

[3] The kan ban cards serve to pull supermarket storage material towards a production line (*Materials Engineering Manual Delphi*, 2008).

[4] Materials use method based on colors (*Materials Engineering Manual Delphi,* 2008).

After having presented the profiles of both maquiladoras and their results of the assessment achieved, a description of the activities that the four maquiladoras (I, II, III and IV) of the Delphi's Electrical/Electronics Architecture Division have accumulated throughout their technological history is provided in Table 5. Such capabilities are mostly related to organizational processes. However, maquiladoras III and IV have been able to develop other capabilities as a result of their liaison work with local agents (educational institutions), through knowledge transfer mechanisms such as opportunities for students to engage in social service, professional practice and internship activities.

Through these mechanisms, the students and practitioners have access to different benefits. For example, they may appropriate tacit knowledge due to their interaction with specialists and experienced engineers. Similarly, they also have opportunities to build capacity through their participation in learning activities in the plants such as courses and workshops.

The data analysis reveals that the main activities of the **investment technical function** are still concentrated in the parent company. The subsidiaries located in Tamaulipas have made little progress. Therefore, the four maquiladoras in Tamaulipas (I, II in Victoria and III, IV in Nuevo Laredo) still continue performing basic operations at the same level, without significant technological improvements and without research or development activities whatsoever.

The **production technical function** reflects the incorporation of organizational models such as DMS, Lean Manufacturing**,** the use of the "Gold Standard" Website, Best practices and Learning Lesson), which have been successful in other subsidiaries at the domestic or even international level. These serve as instruments for the transfer of proven organizational practices or approaches aimed at improving organizational processes.

In the first stage, evidence of basic operation activities is shown. However, the successful implementation of new organizational models in subsidiaries I and II in Victoria and III and IV in Nuevo Laredo is observed. Therefore, the data analysis as shown in Table 3 suggests that a basic innovative capabilities level has been achieved.

The analysis of **the support technical function** shows that subsidiaries in Nuevo Laredo have engaged in more liaison activities within their context than their counterparts in Cd. Victoria. They have also developed higher levels of independent management capability than those in Cd.

Victoria. This can be explained mainly by the fact that Nuevo Laredo has higher levels of industrialization and a wider range of educational institutions linked to the subsidiaries through agreements signed so that their students can participate in social service, professional practice and internship activities, and eventually become employees in such sibsidiaries. The level achieved by the subsidiaries in Nuevo Laredo is that of basic innovative technological capabilities.

4. Conclusions

The analysis of the technological capabilities construction process in both stages of the the four maquiladoras' technological history shows that they have not been able to progress towards more complex processes. Unlike other studies such as that conducted in the state of Chihuahua by Dutrénit (2006) and Lara (2005), which shows an advanced level of innovative capabilities with an enterprise environment linked to subsidiaries in Cd. Juarez, Chihuahua.

The capabilities that these subsidiaries have actually developed are related to the production technical function. This has been evidenced by their implementation of organizational models and production systems that have been successful in other enterprises which have international presence such as Toyota. The purpose of the implementation of such models is twofold: one is to improve organizational aspects; and the second is to save costs, as the world wide crisis, and particularly the declaration of bankruptcy by the enterprise through the chapter 11 in the United States of America in 2007, has affected them negatively.

In this context, the assessment conducted shows a difference of 1.2 between maquiladoras I and II, and one of 1.4 between maquiladoras III and IV. Such difference lies in the support function and can be explained by the fact that Nuevo Laredo offers more favorable conditions such as a more competitive environment, a wider educational system which provides degree programs aimed at preparing professionals with the profile required by maquiladoras of the autoparts sub-sector.

This demonstrates that the settlement of subsidiaries of a multinational enterprise serves a specific function and pursues pre-defined objectives by the multinational's main office. In this particular case, this enterprise's objectives have been clearly defined in their cost saving strategy and global competitiveness, especially due to its insolvency situation that the enterprise underwent during previous years and during the 2007-2008 financial crisis.

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