Supplier involvement in Product Development: a comparative study of Brazilian automotive chains

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Abstract: This paper identifies and compares the PD activities of ten auto suppliers in the context of engine-producing supply chains set up in Brazil. The demand for technological change starts at the engine manufacturers and is then transferred to other parts of their chains. The auto suppliers' PD activities seem to have a strong interrelationship among four aspects: 1) the structural and relational aspects of the chains they belong to – the number of hierarchical tiers, the number and size of companies at each tier and the relationship pattern between companies; 2) the competitive strategies implemented by the engine manufacturers – product diversity and levels of PD capabilities, competences and accumulated knowledge; 3) product-intrinsic issues – technological content, industry segment (metalworking, electronics, polymerics) and strategic relevance to the engine manufacturers; and 4) company-intrinsic issues like size and ownership, considering that large–sized international auto suppliers tend to develop more technologically complex products.

Keywords: Product Development (PD), supply chains, automotive industry.

1. Introduction

According to Carbinato (2008), the automotive industry presents high technological density along the several tiers of its supply chains and, consequently, a meaningful capability to generate and disseminate technology to other industries. Thus, in times of eroding competitive advantages and shorter technology lifecycles, studying technology strategy and product development in the automotive industry can be a fruitful source of knowledge for automotive companies and for other industries.

Since the 80's, the worldwide automotive industry has witnessed transformations in the relationship pattern between automakers and their suppliers, partly due to the diffusion of managerial practices originating from the Japanese industry (ALVES FILHO et al., 2001). In general, such changes involve the management of geographically dispersed suppliers and an increasing focus on product quality and on-time delivery (NEUMANN; RIBEIRO, 2004).

There is a general tendency for large automakers to focus on specialised issues regarding their products, prioritising activities and competences related to the creation of an identity for their products in the market. As a result of such specialisation, first-tier suppliers have become responsible for technological enhancements in the various systems that make up the vehicles (PEREIRA; GEIGER, 2005). These suppliers, in turn, have transferred part of their activities to suppliers located in other tiers of the supply chains, which have mastered the production of parts that compose those systems.

In this context, new forms of organisational and informational coordination have been implemented to foster the cooperation of first-tier suppliers starting in the early stages of Product Development (PD) activities (VOLPATO, 2003).

In Brazil in the 90's, the local automotive industry underwent a major restructuring process when several automakers installed production plants in geographic regions where there was no prior history of this type of industry. During this period of reconfiguration, according to Rachid (2000), the automakers have gained power over multinational auto suppliers and, to an even higher degree, over Brazilian ones.

Another important specificity of Brazilian automotive transformation in the 90's is the amount of investment made in the car engine segment, especially in low-displacement engines (the so-called Brazilian "popular" cars). In such context, Carbinato (2008) analyses the specialization of Brazilian branches in low-displacement cars, and points out that operational processes were transformed according to international guidelines, resulting in deverticalization and

new patterns of client-supplier relationship according to the "strategic relevance" of the supplied part.

In the supply chains of the engine manufacturers set up in Brazil, supply organizations like Modular Consortiums[I] or Industrial Condominiums[II] have not been formed as they were by the automakers set up in the country. Also, initiatives regarding the supply of higher value-added subsystems are still incipient and the engine assemblers have implemented distinct strategies concerning the number of suppliers for each acquired part. The engine manufacturers also show significant differences with respect to the production mix and scale, the level of part outsourcing, supply chain configurations (reflected in the number and localization of suppliers), and the level of cooperation with suppliers. (ALVES FILHO et al., 2003).

Thus, taking into consideration (1) the relevance of Product Development activities to the automotive industry, (2) the profound changes that have taken place in this industry in Brazil, (3) the importance of the "engine product" to the automakers, (4) the fact that studies on engine assemblers are rare and, finally, (5) the heterogeneities found in the automaker supply bases, the main questions addressed by this paper are: (1) What are the different forms of supplier involvement found in PD activities of automotive engine manufacturers with operations in Brazil? (2) What are the main aspects that influence the different forms of supplier involvement in PD activities of engine assemblers in Brazil?

In the context of engine-producing supply chains, this paper seeks to identify and compare the Product Development activities (PD) that take place in ten auto suppliers set up in Brazil. The companies studied all vary in size, capital resources and technological capabilities (competences and accumulated knowledge).

This paper is organized as follows: first, it provides a review of the literature available on Product Development in the Brazilian automotive industry. Then it looks at the literature on supplier involvement in PD activities. The sections that follow present the research method and a description of the case studies. And lastly, some final conclusions are drawn and possibilities for further research are presented.

2. Product Development activities and the Brazilian automotive context

In onder to discuss the Product Development activities undertaken by Brazilian automotive companies, it is necessary to place them inside the broader context of the worldwide automotive market.

Global Product Development implies the (simultaneous) execution of projects in several countries around the globe, in which coporate headquarters and/or local branches take part (SANTIN, 2005). According to this author, the decentralizarion of Product Development activities in the Brazilian automotive industry has originated in transnational companies already set up in the country, or in newcomers which installed their productive plants in Brazil in the late 90's.

The reasons that make a multi-national firm decentralise the development of its global products, according to Dias and Salerno (2003), go far beyond those commonly indicated in the literature, such as the need to be close to the market or to have access to local technology. For the authors, the decision about whether or not to decentralise the development of global products is directly linked to the strategic options that aim to increase the company's competitiveness. Thus, the quest for reducing development lead time is also a factor that explains decentralisation, especially when the products destined for local markets suffer several adaptations when compared to the ones produced by the project centres, and when time is considered an important competitive dimension for the company. Another rationale behind the choice for decentralisation can be the ability to explore opportunities identified in local markets (e.g. the low cost and bi-fuelled cars in Brazil), and also to foster competition among the local branches of multinational companies.

When considering the decentralisation of product development, the accumulation of capabilities and resources at a local branch depends, among other factors, on the creative development and the new forms of combining knowledge (GOMES, 2003). This combining of knowledge is the basis for organisations to assimilate and explore new types of knowledge, and according to Cohen and Levinthal (1990), depends on the absorptive capacity. The absorptive capacity is the result of a long-lasting investment process in which the accumulation of knowledge inside the firm and its resulting deployment follow technological paths (MOWERY; OXLEY; SILVERMAN, 1996), Powell, Koput and Smith-Doerr (1996).

It is worth mentioning that, although competitiveness depends on factors like the entrepreneurship of local branches and the gradual experience accumulated from previous projects, local branches count on resources provided by the local country in order to compete in its market. (AMATUCCI; BERNARDES, 2007). Therefore,

[I]Modular Consortium: project and production processes are divided into modules or subsystems, and supplier employees work directly at the automaker plant, assembling subsystems and installing them into the end product (ALVES FILHO et al., 2001).

[II]Industrial Condominium: a small set of first-tier suppliers physically set up inside the walls of the automaker's plant. Such companies supply the automaker with systems (on a just-in-sequence basis) directly to the assembly line, but they do not take part in the vehicle assembly process (PIRES, 2004).

when the project headquarters are located in Brazil, it is easier for local companies to take part in the project, a fact that would not be possible if the project was implemented in any other country. This fact occurs because when products are locally designed, the control over specifications and homologations to suppliers is exerted by local engineering, thus increasing the chances of a local (not a global) supplier getting into the supply chain.

Boehe (2007), in considering several different multinationals, suggests that there are three different types of projects in the branches of these multinational companies: a) branches that adapt products developed by other company branches to the specific needs of its local markets; b) branches that significantly improve existing products; and c) branches that create new products. Another dimension analysed by the author is the markets served by the company branch: a) the market in the host country; b) markets in other emerging countries (Latin America, Africa, the Middle East and the Far East); and c) markets in developed countries, like Japan, the United States, Canada and Europe).

The results from Boehe's research suggest that there are a small number of units focused on innovative activities and local markets, which suggests that Brazil is still predominantly a technology receiver.

Thus, the automobile industry is one of the most prominent sectors in Brazil, because the PD activities have been evolving in terms of quality, complexity and responsibility, and important local developments can been observed.

For Kaminski, Oliveira and Lopes (2008), Product Development is a strategic area for companies in general, and Consoni (2004) considers Product Development activities to be a key element to competition in the automotive industry. In this paper we consider product development to be "a group of activities that aim to draw up the design specifications of a product and its respective manufacturing process, so that operations can produce it according to the market needs and to technological possibilities and constraints, while taking into consideration the competitive and product strategies undertaken by the company." (ROZENFELD et al., 2006).

In the automotive industry, for the most part, company headquarters tend to have responsibility for activities related to technological research (both basic and applied) (CONSONI, 2004; CERRA, 2005). Therefore, the majority of the PD activities of the branches set up in Brazil (considering here the multinational automakers and suppliers) are largely focused on adapting and improving existing products and processes to the conditions of the local market, to the structure of existing suppliers and to the available production processes (ROZENFELD et al., 2006; CERRA, 2005; TOLEDO et al., 2005; CONSONI, 2004).

Although in Brazil the majority of PD activities involve the adaptation of products and incremental improvements, some larger scale projects have been carried out. Some examples of vehicles being developed by local branches of multinational automakers can be found in the recent trajectory of the Brazilian automotive industry: EcoSport by Ford; Celta, Meriva and the new Vectra by General Motors; Palio partially developed in Brazil by Fiat; and Fox and Gol Generation IV by Volkswagen. Local developments in the car engine segment are the ethanol-fuelled engines, low-displacement (1000cc) engines, and the bi-fuelled engines (called "flex" engines in Brazil), which can operate and maintain appropriate performance levels when fuelled by petrol, ethanol, or any mixture of both.

The operation of the bi-fuelled engine is similar to that of a conventional engine; in fact, the Flex Fuel System is based on the same design principles as a conventional engine. Although there were some mechanical adaptations in the engine, the main changes were in the electronics system that controls the engine's operation (TEIXEIRA, 2005).

According to Salerno et al. (2001), the projects carried out by the host country's automakers end up "inducing" local supplier projects, attracting supply firms set up in the country, and increasing the possibilities for local companies to win orders.

This section provided a brief summary of the literature concerning Product Development (PD) in the Brazilian automotive industry and some empirical studies in the field. Next section will deal with supplier involvement in PD activities.

3. Supplier involvement in Product Development activities

The present section will deal with supplier involvement in product development activities, providing a brief overview of pros and cons of this inter-company involvement. According to Silva, Toledo and Ferrari (2005), several studies (CLARK; FUJIMOTO, 1991; WOMACK et al., 1990; BROWN; EISENHARDT, 1995; KESSELER, 1997) indicate the importance of involving suppliers in Product Development, emphasising the transfer of responsibility to suppliers for innovating and producing parts and systems, so that automakers can focus on their core business (PRAHALAD; HAMEL, 1990): designing and assembling cars.

Supplier Involvement comprises the resources (capabilities, investments, information, knowledge and ideas) that suppliers provide, the tasks they perform and the responsibility they take concerning the development of a part, process or service that benefits a current client or the development of future projects (VAN ECHTELT et al., 2008).

The involvement of suppliers in the preliminary stages of PD can (McIVOR; HUMPHREYS; CADDEN, 2006):

a) increase the availability of information and expertise regarding new ideas and technologies and allow the early detection of potential problems, thus improving the quality of the final product, eliminating rework and reducing costs; b) facilitate the outsourcing strategy, reducing the internal complexity of projects and supplying extra resources that can reduce the critical project phases; c) improve the communication and exchange of information, reducing delays and assuring that the project will be concluded at the set time; and d) improve the relationship between clients and suppliers.

For the authors, potential benefits exist when the process of involving the suppliers in PD is effectively managed. Factors that can negatively interfere would be technological uncertainty, a low level of trust between the client and suppliers as well as poor communication and coordination mechanisms.

According to Lakemond, Berggren and Weele (2006), it is important to consider that not all collaborative efforts lead to benefits like reductions in costs, development time and improved product quality. The supplier's involvement can be associated with the reduction of PD time primarily when the products are mature and the goals for development efforts are well defined. According to the authors, it is necessary an approach for involving the supplier in PD that is based on the analysis of the relevant contingent factors. In summary, the authors argue that activities and tasks can change considerably over the different phases of the project, making it necessary not only to differentiate the coordination of the suppliers from project to project and from supplier to supplier, but also to establish the need for coordination for every single PD project.

For Quiescenti et al. (2006), new product development performance depends on when the supplier gets involved in the process and the level of responsibility assigned to the mentioned supplier. According to Mikkola and Skjoett-Larsen (2003), depending on the technological complexity of the architecture of the product and how it is decomposed, the suppliers can be involved during the planning, design or production stages of the development process of a new product. Mikkola and Skjoett-Larsen (2003) consider, moreover, that the extent to which a system can be decomposed with well specified and standardized interfaces determines whether or not the outsourcing of the analysed component is a feasible strategy for the company.

According to Moreira (2005), the nature of supplier integration in the PD processes varies depending on the type of industry, the type of partners and the type of innovation introduced. This collaboration is the result of a cumulative relationship in which the technology and innovation have only just started to be considered together after a successful accumulation process in operations that involves joint policies in production, quality, information, logistics and supply.

Eisenhardt and Tabrizi (1995) apud Lakemond, Berggren and Weele (2006), assume that the buyer alone can define the project goals and the course of action. On the other hand, for Rouibah and Caskey (2005), the impact of the changes on both sides must be identified (both by client and supplier), but the recent literature on the subject tends to focus on a single company. While they agree on the need for more research in this area, the empirical work of McIvor, Humphreys and Cadden (2006) offers important contributions: analysing both sides of this type of relationship, the authors indicate that the main barriers are the resistance on the part of the client or the supplier when it comes to sharing information relevant to the project and the culture of the client reluctant to share its responsibility in the PD process.

There are still other aspects to be considered in supplier involvement in PD – the potential risks and problems that can occur like the loss of intellectual property (LAKEMOND; BERGGREN; WEELE, 2006), a reduction in the control over the development process and the cost of collaboration management (MIKKOLA; SKJOETT-LARSEN, 2003). In other words, there is a risk of the supplier becoming a competitor, or of losing the focus of manufacturing capabilities.

According to Mikkola and Skjoett-Larsen (2003), if a given supplier does not have the necessary technical capabilities, the firm may have to help it improve them or substitute the supplier. Other risks mentioned by these authors are: diminishing the value of internal competences; facilitating access by competitors to copy and/or acquire key technologies; increasing the dependency on strategic suppliers and increasing the standardization of components due to the specified interfaces.

Van Echtelt et al. (2008) indicate that most of the studies regarding Supplier Involvement in New Product Development tend to focus on short-term projects and success factors. For these authors, long-term strategic processes must also be taken into consideration, like technology mapping and the alignments of client's and supplier's strategies. In this sense, for McIvor, Humpreys and Cadden (2008) a cultural change between client and supplier is necessary, and the concept of "collaboration" must be understood and enhanced.

This section has provived a summary of the literature concerning the involvement of suppliers in the PD process, indicating possible benefits and risks associated with such approach. This review of the literature (sections 2 and 3) will provide the basis for carrying out the empirical study described below.

4. Research method

The research strategy adopted here involved the study of multiple cases in order to empirically identify and compare the Product Development (PD) activities carried out by ten

different auto suppliers. This approach was chosen based on the propositions put forward by Yin (1994) concerning case studies, once that that we wanted to "investigate a current phenomenon in its real context, where the borders between the phenomenon and the context are not clearly defined, while using several different sources of evidence".

In order to conduct the case studies a qualitative method of exploratory research was used. According to Lazzarini (1997), the so-called qualitative methods are characterised by a focus on the overall understanding of the facts rather than in measuring each one separately.

The data was gathered through interviews, which according to Selltiz et al. (1967) apud Gil (1999), are "quite appropriate for gathering information concerning what people know, believe, hope, feel or want, did, do or intend to do, as well as their explanations or reasons for doing so." With that purpose, semi-structured interviews were carried out lasting for about one hour each, at ten different auto suppliers, with the aid of a questionnaire formulated based on a review of the available literature. On average, two interviews were conducted at each company, and the interviewees included individuals with direct responsibility for product and process technology, as well as industrial executives.

Half of the companies selected were Brazilian. Furthermore, the study sought to include companies of varying sizes that produce distinct products and that have different technological capabilities (competences or accumulated knowledge).

5. Case studies

This section presents the companies studied. In order to cross-analyse the various cases studied, the data has been presented in tables rather than in plain text format. Table 1 summarizes the overall characteristics of the companies studied, which will be discussed in the next section.

In an empirical study carried out on automotive engine manufacturers (CERRA; MAIA, 2005), it was possible to observe that suppliers' technological activities are, to a high degree, driven by the engine manufacturers' PD activities, once that when the latter decides to launch a new engine model, they set in motion the demand for new auto parts throughout the upstream supply chain. In some cases, the engine assemblers produce specifications for suppliers to develop components in accordance with the new engine, whereas in other cases the engine assemblers provide the product design to the suppliers, and the latter become responsible for designing the manufacturing process. Yet, there are other cases in which the engine manufacturers transfer all of the know-how regarding product and process, and a supplier with limited technological capability becomes liable for manufacturing the mentioned part.

The auto parts industry is made up of companies that supply several different automakers with varying levels of technological capabilities; as a result, their capabilities for making improvements and innovations in the products that they supply are not homogenous. Most of the companies studied here belong to the metalworking industry segment, except for two companies from the sample: one that produces electronic components and the other that produces polymeric parts.

Although the sample encompasses only one electronic and one polymeric supplier, it allows us to pinpoint some peculiarities in the auto parts segment, depending on the material the supplied part is made of.

In the metalworking industry segment, the supply chain is composed of few hierarchical tiers. In other words, the second tier of suppliers (the suppliers of the companies studied here) is made up of companies that produce basic raw inputs such as aluminium, iron and steel. In general, it is comprised of large-sized Brazilian metallurgical and steel companies.

Regarding inter-firm relationships in these supply chains, there are some cases in which the suppliers (for instance, companies #1 and #3) incorporate parts manufactured or services provided by another supplier into their products (companies #2 and #4, respectively), before delivering them to the corresponding engine manufacturers. This fact calls for a large amount of information exchange between the engineering departments of the companies involved.

In the electronics segment, on the other hand, there are second-tier suppliers that accomplish PD activities on their own.

Turning our attention back to the metalworking industry, which is predominant in the composition of engines and also in the company sample here studied, we can find some differences among the companies when we observe that some have accomplished more expressive local developments than others, a fact that seems to be (at least partially) a consequence of the size of the PD departments and the qualifications of the people in them.

Company #6, a branch of a multinational company, has more people working in the PD department (23 employees) in comparison to the other metalworking companies studied, and has accomplished local developments in automotive pistons. The company handles the product design as well as the production processes.

Brazilian companies #1, #2, #3, #4 and #5 and companies #7 and #9, which are branches of multinational companies, all have smaller PD divisions.

As shown in Table 1, those companies receive the product design from their clients (engine manufacturers) and take responsibility for developing the production processes. Their engineering activities basically consist in making incremental changes in those production processes, after

Table 1. Relevant characteristics of the studied companies.

	Brazilian companies					Branches of multinational[III] companies				
	Company #1	**Company #2**	**Company #3**	**Company #4**	**Company #5**	**Company #6**	**Company #7**	**Company #8**	**Company #9**	**Company #10**
Industry segment	Metalworking industry	Metalworking industry	Metalworking industry	Metalworking industry	Metalworking industry	Metalworking industry	Metalworking industry	Electronics	Metalworking industry	Polymeric
Main products supplied to engine assemblers	Exhaust manifolds, differential housings and camshafts	Machining of exhaust manifolds, housings, flywheels and washers	Flywheel systems (rack and pinion)	Engine flywheels	Cylinder heads, bearings, gearbox parts, exhaust manifolds	Pistons and cylinders.	Transmission housing, crank cases and oil pans.	Fuel filters and modules, injectors, bi-fuel technology.	Springs	Plastic filters, fuel tanks, throttle valves, etc.
Parts (or services) provided by other companies.	Services – some parts are machined by company #2.	None	Flywheels (produced by company #4)	None	None	Pins.	None	None	None	None
Main clients	Volkswagen and Peugeot.	VW and Proema.	General Motors, Toyota, Schaeffler, Valtra, etc.	VW, GM, Fiat, Iveco.	VW and GM, Company #8, among others.	All the assemblers except for Fiat and Peugeot.	GM, Fiat, Ford, Daimler Chrysler, Eaton, AMM.	GM (90% of its total production) VW, Fiat and Renault.	GM, Dana, Delphi, Eaton, Honda, VW, Sachs, etc.	Bigger clients are company #8 and its competitors. Small volume for General Motors,
Employees	390	50	700	500	1200	1200	450	900	500	70
Engineering staff	10 people, 7 of which are college graduates, and three are technicians.	8 people that perform administrative work	7 people, 4 of which are college graduates, and three are technicians.	4 technicians.	18 people; all of whom are college graduates .	23 college graduates, 2 postgraduates and 5 interns.	7 people, only 1 of which is graduated, and six technicians.	60 people, Half of which are engineers, and the remainder support staff.	8 people, 4 of which are college graduates, and four are technicians.	3 people, 2 engineers (one a college graduate) and the other a technician.
Product development	Product design is provided by clients.	Technical specifications provided by clients	Product design is provided by clients.	Product design is provided by clients.	Product design is provided by clients.	Yes	Product design is provided by clients.	Yes	Product design is provided by clients.	Most part is provided by clients. Some of the designs come from the international headquarters. The company also develops products for aftermarket.
Does the company develop manufacturing processes?	Yes, with client support.	Yes, with client support.	Yes	Yes	Yes, with client support.	Yes	Yes	Yes	Yes	Yes
Suppliers	25 suppliers. In addition to the suppliers that provide machining services, others provide raw materials like sand, cast iron and tools.	7 suppliers. Four of which provide steel and tools.	5 suppliers that provide foundry services, each one responsible for the product of a certain client. In addition, there are some steel suppliers.	60 suppliers. The main materials are: cast iron, scrap iron, alloys, etc.	42 Suppliers that provide cutting tools, machines, raw materials and parts.	30 suppliers, one of which is installed inside the company plant. In addition to aggregated parts, there are steel suppliers.	10 suppliers, besides aggregate product (e.g. pin) suppliers. Steel is the main raw material.	176 suppliers, 72 of which are located in Brazil and the remainder offshore.	3 suppliers. Wire is the main raw material.	50 suppliers of plastic, thermoplastic resin, and companies from the metalworking segment.

[III]The term "multinational" is used here in order to refer to any company that has offshore production plants. Empirical studies on the supply chains of car manufacturers set up in Brazil (CERRA, 2005; MAIA, 2006; ALVES FILHO et al., 2006) indicate that multinational companies are predominant, with a small number of Brazilian companies taking part in those chains - except for Volkswagen suppliers. Concerning the newcomers (automakers that started their operations in Brazil during the 90's), however, many parts are still imported and those companies are endeavouring to adopt nationalization policies in order to use suppliers set up in Brazil (not obligatorily Brazilian ones).

having assessed the viability of a given project (elaborated by the client) to be manufactured by the company.

Brazilian companies #1 and #5 have received, in addition to the product design, the process design and all the needed production know-how in order to produce the auto parts. Over time, these companies started to develop the competence needed to make incremental improvements in the abovementioned production processes.

Company #1, has not only broadened its client base, but still keeps the automaker that once aided its development as its main client. Although information and knowledge exchange between company #1 and the automaker is still intense, the company has gained autonomy in order to perform the improvements needed in its production processes.

Company #5, has, over time, broadened its client base and product mix, investing in its innovation capability by hiring new people and training the existing employees responsible for the company's technological activities. Because it is less dependent on a single client, the automaker that once aided its development, and considering the knowledge accumulated, it now has a higher degree of autonomy to discuss product-and process-related issues with its clients.

Company #2 does not perform any technological activities; at least in the way the term is understood here. Even process-related incremental changes are the responsibility of its main client.

It is worth pointing out that this kind of support to suppliers does not seem to be a major concern for manufacturers, yet it seems to take place intensively in some cases when for some reason, the development of a supplier is necessary for the assemblers' operations. In the electronics segment, Company #8 has a much larger technological department (with a total of 186 people) when compared to the metalworking segment. It also has a higher number of engineers with graduate degrees, and has accomplished more expressive local technological developments (both in products and processes).

In the development of bi-fuelled systems by company #8, it was possible to observe a closer relationship between the supplier's and the assembler's PD teams. One possible explanation for this fact is that these systems demand modifications in the engines, thus, the information exchange between both companies tends to be greater.

In Brazil, differently from what took place in the United States, the auto suppliers themselves initiated studies on the deployment of bi-fuel technology - Bosch in 1991, to be more specific. In 1994, the technology was ready to be marketed, but the automakers saw no advantages to invest in this technology given the absence of further incentives: 1) The Brazilian government had denied accepting tax reductions for such engines, and 2) clients were unwilling to change their petrol-fuelled engines for bi-fuelled ones, since at the time the petrol x ethanol price ratio offered no incentive for the clients. In 1999, Magneti Marelli also announced its ability to produce the same technology.

Later on, given important changes in the scenario, especially in the petrol x ethanol price ratio, bi-fuelled automobiles were launched in 2003 and their production, according to ANFAVEA (2006), has risen significantly until now. As a result of the continuous growth of the bi-fuelled engine market, in 2004 the automakers started to make higher-displacement "flex" engines available. In 2005, the newcomers also launched their bi-fuelled versions (Citroën, Peugeot and Renault).

Another important peculiarity of the electronics segment is that company #8 transfers the design of the product it outsources to its suppliers (the assemblers' third-tier suppliers).

In the case of the polymeric company's chain, at least one first-tier supplier should be studied, so that we could indicate the structural configurations and technological capabilities possessed by the companies that belong to this segment more precisely. Although this paper looks at one supplier from this segment (which primarily acts as a second-tier supplier), its main clients are companies that produce electronic parts.

Nonetheless, we can make some inferences concerning such chains. First, we believe they are not as short as the chains from the metalworking segment. Company #10's suppliers, for example, are larger-sized firms, certified by several quality norms – they are the automakers' third-tier suppliers which provide plastics designed to be used in electronics, automotive engineering and other industry segments.

Over time, company #10 has sharpened its knowledge and started to develop the know-how needed to change/improve clients' products and to develop aftermarket parts.

All of the sample companies work with multifunctional teams in order to develop products and/or processes. These teams are composed of members from several departments, such as Engineering, Operations, Quality, Procurement, etc.

As already mentioned, those auto part companies are not inserted into single sourcing relationships with the automakers/engine assemblers, and they usually take part in different chains of the automotive industry. Thus, they need to adopt strategies that are suitable to their clients.

In general, those companies are dependent on the assemblers' strategies, accepting impositions about technical product specifications, quality levels, prices and delivery conditions. This dependence is even greater in cases where the suppliers, at some point in time, have been developed by the assembler(s).

Considering that the main suppliers usually supply several engine manufacturers and that they must implement strategies that fit the ones undertaken by their clients, it can be inferred that the assemblers somehow control the supply chain, even in the case of large-sized and technologically autonomous suppliers.

6. Conclusions and final remarks

Global and local strategies followed by automotive companies have prioritized product and process innovation as an approach for competitive differentiation. Brazilian units play their role in this context, in a non-homogeneus manner, accomplishing tropicalization[iv] or acting like project hosts[v].

Therefore, the growth of competition in the Brazilian and international automotive market has revealed to the automakers (and their corresponding engine manufacturers) urgent demands for improvements in quality and productivity at local levels. In the context of automotive production, engines can be considered rather strategic systems for the automakers' competitiveness, being composed of a great number of parts, from distinct industry segments.

Since the mid-90's, Brazilian engine manufacturers have significantly broadened their product mix, a fact that has implied (ALVES FILHO et al., 2005): (1) product development efforts, (2) changes and adaptations in production lines, including here outsourcing movements, (3) alterations in the supply chain and in the suppliers' coordination.

The government tax policy instituted during this period that exempted low-displacement vehicles from the IPI tax ("*Imposto sobre Produtos Industrializados*", in English "Industrialized Product Tax"), resulted in a significant price reduction for those automotive models. This political measure directed at the Brazilian automotive industry has brought meaningful results for the assembler's local strategies, mainly concerning the PD activities, attracting investments to the automotive engines segment.

Since 2002, when the abovementioned tax exemption was revoked, the engine manufacturers have released a series of 1300cc, 1400cc and 1600cc engines, intended to achieve higher horsepower (compared to 1000cc engines), while maintaining low levels of fuel consumption.

This example shows the influence that Brazilian government policies have had on the competitive strategies undertaken by companies. First, it created the demand for automakers to focus their investments on the development of low cost and low fuel consumption cars and, later, due to cost equalization, to design higher horsepower cars.

The supply chains to which engine assemblers belong are mainly based on the metalworking industry segment. The demand for technological changes is initiated at the engine manufacturers and transferred to the remainder of their chains. Hence, first-tier suppliers tend to have close and long-lasting relationships with the engine assemblers, joining with them in PD activities starting in the early stages of the process.

First-tier suppliers get involved in PD activities in many different forms, which vary according to the technological complexity assigned to products and processes, as well as the degree to which they have mastered such technologies.

In the metalworking segment, the chains have few hierarchical levels and the auto suppliers that are able to carry out their own projects are located in the first tier, dealing with technologically more-sophisticated products, when compared to the second-tier. In this segment, some companies do not perform any technological activities (for example Company #2, from our sample). On the other hand, in the electronics segment, according to information gathered at Company #8, there are second-tier suppliers that carry out PD activities and, in certain cases, transfer the demand for innovations to some of their suppliers, that is, the engine manufacturers' third-tier suppliers.

We believe that the polymeric chains are not as short as the metalworking supply chains. One company from this segment was studied and its suppliers (automakers' second-tier suppliers) are larger-sized firms, certified by several quality norms – they are the automakers' third-tier suppliers which provide plastics designed to be used in electronics, automotive engineering and other industry segments; and are responsible for the technology of their products. In this sense, the intensity of technological activities would hold an intermediary position between what has been observed in the metalworking and electronics chains.

As already mentioned, this company mainly supplies electronics firms, corroborating the fact that second-tier suppliers tend to carry out technological activities in electronics chains.

In Brazil, engine fuelling has brought important implications for local competitiveness and for the structures and relations of the supply chains belonging to the automotive industry. In this context, the electronics segment has gained power in the supply chain, since it dominates knowledge about how to develop and enhance electronic systems and software for controlling and monitoring engine fuelling and operation. Given the fact that such systems are strategically relevant and that the engine manufacturers do

[iv] "Tropicalization" consists of adapting vehicles launched by the headquarters to the local conditions of countries in which automakers' branches operate.
[v] Project host: When local branches present technological capabilities strong enough to develop products based on other models previously developed by headquarters.

not possess such knowledge, the bargaining power in such relations tends to be more balanced when compared to the relationships between the automakers and metalworking companies.

Most of the Brazilian companies that perform product development are branches of multinational corporations. In the suppliers studied here, even when considering those that have a structured engineering department, it was not possible to clearly identify the existence and/or the number of people involved in technological (basic and applied) research, although some interviewees have shown the perception that these activities actually take place. As a matter of fact, the headquarters and external research centres continue to be a source of information and technological knowledge for the Brazilian branches, both for engine assemblers and suppliers.

When these branches started their operations in Brazil, they made an attempt to standardise the product design. However, local adaptations were necessary, given the local consumers' preferences for low cost vehicles, different local conditions like Brazilian fuel and highways, the characteristics of the materials available, etc. Such adaptations have paved the way for local development activities, which have grown in quantity and quality throughout the years, while maintaining relationships with research centres and headquarters.

In this context, development-related activities are decentralised to some extent, although connected to the competences held by the corresponding headquarters. As regards production competences, these need to be controlled by the local plants.

Brazilian companies deal, for the most part, with less technologically sophisticated products and receive the product design from their clients (engine manufacturers), taking on the responsibility for designing the production processes. Besides, there are cases in which such companies have been developed by their clients (e.g. companies #1, #2 and #5), a fact that does not seem to take place in multinational suppliers, even when considering the smaller-sized ones that produce technologically simpler components (companies #7 and #9).

These findings are in line with Kaminski, Oliveira and Lopes (2008), for whom bigger companies tend to present advantages over smaller ones like higher brand equity, scale gains and bigger influence on the development of client and supplier contracts In this context, small companies tend to face more complex difficulties in generating innovations.

In this sense, it can be said that some mastery of product-development and manufacturing capabilities is mandatory for local companies, but they generally rest upon the automakers' competences, which transfer technology for them to manufacture the products according to specified parameters.

Although those engine manufacturers have outsourced a large part of their activities (mainly PD) to their suppliers, the control of interfaces and the knowledge of how to put together the several parts in order to create a unique product with integrated functionality is still up to the engine manufacturer. The ownership of such knowledge suggests that innovative capability in the Brazilian automotive market is still in the hands of the engine manufacturers.

Summarising, the Product Development activities performed by the studied auto suppliers seem to keep a strong inter-relationship among four aspects: (1) structural and relational issues of the chains to which firms belong – hierarchical tiers, the amount and size of companies in each supply tier, relationship patterns that can be observed between the companies involved, etc., (2) competitive strategies undertaken by engine manufacturers – product diversity, degree of mastery of PD competences and capabilities, as well as knowledge accumulated over time, (3) issues that are inherent to the products to be developed or produced – technological content and strategic relevance to the engine manufacturers, (4) issues that are inherent to the companies such as size and capital origin – large-sized multinational suppliers tend to develop more technologically-complex and relevant products. Such issues are shown in Figure 1.

Based on the aspects investigated here, we indicate some possibilities for further research. Although we do not aim to provide an exhaustive list, some themes include: (1) studying other suppliers belonging to the electronics segment; (2) analysing suppliers from other segments, such as polymeric materials, or a wider sample of companies from the electronics segment; (3) studying companies that are positioned at the second tier in the engine manufacturers' supply chains, in each segment (metals, electronics,

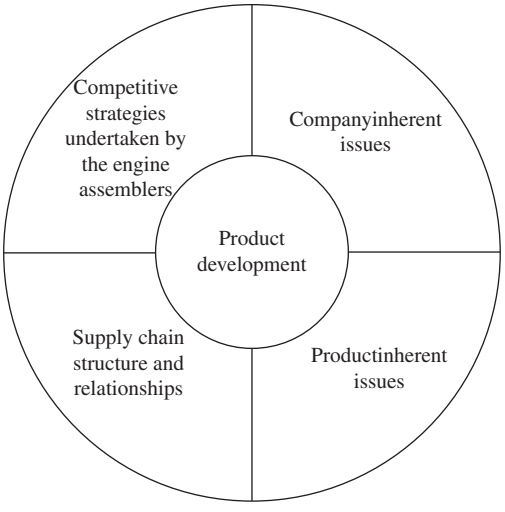

Figure 1. Interrelated issues that influence PD activities.

chemicals and polymerics, etc.); (4) investigating other Brazilian firms, to verify the existence of local companies that develop and produce technologically-complex parts; and (5) analysing the technological trajectories of Brazilian companies that have been taken over by multinational corporations.

Other possibilities include deepening the elements already studied in this paper, analysing in greater detail the PD stages for certain parts, as well as the ways in which suppliers are involved in those stages, in order to explore the relationships between the project teams involved, development lead time, etc.

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