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Operations and Technology Strategy Trajectories followed by automotive engine manufacturers set up in Brazil

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ABSTRACT: This paper aims to identify and analyze recent trajectories followed by two engine assembly plants set up in Brazil (one mature company and one newcomer), regarding operations and technology strategies undertaken by them. In short, the mature company has made efforts to increase quality and flexibility, while the newcomer has prioritized cost reduction and quality enhancements, besides taken action to increase its product nationalization. The main findings indicate that (1) competitive priorities seem to “pull” the trajectories, translating market needs into specific tasks that must be fulfilled by each strategy, while the advances made in each step may “push” the trajectories, setting the basis for new strategies and making them capable of moving further; (2) although advances along trajectories are intended and planned, they cannot be foreseen and alternate decisions may be necessary and (3) secondary factors like the degree of autonomy assigned to firms and accumulated knowledge also influence trajectories.

Keywords: Strategy, Resource Based View, Automotive Industry, Automotive Engines.

1. INTRODUCTION

During the 90's, several changes have been implemented along Brazilian automotive chains, a fact that has meaningfully impacted on the local patterns of interfirm relationship. One of such changes has been the choice made by large automakers to focus on specialized issues regarding their products, prioritizing activities and competencies related to the creation of an “identity” for their products in the marketplace. As a consequence of such specialization, first-tier suppliers have become responsible for technological improvements in the various systems that make up the vehicles (Pereira & Geiger, 2005).

In the context of such strategic transformation, the production of automotive engines is extremely rel-

evant to the operations inside Brazilian automotive industry, once that this component: (1) represents a meaningful portion of production costs, (2) has been impacted by important technological innovations, for example more powerful low-displacement engines, bi-fuelled engines, etc. and (3) is composed of a large number of parts, supplied by companies belonging to distinct industry segments (Maia & Cerra, 2008; Maia, Cerra & Alves Filho, 2005).

Although the engine manufacturers have outsourced a meaningful amount of their activities (mainly Product Development ones) 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 still belongs to the

engine manufacturers. The ownership of such knowledge suggests that innovative capability in the Brazilian automotive market is, to some extent, still controlled by the engine manufacturers (Cerra, 2007).

Also relevant to the contextual understanding of local industry, the set up of Brazilian automotive sector took place in two distinct periods of time: the automakers that started their productive activities at the beginning of Brazilian Automotive Industry (before 1980) are called "mature companies" by Consoni (2004), whereas the automakers that set up their plants in Brazil after 1995 are called "newcomers" by the same author. According to studies conducted by Alves Filho et al (2006) and Maia, Cerra e Alves Filho (2010), there are considerable strategic similarities considering companies inside each group, while there are relevant differences when companies from different groups are compared.

Meanwhile, during the last decades, a new set of ideas has been developed in the field of strategic management, which became known as the "Resource-based View" (RBV). According to Fleury & Oliveira Jr (2001), the main contribution brought in by RBV is to emphasize the competitive relevance of a resource which is costly to imitate, transfer, buy, sell or substitute, and which has a systemic integration with the other company's resources.

With its "inside" focus on companies, the RBV draws on the "path dependence" concept developed by other fields of study (mainly innovation economics) and applies it to the study of strategic decisions. This way, companies are believed to proceed along competence-developing trajectories, with every decision being part of such trajectory and thus having impacts not only on the present, but also on the possibilities the company is able to consider in the future.

Taking into consideration (1) the changes that the automotive industry has experienced in Brazil, and also the different points in time at which Brazilian automotive industry was set up, (2) the relevance of the engine segment, (3) the importance of issues concerning operations and technology inside the mentioned context, and (4) the relevance of strategy trajectories, mainly emphasized by the resource-based view of strategies, two research questions emerge: Considering the engine manufacturers set up in Brazil, how can their trajectories of strategy development be described? Are there differences among the trajectory followed by the mature company and the one performed by the newcomer?

In such context, the objectives of this paper can be defined as to identify and analyze recent trajectories followed by two engine assembly plants set up in Brazil (one mature company and one newcomer), regarding the operations and technology strategies undertaken by them.

The next sections present a literature review on Resource Based View (RBV), Technology Strategies, Operations Strategies and the combination of such concepts in studies on automotive industry. Then, the research method is presented, along with the two cases here studied. Concluding the paper, some final remarks are made, and possibilities for further research are indicated.

2. RESOURCE BASED VIEW (RBV)

The group of theories known as the "Resource Based View" (RBV) or "Resource Based Theory" (RBT) started to emerge during the 80's, with the central tenet that resources owned or controlled by the firms are the real sources of their competitive advantage. Such theories, according to Barney (1999), emerge as a possibility to overcome the shortcomings of strategic planning (the predominant school of thought, so far) in explaining how firms, operating into the same competitive environments, could present different performance levels.

Firm resources comprise all the inputs that make companies able to formulate and implement their strategies (Olavarrieta & Ellinger, 1997), and can be defined as "assets that exist in the firm during certain period of time (Wernerfelt, 1984, p.173)", being either tangible or intangible (Hall, 1992 as cited in Olavarrieta & Ellinger, 1997) and having been either developed inside the firm or externally acquired (Schroeder, Bates & Junttila, 2002).

Barney (1991) argues that two tenets are central to RBV: a) resources are heterogeneously distributed among firms, and b) productive resources are costly to transfer among firms. Based on such ideas, the author puts forward two propositions: a) valuable and rare resources can lead to competitive advantage and b) when these resources are also costly to imitate, non-substitutable, and non-transferable, they will lead to competitive advantage.

Based on the information about RBV presented so far, organizational competence can be defined as a set of coordinated resources which add value to the organization, are costly to imitate, can be applied to

other organizational areas, products or services, and impact (during a certain period of time) on the performance achieved by a firm. (Fernandes, Fleury & Mills, 2006).

According to Teece, Pisano and Shuen (2000), managing competence dynamics is also a relevant issue when discussing resources and competences, once that resources should not be treated essentially as static and stockable variables. In such context, the authors coined the term “dynamic capabilities”, so that the word “dynamic” concerns the ability a firm has to renew its competences, in accordance with market changes.

Thus, “dynamic capabilities” consist of the firm ability to reconfigure, redirect, transform, adequately shape and integrate existing “core competences” with external strategic resources, in order to adapt themselves to the changes occurring in the marketplace (Teece et al, 2000; Bowman & Ambrosini, 2003).

With its “inside” focus on the companies, the RBV draws on the “path dependence” concept developed by other fields of study (mainly innovation economics - Puffert, 1999; Scarborough, 1998) and applies it to the study of strategic decisions. This way, companies are believed to proceed along competence-developing trajectories, with every decision being part of such trajectory and thus having impacts not only on the present, but also on the possibilities the company is able to consider in the future.

As Teece et al, (2000, p.515 as cited in Dannels, 2002) argue, “choices over a competence spectrum are influenced by previous choices. In a given period of time, firms must proceed along a competence development trajectory. This trajectory defines not only which choices are possible for the firm today, but also set limits to its internal repertory and its suitability for the future. Thus, firms in the long-term make almost irreversible trade-offs for certain competence spectra”.

Although exogenous factors have played a secondary role in the literature on RBV, some authors consider them to be an alignment point between RBV and Strategic Planning. For Spanos & Lioukas, (2001), both the internal and external approaches are complementary: while the former emphasizes the development and combination of resources in order to realize competitive advantage, the importance of the environmental effects emphasized by the latter must also be taken into consideration.

Technology Strategy (TS)

According to Dodgson (1989), Burgelman, Maidique & Wheelwright (1998), and Zahra, Sisodia & Das(1994), the literature indicates the need for companies to strategically deploy technology, aligning it to the competitive strategy undertaken by the company, thus ensuring that technology and strategy support one another. The nature of such linkage is usually dealt with by the Technology Strategy (TS) of the firm.

For Ford & Thomas (1997), the firm can alter its technological resources by different means: a) it can improve its resource base by acquisition, including external P&D, mergers and acquisition, licenses, etc., b) it can be engaged in exploring its technologies (deploying them to produce its own products or production methods), or by means of licensing and joint ventures with other companies, c) internally managing these technologies in order to optimize its use and to establish a process for technology decision-making. The following figure illustrates the TS elements for these authors:

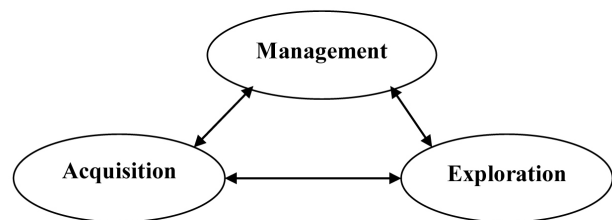


Figure 1: Elements of the Technology Strategy (Ford & Thomas, 1997).

For Dodgson (1989), the strategic management of technology involves the development of new competences and abilities, including, besides technological assessment, the setting up of collaborative relationships with other companies and the integration of them with internal expertise. Therefore, a key factor of TS concerns evaluating the importance that a variety of technologies (internal and external) may have (Ford & Thomas, 1997; Zahra, 1996). This way, the position of the firm inside the chain is defined by the other actors’ role and comparative importance, the resources they control and the activities they carry out.

There is still much debate on the definition of Technology Strategy (Clarke et al, 1995), and a well-established and widely accepted TS concept has not been reached yet. Examples of definitions may be found

in Gibbons and O'Conner (2003), Solomon (2001) as cited in Davenport, Campbell-Hunt and Solomon (2003), and Alves Filho (1991).

According to Davenport et al (2003), the concept of Technology Strategy has been part of the literature on Technology Management since the late 70s (Adler, 1989), but it has not become a distinct area of academic and managerial interest until the 80's (Dodgson, 1991; Drejer, 1996; Jones & Smith, 1997; Pavitt, 1990).

Inside the field of Strategic Management, the growing interest in the Resource Based View of strategy (RBV) has led to renewed attention to technology as a key resource of firms. In this sense, Smith and Rogers (2004) indicate the growth of TS literature as an adequate alternative for firms to deploy their technological resources in the long term.

In this paper, we consider Technology Strategy as a set of efforts made by a company in order to improve its technological capabilities and implement changes, either in productive systems, or in products and processes. Thus, "Technology Strategy concerns a set of efforts and actions aiming at improving company's technological capability, in the context of P&D activities and other organizational areas, in order to implement technological changes. Such changes encompass the creation of new techniques and adaptations in the existing ones that compose and characterize a production system, both from company's point of view exclusively or broadly from an international perspective" (Alves Filho, 1991).

Regarding technological capabilities, Bell and Pavitt (1993) define them as "resources needed to generate and manage technological changes, including skills, frameworks, knowledge, experience and institutional links". Technological changes, according to the same authors, concern all the manners by which new technology is incorporated inside the production capacity of firms and economies.

Dahlman, Ross-Larson and Westphal(1987) and Westphal, Kim and Dahlman, (1985) as cited in Alves Filho (1991) suggest three sorts of TS capabilities:

- Innovation capability: to create new technologies, develop new products and services. It concerns the ability to introduce technological changes (either incremental or breakthrough);
- Investment capability: in order to acquire technology to substitute, upgrade and deploy facilities according to investment conditions;

- Production and adaptation capability: to operate productive facilities with maximum efficiency. It encompasses, besides productive technology itself, the possible technology adaptations.

Ford (1989) suggests a fourth capability, the Technology Exploitation and Protection Capability, to sell products or provide services to the market based on well-known technologies, and also to implement measures that avoid the risk of gained knowledge being copied by competitors.

One should also note that the borders among the four kinds of technological capabilities are not clearly defined. However, specific investments and efforts must be made for each kind of capability (Westphal et al, 1985 as cited in Alves Filho, 1991).

These capabilities are not isolated and there are relevant relations and synergies among them. For Alves Filho (1991), a) the current stage of capability development of a company, b) its goals and strategies and c) the external environment influence Technology Strategy. Therefore, the detailed formulation process, as well as the content of TS related activities, should vary according to such conditions.

3. OPERATIONS STRATEGY (OS)

Several definitions for the concept of Operations Strategy can be found in the literature, each one focusing a particular aspect of Operations Management, or a certain school of thought about Strategy. Here we will adopt the definition proposed by Hayes, Pisano, Upton and Wheelwright (2004, p. 33), for whom "operations strategy is a set of goals, policies and self-imposed constraints that describe how an organization proposes to manage and develop the resources invested in operations so as to best fulfill (and possibly redefine) its mission".

From the Strategic Planning point of view, Operations Strategy is a functional strategy and, thus, must support competitive strategy. In this sense, each type of strategy demands certain tasks from the manufacturing function and specifies certain objectives, known as "competitive priorities", which were initially classified by Skinner (1969) as productivity, service, quality and return on investment.

In subsequent papers, other authors have presented different combinations of priorities. The framework that will be here adopted is the one proposed by Nair and Boulton (2008), which categorizes priori-

ties as cost, quality, deliver, flexibility and innovation. In order to make such categorization more complete, the aspect of “service” will be incorporate, as proposed by Garvin (2003).

Table 1: Operations competitive priorities (Nair & Bulton, 2008 and Garvin, 1993)

	Cost	Quality	Delivery	Flexibility	Innovation	Service
<i>Sub priority</i>	<ul style="list-style-type: none"> – Production Cost – Delivery Cost 	<ul style="list-style-type: none"> – Performance – Characteristics – Dependability – Durability – Service – Aesthetics – Perceived Quality 	<ul style="list-style-type: none"> – Dependability – Velocity 	<ul style="list-style-type: none"> – Supply flexibility – Process flexibility – Output flexibility (mix and volume) – 	<ul style="list-style-type: none"> – Innovation – Breakthrough on incremental – Effects on systems and products – Innovation to actual or new markets 	<ul style="list-style-type: none"> – Client Support – Sales Supports – Problem solving – Information

Competitive priorities should reflect demands imposed by competitive strategy, and set certain goals that need to be reached by the productive system. In order to achieve such objectives, we need to operationalize plans in specific decision areas. In his seminal paper, Skinner (1969) suggested five decision areas: plant and equipment, production planning and control,

workforce and management staff, product design/engineering, and organization and management.

Based on Skinner’s proposition, Hayes et al (2004) proposed a new categorization, with eleven decision areas grouped under two categories: structural and infrastructural (Table 2).

Table 2: Operations decision areas (adapted from Hayes et al, 2004)

	Structural Decisions	Infrastructural Decisions
<i>Decision Areas</i>	<ul style="list-style-type: none"> – Capacity – Supply and Vertical Integration – Facilities – Process and Information Technology 	<ul style="list-style-type: none"> – Human Resources – Quality – Production/Material Planning and Control – Product and Process Development – Performance Measurement and Rewards – Organization – Resource allocation and Capital Budgeting

Structural decisions in a productive operation are those that influence mainly design decisions, while infrastructural decisions are those that affect workforce, planning, control and improvement activities (Slack, Chambers & Johnston, 2002).

4. OPERATIONS STRATEGY, TECHNOLOGY STRATEGY AND RBV: STUDIES IN THE AUTOMOTIVE INDUSTRY

This section intends to review recently published work on Operations Strategy, Technology Strategy and RBV (mainly competence and capabilities trajectories) in the automotive industry, in order to support to the discussion presented in this paper.

First, concerning Operations Strategy, as we have already mentioned, the concept was initially proposed by Skinner (1969) and further developed mainly by Robert Hayes and Steven Wheelwright (Hayes et al, 2004, among other publications) based on research conducted mainly in the automotive industry. The main question, by that time, was how Japanese competitors could use manufacturing as a competitive weapon to overcome American firms on almost every performance perspective.

Even OS having a seminal connection with automotive industry, nowadays few studies explicitly mention using Operations Strategy as a framework for research inside this sector. However, this should not be understood as if Operations Strategy had lost its

relevance in the automotive industry: First, even not directly using the name “Operations Strategy”, research on automotive industry deals with close related themes. Taylor and Taylor (2008) provide a review on contemporary research in this industry, and their findings suggest that most of the work still deals with issues concerning Japanese Production System, like lean production concepts, quality management, integrated production networks and globalization effects. Second, the concept seems to have spread to other industry segments – for example, service operations (e.g. Spring & Araujo, 2009 and Phusavat & Kanchana, 2008), and other manufacturing industries (e.g. Ahn et al, 1999)

Second, and similarly, recent research on automotive industry that explicitly mentions to adopt Technology Strategy can be considered rare. Much of the focus tends to rely on technology capabilities – and that may be the most important confluence point between Technological Strategy and Resource Based View in research inside automotive industry.

Of particular interest, in the mentioned context, is the large number of studies about technology-related capabilities in automotive industry from Asian countries. If Japan and the United States were the two opposite poles of interest at the beginning of the studies on the matter, in the late 2000's Chinese, Korean and Malaysian industries seem to be in focus.

Zhao, Anand and Mitchell (2005) studied the inter-organizational transfer of R&D capabilities in international Joint Ventures in the Chinese automotive industry. The results indicate a strong flow of both individually-carried and group-level knowledge between multinational enterprises and their Joint Venture partners in the Chinese industry, mainly due to the movement of skilled individuals from the Chinese business groups to multiple multinational partners. Also, knowledge flows between the Joint Ventures and the Chinese groups, although more individually carried and with a more limited diffusion.

A similar study was conducted by Sadoi (2008), comparing Malaysian to Chinese experience with technology transfer from foreign to local automotive parts in China. According to the author, Chinese firms were much faster in achieving localization than Malaysian ones, especially due to government policy on foreign direct investment.

In a study on Indonesian and Malaysian companies, Rasiah (2009) compared the automotive industry

from both countries to identify differences in technological capabilities. The findings suggest that Indonesian firms enjoyed higher human resource, process technology, and research and development (R&D) capabilities than firms in Malaysia. Foreign ownership, higher in Indonesia given its liberalized trade regime, was one of the causes indicated by the author.

Oh and Rhee (2008) studied Korean automotive industry to identify types of manufacturer-supplier collaboration and how they are impacted by supplier capabilities. Results indicate that flexibility, dependability, improvement, design and 2-nd tier supplier development/coordination capabilities have a positive effect on manufacturer-supplier collaboration.

Finally, and that should reinforce the contribution of the work presented in this paper, in a survey with recent literature no specific study on capabilities trajectory inside the automotive industry could be identified (although a few longitudinal studies exist).

5. RESEARCH METHOD

This piece of research is basically structured around two main activities: a) review of literature on theoretical themes, i.e., Automotive Industry, mainly the automotive engine segment, Resource Based View, Technology Strategy and Operations Strategy, and b) field research.

Field research was conducted by means of case studies, which were carried out during different periods of time from 1996 to 2008, what characterizes this work as longitudinal, qualitative and descriptive (or exploratory) research.

A longitudinal study is a research approach that provides a single scenario with multiple observations over a long period of time (Yin, 2001). Qualitative methodologies with longitudinal analysis, according to Binder (2006), are indicated when one investigates evolving processes that involve multiple units and levels of analysis.

In this study we combined two different sources of information, to mention: previous academic studies on Brazilian automotive industry conducted by our research group, interviews and secondary data (from ANFAVEA, Brazilian Association of Automakers, FENABRAVE, Brazilian Federation of Automotive Distributors, and the websites from the studied companies).

Case studies were carried out in two automotive engine manufacturers, which were intentionally selected because (1) they belong to different strategy groups (one is a mature company set up in Brazil since the 50s/60s, while the other is a newcomer set up in the country in the late 90s); (2) previous investigation carried out by our research group (Alves Filho et al, 2006) indicated that they keep important similarities with other companies from their strategic groups, but also keep important differences between them.

As mentioned, secondary data was used to build a panorama of the studied companies and their position inside the industry. Annual reports and other statistic data could be gathered from ANFAVEA and FENABRAVE websites, while specific information concerning each engine manufacturer (history, recent news, product-related data, etc) was obtained directly from their websites.

Direct information on strategy trajectories was obtained combining the mentioned previous studies on Brazilian automotive industry with semi-structured interviews (about 2-hours each) that were carried out in the two companies. In average, we've conducted 4 interviews in the mature engine manufacturer in each one of the study periods (1996-1997, 1998-1999, 2000-2001, 2002-2003, 2004-2005 and 2006-2008), while in the newcomer we were able to perform in average 2 interviews in each period.

In the companies, the interviewees were preferably related to a) product and process technology, b) manufacturing processes, c) quality management and d) supply chain management. We prefer not to disclose their positions in the companies in order to protect their identities and also to guarantee impartiality of analyses.

Although we do not intend to present a detailed description of the research instrument, a general overview may be relevant. Companies' operations strategies were examined based on an investigation of the competitive priorities and the characteristics of the companies' decision-making areas – both structural and infrastructural ones (Garvin, 1993; Slack, Chambers & Johnston, 2002). For competitive priorities, a ranking approach was developed so that the interviewee could prioritize their performance perspectives according to the set of competitive goals mentioned in Table 1. Regarding decision-making areas, a group of questions was developed inside each one of them, in order to characterize the pattern of decisions undertaken.

Technological strategies were primarily analyzed based on companies' current product mix, prod-

uct development projects, engineering department structure, branch-headquarters relationship and outsourcing level (Iglecias and Alves Filho, 2000). These data allows the researchers to build comprehension on each of the Technology Capabilities: people working on P&D as a proxy for Innovation Capability; search for new technologies as a proxy for Investment Capabilities; relations between operations and engineering as a proxy for Production and Adaptation capability. Also, product mix serves as a proxy for product complexity in each company.

Combining (1) information gathered from distinct interviews, (2) documentary evidences shown by the interviews, (3) the history brought by our previous studies on the companies and (4) data from secondary sources, we were able to accomplish data circularization, as suggested by Yin (2001), seeking information convergence.

Both Operations Strategy and Technology Strategy data from different sources were then put together and organized in a chronological order. To facilitate analysis, time blocks were created, subdividing the studied period in intermediate years – such approach allow a clearer understanding of how actions put in place during a certain period may change the context and impact the actions that need/could be performed the following years.

6. CASE STUDIES

This section will present the case studies accomplished in two car engine manufacturers from Brazilian automotive industry. In order to keep impartiality in analysis, we prefer not to disclose the company' names, and they will be here identified as "mature company" and "newcomer".

The "mature" company produces car engines (1000cc to 1600cc), involving a great diversity of products. It works on a three-shift system, and the third shift produces half of the production of the others. Each shift has the capacity to produce 600 engines, but ends up producing 550 due to production mix. This way, the plant possesses production capacity of approximate 450,000 engines per year, and exports about 40,000 engines / year.

The "newcomer" engine assembler produces 1400cc and 1600cc gas-fuelled engines in a single plant. Its installed production capacity corresponds to 335,000 engines per year, if working on a three-shift system. However, the production is currently working on a two-shift system, and about 190,000 engines were produced by the company in 2006.

Table 3: Data about the mature company

Mature engine assembler	Start-up 1996-1997	1998- 1999	2000- 2001	2002- 2003	2004- 2005	2006-2008
Operations Strategy						
Competitive priorities		Quality, cost and flexibility (mainly production one)			Flexibility (mainly product and volume one), Cost and Deliver.	
Production capacity	1800 engines/day (600 per shift)	=	=	=	=	1800 engines/day (600 per shift). Tends to increase.
Outsourcing	Only the engine block is produced in-house. The other parts are outsourced.	=	=	=	=	Decided to internally machine and assemble 50% of cylinder heads
Number of suppliers	60	73	100		130	About 130
Workforce	During plant startup, the decision was to hire highly educated people, with age under 30.	658 (380 in manufacturing processes, 58 management staff and 220 third-party workers)	730 (330 third-party)		800 (350 third party).	800 (350 third party). Tendency to reduce headcount, due to process improvements and automation)
Workforce training	170 h /person for direct labor and 120h/ person for indirect labor. Emphasis on technical training.	150 h /person for direct labor and 100h/ person for indirect labor.			Identified gap in behavioral training.	
Work organization		Work groups composed by 10 people, with one monitor. Operators are being trained in other positions, in order to replace absent workers.			Seven work groups, with 8 to 12 people and one leader. Job rotation occurs inside groups.	
Production Planning and Control / Logistics		Forecast for the next 3 months, and a settled demand schedule for the next month. Minimum stock level is 2 days, but there are efforts to decrease level without incurring in stockouts.			Receives monthly orders, which are daily reviewed and confirmed. Also receives forecast for the next 3 months. Minimum stock level is 2 days.	
Production Planning and Control / Logistics (Cont'd)		Operates "milk run" with suppliers			Operates "milk run" with most of the suppliers, and a third-party logistics provider is responsible for it.	
Quality Management	ISO 9001 and ISO 14001 certifications. Quality Award in 1997 on headquarters specific standards.	ISO 9001 e ISO 14001 certifications. Headquarters specific standards. FMEA, SPC (Statistical Process Control), Ishikawa diagram, and starting to implement a suggestion program.			ISO 9001, QS 9000, ISO 14001 certifications. Headquarters specific standards. To obtain ISO TS 16949 certification. FMEA, PFMEA, SPC, process checkpoints and suggestion program.	
Technology Strategy						
Product Diversity	One type of engine (1000cc)	1000cc engines (8 and 16-valve)	1000cc 16-valve turbocharged engines. Also ethanol- and gas-fuelled, 8and 16-valve engines.	1000cc and 1600cc "flex fuel" engines. ¹	1000cc, 1400cc and 1600cc, some for export (25 engine models). In 2004, "flex fuel" technology for high-displacement engine. No longer produces turbocharged engines.	1000cc, 1400cc and 1600cc (36 engine models).
Innovation capability – people working in P&D					180 (number has decreased in comparison to the past). People were relocated and each project is assigned a coordinator.	180
Investment capability – search for new technologies	International headquarters and suppliers as source of technological knowledge.					Autonomy from headquarters has increased in the last years.

¹ Bi-fuelled engines (called "flex" engines in Brazil), which can operate and keep appropriate performance levels either fuelled by gas, ethanol, or any mixture of both.

Production and Adaptation capability – relations between engineering and operations	Projects were implemented in the plant by engineers from the Brazilian R&D.	=	=	=	Set up of an organizational structure in the plant, responsible for implementing new projects.	With the creation of the aforementioned structure, the plant has gained autonomy to plan and deploy process changes.
Exploration and Protection capability	Does not apply technology developed by other companies. As a measure to protect knowledge, new products are kept secret by the engineering team.	=	=	=	=	=

Legend:

- Cells left blank means that we have no data about that aspect in the specified period of time

Table 4: Data about the newcomer engine manufacturer

Newcomer engine assembler	Startup 2000- 2001	2002- 2003	2004- 2005	2006-2008
Operations Strategy				
Competitive priorities			Cost and Quality	
Production capacity	Intends to produce 800 engines/day	=	Production of 450 engines/day	Production of 520 engines/day
Outsourcing	Nationalization index ¹ is about 60%, but there are plans to reach 80% Machining is accomplished in-house, and foundry is outsourced.			Nationalization index is about 75%. In most of the cases, the engine manufacturer uses only one supplier per product (single sourcing), but has two suppliers per item for parts under nationalization process.
Number of suppliers	Approximately 100, being one supplier for each acquired part. In some cases, the engine assembler provided equipment and tools for suppliers		73	92 (it has increased due nationalization strategy)
Workforce	Plans for hiring almost 1000 workers		425 (160 third party workers)	420 (150 third party workers)
Workforce training				Programs for continuous formation and training, mainly concerning people management.
Work organization	4 assembly lines, organized according to lean production concepts. Inflexible and dedicated equipment	=	=	Process-oriented layout, with distinct areas for producing blocks, cylinder heads, crankshafts and connecting rods, and one area for final assembly. Inflexible equipment.
Production Planning and Control / Logistics				Accomplishes Production Planning and Control by means of an ERP system.

¹ Ratio of parts produced in Brazil to the number of imported parts.

Production Planning and Control / Logistics (Cont'd)				6-week stock level (for engines) between the plant and international clients. Concerning raw materials, minimum stock coverage is 1,5 days for national products and 10 for imported ones.
Quality Management			ISO 9001 and ISO14001 certification	ISO 9001, ISO TS 16949 and ISO 14001 certifications. Uses SPC (Statistical Process Control), poka-yoke, Kaizen, FTC (First Time Through Capability) and Kamishibai route.
Technology Strategy				
Product Diversity	Two models of 1600cc 16-valve engines, all of them turbocharged. All products made for export.			1400cc and 1600cc engines – 23 models All of them for export
Innovation capability – people working in P&D	Develops only processes. Seven people are in charge for such developments	=	=	Efforts made (jointly with international headquarters) in order to locally develop products.
Investment capability – search for new technologies	Dependence on the headquarters both in R&D and product development activities. Only processes are locally developed.			With headquarters' support, is seeking to achieve Product Development competences.
Production and Adaptation capability – relations between engineering and operations	Two engineers responsible for the team that develops processes and launches the new products. Keeps close relation with the headquarters, where products are developed.	=	=	=
Exploration and Protection capability	Does not apply technology developed by other companies. As a measure to protect knowledge, new products are kept secret by the engineering team.			
Legend: <ul style="list-style-type: none"> Cells left blank means that we have no data about that aspect in the specified period of time Cells filled with “=” means that there was no significant changes from the immediately previous period of time 				

It is also necessary to highlight that different emphases were given at different moments, mainly as a consequence of the research focus in each one of these moments, besides the willingness of each company to take part in the case studies. Information gathered for the mature company and for the newcomer are presented in Table 3 and 4, respectively.

7. CASE ANALYSIS

Operations competitive priorities in each period of time seem to be important manifestation of path dependence in the studied companies. On the one hand, their changes over time indicate that certain aspects of operations that were until then prioritized have been successfully dealt with by the actions taken in each decision area.

On the other hand, the priorities in a period of time represent a translation of the “strategic intent” (Hamel & Prahalad, 1989) to be pursued by the company in the following periods, acting as a guideline for the coming trajectory.

For example, the mature engine manufacturer focused “quality” in the 1998-1999 period. During this period of time, the company started a process of adoption and consolidation of several quality tools, which, associated to the previously obtained certifications, have allowed the company to reach an

“adequate level of quality”, as one interviewee mentioned in 2004. Supporting evidence for such “adequate level” is the fact that, in the 2004-2005 period, quality was no longer among competitive priorities.

Although production (process) flexibility was one of the major concerns during the 1998-1999 period, in the following periods such competitive priority was not ranked a top concern anymore. Flexibility has changed from Process to Production Volume/Mix flexibility, given that once the processes were stabilized, the company sought to accomplish production volume ramp-up, and develop new products to meet the demands of its client (automaker). Example of such transition may be evidenced by the increase in the number of suppliers during this period, mainly due to increase in the number of products manufactured by the mature company (according to the interviewees).

Besides, the focus of workforce training changed from technical to behavioral. Once that the workers had already developed know-how on how to operate the processes, the issue of interpersonal relationship got in focus.

Given its policy of keeping two suppliers for each purchased part, the mature engine assembler made the decision of starting in-house production of half of the cylinder heads, which until then were totally

outsourced to a single supplier. Besides, the mentioned supplier had been repeatedly presenting quality problems in its parts.

Another fact worth mentioning is that, in 1998, the company evidenced the intention of reducing its minimum stock levels. However, until 2004, such reduction has not proven viable, a fact that somewhat suggests that the company has not been able to evolve along such trajectory and also could account for, at least partially, the "delivery" priority focused by the operations.

The mature engine manufacturer has started its product engineering activities in Brazil together with the setting up of its operations in the country and has accomplished expressive local developments over time, especially in low-displacement and bi-fuelled engines. It's also worth noting that this company pioneered the launch of bi-fuelled 1000cc engines in Brazilian market.

The company presents, therefore, growing technological autonomy to locally develop new models of engines based on existing ones (product Technical Changes) and to accomplish the corresponding production process changes (process Technical Changes).

We could observe that by 2006, the mature assembler was making efforts to increase product-mix and production-volume flexibility. Seeking to diversify the engine models, it was making efforts to improve Innovation Capability and, in order to achieve such goal, it had undergone a restructuring process in its Product Development department.

Concerning Investment Capability, besides keeping its headquarters as an important source of knowledge, the mature company also finds in its supply chain firms that dominate the technology of important engine parts. However, the assembler defines the approval criteria for each part, and keeps control over their application in the final product - in other words, it controls the interfaces and the knowledge of how to combine the different parts in a product with integrated functionality (engine assembly).

Also, by 2006 the assembler increased focus on the Production and Adaptation capability. With the creation of an organizational structure composed by engineers with close relation to assembly line leaders and to Product Engineering, the plant has achieved increased autonomy to plan and implement changes in production processes. Such structure has helped the assembler to accomplish the process changes

needed to launch new engine models and, at the same time, improve production-volume flexibility and introduce cost-reducing improvements.

Since its operational startup, this company has neither taken advantage of technologies developed by other companies (incorporating in its own products and processes), nor explored (sold) technologies developed internally. Besides not focusing the exploration capability, it has not developed a systematic program in order to protect the accumulated knowledge.

With respect to the newcomer engine assembler, data concerning the competitive priorities could only be gathered in the period 2004-2005.

The plant, set up in 2000 with the intent of producing 800 engines/day, has not seen its initial expectations met yet. Since 2004, the total production has averaged 500 engines/day - in other words, almost 40% of idle capacity. This fact has certainly impacted on the economic viability of the plant, which has strongly prioritized cost reduction, given that its planned production level, and consequent revenues, have not become real.

Also we should add to this fact the (unmet) expectation of increasing product nationalization index, which was of 60% in 2000 and should quickly reach to 80%. However, after six years, this goal had not been reached yet (by that time it averaged 75%).

One of the main difficulties in the nationalization process, according to the interviewees, concerns product quality. This fact has major impacts on the "quality" competitive priority (emphasized by the newcomer company) and also on the use and consolidation of quality tools like SPC (Statistical Process Control), Kaizen, FTC (First Time Through Capability) and in obtaining the ISO TS 16949 certification. Besides, the company has altered its sourcing policies, using two suppliers for parts under nationalization process, instead of its typical single sourcing strategy.

The newcomer engine assembler differs significantly from the mature one when it comes to the division and localization of technological-development and product-design activities for the Brazilian branch.

In the Brazilian branch of the newcomer, there was an established department with seven engineers, which were responsible for the technological activities. Such activities consist in adapting the existent production processes to the new engine models developed by the headquarters

In 2006, the newcomer company set the goal of creating a "Product Engineering" department in Brazil. In this context, company's TS had emphasized Innovation and Investment capability. The employees responsible for local technological activities had intensified contact and knowledge sharing with international headquarters. These Brazilian engineers were often attending courses in the headquarters and intended to start developing new engine models, based on the ones that are currently manufactured at the Brazilian plant. However, it is worth mentioning that this goal has not been reached.

In this sense, product Technical Changes by that time were still being accomplished at the headquarters. The Brazilian branch received the product design and adapted it to the current production processes (process Technical Changes). Process technological activities were relatively rare, since the processes were not flexible and only two models of engines were produced.

Comparing the mature and the newcomer engine assembler, we can say that different Technology Strategies lead to distinct Technological Change patterns (directions and pace).

8. CONCLUSIONS AND FINAL REMARKS

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

Central to the present analyses is the idea that companies must develop, reconfigure and integrate their strategic competences, proceeding along competence trajectories that both leverage their competitive success and constraint their strategic options.

In the introduction of this paper, two research questions were proposed. The first, "considering the engine manufacturers set up in Brazil, how can their trajectories of strategy development be described?", has been explored in the previous section (case analysis).

In short, regarding the mature company, the firm has made efforts to increase quality and flexibility both in terms of the production process itself and in terms of

technological capability. The creation of a Process Engineering department, diversification of models and introduction of bi-fuel technology are relevant steps connected with Innovation and Production/Adaptation capability. Concerning the newcomer, the company was still facing unmet demand expectations, while trying to stabilize and improve its operations, as well as to increase nationalization of its products.

Recalling the second research question proposed, "Are there differences among the trajectory followed by the mature company by the newcomer?", the case analysis has shown important points of distinctiveness.

First of all, it is worth to mention that this paper do not intend to make generalizations about mature companies and newcomers in Brazilian automotive industry. However, its important to mention several studies by Cerra (2007), Alves Filho et al (2006), Consoni (2004), which argue that, regarding operations and technological strategies in this industry, 1) mature engine manufacturers keep important similarities among them, 2) newcomers are even more similar inside their group, and 3) mature companies and newcomers are different when compared with one another. This fact suggests that the companies here studied may bring meaningful information about the trajectories followed by companies belonging to Brazilian automotive industry.

Regarding the operations strategies undertaken by the mature company and the newcomer, there are substantial differences between both. It was noticeable that the mature company has focused on priorities such as flexibility (of both products and volume mixes) during the last years. On the other hand, the newcomer has focused cost reduction and quality enhancements among their operations priorities.

Concerning technological strategies, Product Development (PD) issues seem to play a key role in the future competences that companies need in order to achieve competitive success. The mature company has taken action to improve its flexibility for launching new products, and the newcomer has been making efforts to increase its product nationalization.

Considering both operations and technological trajectories, it seems that the engine manufacturers are already following competence trajectories, as proposed by Teece et al, (1997, p. 515) as cited in Dannels (2002). Those competence trajectories are directly related to uniqueness and appropriability of interfirm resources, as originally described by Barney (1991).

Despite having undertaken a deep outsourcing process, these engine manufacturers (mainly the mature ones) have had a major concern about keeping in-house property of their core competencies, i.e., of technologies regarded as strategic for their products (engine core). 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 still belong 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.

Finally, we would like to summarize the main conclusions of this paper. The first point concerns the distinct forces that "drive" strategy trajectories. As mentioned, competitive priorities seem to "pull" the trajectories, translating market needs into specific tasks that must be fulfilled by each strategy. In this sense, strategy must make its best efforts, despite how demanding they should be, to reach the intended goals. On the other hand, the advances made in each step may "push" the trajectory, setting the basis for new strategies and making them capable (or not) of moving further. If operations and technology evolve, reaching its goals inside each strategy, the companies are able to (or pushed to) cater to new market needs.

In this sense, the studies of strategy trajectories seem to face a similar dichotomy found in other related areas, like the Market Pull x Technology Push discussion presented in the Innovation literature (Martin, 1994), or the Market Based x Resource Based View debate found in Strategic Management (Barney, 1991).

The second point is that, although advances along trajectories are intended and planned, they cannot be foreseen. If firm succeeds, the advances may "push" the trajectories, but if strategies partially fail, companies are compelled to keep insisting on achieving such progress or even to change plans and start implementing alternative decisions. The efforts made by the newcomer to increase nationalization index are an example of the first alternative, while the decision of the mature manufacturer to insource cylinder heads (opposite to its major outsourcing strategy) illustrates the second one.

The third conclusion points to secondary factors that may also influence trajectories. First, the degree of autonomy assigned to firms defines what they are actually allowed to do and, thus, the advances they may ultimately perform. For example, the mature assembler had the necessary autonomy to restructure its

Product Development department to improve Innovation Capability and product-mix flexibility. Second, the degree of accumulated knowledge defines what firms are capable of doing and, hence, the advances they may obtain. For example, the mature company keeps control of the knowledge of how combining several outsourced parts into a fully functional product, controlling advances on products/process and their impacts on technology strategy trajectory.

Compared to other similar studies, the main contributions of this paper can be outlined as: First, we were not able to find other studies with a longitudinal approach on strategy trajectories in Brazilian automotive industry. Second, the results here presented seem to be in tune with other studies focusing on RBV and Operations/Technology strategy in the automotive sector. Just as Taylor and Taylor (2008) suggested, themes related to the Japanese Production System like inventory reduction, quality management, etc. were also key concerns of Brazilian automotive executives. Also, as proposed by Sadoi (2008), Rasiah (2009) and Zhao, Anand and Mitchell (2005), supply relations are crucial for the development and transfer of technology capabilities. The mature company has outsourced a meaningful amount of its parts to suppliers that have mastered the technology of such products, but still controlled the interfaces and the knowledge of how to combine the different parts. The newcomer was still struggling to develop a network of local suppliers technological capable of supplying good-quality parts.

Based on the aspects here investigated, we indicate some possibilities for further research. Although we do not aim to provide an exhaustive list, some themes include: (1) studying other engine manufacturers, in order to analyze different trajectories; (2) analyzing auto suppliers, to identify their trajectories and the mutual influences between trajectories followed by engine assemblers and by their suppliers; (3) analyzing the technological trajectories followed by Brazilian companies that had been taken over by multinational corporations and (4) analyzing in greater detail the decisions made in each operations area, the product and process development process by each company, etc.

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