TECHNOLOGY STRATEGY IN ENGINE ASSEMBLY SUPPLY CHAINS OPERATING IN BRAZIL

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ABSTRACT
This research seeks to identify and examine the Technology Strategies of three engine assemblers and eight suppliers, through case studies, discussing the relationships between the Technology Strategies of each assembler and those of its suppliers in each one of the production chains studied, and, then comparing the three technology strategies adopted in these chains. Two of the chains chosen are run by subsidiaries of companies that have been operating in Brazil for several decades, performing a variety of R&D activities. The third chain is headed by one of the subsidiaries that started operations in Brazil after the 1990s and whose technological activities are extremely centralized abroad. The suppliers differ in terms of size, technological capability, etc. It was found that the chains’ Technology Strategies are different, because they vary among the assemblers and the suppliers; therefore the influence that each assembler exercises over each supplier is distinct.

KEYWORDS

INTRODUCTION
Technology is a very complex and important factor that has not received sufficient attention from researchers of operations management.

Some of the well-known researchers of operations management have considered “technology” or “product and process technology” as one of the main structural decision areas when discussing operations strategy. Some of them (Hayes et al, 2005) have also discussed important topics related to technology development, considering for example the pervasiveness and the effects of information technology (IT) on management and on a firm’s competitiveness.

We believe that researchers of operations management could help to develop reference models as they have done in the case of operations strategy, and we try here to make a small contribution to the discussion of technology strategies in supply chains. More specifically, in this paper, we espouse a concept of Technology Strategy proposed elsewhere (Alves Filho, 1991) and try to identify and analyse the technology strategies adopted by three automotive engine manufacturers (owned by three different automakers, branches of multinational companies) and eight suppliers positioned at the first and second tiers of their (three) supply chains, all of them operating in Brazil.

Two of the engine assemblers are referred to as “mature” companies because they started their operations in Brazil many years ago. The other engine manufacturer is called a “newcomer” since it started operating in Brazil only after 1990.

In the Brazilian Automobile Industry, the technology strategies utilized by the firms have been influenced by changes in the supply chains, such as new assemblers emerging on the market and the consolidation and denationalisation of the auto parts sector, as well as impacts from phenomena specific to the Brazilian scenario such as the use of low cylinder displacement 1000 cc engines and flexible fuel systems.

From the point of view of the research issues being considered here, the most relevant is that the engine assemblers in Brazil adopted different competitive strategies (in important aspects and for given periods of time, at least) and established new types of relationships with auto parts suppliers.
in new industrial chains. Thus they had to adopt Technology Strategies appropriate to these new contexts.

Thus, the central questions of this research are: What aspects influence the Technology Strategies of the assemblers and the suppliers? How do the supply chains influence the Technology Strategies of the assemblers? With regard to the suppliers, what are the main characteristics that distinguish their Technology Strategies? Are the Technology Strategies in each chain different? Why?

To do this research, case studies were carried out in the eleven companies from mid 2006 until the end of 2007, through semi-structured interviews.

The interviewees at the different companies consisted of employees who work with the technology of products, processes and management, in other words, managers involved with technology, industrial managers, as well as purchasing/supply managers.

The relevance of the theme Technology Strategy, and in particular the relationships between the strategies of different companies that make up the industrial chains justifies the need for this exploratory research and also in light of the fact that there are so few studies that focus on the automobile engine segment.

TECHNOLOGY STRATEGY

The variety of concepts found in the literature on technology is, according to Alves Filho (1991), the result of the different views and objectives of the researchers. Iglesias (2001) points out some characteristics that are common to the majority of the definitions presented: technology originates from the sciences; it should be oriented for a practical purpose; it should be reproduced on an industrial scale; and it can be applied not only to goods and services, but also to the production process and its management.

In this research the creation of both intra-organizational and inter-organizational know-how is examined (Nonaka and Nishigushi, 2001), particularly in the context of supply chains. Considering the external sources of knowledge, indeed, the current competitive trends require that the strategic planning also include the elements of the supply chain addressed in the next section that briefly describe the available literature on Supply Chain Management.

We understand Technology Strategy to be the combined effort that the company expends to increase its technological capabilities and implement changes, whether they are in the production systems, products, processes or management:

“Technology Strategy refers to the corporate set of efforts and actions aimed at increasing technological capability, both within the scope of R&D and in other areas of the company as a way of implementing technical changes. Such changes comprise the creation of new techniques and (not necessarily new) changes in the elements that constitute and characterize the production system, either from the company’s point of view or related to international borders” (Alves Filho, 1991: 27).

Several authors have made efforts to categorize the different technological capabilities. Dahlman, Ross-Larson and Westphal (1987) suggest that there are three types of capabilities in Technology Strategy: innovation capability, investment capability and production & adaptation capability. Ford (1989) suggests a fourth capability, namely exploration and protection capability.

Although the boundaries of these four capabilities are not clearly distinguished, each one of them requires specific investments and efforts (Westphal, Kim and Dahlman, 1985). Also, these capabilities are not isolated and to some extent a relationship and synergy can be identified among them.

The main information regarding Technological Capabilities obtained from the companies is presented in the following figure:
The existence (or non existence) of structured R&D in the company; the technological autonomy of the subsidiary in relation to the foreign headquarters; the number of engineers/scientists that work in R&D; the launching of new products, recent projects and the introduction of significant changes in the production processes; and the involvement of suppliers in the local R&D activities.

The company’s projects for acquiring new technology; the relationship with research centers and universities for the development of projects and/or acquisition of technology; and the participation in cooperative networks for the development of new technologies.

The incremental changes (and the sources of these changes) in products and production processes; and the organizational structure that promotes contacts between Engineering and the plant.

The existence of projects in the companies for the commercial exploration of known technologies (if the company buys or licenses technologies of products and processes developed by other companies to incorporate into their own products and processes and explores (sells) those technologies).

The measures are implemented so that the knowledge acquired is not passed on to the competition.

The capabilities have been identified in all eleven firms through an analysis of the information gathered in interviews with managers. It was then possible to analyse and compare the Technology Strategies adopted by the engine manufacturers, the suppliers and the Technology Strategy adopted in some of the tiers of the three engine supply chains.

It is important to mention that the elements of the Technology Strategy analysed in the companies studied are: the Technological Capabilities and the Technical Changes in products and processes. The technical changes in the area of management are not addressed in this empirical work.

SUPPLY CHAIN MANAGEMENT

A supply chain, according to Chopra and Meindl (2003), encompasses all of the stages (clients, retailers, distributors, manufacturers and suppliers) involved directly or indirectly, in filling a customer’s order. Thus, a successful chain is conceived in a context of flexibility and the creation of a composite value, and not just exchange (Kanter, 1994 apud Souza, Moori and Marcondes, 2005).

The main objective of SCM is to make the business processes more efficient and effective, reducing costs, the levels of stock, improving quality and creating a competitive advantage and value for the supply chain (Alves Filho et al, 2001).

For Padovani (2007), SCM is the way organizations, organized in chains, add value to their products and services through cooperation, cost reduction and interaction in the business processes (internal and external).

Alves Filho et al (2004) consider SCM to be a body of knowledge that is being constructed. The authors point out that the literature on the subject, both that of a more prescriptive or empirical nature, takes on a set of presuppositions that in many cases are enunciated as guiding principles of best management practices, as if the set of such presuppositions could be adopted and be the most effective and efficient under any circumstances.

Based on the work of Alves Filho et al (2004), the main presuppositions of SCM, that are interrelated, are:

- The competition in the market occurs at the level of the supply chains and not just at the level of the companies (Christopher, 1992).
- The alignment of the companies’ strategies with that of the supply chain is fundamental to improving performance in the relationship between suppliers and customers (Handfield and Nichols (1999) apud Assumpção (2003)).
- The number of suppliers tends to drop off (Tan, 2002) and they start to be hierarchized according to the level they occupy in the supply chain (Miranda, 2002).
• The supply chain should be coordinated. This requires that each stage take into consideration the impact that its actions have on the other stages (Chopra and Meindl, 2003).
• There should be a bi-directional flow of products (materials and services) and information among all of the companies that belong to the supply chain (Lambert, Emmelhainz and Gardner, 1996).
• The companies focus on the outsourcing strategy.
• True cooperation becomes necessary among the firms involved in supplying the final product (Lamming, 1993), this way the companies invest in partnerships.
• The companies should seek out suppliers that are capable of building a long-term relationship based on mutual trust. (Christopher, 1992).
• The companies should invest in the growth of suppliers, which, according to Handfield et al (2000), includes any activity that a buyer undertakes to improve the performance capabilities of a supplier to satisfy long or short-term purchasing needs.
• Another practice that has expanded in the context of SCM is the joint involvement of the companies in R&D (Ellram, 1991 apud Miranda, 2002) and the involvement of suppliers in the process of new product development and manufacturing (Tan, 2002).

The discussion of Alves Filho et al (2004), which serves as the foundation for this section, suggests that the SCM approaches should include an initial phase for “verifying presuppositions”, or identifying the configuration of the supply chain, since it is a way to reveal the types of contexts in which the relationships among the companies and the SCM can develop.

**CASE STUDIES**

*Presentation of the companies*

The companies are presented here in a chart format to provide a broader comparative vision of the suppliers with a description of the general characteristics of the companies. First the assemblers are presented and then the suppliers.

**Table 1: General characteristics of the assemblers studied**

<table>
<thead>
<tr>
<th>Component</th>
<th>Veterans</th>
<th>Newcomers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lines of Products (engines)</strong></td>
<td>Assembler A</td>
<td>Assembler B</td>
</tr>
<tr>
<td></td>
<td>Engines 1000 cc, 1400 and 1600, 1900 (diesel) and 2000. Includes 57 engine models.</td>
<td>* Engines 1000 cc, 1400, 1600 and 1800; * Engines 1800, 2000, 2200 and 2400.</td>
</tr>
<tr>
<td><strong>Installed production capability</strong></td>
<td>2200 engines / day</td>
<td>* 1650 engines / day</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td>2200 engines / day</td>
<td>* 1650 engines / day</td>
</tr>
<tr>
<td><strong>Components made internally and outsourced components</strong></td>
<td>Internal machining of the engine block. Machines and assembles the cylinder heads since 2006. Outsources the foundry work and the other components. (2 components made internally)</td>
<td>Does the foundry work on part of the components internally. Intends to outsource it. Outsources the machining and the other components. (7 components made internally)</td>
</tr>
</tbody>
</table>
We can observe that the veteran assemblers present more diversified product lines and greater production capabilities when compared to the newcomers. While with regard to the level of outsourcing of components, we did not find greater similarities between the veteran assemblers, since the newcomer occupies an intermediary position between the both.

Table 2: General characteristics of the multinational and Brazilian suppliers

<table>
<thead>
<tr>
<th>General Characteristics of Suppliers</th>
<th>Multinational Companies</th>
<th>Brazilian Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Company 1</td>
<td>Company 2</td>
</tr>
<tr>
<td><strong>Supply Level</strong></td>
<td>1st level</td>
<td>1st and 2nd levels</td>
</tr>
<tr>
<td><strong>Segment (Predominant)</strong></td>
<td>Electronic</td>
<td>Metal-working</td>
</tr>
<tr>
<td><strong>Number of Employees</strong></td>
<td>430</td>
<td>450</td>
</tr>
<tr>
<td><strong>Main Products</strong></td>
<td>Bi-fuel technology, fuel injectors and fuel pumps, etc.</td>
<td>Pressure casting and machining of components in light alloys, such as the oil pan, etc.</td>
</tr>
</tbody>
</table>

The sample of companies is composed of 3 multinational suppliers, each one belonging to a different segment (electronic, metal and polymeric). In addition to these, there are 5 Brazilian suppliers that produce components from the metalworking segment. In general, these companies vary in size.

Technology strategy of the assemblers
- Innovation Capability: there are significant differences when comparing the veteran companies with the newcomers. While the former achieved increased autonomy in relation to the foreign headquarters and currently can execute local R&D activities, which in the beginning were done for them, the newcomers are highly dependent on the headquarters.

In the case of Assemblers A and B, the product development sectors are not located in the plants studied – there are instead engineers that participate in the R&D activities (in plants operating in Brazil) and participate in the development of production processes. This way, the new product models come from an already existing model and the changes in processes can be related to the introduction of new products in the lines or in improvements in the operation lines.

At Assembler C there is an Engineering sector directly linked to the R&D center of the foreign headquarters. Changes in the product models still do not happen locally. The changes in processes can be related to the introduction of new products in the lines or to improvements in the lines in operation. At this assembler, unlike the others, there is very little flexibility in the processes.
- Investment Capability (Acquisition): There is a greater demand for know-how from the foreign headquarters in the case of the newcomer companies that do not develop products in Brazil. In addition to the headquarters, suppliers can be considered sources of knowledge, especially those that master the technology (products and processes) of the components delivered to the assemblers.

- Production and Adaptation Capability: Only Assembler A has a structure that promotes contact between the Engineering department and the factory, in addition to the multifunctional team that works on R&D activities (made up of representatives from various areas – Production, Quality, Purchasing, Finance, etc). A sector was created at Assembler A that is responsible for the implementation of new projects at the plant, it is made up of 5 Process Engineers and two industrial Engineers who participate in the R&D stages from the beginning (which occur in the other plant).

- Exploration and Protection Capability: None of the assemblers buy or license product or process technologies developed by other companies to incorporate into their own products and processes. Nor do they explore technologies developed by other companies.

The figure below summarizes the Technology Strategies of the assemblers:

<table>
<thead>
<tr>
<th>Veterans</th>
<th>Newcomers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembler A</td>
<td>Assembler B</td>
</tr>
<tr>
<td><strong>Technology Strategy</strong></td>
<td>To increase its flexibility in its mix of products and production volume (generating Technical Changes in products and processes), Assembler A has sought to expand its Innovation, Acquisition, Production and Adaptation capabilities.</td>
</tr>
</tbody>
</table>

**Figure 2: Technology Strategy of veteran and newcomer assemblers**

Supply chain – assemblers
With regard to the structure of the supply chains, greater similarities were not found between the two veteran assemblers. Although the Assembler C supply chain is a newcomer, it has a larger number of suppliers abroad and its characteristics are closer to those of Assembler B, a veteran.

Assembler A shows a greater level of component outsourcing through a larger number of small companies and has two suppliers for each outsourced item.

The differences presented in the structures of the chains are reflected in the relationships between the companies that make up the chains. Assembler A, with a larger number of smaller Brazilian companies, developed a larger number of companies and prioritises cost when selecting suppliers.

Technology strategy of the suppliers
- Innovation Capacity: Company 1, which belongs to the electronics segment, stands out in relation to the other companies in the sample: i) it invests in research activities, ii) it has a sector that focuses on R&D activities with a large number of people (in addition to the multifunctional R&D team) and iii) it is responsible for the product design projects supplied to the assemblers.
Technology Strategy (TS)

<table>
<thead>
<tr>
<th>Multinational Companies</th>
<th>Brazilian Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Company 1</strong></td>
<td><strong>Company 2</strong></td>
</tr>
<tr>
<td>To meet customer demands, especially Assembler B, the company strives to develop new products (Technical Changes in products and processes). The company’s TS focuses on Innovation and Protection capabilities.</td>
<td>To meet customer demands (assemblers and auto parts), that grant them the product designs, the company strives to develop production processes (Technical Changes in processes). The company’s TS focuses on Innovation, Acquisition, Production and Adaptation.</td>
</tr>
</tbody>
</table>

On the other hand, 4 of the 5 Brazilian companies do not have a structured sector that focuses on technological activities. At these companies, it was found that there are only multifunctional teams that make adaptations in the production processes.

- Investment Capability (acquisition): the suppliers present the headquarters as the main source of know-how, followed by the customers (assemblers), that is, multinational subsidiaries. Meanwhile the Brazilian companies seek out information from the customers, especially those that acquire the majority of their total production volume.

- Production and Adaptation Capability: at the suppliers there is no structure or sector that promotes contact between Engineering and the factory, as in Assembler A.

At these companies, it was found that there were representatives from the production area accompanying the engineering activities of the sectors responsible. These representatives are part of a multifunctional development team (products and/or processes).
There are also cases where suppliers do not have a structured Engineering sector and decisions are then made by the multifunctional team, of which representatives from the production areas are part.

In general, these production representatives indicate the adaptations to be made in the production processes for the implementation of a new product model in the lines. In the case of suppliers who receive the product design from the customers, the representatives also indicate favorable (or unfavorable) points to carrying out the project and can suggest some modifications.

- Exploration and Protection Capability: the suppliers do not explore technology and half of them are not concerned with protecting the know-how they have acquired. This is due principally to the fact that these companies do not control the technology of the supplied products. Only two suppliers patented products as a way of protecting their know-how.

*Supply Chains – suppliers*

With the exception of Companies 2 and 3 which have a more diversified customer base, the other companies have one of the assemblers studied as their main customer. In general, the suppliers pass on to the next closest link in the chains, some of the requirements that their customers (assemblers) impose on them.

The multinational companies (first tier suppliers) work with larger suppliers, which are also subsidiaries of multinationals in the majority of cases. While the Brazilian companies have shorter chains and their suppliers are the large metallurgy and steel companies. Thus they are faced with pressure from both the assemblers, and the large supplier companies.

**FINAL CONSIDERATIONS**

In doing this work it was possible to observe that the Technology Strategies are conditioned by the main competitive priorities of the firms, the level of technological autonomy presented by the local subsidiaries in relation to the technological research centers of their foreign headquarters and the structural and relational aspects of their supply chains.

To illustrate the first determinant, i.e., competitive priorities, we can look at the case of assembler A. It was found that flexibility (in terms of the mix of products and the production volume /increase in production capability) is one of the most valued attributes for this assembler. To achieve this, it directed its efforts towards the Acquisition, Protection and Adaptation Capabilities. This also indicates that Capabilities are not isolated, they are interrelated.

The two veteran assemblers presented very similar Technology Strategies regarding the types of technological capabilities. There are differences concerning the efforts made to develop each capability, which are related to the pace of change or to the moments at which such changes were implemented.

Mature assemblers have been acquiring increasing autonomy to develop (at least part of) some automobile models and engines (or engine components). Although most of these developments are destined for Brazilian and other emerging markets, there are cases of products being exported to developed countries (ex: VW Fox or VW Lupo to Europe). The newcomer, on the other hand, does not have autonomy to develop technology and does not execute significant technological activities in Brazil.

The demand for technological change begins at the automakers and it is spread throughout the rest of the supply chains. The Technology Strategies of suppliers vary according to the role they play in component design. Some of the suppliers have the technological capability to design the required parts and some of them are only able to produce the components designed by the assemblers. Yet, there are suppliers that depend on the automakers to adjust their production processes.

Generally speaking, foreign capital companies tend to have a higher degree of innovation capability when compared to Brazilian companies. The majority of Brazilian companies develops
less sophisticated products or receives the product design from their customers and then takes responsibility for designing the manufacturing process.

Finally, differences were found between the Technology Strategies of assemblers associated with the differences in the structural and relational characteristics of the supply chains.

We can say that these assemblers inserted in chains with different structural configurations assume distinct relationship standards among the companies, adopting different Technology Strategy and Supply Chain Management actions to make their strategic priorities viable.

Assembler A, with the largest number of smaller suppliers and limited technological capability must expend greater efforts to develop the suppliers and guarantee their adequate performance. The assemblers that have a greater number of large suppliers and are more qualified technologically, in turn, must put more effort into negotiations (of transactions) with suppliers and less effort into developing the suppliers.

In summary, it was found that the Technology Strategies in the supply chains are different, since the strategies vary among suppliers and the influence that each assembler exercises over each supplier is therefore distinct; the differences are greater when we compare the Technology Strategies of the chains run by the veteran assemblers and those found in the chain run by the newcomer.

REFERENCES


