ABSTRACT
The main purpose of this article is to identify and compare operations strategies implemented by six engine assembly plants in Brazil, taking into account the possible influence of the structural and relational aspects of supply chains on the strategies implemented by these companies. The main questions addressed in this article are: What types of operations strategies have engine assembly plants been implementing in Brazil over the last few years? What aspects of implemented operations strategies are influenced by the characteristics of supply chains? Data on the companies were gathered through interviews with production managers. Mature companies were found to have favored priorities such as flexibility in recent years, while the competitive priorities of newcomers were more focused on cost reduction and quality enhancement. Mature companies also showed a tendency to follow similar paths with respect to operations and supply chain management.

Keywords: Operations strategies, Engine assembly plants, Supply chains.

INTRODUCTION
The main purpose of this article is to identify and compare operations strategies adopted by engine assembly plants in Brazil, considering the possible influence of the structural and relational aspects of supply chains on the strategies implemented by these companies.

More in-depth research topics on strategic planning covering the abovementioned issues have been suggested by Baum and Dutton (1996), clearly indicating that researchers should focus on the theme of the “embeddedness of strategy”. This approach takes into account the fact that companies are predominantly located within supply chains and very often closely linked to other companies in the same supply chain.

According to the literature on operations management, the issues addressed here are also part of the areas of operations strategy and supply chain management – two broad and relevant topics that have been developed separately so far. In fact, some authors have stated the need for “crossing and combining” the contributions of both topics of operations management in order to better understand the performance of companies in supply chains (Lowson 2003, Chopra, Lovejoy and Yano 2004, Voss 2005, Slack 2005).

In this article, our specific purpose is to identify and examine the operations strategies of six engine assembly plants located in Brazil. These six production units manufacture engines for their respective (six) automakers. Altogether, seven automakers have established engine assembly
plants in Brazil, so only one of them is not included this study. We have attempted to compare the operations strategies implemented at the six production units taking into account – as mentioned before – some of the key features of the supply chains within which the engine assembly plants operate.

The main questions addressed by this article are: (1) “What types of operations strategy have engine assembly plants been implementing in Brazil over the last few years? (2) What aspects of implemented operations strategies are influenced by the characteristics of supply chains?

The company data examined here were collected during interviews with the plants’ production managers (using semi-structured questionnaires) and actual visits to the six plants. In some cases, quality, procurement and logistics managers were also interviewed.

The companies’ operations strategies were scrutinized based on their competitive priorities and the characteristics of their decision-making areas – both structural and infrastructural (Hayes et al. 2004, Hayes, Wheelwright and Clark 1988, Garvin 1993, Slack 1991, Slack et al. 1997). The questionnaire included questions on the structural and relational characteristics of the supply chains and were designed based on Lambert, Cooper and Pagh (1998) and on Rudberg and Olhager (2003).

After briefly describing the conceptual foundation of this piece of research in the next section, we analyze the data obtained on operations strategies and on supply chains from the six companies, and present our main conclusions.

OPERATIONS STRATEGIES IN SUPPLY CHAINS

In recent years, a growing body of knowledge has accumulated on operations strategies or on the coordination of operations (from suppliers’ suppliers to clients’ clients) that constitute supply chains. However, little research has focused on the topic of Operations strategies in Supply Chains so far. Although some of the dimensions of these two areas (Operations strategy and Supply Chain Management) are identical or very closely connected, a specific research effort targeting this theme is still awaited.

The dynamic nature of the relationships among organizations is revealed by mergers and acquisitions, co-makerships, joint ventures, franchising, and consortiums of companies. Articles on Supply Chain Management by Lambert, Cooper and Pagh (1998) and Rudberg and Olhager (2003) have suggested an integration of actors and business processes to promote competitiveness of the supply chain as a whole. Despite the limitations attending such transformations, the automotive industry has made changes in that direction, e.g., world platforms, commonalization of components, follow and global sourcing, industrial condominiums, co-design of systems and components, hierarchization of suppliers, etc. According to Humphrey, Lecler and Salerno (2000), changes in assembler/supplier relationships are central factors in the strategies of companies operating in the automotive industry.

Specifically in the area of strategic planning, works such as that of Baum and Dutton (1996) reveal the need for research on “the embeddedness of strategy”. What strategies can or should companies adopt, in view of the fact that they are embedded in supply chains or in the relationships that they maintain with one another?

Operations strategies, in particular, are also conditioned by the characteristics of the supply chains in which companies operate. Operations strategies have been described by Hayes, Wheelwright and Clark (1988) and by Hayes et al. (2004) as being composed of competitive priorities – Cost, Quality, Delivery and Flexibility – and action plans designed for implementation in decision areas. These decisions areas are subdivided into structural (Capacity, Supply and vertical integration, Facilities, Process and information technologies) and infrastructural (Resource allocation and capital budget systems, Human resources systems, Planning and control systems, Quality systems, Measurement and reward systems, Product and process development systems, Organization) areas.
In this paper, we seek to identify operations strategies adopted by engine assemblers in automotive supply chains.

OPERATIONS STRATEGIES ADOPTED BY ENGINE ASSEMBLERS
This section presents a comparative analysis of the operations strategies adopted by six automobile engine assembly plants established in Brazil. All the companies of this study are large multinationals that belong to corporations manufacturing automobiles in this country.

We begin with a discussion of the competitive priorities emphasized by the six companies, followed by a description of the characteristics observed in the structural and infrastructural decision-making areas. To conclude this section, we present and analyze the principal actions recently implemented to achieve the strategic objectives of their production systems.

With regard to the competitive strategies, as indicated in Table 1, the three companies that have been operating in Brazil for the longest time, i.e., Assembler A, Assembler B and Assembler C, consider flexibility of the highest relevance among their priorities. In the opinion of the interviewees, mix and volume flexibility are the main attributes to be developed by their production systems, aiming to make production a core strategic resource to meet the needs of their clients – the automakers.

With regard to Assembler C in particular, the interviewee also emphasized the importance of product flexibility, in other words, the company’s ability to adapt its products to customer needs.

For the engine plants, the quality, cost and delivery priorities are relatively less important, i.e., in the words of Hill (2000), they can be considered qualifying performance objectives.

The emphasis these three older companies place on flexibility derives from factors inside and outside its manufacturing units. The external factors refer to the demands of the competitive strategies of their clients – automakers, who, because they operate with a wide range of products in different income segments, require a large variety of types of engines produced in high volumes. Still with regard to external factors, in recent years the automakers have been under strong market pressure to develop new engines aimed at customization. The offer of optionals in vehicles – power steering, air conditioning, etc. – and the possibility of fueling vehicles with more than one type of fuel – bi-fuel – are major consumer demands. As a result, the plants began to operate with a wider variety of engines, requiring greater flexibility of their productive systems.

The plants’ internal factors involve management of the production system as such. Market changes over the last few years have required these plants to operate with a greater mix of products and volumes at a given standard of quality and costs. These changes have increased the complexity involved in managing the productive systems, requiring improvements in efficiency and efficacy. One must also keep in mind that production in these companies has reached volumes close to total

<table>
<thead>
<tr>
<th>Automaker</th>
<th>1st Priority</th>
<th>2nd Priority</th>
<th>3rd Priority</th>
<th>4th Priority</th>
<th>5th Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembler A</td>
<td>VF</td>
<td>MF</td>
<td>R</td>
<td>C/Q</td>
<td></td>
</tr>
<tr>
<td>Assembler B</td>
<td>MF</td>
<td>VF</td>
<td>Q</td>
<td>R</td>
<td>C</td>
</tr>
<tr>
<td>Assembler C</td>
<td>MF/VF</td>
<td></td>
<td>C/Q</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Assembler D</td>
<td>MF</td>
<td>R</td>
<td>Q</td>
<td>C</td>
<td>VF</td>
</tr>
<tr>
<td>Assembler E</td>
<td>C</td>
<td>Q</td>
<td>R</td>
<td>VF</td>
<td>MF</td>
</tr>
<tr>
<td>Assembler F</td>
<td>Q</td>
<td>C</td>
<td>R</td>
<td>MF</td>
<td>VF</td>
</tr>
</tbody>
</table>

MF: Mix flexibility; VF: Production volume Flexibility; Q: Quality; C: Production cost; R: Reliable deliveries

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production capacity, i.e., these companies operate with low idle capacity; hence, flexibility is a key factor in enabling the operations system to meet market variations.

Assembler D prioritizes mix flexibility and reliable delivery, in that order. In 2005, Assembler D enjoyed a significant growth in automobile sales, thus increasing its demand on the engine assembly plant. During this period, engine production almost doubled, causing the company to operate with a very low idle capacity of only around 2%. Engine variety also increased due to the introduction of a new type of engine and to the bi-fuel versions for the existing types. This combination of factors – a marked increase in production and in the variety and almost total utilization of production capacity – justifies the company’s focus on mix flexibility and reliable deliveries.

Assembler E and Assembler F show a similar behavior with respect to competitive priorities. These two companies emphasize cost and quality as their top priorities. The difference is in the order of these priorities, since Assembler E puts cost first and quality second, while Assembler F inverts this order, as indicated in Table 1.

This prioritization can also be explained by external factors, market conditions, and factors inside the plants. Assembler E has failed to meet its forecasted growth in vehicle sales, a fact that is reflected directly in the internal operations of the engine assembly plant, forcing it to operate well below its production capacity. While other measures are being implemented to alter the company’s market variables, the attention in production centers upon the priority of cost and on the efficient utilization of certain production factors to mitigate the effects of operating with a significant idle capacity. It should be noted that none of the efforts aimed at reducing cost can affect quality in any of its dimensions, because of the latter’s major role in the automaker’s competitive strategy.

Assembler F prioritizes quality, followed by cost. Although the two primary priorities are the same as those of Assembler E, since their order is inverted, the external and internal factors that justify this prioritization are different. Assembler F sells its engines only on the export market, more specifically to the European market, the United States and South Africa, in that order. These markets have a more stable demand, particularly when compared with the Brazilian market, a fact that favors (or facilitates) operations management. Moreover, the company offers a small number of models, which also helps reduce the complexity involved in managing the production system. Similarly to Assembler E, Assembler F currently operates with a significant level of idleness, and therefore, its priorities of flexibility and reliable delivery are under little pressure for improved performance. The company thus channels its initiatives into quality and cost, until such time that decisions at the business strategy level are taken to revert its production demands.

To meet their competitive priorities, companies conceive their operations strategies based on plans and implement actions involving the structural and infrastructural decision-making areas proposed by Hayes and Wheelwright (1988).

Assembler A, Assembler B and Assembler C, which are prioritizing mix and volume flexibility, adopt operations strategies with similarities and differences in the structural areas. Assembler B and Assembler C concentrate their production in a single plant, while Assembler A manufactures engines at two plants. Assembler C’s plant is located in the same manufacturing unit where its vehicles are assembled, while Assembler B, which has three vehicle assembly units in Brazil, has its engine plant next door to one of those units. Assembler A has a plant, its oldest one, at the same location as the unit that assembles some of its car models, while the other plant is dedicated to the manufacture of engines.

The three companies have a high production capacity and produce a wide range of models that are differentiated by their power, type of fuel and accessories. Assembler B stands out for having the largest installed capacity. The three companies have similar levels of automation and products with similar technological content, but differ in terms of the degree of vertical integration in their plants. Of all the companies studied here, Assembler B is the most verticalized, since it casts its cylinder block and machines the entire block, as well as the crankshaft and the cylinder head. In contrast, Assembler C purchases the cylinder block from a third party but machines the block, the crankshaft
and the cylinder head, while Assembler A machines only the engine block, purchasing the crankshaft and cylinder head in finished form.

Similarities and differences can also be observed in the infrastructural areas in general. The three companies have information systems for PCP developed from the ERP logic, EDI for connection with the vehicle assembler and with the suppliers, a corporate quality policy, their quality systems are certified, they use the principal basic and management tools for quality control and improvement, and they evaluate their suppliers based on the principal reference of the requisites of quality standards.

With regard to their work organization, they use the concepts of cell, team work, and suggestion programs, and invest in shop floor employee training, etc. All these companies have a well developed structure for product development, involving a large staff of engineers and designers. From this standpoint, it is worth noting that these companies show differences in their degree of integration with the engineering area at their foreign headquarters, as well as in their technological autonomy.

As for supply management, the companies have in common the fact that they work with numerous suppliers, most of them large companies with good technological capacity, they have no exclusive suppliers, they use EDI for their information flow, and they maintain relationships only with the first tier of the supply chain. However, there are substantial differences in the structure and management of their supply chains. Assembler C, for instance, is located far away from Brazil’s main autoparts manufacturing center in the state of São Paulo, thus requiring a totally different logistical structure involving a center for receiving materials in São Paulo and warehouses of some of its suppliers close to its plant in the state of Minas Gerais. Assembler A, it should be noted, works with 30% more suppliers than the other two automakers, the company does not establish formal contracts, and it has two suppliers for most of its items.

Some movements toward promoting changes have been observed in these companies. With regard to the structural areas, Assembler B is developing actions aimed at reducing its degree of vertical integration. The company is slated to close its foundry and outsource this activity. In addition, Assembler B has invested in machinery and equipment to meet the needs of the new generations of engines it is manufacturing. Assembler C, in turn, has outsourced the machining of less important engine parts, while Assembler A has promoted improvements in its fabrication process aimed at enhancing quality and reducing costs (engine cold start testing) and is beginning a project designed to carry out machining of the cylinder head internally.

Still with regard to the infrastructural areas, Assembler A has invested in logistics improvements through rationalization of transport (cargo) and increased contact with suppliers. Assembler B is investing in the development of new products, new generation engines which, according to the interviewee, present gains in power, autonomy and economy. Also worth mentioning are Assembler C’s efforts to meet market needs, which has driven the company to make constant alterations in product design and increase its product mix.

Assembler D, which prioritizes mix flexibility in the first place and reliable deliveries in the second, has a differentiated operations strategy among the four companies studied here insofar as the structural areas are concerned. Assembler D concentrates its engine production at a single plant in the same manufacturing unit where it assembles is vehicles. Its production capacity is low compared with the other automakers, but is compatible with the company’s market share. Among the companies studied it is the most outsourced, since it does not manufacture any component, but only assembles the engine. Its assembly line is less automated than that of the other automakers installed in Brazil and the company’s engine unit is located in its country of origin. With regard to product technology, Assembler D’s products have the same technological standard as that of the other automakers, although the company works with a limited product mix when compared with that of Assembler A, Assembler B and Assembler C, for example.
In the infrastructural areas, Assembler D used an ERP system developed internally for production planning and control. It has a corporate quality program and holds quality system certification, using the various quality tools to control and improve the quality of its products. In the area of supplies, the company has 60 suppliers per type of engine, most of them located in the state of São Paulo, with whom it communicates through an EDI system. The work organization prioritizes manual labor – only 20% of the processes are automated – and uses diverse tools and concepts based on the Toyota Production System.

Assembler D has also promoted changes in its structural areas, the most important of which at this time is the 30% expansion of its production capacity through the introduction of new equipment and changes in the work organization of the assembly line. Two aspects deserve to be highlighted in the infrastructural areas. The first is the intensive effort the company has made to increase the index of nationalization of its supplies. Two of the main results of this process are cost reduction and increased flexibility (agility). The second aspect is the hiring of a significant number of engineers over the next few years.

Assembler E and Assembler F regard quality and cost their primary priorities. The two companies have a single plant in Brazil, with similar production capacity, level of automation and product technology. With regard to vertical integration, they also show similarities. Three of the main engine parts, i.e., the engine block, crankshaft and cylinder head, are purchased from third parties and machined in-house.

In the infrastructural areas, both Assembler E and Assembler F use an operations management system based on the Toyota Production System or Lean System. Thus, they utilize a set of concepts and tools aimed at standardizing operations, increasing production flow, and providing ongoing quality improvements. In addition, they have their own ERP information systems for production planning and also use JIT and Kanban concepts. With regard to quality management, like the other companies studied here, Assembler E and Assembler F have a corporate quality program, their quality systems are certified, and the use of quality tools is widely disseminated throughout the companies. The work organization on the shop floor at both companies is characterized by the use of resources inspired on the Japanese model (team work, versatility, intensive signaling, etc.). In terms of supply management, the two companies have a similar degree of component nationalization, acting with one supplier per item, components are delivered with quality guarantee, most of their suppliers are concentrated in the state of São Paulo (450 km away), and the delivery logistics are under the responsibility of third parties.

Among the actions recently implemented by these companies is the implementation of the management system based on Lean Manufacturing. It should be noted that the management system at Assembler F appears to be more consolidated, since it was implemented earlier. In 2005, Assembler E concentrated its efforts on drastically reducing the level of its inventories and making effective use of the various tools that constitute the management model adopted (Kaisen, TPM, FMEA, PDCA, etc.), aiming to improve quality and reduce costs. Assembler F, in turn, invests in increased nationalization of its supply base and in supply chain management, since it considers that 70% of its costs are outside the plant. To this end, it is bringing its suppliers to the Assembler F plant and offering training in Lean Manufacturing tools to reduce stocks, waste and lead time.

Table 2 summarizes some of the main actions that are being implemented by the companies of this study, aiming to reach the performance levels dictated by their strategies.

To conclude this analysis, it is opportune to highlight the similarities and differences in the following strategic groups of companies: Established (Assembler A, Assembler B and Assembler C – operating in the Brazilian market for more than 20 years) and Newcomers (Assembler D, Assembler E and Assembler F – operating in the Brazilian market since the mid-90s).

Within the group of Established companies, it is clear that the automakers adopt similar competitive strategies, participating in about the same way in the various market segments of the automotive industry and attributing similar roles to their engine plants. Thus, when analyzing their
respective operations strategies, it should not be surprising to find that their competitive production priorities over the years have been similar. However, their operations strategies also reveal significant differences, marked by some of their structural and infrastructural decision-making areas – especially the degree of vertical integration and supply management.

**Table 2 – Principal Actions carried out by the Engine Plants**

<table>
<thead>
<tr>
<th>Automaker</th>
<th>Principal Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembler A</td>
<td>Improvements in supply and delivery logistics; increased contact with suppliers; incremental improvements in the manufacturing process aimed at improving quality and reducing costs; project for in-house machining of the cylinder head.</td>
</tr>
<tr>
<td>Assembler B</td>
<td>Reduction of the degree of vertical integration; investment in machinery and equipment for the new generation of engines; development of new products.</td>
</tr>
<tr>
<td>Assembler C</td>
<td>Outsourcing of the machining of less important engine parts; constant alterations in product designs, expanding the product mix.</td>
</tr>
<tr>
<td>Assembler D</td>
<td>Expansion of production capacity; increase in the degree of nationalization of its supply base; development of the product design area in Brazil.</td>
</tr>
<tr>
<td>Assembler E</td>
<td>Implementation of a Lean Manufacturing-based management system; reduction of stocks; effective use of management tools for reducing cost and improving quality.</td>
</tr>
<tr>
<td>Assembler F</td>
<td>Implementation of a Lean Manufacturing-based management system; increased nationalization of its supply base; and improvements in supply chain management.</td>
</tr>
</tbody>
</table>

The past trajectories of these companies (insofar as operations strategies, production structures, and experienced and accumulated competencies are concerned) strongly shape their present and future initiatives. Thus, for instance, Assembler B and Assembler C’s shift toward outsourcing (of engines) can still be considered slow compared to that of Assembler A. Also with respect to relationships with suppliers and supply management, the three companies analyzed here employ distinct schemes. Assembler C seeks long-term relationships with large suppliers geographically located more than 350 km away. Assembler B adopts practically the same policy, but within a structure in which its suppliers are located closer to some of its manufacturing units. As for Assembler A, it does not apply the principle of long-term relationships so strictly, seeking, instead, to exploit the advantages that may be gained from relationships with smaller suppliers located closer to its engine plant.

Among the newcomers, one notes initially that Assembler E and Assembler D have similar competitive strategies, for they maintain – at least for the time being – a relatively small product mix directed at the same segments of the Brazilian and Mercosur markets. However, their operations strategies (and respective trajectories) are quite dissimilar. Assembler D is the most outsourced of the companies analyzed here, while Assembler E has a high degree of vertical integration similar to that of Assembler C, higher than that of Assembler D and Assembler A but lower than that of Assembler B. Moreover, Assembler E and Assembler D’s competitive production priorities differ, basically because their idle capacity rates are very different. Apparently, Assembler D gained advantages from the later (in time) implementation of its engine plant – already in an environment in which low displacement engines (1000cc) were losing market share, and after having benefited from a partnership with Assembler E – and from its strategy of incremental additions to its production capacity. Assembler D is also making gradual advances in its component nationalization rate and in the local formation of a product/process development structure.
Assembler F’s competitive strategy is very different from that of the other companies (including the two newcomers): the company produces a small mix of engines, all destined to the export market. Its operations strategy is comparable to that of Assembler E. These two companies have similar competitive priorities, which may be explained by the similarity in their production-to-capacity ratio. Both invest in the implementation of the lean production model, aimed primarily at improving the efficiency of their production processes, thus reducing costs and enhancing quality.

CONCLUSIONS
To summarize the main findings of this survey, we began by compiling the similarities and differences that are independent of the subgroups (mature or newcomers) to which these companies belong. As we have seen, an important characteristic of these companies, simultaneously the operations strategy and the supply chain, is the degree of outsourcing. Companies in the mature and newcomer groups adopt relatively low or high degrees of outsourcing, which are associated to other characteristics of their structural and infrastructural areas, particularly to the structural characteristics of the supply chain.

Other strategic choices involving supply chains, a good part of them made during the period of installation of these companies or of new plants, such as plant location and supply policy – involving the choice of ports, technological capacities, number of suppliers per item, location of suppliers and types of relationships with suppliers –, have a long-term impact and shape the operations strategies.

There are also similarities and differences among the companies with respect to the decision-making areas unrelated to the classification of mature or newcomer companies. The logic behind decisions about the management of operations, production planning and control, and quality is given by the lean production model, although there are variations in the practices adopted and in the stage of their application in relation to the theoretical model. In the case of quality system, for example, the required certifications and the wide diffusion of quality practices ensure a fairly homogeneous standard of behavior in these areas of the automotive industry.

We also found important differences between the mature and newcomer groups, a significant part of them resulting from the length of time the companies had been operating in the Brazilian market, as well as from the varieties of models produced. The mature companies have prioritized dimensions relating to the flexibility of production systems, while the newcomers have focused on quality improvements and cost reduction, seeking to increase their competitiveness and market share.

In the group of mature companies, the choices regarding the degree of outsourcing have varied over time, but recently the implemented moves have rendered their production systems more similar to each other. On the other hand, it is interesting to observe that distinct supply chain policies have reinforced the differences in their operations strategies.

As for the newcomers, the three companies produce only a few types of engines in relatively small numbers. One of them directs its production to the export market and stands out for adopting a production system with an intermediary level of outsourcing, managed along the lines of lean production. The other two companies, oriented toward the domestic market, adopt different market penetration strategies that condition the operations strategies adopted so far. One of them has adopted a strategy of greater outsourcing and has sought to expand its production (assembly) capacity at a pace consistent with the growth in the demand of its products. The other company established a plant with a lower level of outsourcing and with an initially high production capacity in relation to its market share.

We have seen, therefore, that decisions involving supply chains – location, degree of outsourcing and supply policy – can shape the operations strategies of companies for many years to come. These decisions are made, however, considering the competitors’ moves, so that significant differences tend to diminish in the medium and long term.
REFERENCES


