5
Empirical Study on SCF

This section presents and analysis the empirical findings gathered with the exam of the main restrictions at various tiers that limit the SC ability to provide flexibility to the end-customers of the three supply chains studied.

5.1.
Supply Chain A

This SC is already well-established and responsible for producing and distributing vehicle models from a multinational OEM, including one of the best-selling passenger cars in South America. Most of these models belong to the low-cost market segment, and most of their sales include a 1.0 liter engine.

During the recent years, the Brazilian auto market was experiencing significant and beyond the expected demand growth. As a result, dealers and the OEM's regional sales departments increased their orders to the OEM plants. However, during the interviews at the distribution channel, it was evident that end-customers were limited to two external flexibility types regarding the most popular vehicle model: volume, as the market demand for this model was higher than the dealers' offerings, and mix of the available offer, as the engine requested by the market was the 1.0 liter, and the engine offered by most dealers was the 1.6 liter.

One significant flexibility restriction in the SC was the engine plant for both 1.0 and 1.6 liters. Even though this first-tier supplier could enhance its overall output from 454,000 engines to 555,000 (more than 20%) just by implementing flexible labor force journeys and contracts, this increase was not sufficient to meet the end-customers' new demand. From this perspective, this first-tier supplier creates a supply-chain limitation by restricting the volume flexibility, resulting in a loss of sales to end-customers. This supplier decided to invest US $50 million to

increase its daily production from 1,964 to 2,300 engines. In one year, the investment should conclude, and the plant should be able to meet the demand requirements. A potential problem could then arise if the flexibility limitation in the SC moves to the second-tier suppliers, especially those responsible for the engine blocks and crankshafts. Both OEM and engine suppliers are aware of this possibility and negotiate capacity increases with these second-tier suppliers, but this requires significant investments and time for negotiations and implementation. The second-tier supplier has two problems increasing its volume capacity. The first is the high investment for the tools for machining crankshafts and the time to start the new production (up to two years). Another problem is that second-tier suppliers are afraid of a future demand decrease that would make them idle again, which happened in the late 1990s after a boom in demand and high investments in capacity in the Brazilian automotive industry.

The engine case offers another interesting perspective and highlights another SC restriction by a second-tier supplier that limits the chain's ability to provide flexibility to its end-customers. The aforementioned increase in demand was stronger for the models and versions with a 1.0-litre engine, but the volume production increase was limited at the vehicle assembly plants due to a lack of this specific engine. From this perspective, the SC limitation was not the engine plant itself, but its electronic injection supplier. This second-tier supplier could not meet the engine plant's demand for the 1.0-litre engine because its production was designated for another customer with priority (another OEM that was also the supplier's owner). Because this engine component was a "black box" developed under an early supplier involvement (ESI) approach and the development of a new supplier requires time and investment, the engine plant increased the production of another engine type (1.6 liter) with another electronic injection supplier that could increase its volume sales. The availability of more 1.6-litre engines made the OEM produce more models using these engines. As a result, these models were pushed to dealers, resulting in a mix flexibility restriction to end-customers that absolved the 1.6-litre engine vehicles with discounts. Figure 1 summarizes the SC A findings, concerning demand increasing.

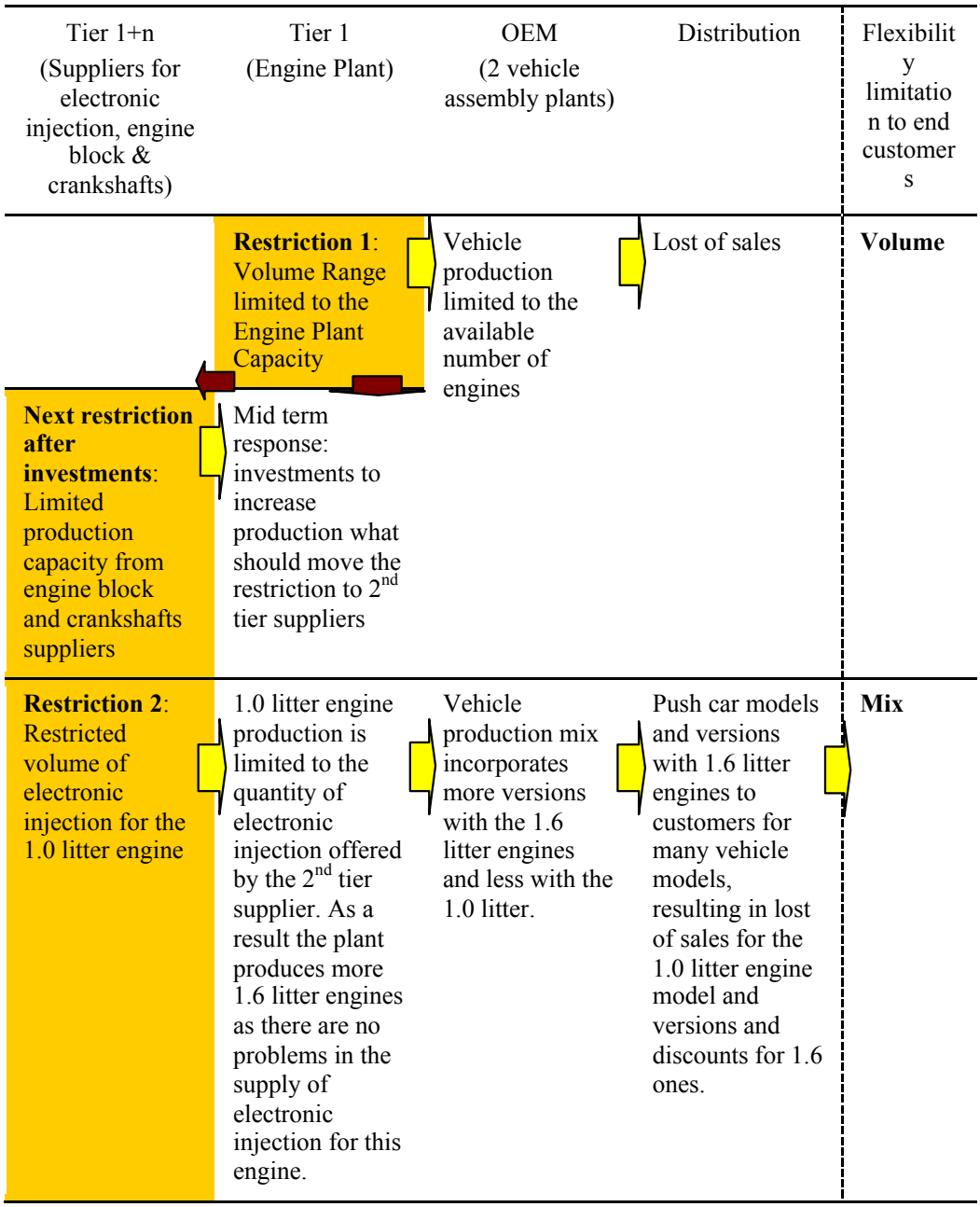

Figure 2- Flexibility Restriction in Supply Chain A due to an unexpected increase in demand.

During the interviews with the managers of the OEMs and the engine plants, it was possible to identify another case in which restrictions in the SC at the second-tier supplier level limited the chain's overall ability to provide flexibility to its end-customers. This case resulted from an unexpected supplying process breakdown. One second-tier supplier responsible for two key components of the diesel engines had to stop production due to financial problems. Because it was a single sourcing operation, the engine plant of SC A could not produce diesel

engines to deliver to the vehicle assembly plant, which led to cancellations of sales by the OEM of vehicle models and versions with this fuel for several months. A new second-tier supplier was developed, but in the short term, there was a loss in sales and a high inventory level of diesel engine components that could not be used. Figure 2 summarizes the SC A findings, concerning supplying process breakdown.

Tier 1+n (supplier of diesel engine components)	Tier 1 (Engine Plant)	Vehicle assembly (3 vehicle assembly plants)	Distribution	Flexibility limitation to end customers
Restriction: no production of 2 key components for diesel engines due to their plant bankrupt.	Stop of the diesel engines production. The plant has changed its production mix to other engines.	The plant cannot produce models' versions with diesel engine, changing the mix to other versions that use different fuels.	Lost of sales: no exports of vehicle models with diesel engines.	**Mix**

Figure 3- Flexibility restriction in Supply Chain A due to a supplying process breakdown

5.2. Supply Chain B

This SC produces different vehicle models in Brazil. One of these is a highly valued compact model that is considered sophisticated for the South American market. Therefore, its end-customers are more demanding of quality and product variety. Another significant model produced is a low-cost subcompact vehicle that is largely exported to other South American markets. The SC B also has experience with component suppliers that contributed to the flexibility limitations of the chain for end-customers. Air conditioning, power steering and alloy wheels were identified as the main problems for the two vehicle models.

The first two components influenced the production mix of the vehicle assembly plants because these plants had to consider the supply volume restrictions of the component suppliers' production capacities. Thus, the OEM sales department could not offer dealers more cars with these components, resulting in a forced "push" to dealers with a mix that was not ordered. This was a

significant issue for the highly valued compact model, where only 60% of the dealers' orders containing air conditioning were delivered with the component by the OEM. Again, the SC's ability to provide flexibility to its end-customers was limited. In the case of these components, the limitation for the end-customer was mix caused by volume capacity from the OEM plant's first-tier suppliers. End-customers of the low-cost subcompact model were not completely disappointed because dealers were able to configure some of the units at their points of sales with these missing components. However, this action was not successful for the highly valued compact model because the customers were more demanding of the quality of the product and were concerned about the late configuration service done at the dealerships rather than at the vehicle assembly plants. The SC reaction took two months. A new contract was developed with the power steering supplier that involved a larger volume of procurement so that the first-tier supplier could contract and train new employees. Meanwhile, flexible labor force journeys were used to increase the production level. A second air conditioning supplier was selected because the current supplier could not cover the gap in the demand for this component.

The supply limitation of alloy wheels offers another interesting case. Depending on the vehicle model, the consequence to end-customers was different. For the cheap subcompact model, there was a mix flexibility restriction to end-customers because the model was pushed downstream with steel wheels instead of alloy wheels. For the highly valued compact model, there was a volume flexibility restriction. Because this model could not be pushed downstream with steel wheels due to its basic configuration, the OEM had to reduce its production at the vehicle assembly plant. The potential end-customers for this model were disappointed because the units delivered to dealers were insufficient to meet the demand, resulting in lost sales. Within the next six months, the OEM negotiated an increase in production capacity with the alloy wheel supplier because it did not succeed in finding available capacity from other suppliers. Figure 3 summarizes the SC B findings.

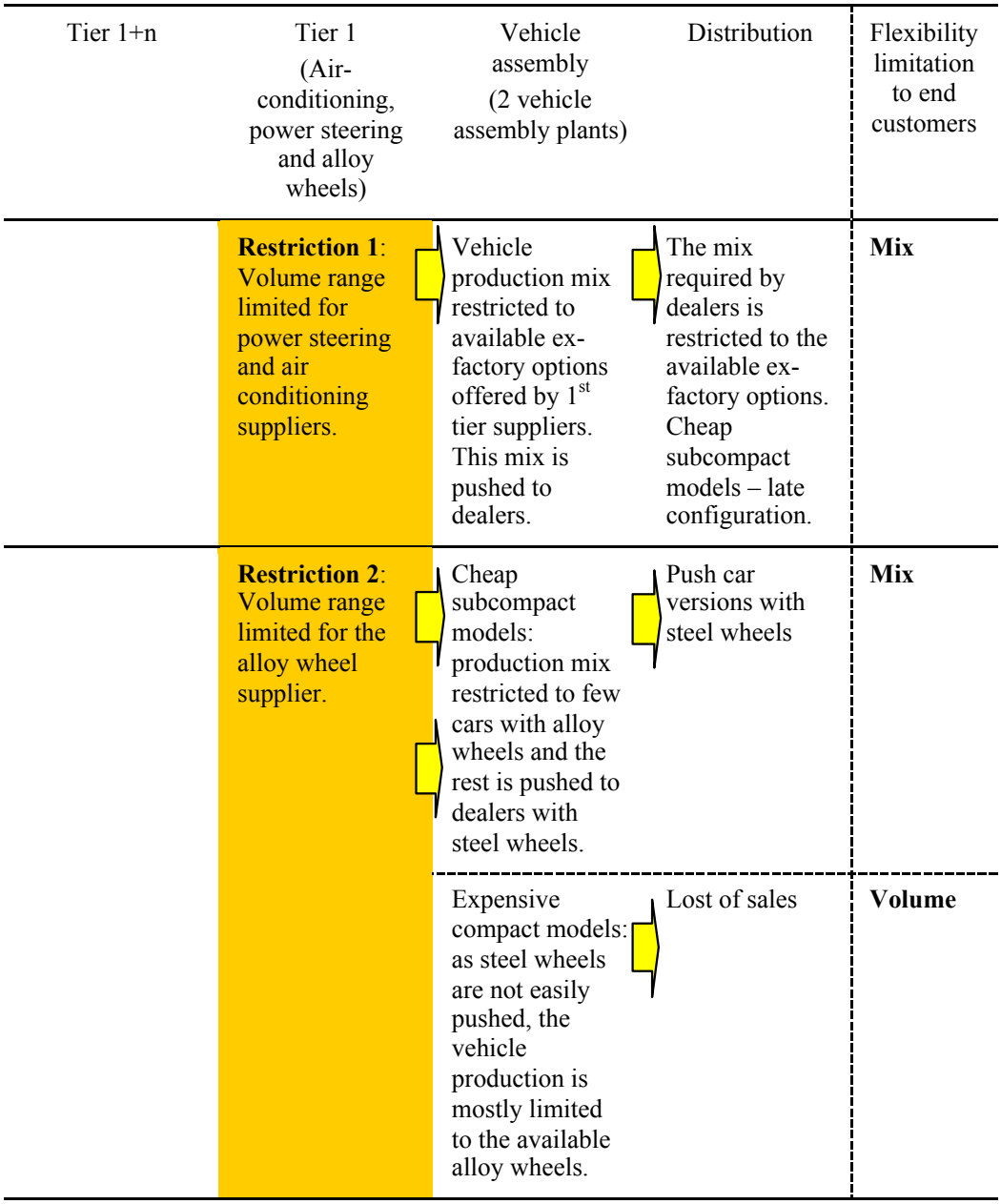

Figure 4- Flexibility restrictions in Supply Chain B due to an unexpected increase in demand focusing on significant auto parts

5.3.
Supply Chain C

In contrast to the other SCs where the respective OEMs had been producing in plants in Brazil from the 1960s, the OEM of SC C is a newcomer to the Brazilian market that established its first local vehicle assembly plant in the 1990s. Like many newcomers, this OEM began producing in a greenfield area, attracted by government incentives. Far from important auto-part suppliers and

with poor road and train connections, the new plant established a supplier park nearby to locate significant first-tier suppliers, mitigating the logistics problems associated with the greenfield location choice and increasing its logistics flexibility (the potential to receive products rapidly and cost effectively). Another common characteristic of many newcomers is the initial production of only one vehicle model based on many imported components but with an increasing local content program. Because this vehicle model was highly valued, the product variety offered to end-customers was an important issue for the OEM.

The interviews at dealers and the OEM's regional office highlighted the mix flexibility limitation to end-customers during the first year of vehicle production in Brazil. During the launch of the new vehicle model, the local market currency experienced a significant devaluation. Because many of the vehicle components were imported (as is the case of engines and transmissions), its cost/price increased significantly, resulting in a significant decrease in this vehicle model's sales from the planned forecast. As a result, the vehicle assembly efforts were concentrated in just two of the four original versions, which reduced the mix range offered to end-customers. These two versions had to use components that were already in the pipeline, further reducing the mix within these two versions. For instance, vehicles were produced during the first year with the doors and seat trims that were in stock or with orders already placed (purchased). This prevented end-customers from ordering available trims in the catalogue, restricting their choices to the available trim in the SC pipeline. Figure 4 summarizes the SC C findings.

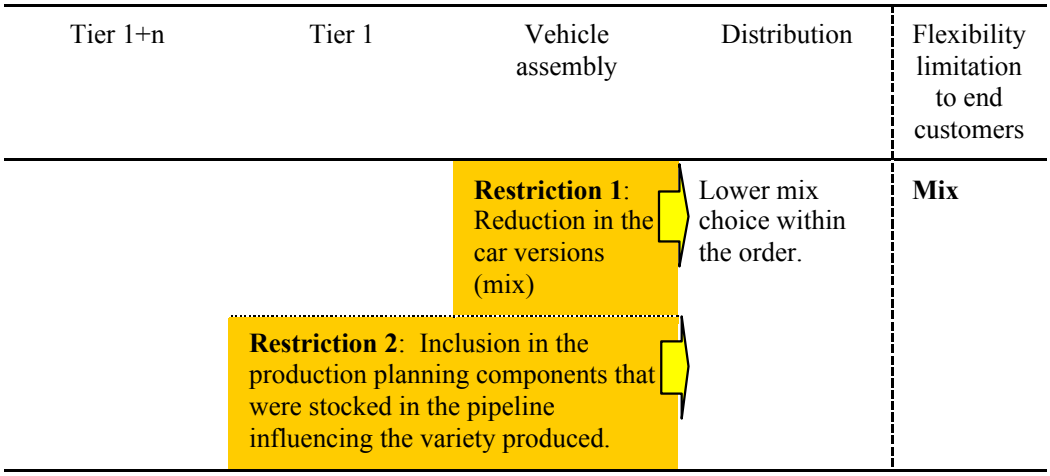

Figure 5- Flexibility restriction in Supply Chain C due to an unexpected decrease in demand

5.4. Additional findings

The OEMs' order-to-delivery strategies for SCs A and B are mainly forecast driven for their low-cost vehicle models, with no significant vehicle sales built to customer orders (less than 1%). Accordingly, dealers must fully specify their orders (in terms of volume and mix) many weeks prior to production. This period is considerably longer compared to their parent companies' operations, where minor changes can be accommodated up to a week prior to production. As a result of this long order lead-time, dealers postpone decisions about the final specification of a vehicle until they have a specific customer order for it because they find it difficult to accurately match actual consumer preferences. Therefore, they prefer not to order certain specifications ex-factory to reduce their forecasting error if these specifications can be late configured once an actual customer order is received.

The chains' ability to provide flexibility to their end-customers is initially restricted because dealers only order mainstream combinations to OEMs to avoid the high inventory costs of low-cost vehicles with undesirable combinations at the distribution channel. However, late configuration is adopted among dealers (with a high mix response/ short lead time for end-customers because the inclusion of options is done within one day at the dealer) in an attempt to increase the mix range number output to end-customers. However, the heterogeneity of individual

product variants must be considered. This increase is mainly for peripheral variants that have a lower degree of difference compared to fundamental varieties (i.e., factors that lead to a different body-in-white manufacturing process). This leads to a low mix range heterogeneity offered to end-customers. Figure 5 summarizes the additional findings on SC A and SC B.

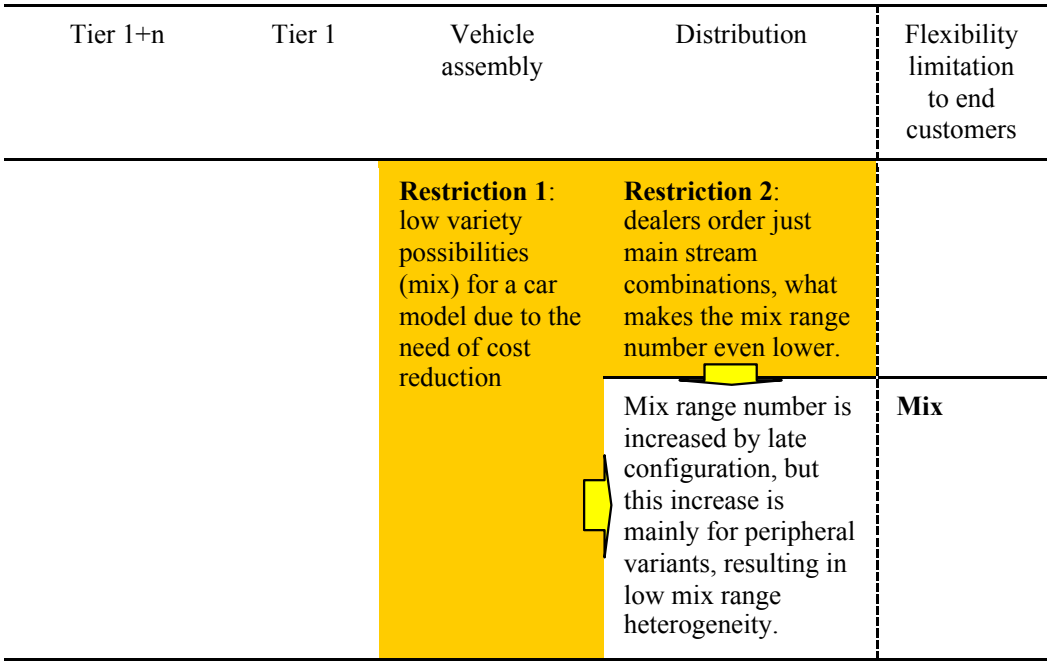

Figure 6- Flexibility restrictions in Supply Chains A and B due to long order lead-time