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# Information Systems for Early Supplier Involvement in Brazilian Automotive Supply Chains

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ABSTRACT

The aim of this paper is to identify whether in an automotive industry context with structural, technological and regulatory problems, information systems help the new product development (NPD) process to achieve development time reduction, cost reduction and product quality improvement due to an easier and more accurate data exchange or only because they allow faster information sharing among chain members. The research was developed using a qualitative and descriptive methodology and adopted as focal company a Brazilian auto parts company in order to evaluate its relationships with three suppliers and its three largest customers, composing three different supply chains (SCs). Results suggest that information systems have been widely used as tools for collaboration among the SC members, with expressive gains in competitiveness because it makes data exchange faster. Nevertheless, significant shortcomings still exist, especially regarding system integration and the consequent integration level among SC members.

PALAVRAS-CHAVE

Gestão da cadeia de suprimentos, Envolvimento antecipado de fornecedores, Sistemas de Informação, Indústria automotiva.

RESUMO

O objetivo deste artigo é identificar se, em um contexto da indústria automotiva com problemas estruturais, tecnológicos e regulatórios, os sistemas de informação auxiliam no processo de desenvolvimento de novos produtos (DNP) para redução do tempo de desenvolvimento, redução de custos e melhoria da qualidade do produto devido a uma troca de dados mais precisa ou apenas porque permitem o compartilhamento mais rápido de informações entre os membros da cadeia. A pesquisa foi desenvolvida utilizando uma metodologia qualitativa e descritiva e adotou como empresa focal uma empresa brasileira de autopeças para avaliar suas relações com três fornecedores e seus três maiores clientes, compondo três diferentes cadeias de suprimento (CSs). Os resultados sugerem que os sistemas de informação têm sido amplamente utilizados como ferramentas de colaboração entre os membros da CS, com ganhos expressivos de competitividade, pois fazem com que a troca de dados seja mais rápida. No entanto, ainda existem deficiências significativas, especialmente em relação à integração de sistemas e ao consequente nível de integração entre os membros da CS.

## 1 Introduction

Supply Chain Management (SCM) has been developed in a particularly intensive way in the automotive industry. Among the SCM processes, this paper focuses on the New Product Development (NPD) process, which is critical in terms of both strategic and operational perspectives of automotive Supply Chains (SCs) (Toledo et al., 2008; Matos, 2014).

NPD in the automotive industry is complex, as it requires the active participation and coordination of several chain members with different organizational structures, human and technological resources, and knowledge that must be aggregated with the project to generate a safe and competitive product (Toledo et al., 2008). In this sense, Early Supplier Involvement (ESI) is one of the SCM practices that has been growing and becoming common in organizations, partly due to the adoption of an open and innovative approach, and also due to the growing trend of using external sources in NPD (Schiele, 2010; Terpend et al., 2008; Hernández-Espallardo et al., 2010).

As in other SCM processes, NPD must occur in an effective way, which requires continuous information flow (Pires, 2016) and support from appropriate information systems among SC members (Prajogo & Olhager, 2012). Studies have suggested better SC performance resulting from partner involvement in NPD processes, mainly through developed capabilities to handle changing environments (Mishra & Shah, 2009; Lau, 2011; Feng & Wang, 2013). Through better Supply Chain Integration (SCI), enterprises can absorb and share specialized knowledge more effectively (Flynn et al., 2010). Effective integration among suppliers to develop new products can provide cost reduction, quality improvement and development time reduction (Majumder et al., 2017; Eisto et al., 2010; Luo et al., 2010; Cerra et al., 2011; Dalvi & Kant, 2015). These benefits are particularly important in environments such as Brazil, a country that faces several challenges in developing its automotive industry.

Nowadays, the automotive industry in the country faces structural, technological and regulatory problems. The structural challenges are related to the nation’s infrastructure, as the country still needs to develop its internal logistic infrastructure. The technological issues are related to the cost of accessing and developing new technologies, including hardware and information systems. As far as regulatory problems go, automotive executives are asking for more transparency in the guidelines/rules on the subject (Keese et al., 2014; Pascoal et al., 2017).

Therefore, the aim of this paper is to identify whether in the automotive industry context with structural, technological and regulatory problems, information systems help the NPD process to achieve development time reduction, cost reduction and product quality improvement, and if this occurs due to easier and more accurate data exchange or because they enable faster information sharing among chain members.

One justification for this research is the automotive industry’s importance to the Brazilian economy, which in 2015 accounted for 22% of the industrial gross domestic product (GDP) and 4% of Brazil's GDP, generating about 1.3 million direct jobs and indirect jobs (Anfavea, 2019). An important part of this industry, the auto parts sector has been recording worrying deficits in the trade balance since 2007, with a peak in 2013 of around 10 billion dollars negative. In 2014 the negative result was about 9 billion dollars and since then it keeps a deficit of 5 billion dollars each year. This deficit is due to the great increase of imports, much higher than that of exports. This threat to the national automotive industry is a consequence of Brazil’s low competitiveness compared with the global market, and it is due, among other factors, to the country's macroeconomic situation, especially its high production and distribution costs (structural issues), high capital costs leading to difficulties with accessing new technologies (technological issues), high tax burden and inflexible employment legislation (regulatory issues) (Sindipeças, 2018).

Another justification for developing this study is that, according to Feng and Wang (2013), little empirical evidence shows how different SC partners’ integration (SCI) degrees influence NPD performance process. In this sense, some authors argue that studies have investigated NPD performance through separate efforts, for example: through a focus on customer involvement (Fang et al., 2008; Svendsen et al., 2011), supplier involvement (Lakemond et al., 2006; Johnsen, 2009) and internal involvement (Troy et al., 2008; Love & Roper, 2009), but not considering enterprises’ internal and external resources in SCI along the SC.

## 2 Theoretical Framework

### 2.1 SCM and New Product Development process

SCM has been increasingly recognized as the key to efficient and effective companies' integration in their SCs and business processes (Lambert & Schwieterman, 2012). The SCM concept includes planning and coordinated management of the processes and activities of a SC, which integrate offer and demand management with the flow of money, materials and information within this chain (Mentzer et al., 2001; CSCMP, 2019).

Among the SCM models available in the literature, one of the most important is described by Lambert and Enz (2017), detailing eight SCM processes: (1) customer relationship management; (2) supplier relationship management; (3) customer service management; (4) demand management; (5) order fulfillment; (6) manufacturing flow management; (7) product development and commercialization; and (8) returns management.

Thereby, the NPD and commercialization is a key process for company and SCM success, demanding interaction between chain links for joint creation of goods that can generate a competitive advantage (Lau, 2011; Feng et al., 2010; Matos, 2014). Feng and Wang (2013) argue that two kinds of SCI exist: II (Internal Involvement) and EI (External Envolvement). Regarding EI, Mentzer et al. (2001) argues that it arises from customer and supplier integration. Mishra and Shah (2009) and Feng and Wang (2013) specify II as the result of internal coordination to share information and resources to develop costly and time-efficient NPD, whereas EI concerns the degree to which a company can involve its more relevant SC members in the NPD process.

Zhang and Li (2010) also consider that customer and supplier integration is essential for filling gaps related to the technical resources and capabilities needed in the NPD process. Gimenez and Ventura (2005), however, point out that due to the nature of organizations and people, conflicts can arise from joint work. Therefore, enterprises must act in a synergic and collaborative manner to solve internal problems before initiating joint work with SC external partners. Otherwise, these conflicts can become more complex and difficult to solve (He et al., 2015).

The product development and commercialization process systematize the introduction of new products into the market, together with customers and suppliers, and if properly conducted, it may represent a significant competitive advantage for companies. This is because it coordinates SC activities required for efficient materials and information flows from marketing, manufacturing, logistics and other areas reducing time to market, which is critical for company's success in long term (Rogers et al., 2004).

From the standpoint of product project, developments are classified into four types: new product platforms, derivatives of existing product platforms, incremental improvements to existing products and new products. Development strategies must consider these differences among the four types and also the growth trend of incorporating services into the product, which is an important differentiation source and value added to the product (Rogers et al., 2004; Lambert & Schwieterman, 2012).

NPD in the automotive industry is, in general, performed according to the advanced product quality planning methodology (APQP), which a set of values, notably the cross-functional team and concurrent engineering, guides. Diverse organization sectors involved in a project form the cross-functional team, and participation of customers and suppliers should ensure it. Concurrent engineering recommends carrying out development activities in a parallel way with the aim of reducing time and development costs and increasing the product quality. APQP involves data and information exchanges among SC companies, especially in product drawings, engineering specifications, mathematical data from product modelling, assessment reports and approval of products and processes, which requires compatibility among customer systems, suppliers and subcontractors. The APQP demands SC links involvement in product development process and considers, besides the product design, aspects related to production process and logistical issues. In this way, it is aligned with SCM concepts, especially regarding ESI (IATF, 2008).

### 2.2 Early Supplier Involvement

ESI is a SCM practice that proposes suppliers' involvement in early stages of product development and incorporation of their skills into the process (Pires, 2016). The degree of supplier involvement in NPD is part of decision-making process of "making or buying". Le Dain et al. (2010) point out that both academia and business environment treat this as a binary process, but its complexity is greater. This complexity is due to decisions as design internally, buy the project, involve supplier in the various stages of development or even develop the project together with what can be called project chain. The automotive sector is one of the most dedicated to structuring the decision-making process of "designing or buying the project," as it has traditionally been inefficient, mainly due to the lack of synchronism between design and purchase decisions.

The interaction between customer and supplier in NPD can occur at several points of project: (a) idea generation: customer voice; (b) preliminary business/technical assessment; (c) product/process/service concept development; (d) product/process/service engineering and design; and (e) prototype building, testing and piloting/ ramping up for operations (Petersen et al., 2005). The degree of each supplier's involvement in a specific project depends on factors such as the supplier's responsibility level in project, and associated development risks (Hudnurkar et al., 2016). The higher the development risk and the greater the supplier's responsibility in process, the more intense and earlier the supplier's involvement in NPD must be (Quiescenti et al., 2006; Petersen et al., 2005; Schiele, 2010).

ESI benefits have been widely reported in both qualitative and quantitative studies. Suppliers' integration allows for performing activities in parallel, advances the preparation of customer orders, provides extra personnel and reduces the internal complexity of projects that might shorten the critical path, resulting in development time reduction (Petersen et al., 2005; Le Dain et al., 2010; Eisto et al., 2010; Cerra et al., 2011). Incorporation by suppliers of technical process knowledge into product design, along with proposed changes in materials and geometry lead to improved product manufacturability and reduction of scrap and rework rates, thus positively impacting product quality (Mcivor & Humphreys, 2004; Eisto et al., 2010). Suppliers' contributions to solutions that increase process productivity and improve manufacturability allow for cost reduction (Mcivor & Humphreys, 2004; Luo et al., 2010). Proving these points, Kanapathy et al. (2014) conducted a survey with 146 manufacturing companies in an emerging economy and demonstrated that supplier involvement has a significantly positive impact on NPD project performance in terms of quality objectives, design objectives, cost objectives and "time-to-market" objectives.

Dekkers et al. (2013) address the interface between product design and manufacturing and highlight the importance of supplier involvement and articulation through information and communication technologies (ICT), both hardware and software. Early involvement, knowledge sharing and supplier strategic focus on innovation have a strong impact on product development and in SC. The authors emphasize that especially information systems feature, like interface among design, engineering and manufacturing, needs to be further explored.

## 2.3 Information System in New Product Development

Supply chain materials flow must be backed by information flow that is supported by an appropriate technological infrastructure aimed for sharing information with other chain members. Information systems' integration thus involves technological and management aspects. Both information and material flow integration are important for SC integration, having significant effects on quality, flexibility, delivery and cost performance. Moreover, building good communication and trust for information sharing are essential in SC integration (Prajogo & Olhager, 2012; Qrunfleh & Tarafdar, 2014; Aguiar et al., 2015).

Information flow plays an important role in NPD because it facilitates and influences decision-making throughout the process. An example is the use of information about customer needs, available technologies and production costs in decisions concerning establishment of product specifications during concept phase. Product specifications are used in making decisions during project detailing and prototype design (Yassine et al., 2008).

Nambisan (2003) discusses the contribution of information systems to NPD, mapping four major potential contribution areas: (a) process management; (b) project management; (c) knowledge management and information; and (d) collaboration and communication. The information systems stand out as support for product data exchange between companies, due to their potential for use as visual modelling tools and to their ability to facilitate concurrent product development and engineering.

One information systems used for NPD in automotive industry is Computer-Aided Design (CAD). Fernandes et al. (2005) point out the importance of CAD systems in the simultaneous engineering implementation. Managing large amounts of data and information exchanged between multidisciplinary teams was a bottleneck without involvement of advanced tools, such as CAD systems. CAD systems are widely applied in the geometric definition, in engineering analysis and product documentation, and in information exchange with other information systems among SC members, serving as main integration tool among different product development systems (Figueiredo & Romeiro Filho, 2011).

However, the existence of many CAD systems on the market, despite causing a large amount of sector competitiveness and providing more choice to users, causes difficulty in integrating data among various systems used throughout the SC, and even inside an organization, because most of these different systems do not recognize directly the data that other systems generate. To get around this limitation, translators and neutral formats for exchanging geometric data were developed, such as STEP, IGES, DXF and SAT, which allow a system's files to be converted into another system format, first passing by a neutral format. File conversion provides significant time saving and quality because it avoids the need to reshape product in each system used throughout process, which, besides being costly in terms of both time and resources, may lead to discrepancies between original model and its versions. Nevertheless, conversion process is not perfect and often results in information loss, which generates rework and can, in extreme cases, cancel data conversion benefits (Madenas et al., 2015; Kim et al., 2008).

In addition to CAD systems, other important systems that, together with CAD, form the concept of Computer-Integrated Manufacturing (CIM) are the Computer-Aided Manufacturing (CAM) and Computer-Aided Engineering (CAE). These systems, when mainly used together with data shared by SC members, provide a significant competitiveness increase for involved companies (Figueiredo & Romeiro Filho, 2011) and can truly represent a shift paradigm in NPD (Kanapathy et al., 2014).

## 3 Methodology

Literature review was foundation for methodology definition, since research objective arose from it and allowed creation of two propositions:

**P1**: Information systems provide a high level of integration among SC members, making data exchange easier and more accurate, which results in development time reduction, costs reduction and product quality improvement in the NPD process.

**P2**: Information systems can help companies' NPD, especially concerning the ESI practice, and positively impact the development time reduction, cost reduction and product quality improvement because they allow faster information sharing among chain members.

These propositions resulted in three analysis categories: product quality, development time and product cost. This paper is based on case study protocol and conducted through a qualitative and descriptive research type, with an intentional and non-probabilistic sample.

Case study is considered a good research strategy because it helps understand a specific social reality that would be very difficult to capture through other procedures (Yin, 2015). Although case study method has limitations toward results generalization and can present issues such as self-evident findings and bias in data collection process, this approach was considered suitable due to focal company importance.

Brazilian automotive industry, besides its importance to Brazil economy, is considered very meaningful to automotive industry in general. With several multinational brands operating in a country with structural, technological and regulatory problems, it is very important to identify how to improve its productivity and overall product appeal (Keese et al., 2014; Pascoal et al., 2017) that could be used in other markets. The chosen focal company is relevant in this context because it is an auto parts company that fulfills the main Tier 1 suppliers and automakers in Brazil. The analysis unit is meaningful and methodologically relevant since the company is an integral part of several

Brazilian automotive SCs, with a unique insight into NPD in the sector. Therefore, the company represents a critical case, following Flyvbjerg's (2006) definition. A critical case permits logical deductions as valid or not valid and allows researchers to understand important lessons about proposed topics.

The research investigates customers' SCs that represent about 90% of focal company revenues, since they are global enterprises and are situated among the greater automakers in Brazil and worldwide, with great power to impose their management practices over their SCs. The focal company's suppliers carry out essential NPD services and three suppliers were considered. The NPD was analyzed regarding interaction between focal company, its three main customers and three service suppliers. Thereby, the research considered three automakers chains that focal company is part of. Data collection occurred through direct and participant observation, and data were also derived from seven semi-structured interviews with focal company representatives of areas:

– Logistics: logistics supervisor;

– Quality: quality manager and quality analyst;

– Engineering: engineering manager and senior tooling designer;

– Commercial: sales manager and NPD coordinator.

The interviews sought to evaluate how the NPD is conducted and managed in focal company, what information systems are used, what kind of interaction there was among the focal company, its customers and suppliers and how, in the interviewees' opinion, information systems assist in this process and impact product quality, development time and costs.

The way NPD is conducted and managed in focal company impacts the three automaker chains that focal company is part of. A semi-structured questionnaire was created from literature review, and examples of the questions that verified these topics are: "what types of information and electronic data are exchanged by the focus company, the customer and the suppliers?"; "how are the exchanged data used by the focus company, the customers and the suppliers?"; "what benefits are obtained and what difficulties are encountered in the process?"; "how are information and data exchanged during the NPD's impact on product quality, development time and product costs?"

Data analysis had a similar structure to that suggested by Miles and Huberman (1984). Thus, after being transcribed, data were organized with respect for topics of the applied questionnaire. Information was then reduced in relation to created analysis categories. As a next step, within each analysis category, data were separated and displayed identifying associations and differences in order to clarify the findings. To avoid self-evident findings and bias in collected data, researchers also used the knowledge gained during observations on company operations. This strategy allowed interviews and data to be compared to company activities alongside comparisons to assumptions pointed out in the literature review. Finally, data verification and a draft of conclusions were created in order to identify main points that could contribute to research objective. At this point, the conclusions and the case's main aspects were confronted against the two created propositions in order to identify similarities and differences. Therefore, the propositions were evaluated through verification of their confirmation/refutation.

Although the study has a clear limitation related to the quantity of interviews made, it is understood that it can contribute to generalization on theory rather than on populations (Yin, 2015). In this sense, according to Flyvbjerg (2006), the research sought to demonstrate that if proposition 1 (P1) and/or proposition 2 (P2) are valid in a context with structural problems that demand investments, economic difficulties to access information systems and regulatory demands that make operations complex, they can be valid in better contexts.

## 4 Analysis

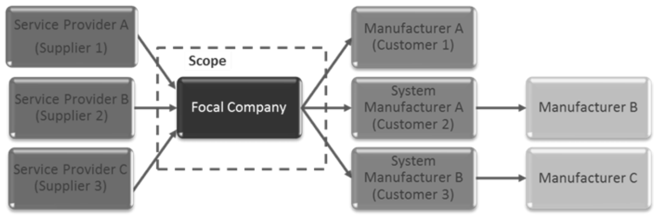
### 4.1 Case Presentation

This research considers as focal company a medium-sized Brazilian enterprise sited in São Paulo State, which is components supplier to automotive industry. The investigation focuses on use of information systems in NPD process, with particular interest in data exchange and communication among SC diverse links. The NPD and information systems used were identified and mapped by the examination of relevant internal documentation and by interviews with area representatives of the focal company that -

according to its development procedure - are directly involved in the development process.

In order to compare information exchange, a new product design was analyzed for each of the focal company's three main customers. These projects also involved focal company suppliers who participated at different stages of the process. Figure 1 shows focal company and its position in SCs as well customers and suppliers involved in analyzed projects.

**Figure 1:** Research Scope




*Source: Research results*

The involved companies' main characteristics are detailed in Table 1 and described below.

*Focal Company*

The focal company is a 100% Brazilian capital family business that has a solid and respectable reputation with customers, which has been built over a span of fifty years, regarding its deep technical knowledge in productive processes and tooling designs. Its engineering division is equipped to develop tooling design and device projects using technology aligned with best world practices such as CAD, CAM and CAE. The company also has a tooling area qualified to build part of tooling. In the case of a lack of capacity or technical resources for construction, this function is outsourced to previously evaluated and selected suppliers.

*Customer 1*

Customer 1 is focal company's biggest customer, and it registers a distinctive position in global automotive market, having a well-developed engineering area in Brazil with the autonomy to carry out its own projects or adapt projects arising from its European headquarters.

*Customer 2*

This is the focal company's second largest customer, standing out in global automotive market and being an important Tier 1 supplier that sells its products to direct competitors of Customer 1. In Brazil, it has its own engineering department prepared to develop the product independently of the American headquarters.

*Customer 3*

Customer 3 is focal company's third largest customer and, like the other mentioned customers, stands out in the global automotive market. Its engineering department has the ability to develop high-technology products independently of its European headquarter.

*Supplier 1*

Despite having only a small office in Brazil, it is a world leader in innovation and software development for engineering simulation (CAE). Supplier 1 has a highly specialized team and, in addition to selling software, provides engineering simulation and optimization services to largest industries in Brazil. The focal company, in addition to having a license for its simulation software, uses simulation and optimization services offered by this supplier.

*Supplier 2*

Supplier 2 provides tooling services to the focal company. It has computerized numerical control equipment and CAM software to define tooling machining processes.

*Supplier 3*

It provides focal company with machining service products in production phase. During product development phase, this supplier helps focal company with design of its machining devices and uses CAD and CAM systems, not only for tooling projects but also for machining process definition.

| **Table 1**: Analysed companies in research. Company | Product | Region | Size | Location | Capital |
|---|---|---|---|---|---|
| Focal Company | Parts for engines and transmission | Brazil | Medium (300 employees) | São Paulo state | 100% Brazilian privately held |
| Customer 1 | Trucks and buses | Europe | Large (12.000 employees in Brazil) | São Paulo city | Publicly traded multinational |
| Customer 2 | Engines for trucks and generators | United States | Large (2.000 employees in Brazil) | São Paulo city | Publicly traded multinational |
| Customer 3 | Electronic systems for cars | Europe | Large (2.000 employees in Brazil) | São Paulo state | Publicly traded multinational |
| Supplier 1 | Software and engineering simulation services | Europe | Small (20 employees in Brazil) | São Paulo city | Multinational privately held |
| Supplier 2 | Tooling services | Brazil | Small (20 employees) | São Paulo city | 100% Brazilian privately held |
| Supplier 3 | Machining services | Brazil | Small (50 employees) | São Paulo city | 100% Brazilian privately held |

Source: Research results

## 4.2 Findings

### *4.2.1 Product Development Processes in Focal Company*

In focal company, products are developed according to an internal procedure based on APQP manual (IATF, 2008) and also based on customer-specific requirements, as required by ISO/TS 16949, which sets quality management standard system in global automotive industry.

**Table 2:** Current stage of ESI use by focal company and its customers.

| Company | Stage where supplier is involved in project | Policies and criteria for supplier's involvement |
|---|---|---|
| Focal company | Project's initial stage: supplier involvement occurs as soon as three-dimensional (3D) models and 2D drawing are received. | It has no policy or criteria for supplier involvement. ESI application is due to the nature of projects. |
| Customer 1 | Project's intermediate stage: Focal company is involved after setting 3D model and prior to making prototypes. | Focal company doesn't know about policies and formal criteria for ESI practice. Informally, customer's engineering area communicates to focal company representatives' customers' intention to apply ESI in new developments. |
| Customer 2 | Project's initial stage: Focal company is involved in preliminary stage of product conception. | It has formalized a policy for supplier participation in early stages of development. However, there are no established criteria defining degree of supplier involvement in projects. |
| Customer 3 | Project's intermediate stage: Focal company is involved after setting 3D model and prior to making prototypes. | Focal company has no knowledge about existing policies and formal criteria to ESI practice and doesn't intend to adopt it in the short term. |

Source: Research results

The focal company does not make product design because customer is the one responsible for preparing drawings and setting specifications applied to the product. However, involvement with customers and suppliers in NPD is usually an intense and critical co-development type, because neither customer, focal company nor its suppliers have all needed knowledge to develop the product.

The high degree of uncertainty requires strong interaction between SC members. Supplier involvement has been a trend in focal company and has been occurring increasingly in early NPD phases. Additionally, involvement intensity and beginning of interaction vary according to customer and even to developed product. Table 2 shows ESI current stage use by focal company and its customers.

According to interviewees, in a typical project, customer sends to focal company preliminary CAD models, specifications and standards still in product conception stage. The customer requests that focal company, based on its own knowledge of production process, tooling design and engineering simulations, analyze the project and propose product changes, thus obtaining a more reliable product and a more robust production process.

Since there is an intense exchange of CAD files in this development stage, when the customer's CAD system and focal company system are different, it is necessary to dedicate special attention toward avoiding data loss that can severely compromise project quality and final product. This data loss can also compromise integration level among SC members, demonstrating that information systems use needs to be accompanied in order to provide a high level of integration that brings other benefits, as P1 asserts. At this development stage, ESI seems to be difficult and delays process because customer must constantly upgrade its project in line with changes proposed by suppliers and assess the impact of these changes in several of vehicular systems affected.

However, when project progresses, benefits clearly outweigh apparent initial drawbacks because a more robust project tends to avoid late product changes, which may not only compromise launch timetable but also project costs and final product quality. Therefore, it is clear that P1 and P2 were correct when they mentioned that information systems can help in development time reduction, cost reduction and product quality improvement in NPD process.

Once product is defined, tooling design, which had already been started simultaneously with product conception, is completed together with service suppliers. This stage also involves information exchange in electronic format, mainly CAD files. All data exchange among customer, focal company and its suppliers is done after signing confidentiality agreements between involved partners.

*4.2.2 Information Systems use in Focal Company's Product Development process*

Tables 3 through 6 show interview results, respectively, with focal company's commercial, engineering, quality and logistics areas.

Tables' columns describe information types exchanged between focal company and its customers and suppliers, systems used to generate information, format and media used in exchanging information and benefits and difficulties reported by interviewees arising from use of current systems.

**Table 3:** Information collected in interview with focal company's commercial area.

| Information | Company | System | Format | Exchange media | Benefits | Difficulties |
|---|---|---|---|---|---|---|
| Supply contracts or purchase order | Customer 1<br>Customer 2<br>Customer 3 | Customer ERP | .doc or .pdf | e-mail | Universal format, without the need for data conversion.<br>Ease of access for all SC members. | Lack of integration with focal company ERP. |
| | Supplier 1<br>Supplier 2<br>Supplier 3 | Focal company ERP | | | | |
| Confidentiality agreement | Customer 1<br>Customer 2<br>Customer 3<br>Supplier 1<br>Supplier 2<br>Supplier 3 | Text editor | | | | |
| Schedule development | Customer 1<br>Customer 2<br>Customer 3<br>Supplier 1<br>Supplier 2<br>Supplier 3 | Project management software | .pdf | | | |

Source: Research results

**Table 4:** Information collected in interview with focal company's engineering area.

| Information | Company | System | Format | Exchange media | Benefits | Difficulties |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 3D mathematical models | Customer 1 | Customer parametric CAD | Software original | Customer web portal or e-mail | Same focal company system, which eliminates need for data conversion. | Need for data conversion to send them to suppliers, with risk of data loss. |
| | Customer 2<br>Customer 3 | Customer parametric CAD | STEP or IGES | e-mail | Standardized format, which allows use of data by other SC members. | Need for data conversion, with risk of data loss. |
| | Supplier 1<br>Supplier 2<br>Supplier 3 | Focal company parametric CAD | | | | |
| 2D drawing | Customer 1<br>Customer 2<br>Customer 3<br>Supplier 1<br>Supplier 2<br>Supplier 3 | Parametric CAD | .pdf | e-mail | Universal format, without need for data conversion.<br>Ease of access for all SC members. | Lack of integration with focal company ERP and from suppliers. |
| Standards and engineering specifications | Customer 1 | Text editor | .pdf | Customer web portal | | |
| | Customer 2<br>Customer 3 | Text editor | .pdf | e-mail | | |
| | Supplier 1<br>Supplier 2<br>Supplier 3 | Not applicable | - | - | | |

Source: Research results

**Table 5:** Information collected in interview with focal company's quality area.

| Information | Company | System | Format | Exchange media | Benefits | Difficulties |
|---|---|---|---|---|---|---|
| Product and Process Approval Report | Customer 1<br>Customer 2 | To the discretion of the issuer | .pdf | Customer web portal | Universal format, without need for data conversion.<br>Ease of access for all SC members. | Lack of integration with focal company ERP. |
| | Customer 3 | To the discretion of the issuer | .pdf | e-mail | | |
| | Supplier 1 | Not applicable | - | - | | |
| | Supplier 2 | | | | | |
| | Supplier 3 | To the discretion of the issuer | .pdf | e-mail | | |

Source: Research results

**Table 6:** Information collected in interviews with focal company's logistics area employees.

| Information | Company | System | Format | Exchange media | Benefits | Difficulties |
|---|---|---|---|---|---|---|
| Delivery Schedule | Customer 1 | Customer ERP | .xml | Customer web portal | Universal format, without need for data conversion.<br>Ease of access for all SC members. | Lack of integration with focal company ERP. |
| | Customer 2 | Customer ERP | .doc | e-mail | | |
| | Customer 3 | Customer ERP | .txt | e-mail | | |
| | Supplier 1 | Not applicable | - | - | | |
| | Supplier 2<br>Supplier 3 | Focal company ERP | .pdf | e-mail | | |
| Packing Specifications | Customer 1<br>Customer 2<br>Customer 3 | At the issuer's discretion | .pdf | e-mail | | |
| | Supplier 1<br>Supplier 2 | Not applicable | - | - | | |
| | Supplier 3 | At the issuer's discretion | .pdf | e-mail | | |
| Means of transportation and delivery windows | Customer 1<br>Customer 2<br>Customer 3 | At the issuer's discretion | .pdf | e-mail | | |
| | Supplier 1 | Not applicable | - | - | | |
| | Supplier 2<br>Supplier 3 | At the issuer's discretion | .pdf | e-mail | | |

Source: Research results

According to focal company's sales manager, exchange of development information among members of design chain is fully satisfactory, since it occurs in a simple, clear, quick and reliable way. This statement helps to support P2, since it affirms that information systems allow faster information sharing among chain members. The only improvement point, in this view, is the lack of integration among the Enterprise Resource Planning (ERP) systems of those involved, which generates the need for manual insertion of the orders' information into each system, with risks of typing errors. However, these risks are low, and there is no history of occurrences that have impaired progress of any development. Even with risks being considered low by interviewee, this comment leads to conclusion that information systems themselves cannot provide a high level of integration among SC members, making data exchange easier and more accurate. If there is a chance for errors in exchanged information, this may lead to less accurate data and necessity for complex data exchange processes.

All interviewees considered exchange of engineering data, notably 3D CAD models, as the most important and critical activity of development process, concerning information systems, since these mathematical models are basis for production tools elaboration projects. Focal company senior designer stated that "it is rather common the need to convert 3D models, because hardly all members of design chain have same CAD system. There have been cases of 3D model integrity loss after conversion, especially when using IGES system, which greatly hindered development. For example, in air tube development of some products, surfaces simply disappeared after data conversion and CAM system, used in tooling manufacturing, interpreted that failure as a hole in mold and machined that hole. We did not lose mold, but it was necessary to rework it, which delayed development, increased costs, and decreased tooling durability".

According to focal company quality manager, information exchange regarding quality is intense throughout development, and includes critical analysis and deployment of customer engineering specifications into both focal company's and its suppliers' process specifications and control plans. This culminates in final product and manufacturing process approval. In the words of quality analyst, who is responsible for reports approval, preparation of these reports is "extremely labor-intensive and requires duplicate work, since documentation must necessarily be produced in focal company ERP system, because it will be used during serial production. And it will later be inserted into client systems and will be available on the web, which is different for each customer and is not integrated into internal system. In cases of more complex products, approval documentation involves preparation and verification of hundreds of report pages, what can lead to errors and delays. It is clearly a waste of time and resources." Again, this point of view opposes easier and more accurate data exchange mentioned in P1.

The focal company's logistics supervisor said during the interview: "involvement of our logistics area in developments is generally small, as new products almost always fit pre-existing structures and systems, both internally and externally. For example, transport routes between customers, focal company and suppliers are already established, packages are standardized and logistic protocols and information exchange systems, such as EDI, are the same as other products. Thus, work of logistics for development has been summarized to elaboration of products packaging plans, and data insertion of new product in ERP".

## 4.3 Data Discussion

The research found a well-structured NPD in focal company, with NPD aligned with sector requirements, especially in involving diverse SC members in product project. The ESI has been applied increasingly in automotive sector, resulting in significant company gains, although there are still no comprehensive and clearly defined criteria and policies to determine each SC member's stage and involvement degree in NPD. This is evidenced by the fact that both focal company and its partners use ESI to a greater or lesser degree.

According to interviewed professionals, major obstacle to making full use of ESI is cultural, since, at first glance, customer–supplier interaction seems to delay and hamper the process. However, experience shows that benefits outweigh any objections. During development process, both information systems usage and data exchange is intense between involved companies, especially concerning engineering data, which demonstrates that information systems help NPD process in Brazilian automotive industry, despite its structural, technological and regulatory problems.

Table 7 examines situation and impact of information exchange in focal company, comparing expected situation according to literature review and real situation found in case study. Table 7 also shows information exchange impact of NPD results regarding analysis categories defined in this study: product quality, development time and product cost.

**Table 7:** Situation and impact of information exchange in the focal company's NPD

| Area | Information | Expected situation (Literature review) | Situation found | Impact on NPD | | |
|---|---|---|---|---|---|---|
| | | | | Quality | Time | Cost |
| Commercial | Supply contracts or purchase order<br>Confidentiality agreement<br>Development schedule | Full integration of information systems along supply chain, especially mathematical models of products and use of CAD, CAE and CAM technologies. | Moderate exchange of electronic data. Lack of integration regarding ERP systems. | Medium | Medium | Medium |
| Engineering | 3D mathematical models<br>2D drawing<br>Standards and engineering specifications | | Intense exchange of electronic data, mainly CAD, CAE and CAM, but with partial integration due to use of different systems by supply chain members. | High | High | High |
| Quality | Product and process approval reports | | Moderate exchange of electronic data. Lack of integration regarding ERP systems. | Medium | Medium | Medium |
| Logistics | Delivery schedule<br>Packing specifications<br>Means of transportation and delivery windows | | Moderate exchange of electronic data. Lack of integration regarding ERP systems. | Medium | Medium | Medium |

Source: Research results

In "Situation found" column in Table 7, the term "intense" means that information exchange among supply chain members occurs throughout project development. The term "Moderate" applies to information exchange that occurs at specific stages of development. The term "Low," which did not appear in the interviews, would mean that information exchange would occur episodically during development. These terms were defined in consensus with interviewees. The NPD impact classification in Table 7 was also defined in consensus with the interviewees: "High" impact means that information has a direct influence on the product, tooling or manufacturing process design, where a failure might indicate the need to revise project bases and, possibly, need to restart entire product validation procedures. "Medium" impact means that information might generate changes that require, for example, minor changes in product design or adaptations in tooling or manufacturing process. "Low" impact means that information would affect only documentation.

It was consensus among interviewees that ERP systems have greatest impact on NPD information systems; CAD systems, which from a supply chain context are key NPD success factors, had a particularly strong impact. ERP systems integrate and organize information within each organization and generate important information for NPD that is transmitted to suppliers. However, interviews still found low integration between customers' ERP systems and other SC members' ERPs. This finding refutes P1, since it mentions that information systems provide a high level of integration among SC members, making data exchange easier and more accurate and leading to development time and costs reductions and improving product quality throughout the NPD process.

CAD system use was identified as a key factor in not only speeding up and adding reliability to SCs information flow but also in promoting deep and innovative changes in products development, generating significant gains in quality, time and development costs, which leads to increased sector competitiveness. Thus, regarding categories of analysis in this research, it should be noted that quality gains and product costs are mainly related, in interviewees opinion, to product geometry changes requested by focal company.

These changes are based on finite element simulations (CAE) and tooling projects experience by focal company and its suppliers. These changes reduce rejection rates and improve product manufacturability and productivity. Development time reduction is due both to reduced need for each chain member to redesign product and tooling in their own CAD system and to reduced number of product changes and processes arising from focal company's and its suppliers' early involvement.

Furthermore, development time is reduced due higher likelihood of change identifications in process' initial stages, which reduces both project's rework and product validation test repetition, which are, in general, time consuming and costly. Therefore, P2 can be confirmed, because case shows that information systems such as CAD and CAE help companies' NPD, especially concerning ESI practice, and impact positively in development time reduction, costs reduction and product quality improvement, because they allow faster information sharing among chain members.

## 5 Conclusion

NPD in automotive industry is a complex process and involves interaction and coordination of a large number of companies in SC at several levels of its structure. Due to its potential benefits, ESI has been globally applied in this industry, including in Brazil. However, in order to be implemented properly, ESI requires a continuous information flow supported by robust information systems that can ensure to chain members data availability and reliability as well as information and knowledge confidentiality.

Considering this requirement, it is important to verify if, in an automotive industry context with structural, technological and regulatory problems such as Brazil's, information systems also help NPD process achieve development time reduction, costs reduction and product quality improvement. In the same context, it was interesting to identify whether this help occurs due to information systems providing a high integration level among SC members, making data exchange easier and more accurate, or only because information systems connect companies, resulting in faster information sharing among chain members.

To support this study, two propositions were created from literature review: (**P1**) information systems provide a high integration level among SC members, making data exchange easier and more accurate and resulting in development time reduction, costs reduction and product quality improvement in NPD process; (**P2**) information systems can help companies' NPD, especially concerning ESI practice, impacting positively in development time reduction, costs reduction and product quality improvement, because they allow faster information sharing among chain members.

Findings indicate that NPD process in Brazilian automotive industry is in a well-developed stage, covering relations with suppliers at all SC levels, including large, medium and small companies. APQP methodology, used as a standard in this segment, is in accordance with SCM procedures and especially with ESI, since both procedures' goals are the same and both advocate participation of various SC members throughout product development process. ESI use has been growing over time and across different levels of SCs, but there are still no policies or clearly defined criteria for establishing supplier involvement degree in NPD process.

The study showed that information systems are widely used for data exchange during NPD process, although systems integration level among SC members is still low; this is evident in the ERP and CAD systems of the evaluated chains, in which data exchange requires use of intermediate formats that, in addition to obstructing process, still raise risk of data exchange loss or quality deterioration.

Based on research findings about NPD in Brazilian automotive industry, **P1** was refused, specifically regarding high level of integration among SC members that information systems can provide, which makes data exchange easier and more accurate. Since companies use different systems, obstacles arise from distinct system structures such as application languages and databases management systems not being compatible with each other; this generates further manual activities that render data exchange more complex and less accurate.

However, CAD and ERP system use is fundamental for supply chain members' integration since, as well as providing development time savings and reliability, they represent an innovative and new paradigm in project development. In the case of CAD systems, quality gains and lower product costs arise mainly from product changes suggested by focal company in a streamlined system that reduces rejection rates and increases product manufacturability. Likewise, these systems shorten development time due to quick data exchange between chain members, which reduces rework and results in a smaller number of later changes in product projects.

These research findings demonstrate that **P2** can be confirmed. Information systems such as CAD and ERP have a positive impact on product quality improvement, development time reduction and cost gains, which can contribute to increase sector competitiveness, especially because these systems allow faster information sharing among chain members.

## 6 Implications and Further Research

Considering this research objective, is possible to assume that even in a country that has structural, technological and regulatory problems in its automotive industry, information systems help NPD process to achieve development time reduction, cost reduction and product quality improvement. These benefits arise because information systems allow faster information sharing among chain members and not because information systems provide a high level of integration among SC members, making data exchange easier and more accurate. This means that, even with low integration and less accurate and more complex data exchange processes, development time reduction, costs reduction and product quality improvement can be reached through information systems use in NPD. Regarding theory generalization, if this conclusion is valid in a context with structural, technological and regulatory problems, it can be also valid in better contexts.

Further investigations in other companies and chains would be necessary to verify if these findings could be generalizable empirically rather than only in theory but, especially given the dynamics of studied sector and different interactions observed in the research, it is believed that this paper can contribute to discussions about the importance of using information systems in automotive chain product development, especially in a context with several barriers to be overcome..

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