Faculdade de Design,
Tecnologia e Comunicação
Universidade Europeia

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RICARDO PAULO DA SILVA CAMEIRA DOS SANTOS

WHY DESIGN MATTERS? MAKING THE CASE FOR SMALLER COMPANIES IN THE AUTOMOTIVE INDUSTRY.

Tese apresentada ao IADE - Faculdade de Design, Tecnologia e Comunicação da Universidade Europeia, para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Design realizada sob a orientação científica do Doutor José Manuel Pereira Ferro Camacho, *Professor Auxiliar da Universidade Europeia* - *IADE* e do Doutor José Rui de Carvalho Mendes Marcelino, *Professor Auxiliar da Universidade de Lisboa - FAL*.

Documento definitivo: 27 de Janeiro, 2022

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Para a Júlia…

agradecimentos

Aos meus orientadores pela excelência na orientação científica e pela inspiração e motivação para a realização desta investigação, o Professor Doutor José Ferro Camacho e o Professor Doutor José Rui de Carvalho Mendes Marcelino.

Aos meus professores do curso de Doutoramento em Design no IADE e colegas de investigação da IADE-UNIDCOM, pelo apoio incondicional à minha investigação e contributo académico na metodologia de investigação, a Professora Doutora Emília Duarte, a Professora Doutora Ana Margarida Gomes Ferreira, o Professor Doutor Carlos Duarte, o Professor Doutor Carlos Rosa e o Professor Doutor Rodrigo Morais.

Aos correspondentes da indústria que se mostraram sempre disponíveis para participar nos estudos de caso apresentados nesta investigação, a Veneporte: o Dr. Abílio Cardoso e o Eng. Luís Pinho, a KLC: o Dr. Pedro Colaço e o Eng. Pedro Pires e a Sodecia: o Eng. José Noronha.

Aos profissionais de I&D e Design pela revisão dos textos e suporte técnico, Doutor Paulo Parra, Eng. Tiago Rocha Pereira e Karah Shaffer.

À minha família, pelo apoio incondicional, Maria da Assunção Santos, Norberto Cameira Santos, Cândida Cristo Gomes, Amílcar Bravo Gomes e Pedro Santos.

Aos meus amigos, porque sem eles seria impossível realizar este projeto, Catia Barros, Eva Alves, Filipa Coelho de Sousa, Susana António, André Ribeiro, Alexandre Mendes, Aníbal Rodrigues, Artur Moura, Carlos Ferrão, Claúdio João, Francisco Agostinho, Gonçalo Gomes, Hugo Brito, João Noronha, João Pires, Luís António, Luís Coelho de Sousa, Pedro Costa, Pedro Homem, Rui Gama, Rui Rocha, Tiago Silva.

Por último quero expressar a minha mais profunda gratidão à Cristina Bravo, pelo seu amor, companheirismo, compreensão e paciência.

palavras-chave

Design Industrial; Competências em Design; PME; Dynamic Capabilities View; Indústria Automóvel.

resumo

Este é um trabalho de investigação sobre design industrial, gestão estratégica e, mais especificamente, sobre a forma como o desenvolvimento das competências da prática do design podem influenciar a posição estratégica no mercado das pequenas e médias empresas portuguesas fornecedoras da indústria automóvel.

O design industrial não é referido, pela maioria das pequenas e médias empresas (PMEs) da indústria automóvel, como pilar base das suas competências. No entanto, a prática sugere um duplo pendor tanto na definição de design (por vezes tendencialmente associado ao estilo e associado aos construtores), quanto ao seu papel no desenvolvimento do posicionamento das PMEs nas redes de fornecimento. Esta linha de raciocínio corrobora a questão principal da investigação: porque é que o design é importante para as pequenas empresas da indústria automóvel?

Atualmente, o design industrial encontra-se estabelecido nas PMEs da indústria automóvel como um processo de combinações de recursos-competências, consequência de um ambiente altamente dinâmico que caracteriza esta indústria. Esta condição cria a necessidade de uma nova abordagem de investigação, integrando os processos de design industrial e as teorias estratégicas da *dynamic capabilities view* (DCV).

A *dynamic capabilities view* (DCV) é a mais recente perspetiva que se estende à *resource based view* (RBV) e tem sido reconhecida pelos académicos como um dos conceitos mais relevantes no campo da gestão estratégica. Assim, através da revisão da literatura, foi entendido que a *dynamic capabilities view* (DCV) é definida como a capacidade da empresa de integrar, construir e reconfigurar competências internas e externas para lidar com ambientes em rápida mudança. Assim, a teoria da visão das capacidades dinâmicas, reflete a capacidade de uma organização em alcançar novas e

inovadoras formas de vantagem competitiva, segundo determinadas dependências do caminho e posições de mercado.

Desta forma, existe uma necessidade, não só de analisar a relação entre o design (recurso) como vantagem competitiva das empresas e o seu desempenho (resultado), mas também a combinação de recursos e competências como competências dinâmicas, com o *background* de um segmento industrial, que opera numa rede densa e complexa como a da indústria automóvel. Esta relação pode ser traduzida através de um modelo que ilustra as relações entre recursos, competências, vantagem competitiva e, em última instância, relacionando-se com o desempenho da estratégia da *dynamic capabilities view* (DCV).

Por conseguinte, o segundo construto a ser revisto é o design como um processo para o desenvolvimento de produtos e processos industriais na indústria automóvel. Assim, foi feita uma extensa análise e revisão de diferentes processos como estratégia global para o desenvolvimento de produtos. São ainda descritas algumas das principais definições de design e a sua finalidade, bem como apreendidas algumas das fronteiras dos diferentes processos de design. É apresentada a definição de produto, o conceito do processo de design e discutidos alguns dos mapas de modelos mais representativos de processos.

Com efeito, todos os modelos de processo encontrados através da revisão da literatura abrangem uma gama diversificada e extensa de problemas e disciplinas de projeto. Assim, o objetivo desta revisão é obter uma perspetiva equilibrada. Contudo, embora todos os modelos de processo revistos ofereçam uma visão sobre a natureza do processo de design, são considerados demasiado generalistas para apoiar as atividades de planeamento do projeto ou mesmo para orientar algumas das decisões diárias inerentes à atividade dos profissionais de design industrial.

No contexto da indústria automóvel, e embora adaptado à especificidade do modelo de negócios dos construtores automóvel, o planeamento de qualidade de produto avançado (APQP) não é apenas a principal fonte para a definição de um conceito operacional de processo de design industrial, mas também uma ferramenta de interação entre os diferentes polos da rede fornecedora. De acordo com o APQP, as etapas de design de produto e processo são descritas em detalhe. Assim, o APQP não é apenas um processo de desenvolvimento de produto, mas um processo padrão da indústria automóvel.

Além disso, a definição de competências para o design de produto, design de processo e design de domínio integrado no processo APQP para fornecedores da indústria automóvel foi também adquirida através da presente revisão de literatura. Estas competências específicas em design industrial serão posteriormente desagregadas com a introdução dos micro-fundamentos da teoria da DCV.

A abordagem ao sistema da indústria automóvel internacional é feita através de uma descrição estrutural com foco na rede organizacional de fornecedores. Assim, um perfil da indústria é descrito inicialmente através da definição da modularidade do automóvel e da forma como este tipo de arquitetura configura de uma forma piramidal toda a cadeia de valor da indústria. Além disso, é apresentada a produção mundial de automóveis de passageiros, veículos comerciais leves e pesado e autocarros.

O cluster automóvel português é descrito numa perspetiva histórica, dando uma visão clara da evolução dos fornecedores portugueses, e da contribuição do seu valor não só para a economia portuguesa, mas também para um crescimento sustentável da criação de emprego e desenvolvimento de competências em design e investigação e desenvolvimento (I&D) através de toda a rede de *stakeholders*.

Os construtos teóricos e a sua contextualização, apoiados através da literatura e da revisão do perfil da indústria automóvel (internacional e nacional) revelam um procedimento de investigação apoiado num processo de trabalho interdisciplinar. A natureza exploratória deste estudo exige um tipo de investigação qualitativa, sendo a utilização de estudos de caso a estratégia de investigação mais adequada.

Três empresas do cluster automóvel português foram selecionadas para o estudo de caso, representando uma amostra adequada para análise de casos cruzados. A análise dos dados recolhidos exigiu três fases: a análise e relato de casos individuais; a análise e relatório de casos cruzados; e as conclusões e implicações dos casos cruzados tanto para a teoria como para a prática do design industrial.

Para além de responder às questões de investigação, este estudo dá um contributo alargado para as pequenas empresas portuguesas fornecedoras da indústria automóvel. Portanto, esta contribuição pode ser dividida em dois tópicos. O primeiro são recomendações para o desenvolvimento de competências em design industrial como competências dinâmicas. Através da análise dos três estudos de caso, é evidenciado como a implementação de competências em design industrial pode ser explorada por meio de competências ao nível da deteção, apreensão e reconfiguração (micro-fundamentos da DCV). Como resultado, uma lista de práticas positivas e negativas sugeridas é proposta. Estes resultados podem ajudar os gestores a compreender as práticas em que as competências dinâmicas operam e fornecerem orientação para a implementação das competências em design industrial na sua empresa dentro do ambiente da indústria automóvel.

O segundo tópico tenta evidenciar a importância do desenvolvimento de competências em design industrial para uma determinada estratégia de negócios na rede da cadeia de fornecimentos da indústria automóvel. Este resultado tenta também ajudar os gestores a reconhecer que o desenvolvimento de competências em design industrial é fundamental para o desenvolvimento de produtos de alto valor acrescentado para o fornecimento de peças complexas ou módulos para montagem direta nas fábricas dos construtores.

Do mesmo modo, este estudo revela uma lacuna para uma oferta educacional adequada de design industrial e contribui para a construção de uma consciência para o reconhecimento e apoio entre as PMEs a operar na cadeia de fornecimento da indústria automóvel. Assim, para os programas educacionais ao nível da licenciatura, sugere-se que temas como a incorporação do design para transformações empresariais sejam integrados. Para os programas de pós-graduação, sugere-se a introdução de unidades curriculares que garantam a formação adequada às redes de empresas com características semelhantes às estudadas para integração e desenvolvimento de competências de design diferente das já referidas perspetivas clássicas.

A presente investigação integra o design de um caso de estudo múltiplo composto por três estudos. Porém, uma das maiores preocupações da investigação pelo método de estudos de caso é talvez a delicada extração de dados para uma generalização científica. Contudo, os fatos científicos dificilmente se baseiam em experimentações únicas, pois são normalmente baseadas em múltiplas experimentações que tentam replicar o mesmo fenómeno em diferentes condições.

Estes três estudos de caso são considerados uma amostra muito conveniente das PMEs que integram a maior parte do cluster automóvel português através de uma inovadora abordagem ao seu posicionamento no mercado, com ênfase em percursos exploratórios e explicativos. No entanto, o tempo e os recursos limitados para o desenvolvimento deste estudo tiveram um impacto significativo no tamanho da amostra da investigação para o estudo de caso. O resultado destes estudos de caso estabelece o domínio de um novo conhecimento, não existente. Este conhecimento, ligando micro-desenvolvimentos - nos quais o design industrial é um fator-chave - com mudanças macro, cria um ponto de partida para uma nova e futura fase de pesquisa com ênfase em métodos mais quantitativos e amostras de maior dimensão.

Outros domínios e setores podem ser igualmente interessantes para explorar não só na área dos transportes, mas também nas tecnologias de informação (IT) assim como, comboios, aeroespacial, computadores e telemóveis. Em comum, partilham uma lógica semelhante de organização do produto e na forma de estabelecimento de redes de fornecimento.

keywords

Industrial Design; Design Capabilities; SME; Dynamic Capabilities View; Automotive Industry

abstract

This research focuses on industrial design and strategic management and more specifically on the way the development of design capabilities can influence the strategic product market position of the Portuguese small and medium supply companies for the automotive industry.

Industrial design is not usually highlighted as a cornerstone skill of most small-scale automotive supply companies. Instead, it is usually established as a process in resource-capability combinations due to the highly dynamic environments that characterize this industry. Practice suggests a double bias either in the definition of design, sometimes emphasized as style and associated with carmakers, or in design's role in developing the position of small and medium enterprises in supply networks. This line of reasoning supports the lead research question: why design matters for smaller companies in the automotive industry?

The theoretical constructs and context field supported through the literature and the automotive industry profile (international and Portuguese) review reveal a research procedure supported on an interdisciplinary work process. The exploratory nature of this study calls for a qualitative type of research to be conducted as the use of case studies is the most appropriate research strategy.

Three firms from the Portuguese automotive cluster were selected for the case study representing an appropriate automotive industry supplier sample for cross-case analysis. The analysis of the gathered data required three phases: analysis and report of individual cases; analysis and report of cross cases; and the conclusions and implications of the cross cases for both theory and practice.

As a result, it is revealed the importance of the development of design capabilities for a determined business strategy. The development of design capabilities is key for the development

of high added value products for the supply of complex parts or modules. Hence, a list of suggested positive and negative industrial design practices are proposed.

Presidente do Júri:	Doutor Carlos Miguel Lopes Rosa, Professor Associado do IADE da Universidade Europeia.[1]
Vogais:	Doutora Rita Assoreira Almendra, Professora Associada c/Agregação da Faculdade de Arquitetura da Universidade de Lisboa; Doutor Luís Manuel do Carmo Farinha, Professor Adjunto da Escola Superior de Gestão do Instituição Politécnico de Castelo Branco; Doutor Pedro Paulo Eugénio de Oliveira, Professor Auxiliar do IADE da Universidade Europeia; Doutor José Manuel Pereira Ferro Camacho, Professor Auxiliar do IADE da Universidade Europeia; Doutor José Manuel Pereira Ferro Camacho, Professor Auxiliar do IADE da Universidade Europeia.

[1] Por delegação da Doutora Hélia Gonçalves Pereira, Reitora e Presidente do Conselho Científico da Universidade Europeia.

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List of Abbreviations

ACEA – European Automobile Manufacturers' Association

AFIA – Associação de Fabricantes para a Indústria Automóvel

APQP – Advanced Product Quality Planning

BEV – Battery Electric Vehicle

BIW – Body in White

BMW - Bayerische Motoren Werke AG

BOM – Bill of Materials

BOP – Bill of Process

CAD – Computer Aided Design

CAM – Computer Aided Manufacturing

CCB – Cross-Car Beam

CEDP – Centro de Engenharia e Desenvolvimento de Produto

CEIIA – Centro para Excelência e Inovação para a Indústria Automóvel

CKD – Complete Knocked Down

DCT – Dual Clutch Transmission

DCV – Dynamic Capabilities View

DPF – Particulate Filter

EAS – European Automotive System

EEC – European Economic Community

EFTA – European Free Trade Association

EIB – European Investment Bank

EMU – Economic and Monetary Union

ERDF – European Regional Development Fund

ESF – European Social Fund

EU – European Union

FAP – Fabrica de Automóveis Portuguesa

FCEV – Fuel Cell Electric Vehicle

FCA – Fiat Chrysler Automobiles NV

FDA – Food and Drug Administration

FDI – Foreign Direct Investment

FIAT – Fabbrica Italiana Automobili Torino

FMEA – Failure Mode and Effects Analysis

GDP – Gross Domestic Product

GM – General Motors Corporation

HEV – Hybrid Electric Vehicle

HRST – Human Resources in Science and Technology

IAM – Independent Aftermarket

IATF – International Automotive Task Force

ICE – Internal Combustion Engine

ICSID – International Council of Industrial Design

ICT – Information and Communication Technologies

IDSA – Industrial Designers Society of America

IML – In Mould Labelling

IMD – In Mould Decoration

INAUTO – Inteligência e Inovação para o Desenvolvimento da Indústria Automóvel

INE – Instituto Nacional de Estatística

INTELLI – Agência para a Inteligência e Inovação

IP – Instrument Panel

IST – Instituto Superior Técnico

IVI - In-Vehicle Infotainment

JIT – Just in Time

KAT – Catalytic Converter

KPI – Key Process Indicator

MIT – Massachusetts Institute of Technology

MPV – Multi-Purpose Vehicle

M&A – Mergers and Acquisitions

OEM – Original Equipment Manufacturers

OECD – Organization for Economic Co-operation and Development

OES – Original Equipment Supplier

OESA – Original Equipment Suppliers Association

OICA - Organisation Internationale des Constructeurs d'Automobiles

PAPP – Production Part Approval Process

PB – Park Brake

PEDIP – Programa Específico de Desenvolvimento da Indústria

PHEV – Plug-in Hybrid Electric Vehicle

PSA – Peugeot Société Anonyme

PSU – Pennsylvania State University

PVD – Physical Vapor Deposition

QFD – Quality Functional Deployment

RBV – Resource Base View

RFQ – Request for Quote

RNUR – Régie National des Usines Renault

R&D – Research and Development

R&D&I – Research and Development and Innovation

SBHA – Seat Belt Height Adjusters

SCR – Selective Catalytic Reduction

SEAT – Sociedad Española de Automóviles de Turismo

SIL – Silencer Tube

SKD – Semi-Knocked Down

SME – Small and Medium-sized Enterprise

SPC – Statistical Process Control

SS – Shift Systems

TDL – Tie Down Loops

TE – Thread Extrusions

TQM – Total Quality Management

VDI – Verein Deutcher Ingeniure

UNECE – United Nations Economic Commission

VRIN – Valuable, Rare, Imperfectly Imitable and Non-Substitutable

VW – Wolkswagen AG

Glossary

APQP

Complex products and supply chains present plenty of possibilities for failure, especially when new products are being launched. Advanced Product Quality Planning (APQP) is a structured process aimed at ensuring customer satisfaction with new products or processes.

APQP has existed for decades in many forms and practices. Is used by companies to assure quality and performance through planning. Ford Motor Company published the first Advanced Quality Planning handbook for suppliers in the early 1980’s. APQP helped Ford suppliers develop appropriate prevention and detection controls for new products supporting the corporate quality effort. With lessons learned from Ford AQP, the North American Automotive OEMs collectively created the APQP process in 1994 and then later updated in 2008. APQP is intended to aggregate the common planning activities all automotive OEMs require into one process. Suppliers utilize APQP to bring new products and processes to successful validation and drive continuous improvement.

BIW

Body in white is the stage in automobile manufacturing in which a car body's frame has been joined together, that is before painting and before the engine, chassis sub-assemblies, or trim (glass, door locks/handles, seats, upholstery, electronics, etc.) have been integrated into the structure. Assembly involves different techniques such as welding, riveting, clinching, bonding and laser brazing.

In the design of a car, the BIW phase is where the final contours of the car body are worked out, in preparation for the ordering of production process stamping dies. Extensive computer simulations of structure, crash, manufacturability, and automotive aerodynamics are required before a clay model from the design studio can be converted into a body in white ready for production.

BOM

A bill of materials or product structure is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and the quantities of each needed to manufacture a product. A BOM may be used for communication between manufacturing partners or confined to a single manufacturing plant. A bill of materials is often tied to a production order whose issuance may generate reservations for components in the bill of materials that are in stock and requisitions for components that are not in stock. There are two types of bill materials: bill of materials (product) and bill of process (production process).

A BOM can define products as they are designed (design bill of materials), as they are ordered (sales bill of materials), as they are built (manufacturing bill of materials), or as they are maintained (service bill of materials).

CKD/SKD

A knock-down kit is a collection of parts required to assemble a product. The parts are typically manufactured in one country or region, then exported to another country or region for final assembly.

A common form of knock-down is a complete knock-down (CKD), which is a kit of entirely unassembled parts of a product. It is also a method of supplying parts to a market, particularly in shipping to foreign nations. CKD is a common practice in the automotive, industry, as well as electronics, furniture and other products. Businesses sell knocked-down kits to their foreign affiliates or licensees for various reasons, including the avoidance of import taxes, to receive tax preferences for providing local manufacturing jobs, or even to be considered as a bidder at all (for example, in public transport projects with "buy national" rules). A semi-knocked-down kit (SKD) is a kit of partially assembled parts of a product

The degree of "knock-down" depends on the desires and technical abilities of the receiving organization, or on government import regulations. Developing nations may pursue trade and economic policies that call for import substitution or local content regulations.

Knock-down kit assembling plants are less expensive to establish and maintain, because they do not need modern robotic equipment, and the workforce is usually much less expensive in comparison to the home country. The plants may also be effective for low-volume production. The CKD concept allows firms in developing markets to gain expertise in a particular industry. At the same time, the CKD kit exporting company gains new markets that would otherwise be closed.

FMEA

Failure Mode and Effects Analysis, or FMEA, is a methodology aimed at allowing organizations to anticipate failure during the design stage by identifying all of the possible failures in a design or manufacturing process.

Developed in the 1950s, FMEA was one of the earliest structured reliability improvement methods. Today it is still a highly effective method of lowering the possibility of failure.

Failure Mode and Effects Analysis (FMEA) is a structured approach to discovering potential failures that may exist within the design of a product or process.

Failure modes are the ways in which a process can fail. Effects are the ways that these failures can lead to waste, defects or harmful outcomes for the final customer. A FMEA is designed to identify, prioritize and limit these failure modes.

TQM

The basic goal of Total Quality Management (TQM) is to involve all levels and functions of an organization in continually meeting and exceeding the customer's expectations of their daily operations, products or services. Within TQM, organizations are viewed as a collection of processes that must be continuously improved using the knowledge and experience of associates in all functions and at all levels. TQM philosophy deems that everyone within the organization should focus their efforts on meeting the needs of the customer and achieving the goals of the organization. The focus should not only be on doing things right but doing them right every time. Originally, TQM was primarily applied to manufacturing operations. However, TQM methods and tools are now becoming recognized as a universal management tool, just as applicable in service and public sector organizations.

1. Introduction

The Automotive System – Study's Background

Through the last half of the 20th century, the automobile industry has undergone through a massive reorganization of its production system hence its design process (Womack et al, 1990). Gone are the ages where a manufacturer had to design and produce all the components from all the systems of a car. Most car manufacturers, learning from the Japanese manufacturers, had to go through a massive restructuring either in its internal organization, platform optimization, suppliers' development and lean production processes on their factory's shop floors. Not only had the suppliers the responsibility to produce and deliver modular complex parts to the final assembly factories but also to design according to the manufacturer's specifications. Hence, the specific field where this research applies to, is the design capabilities of small supplier companies in the automotive industry and its dynamics towards its own resources, market, and the development of complex products.

More than ever before, industries need to adapt to new markets, different customers, new technologies, different resources, new challenges but always the same objective. So, the concept of industry is no longer defined as a group of firms manufacturing products demand-oriented or supply-oriented (Sako, 2007). Mari Sako, a seminal author in global strategy, has established a methodological approach arguing that industries matter from three distinct perspectives (Sako, 2007). One of the perspectives this author introduces is that a single industry is chosen for study, not to control for a source of variation, but for further understanding of specific institutions and configurations of practices in an industry (Sako, 2007).

Today's conceptual definition of an industry is of a firm carrying an indefinitely large number of activities, activities related to the discovery and estimation of future wants, to research, development and design (Richardson, 1972). We can call this conception of industry as resource-based view – RBV (Sako, 2007). These activities must be carried out by organizations with appropriate capabilities – knowledge, experience, and skills. These are carried out through a dense network of links where car manufacturers, dealers, service providers, component and materials suppliers can be found.

MacDuffie (2013) describes an historical overview of the architecture of an automobile and its relationship with suppliers. He also introduces the definition of “module”, as a large chunk of physically adjacent components produced as a subassembly by a supplier and then installed in a single step in an automaker’s assembly factory. This author refers that the auto industry managers and engineers began to pay attention to modular concepts in the early 1990s, following an earlier logic of unbundling production activities to be carried out by suppliers. In addition, (MacDuffie, 2013) characterizes the separation of subassemblies as a way of achieving modular production to move work off the main assembly line to subassemblies and to suppliers as a strategy for the de-verticalization in affinity with the Japanese industries as described earlier by J. P. Womack studies (Womack et al, 1990).

Moreover, MacDuffie describes how U.S. and European automobile manufacturers also sought the allocation of design tasks to suppliers, under the frame of “module design” to tap their specialized knowledge (MacDuffie, 2013).

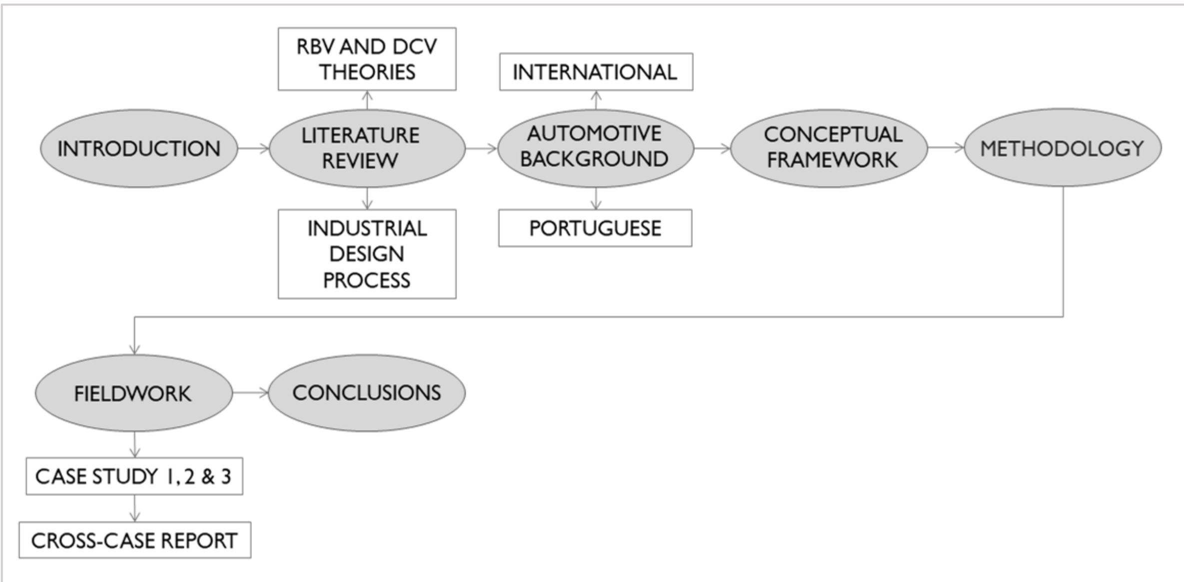
The Resource Based View (RBV) and the Dynamic Capabilities View (DCV)

As per Mari Sako Resource-based view (RBV) conception of industry, Barney (1991) explores that in a Resource-based view conception, there is a relation between firm resources and sustained competitive advantage. Meaning that the resource-based view (RBV) concept offers strategists a means of evaluating potential factors that can be deployed to confer a competitive advantage to a firm. However, not all resources are of equal importance, nor possess the potential to become a source of sustainable competitive advantage. Nevertheless, Barney explains that understanding the causal relationship between the sources of advantage and successful strategies can be exceedingly difficult in practice (Barney, 1991). Hence, Barney developed the VRNI criteria (Barney, 1991) where the firm’s key resources should be evaluated as: Valuable, Rare, Imperfectly Imitable and Non-Substitutable (Barney, 1991). Strategic management decisions should point to develop, nurture, and protect resources that follows these criteria.

Moreover, the highly challenging environment on the automotive industry competitiveness, demands that the competitive advantage of firms lies with its managerial and organizational processes, shaped by its (specific) asset position, and the paths available to it (Teece et al., 1997). Additionally, scholars have extended RBV to dynamic markets (Teece et al., 1997). The underlying principle is that RBV has not adequately explained how and why certain firms have competitive advantage in situations of rapid and unpredictable change as the Automotive firms. In this market, where the competitive landscape is quickly shifting, the dynamic capabilities by which firm managers “integrate, build, and reconfigure internal and external competencies to address rapidly changing environments” (Teece et al., 1997: 516) become the source of sustained competitive advantage. This theory is still up to date due to the transformations taken place over the last few decades by the industry itself.

Figure 1

Study Structure Diagram



Note. Source: Own

Takahiro Fujimoto argues that organizational capability is the source of competitiveness, and that product architecture should have a dynamic fit with the organizational capability

(Fujimoto, 2014). These two arguments are in line with the dynamic capabilities view (DCV) defined by Teece et al. (1997). Fujimoto refers that product-process architecture is designers' basic way of thinking when creating design information for the product and processes (Fujimoto, 2014). Hence, we can identify Design as a developed capability for a business strategy.

Additionally, researcher Brigitte Borja de Mozota has explained the substantial value of Design for industries at three design value levels, design as tactical driver, design as organizational driver and design as strategic driver (Mozota, 2003). Moreover, Mozota connects the resource base view business perspective with the design perspective, the design resource capability. Design management has been moving from considering design as an external competitive advantage (fit with the external environment) to also thinking of design as an internal, sustained competitive advantage (a resource or a core competency), (Mozota & Kim, 2009). Design valuation has transitioned from an economic view (increasing market share and brand) to a process performance view (reducing cost or time to market and improving innovation systems) to a strategic view of resources (creating new markets and retaining valued employees), (Mozota & Kim, 2009).

After an extensive review of the literature, a research gap was found. While design issues and strategic management for automobile manufacturers and large suppliers have been the subject of a wide research, there is a lack of studies focused on smaller companies. This is the current situation of a good part of the companies of Portuguese origin that supply the automotive network.

The motivation of this research is to foster these smaller firms with the development of Design as a dynamic capability. Also, to upgrade the strategic positioning enabling a better performance of these firms in the dense network of automotive manufacturers, suppliers, purchasing, after sales and other stakeholders. Additionally, this research aims to answer the question that gives the name for the current thesis: Why Design matters for smaller companies in the automotive industry?

The automotive supplier firms and its dense network represent a suitable setting for inductively model a theoretical model of dynamic capabilities and therefore setup the framework for the proposed empirical research.

One of the many qualitative research approaches, and due to the nature of the research problem is the case study. Therefore, the case study is a qualitative research framework that provides the necessary tools for a researcher to study a complex phenomenon by using a variety of data. This phenomenon can be any situation, occurrence, or a fact that is observed to happen (Muratovski, 2016). The phenomenon is studied in-depth for a defined period and within a set context (Muratovski, 2016). According to the definition given by Robert Yin (2009), the realization of case studies is the most appropriate research strategy for the object of the present study.

This study is organised as follows. The first section is a deep dive review on the theoretical constructs literature that give support to this research: Strategic management and Design as a process for product development. Therefore, the first topic on strategic management is dedicated to the review of theoretical concepts such as competitive advantage, the resource-based view (RBV) and the dynamic capabilities view (DCV) perspective. Following this extensive review, a section on critical appraisals and theoretical reviews for these state-of-the art strategic theories follows. Afterwards, there is a review on the rare available studies due mainly to the dearth of evidence on application of the dynamic capabilities model to build and exploit firm capabilities as dynamic capabilities.

Design as a Process for Product Development

The following topic on the literature review is another core construct - Design as a process for product development. This topic aims to describe a theoretical framework of the Design as a language that requires processes. An extensive analysis and review of different processes is made as a comprehensive approach for product development. Additionally, several definitions of Design and its goals are described, as well as perceived some of the boundaries of the different processes. It is described the definition of product itself, the design process concept and discussed some of the most representative model maps for processes including the advanced product quality planning (APQP) process, the standard to be used by the automotive industry suppliers. This second topic is concluded with the definition of a classification framework for design capabilities (Akabane et al., 2016) which will be later disaggregated into Teece's dynamic capabilities model (Teece, 2007).

The second section of the document is an extended overview of the Automotive industry business. It is divided in two topics. The first is a deep historical dive on the foundations of the Portuguese automotive cluster and the second is an international overview of the business.

The Automotive Industry – The Portuguese Case

The first topic of the automotive industry overview section is the Portuguese case. This is a deep and extended historical overview of Portugal's automotive cluster from the end of the Second World War to the current time. And is of the outmost importance to characterize this industrial sector since it is the background field of this research.

This topic is structured in five sections. The first is a general overview of the period between the end of World War II and the Renault project. The second is the Renault project, seeking to characterize its main endeavours and their impact, especially regarding the development of local component suppliers. The third part relates to the period between Renault and the AutoEuropa projects. This is a complex and especially important period, evidenced by the adhesion of Portugal to the EEC, (which has significantly influenced the car manufacturers' strategies of approaching the Portuguese market and created an Iberian automotive manufacturing and trade space). The fourth section is reserved exclusively to the AutoEuropa project, from the contract conditions to the induced effects, and its main features.

The last section of the Portuguese Automotive industry review is about the status and its future challenges, focusing on local component and systems suppliers. This topic concludes with a summary, highlighting the main items to be considered in the analysis of the smaller companies that shape the main body of the Portuguese automotive cluster which is the focus of this work.

The Automotive Industry – an International Overview

In the second topic of this section, an approach on the international automotive industry is assessed, first through its economic weight, then through a profile characterization of this specific industry from the automotive manufacturers perspective and then from the supplier's perspective. An historic review is completed from the consolidation and restructuring lenses (also from manufacturers and supplier perspective). Likewise, there is an approach on innovation and competitiveness and the significance for the automotive industry as R&D activities and product development are the main sources of technical progress. This first topic is concluded with a viewpoint from the challenges and opportunities that the current automotive industry suppliers face, suggesting that the concept of incomplete modularity is a strategic opportunity for smaller firms (Frigant, 2016).

The Conceptual Framework

The third section of this document is dedicated to structuring the conceptual framework. After the literature review, it is outlined the research gap and the problem. Therefore, the purpose of this chapter is to state the theoretical assumptions underpinning this study, hence connecting the empirical data to existing knowledge and to finally emerging propositions, concepts, or hypotheses to answer the research question. Thus, the proposed framework, comprises two outcomes: the propensity to change the resource base to develop design capabilities deploying a design process and a performance outcome.

After building the theoretical framework the focus is, as already mentioned, on the small subset of concepts. There is a description of the desegregation from the dynamic capabilities microfoundations according to Teece (2007) that will provide a basis for the desegregation of the design capabilities defined on the literature review into practices that underpin each defined capability. From this point it is possible to formulate the methodology.

Methodology

Consequently, the fourth section is dedicated to the development of the methodology. As already mentioned, the theoretical constructs and context field supported through the literature and the automotive industry profile review leads us to conclude that this is a interdisciplinary research. This research crosses Industrial Design, Strategic Management, with the automotive industries as background field. Likewise, the methodological transdisciplinary approach is the most suitable to work on complex problems for which no single discipline possesses the necessary methods on its own to frame or resolve them (Muratovski, 2016).

Additionally, a qualitative research aims to collect numerous forms of data from a wide range of sources and examine this data from different angles. Therefore, it can be said that the purpose of qualitative research is the construction of a rich and meaningful picture of a complex and multifaceted situation. According to the definition given by Robert Yin (2009) and Muratovski (2016), the realization of case studies is the most appropriate research strategy for the object of the present study. Also discussed is the rationale for a multiple case study research.

Through this section it is also identified the components of the research design as per Yin (2009) definition. Therefore, all the study's questions, propositions, unit of analysis, the way the collected data is linked to the propositions and the criteria for interpreting the study's findings are defined here. It is also characterized the criteria for judging the quality of the research design a per Yin (2009). Four tests have been defined: construct validity, internal validity, external validity, and reliability (Yin, 2009). The related case study tactics and tasks of research which the tactic occurs are also defined.

In addition, it is also developed the case study protocol as per Yin (2009). This procedure is especially desirable if the research is based on a multiple-case design (Yin, 2009). The protocol is more than a questionnaire or instrument. Thus, it is a major way of enhancing the reliability of the case study research and is meant to guide the researcher in carrying out the data collection from the multiple-case study.

Field Work – Case Study

To meet the present study's purpose, it was selected three performing firms from the Portuguese automotive cluster. The selected case study firms seem to represent an appropriate sample for cross-case analysis, particularly when looking for and identifying common patterns and differences concerning the use of dynamic capabilities. Additionally, oral, and written invitations to take part in the research were sent to the chosen firms. After, meetings were arranged to describe the study's goals and data collection methodology. The qualitative nature of the current study and the related potential benefits and deficiencies were explained.

The analysis of the acquired data required three phases according to Yin (2009): the analysis and report of individual cases; the analysis and report of cross cases; and the conclusions and implications of the cross cases for both theory and practice.

One of the main ambitions in a multiple-case study is building a general explanation that would fit each individual case (Yin, 2009). The goal for this research is to create a global explanation for the outcomes of the multiple conducted experiments. From the multiple case report analysis, it was possible to understand that the three studied firms have different approaches on the relation of their design capabilities deployment with their business strategy.

Conclusions and Recommendations

Further from debating some valuable propositions from academics and answering the research questions, this study makes a widen contribution to the Portuguese smaller supplier firms driving through this complex network which is the automotive industry system. The contribution can be split into two axes. The first one is recommendations for developing design capabilities as dynamic capabilities. Therefore, through the analysis of the three case studies, it is shown how deployment of design capabilities can be explored through sensing, seizing and reconfiguring capabilities. These lenses enable a better understanding of the logic behind the dynamic capabilities view (DCV) theory.

As a result, a list of suggested positive practices (that can help firms develop their design capabilities as dynamic capabilities), and negative practices (that firms need to minimise on developing their design capabilities as dynamic capabilities) are proposed. These results may help managers understanding the practices in which dynamic capabilities operate and provide guidance while seeking to deploy and take advantage of their firm's design capabilities in the automotive environment.

The second axis fosters to demonstrate the importance of the development of design capabilities for a determined business strategy in the automotive supply chain network. This result may also help managers recognize that the development of design capabilities is key for the development of high added value products for the supply of complex parts or assembly modules.

2. Literature Review

The foundations for any research study are to be consolidated with ideas, thoughts, concepts, and methodologies formulated and adopted by different associated research studies. The constructs and variables are defined as per the explanations and evidence found in the existing literature and related state-of-the-art research. Setting up a literature review is fundamental to set up a theoretical framework, showing a clear understand of the key concepts and exploring the ideas and studies related to the topic. It is for the utmost importance to manifest knowledge about the history of the research topic and related controversies.

The starting point of the literature review was author Mari Sako, who defined the automotive industry (where network links are dense) plus dealers, service providers, systems, and materials suppliers as a resource-based view industry concept (Sako, 2007). Furthermore, she also reflects on the concept of industry which is no longer defined as a group of firms producing products demand-oriented or supply-oriented (Sako, 2007).

This document strives to understand the importance of design to small, tier one, Portuguese automotive suppliers, as fundamental resource for performance. This study will take the resource-based view theory and dynamic capabilities as the platform to develop a model for performance heterogeneity under de umbrella of a complex and dense network as per the European Automotive System - EAS (CoCKEAS, 2002). The concepts of the resource-based view theory, dynamic capabilities, and design as a process for product development are reviewed to build up the baseline for this study.

2.1. The Resource-Based and the Dynamic Capabilities View Theories

One of the constructs for the present literature review is the Resource-Based view theory and the Dynamic Capabilities View. These theories, originally from the scientific field of strategic management research, conceptualize a framework to determine or identify the strategic resources available or needed within the needs of a company. The fundamental principle of the RBV (Resource-Based View) is that the basis for a competitive advantage of a firm lies primarily in the application of the bundle of valuable resources identified and at the firm's disposal and the combinations with its capabilities.

Many authors and researchers (Penrose, 1959; Porter, 1985; Wernerfelt, 1984; Barney, 1991, Teece et al., 1997) have placed numerous discussions and arguments as an attempt to describe and explain what a competitive advantage is and most important, how can a competitive advantage be sustainable. The competitive advantage concept has long been a focus area of strategic research; consequently, many approaches have taken shape and several theories have been proposed. Understanding sources of competitive advantage for firms has become a major area of research in the field of strategic management (Porter, 1985; Rumelt, 1984). These approaches have been developed and discussed in a few seminal academic works. One of the approaches is the Resource-Based View (RBV).

As a theory, RBV articulates the relationships between resources, capabilities, and competitive advantage of a firm. RBV attempts to explain competitive advantage and its sustainability based on competences and capabilities developed by the firms with the availability and deployment of resources they possess. The evolution and development of the RBV as a theory and strategic tool is needed to be addressed to understand the role played by key resources and capabilities for attaining sustained competitive advantage within the firm.

One of the authors that is deeply related to the origins of the RBV, is Edith Penrose. Her seminal work (Penrose, 1959) attempts to understand the process of a firm’s growth and the limits of it. Penrose had an assumption that firms can be appropriately modelled as if they were relatively simple production functions. According to Penrose, a manager has a task to exploit the bundle of productive resources controlled by the firm using an administrative framework created in the firm, to generate advantage (Penrose, 1959). Hence, Penrose emphasizes a firm's growth is based on a firm's resources and limited by managerial resources.

The Wernerfelt (1984) and Barney (1991) articles are seminal works in the RBV stream. While Wernerfelt (1984) highlights resources and diversification, Barney (1991) provides what is arguably the most detailed and formalized depiction of the business-level resource-based perspective.

One of the seminal authors prior to the foundation of RBV theory was Birger Wernerfelt whom analyzed firms from the resource side rather than from the product side (Wernerfelt, 1984). This author developed a simple economic tool for analyzing a firm’s resource position relating it within its profitability. Nevertheless, Wernerfelt (1984) stated that “For the firm, resources and products are two sides of the same coin” (Wernerfelt, 1984, p. 171), an innovative strategic approach. As a matter of fact, Wernerfelt (1984) theory launches the basis for the RBV theory that later author Jay Barney (Barney, 1991) matured and detailed. Nevertheless, Wernerfelt (1984) attempts to develop a simple strategic tool to examine a firm's resource position and to develop some strategic options that this analysis would suggest.

Therefore, Jay Barney is another seminal author and theorist of the resource-based view concept. This author explores that in a Resource-based view conception, there is a relation between firm resources and sustained competitive advantage. Meaning that the resource-based view (RBV) concept, offer strategists a means of evaluating potential factors, so that they can be deployed to confer a competitive advantage to a firm (Barney, 1991).

According to the RBV theory, an organization can be considered as a collection of physical resources, human resources, and organizational resources (Barney, 1991). Resources of organizations that are valuable, rare, imperfectly imitable, and imperfectly substitutable are the main source of sustainable competitive advantage for sustained superior performance (Barney, 1991). In this specific work (Barney, 1991), the author assumes that firm resources are heterogeneous and immobile and that a firm that exploits its resource advantages is simply behaving in an efficient and effective manner (Barney, 1991).

Not all resources are of equal importance, nor possess the potential to become a source of sustainable competitive advantage. Nevertheless, Jay Barney explains that, understanding the causal relationship between the sources of advantage and successful strategies can be exceedingly difficult in practice (Barney, 1991). Thus, Barney (1991) developed the VRIN criteria (Barney, 1991) where the firm's key resources should be evaluated as: Valuable, Rare, Imperfectly Imitable and Non-Substitutable (Barney, 1991). These criteria form a framework suggesting questions to be addressed in order to understand whether a given firm resource is a source of sustained competitive advantage (Barney, 1991). This resource-based model of sustained competitive advantage also has a variety of implications for the relationship between strategic management theory and other business disciplines. Therefore, strategic management decisions should point to develop, nurture, and protect resources that follow these criteria.

Another important theorist of the resource-based view concept is George Day and Robin Wensley, which introduce the idea of sustained competitive advantage (G. Day & R. Wensley, 1988). These authors propose an integrated view based on positional and performance advantage because of relative superiority in the skills and resources existing on a business. "These skills and resources reflect the pattern of past investments to enhance competitive position. The sustainability of this positional advantage requires that the business set up barriers that make imitation difficult. Because these barriers to imitation are continually eroding, the firm must continue investing to sustain or improve the advantage." (G. Day & R. Wensley, 1988, p. 2). The proposed framework identifies as superior skills and superior resources the sources of advantage. Only the sources of advantage can become a source for a firm's strategic positional advantage as superior customer value and lower relative costs. This strategic positional advantage would then be the performance outcome that leads to a sustained competitive advantage (satisfaction, loyalty, market share and profitability). These authors also state that part of the profits should be re-invested directly on the sources of advantage as a way to sustain them (G. Day & R. Wensley, 1988).

Nevertheless, G. Day & R. Wensley, (1988) emphasize the importance of the correct diagnosis of the current and prospective advantages of the business within the supplied market (G. Day & R. Wensley, 1988). They also make the following question “How do managers know whether the available assessments are aiding the search for advantage or hindering it with misleading and partial information?" (G. Day & R. Wensley, 1988, p.16). Lack of a good internal assessment on the firm’s actual skills and resources can mislead to a correct strategic positional advantage.

Author Robert M. Grant (1991) shares a similar view. According to Grant (1991), the resources and capabilities of a firm are central considerations in strategy formulation; resources are also termed as primary sources for profitability of firms. Criticising the resource-based theory itself due to the lack of a single integrating framework and due to the lack of effort on developing a practical implication of the theory (Grant, 1991), this author proposes a framework for a resource-based approach to strategy formulation. This proposed framework is based on the comprehension of the relations between resources, capabilities, competitive advantage, and profitability as well as to understand how the competitive advantage can be sustained over time. Grant further argues to identify the resource gaps and develop a resource base for the firm. Robert M. Grant also focuses on filling of resource gaps by exploiting resources to extend positions of competitive advantage and broaden the firm’s strategic opportunities. As per (G. Day, R. Wensley, 1988), sustaining the advantageous situations requires the constant development and reinvestment on resource bases.

Through Wernerfelt (Wernerfelt, 1984), the strategic position of the firm should be according to its internal assets and not to the market. This author used the “two sides of the same coin” metaphor for product/market strategic positioning. From this point, seminal authors, Ingemar Dierickx and Karel Cool (I. Dierickx, K. Cool, 1989) wrote that managers often fail to recognize that a bundle of assets, rather than the particular/product market combination chosen for its deployment, lies at the heart of their firm’s competitive position. Thus, low or no attention is given to the inside of the firm, to its own assets where the core resources and assets lie. Furthermore, these authors (I. Dierickx, K. Cool, 1989) discuss the notion of accumulation of asset stocks. Meaning that strategic assets stocks are accumulated by choosing appropriate time paths or flows over a period. Also, in this paper, and particularly for the R&D case, it is explained that the presence of time compression diseconomies implies that maintaining a given rate of R&D spending over a particular time interval produces a larger increment to the stock of R&D know-how than maintaining twice this rate of R&D spending over half the time interval (I. Diericxx, K. Cool, 1989).

As market is dynamic, firm's resources also need to change over a period to make them relevant in regimes of rapid change. This perspective, based on the resource-based view conception, is the dynamic capabilities view (DCV) and was developed by authors David Teece, Gary Pisano, and Amy Shuen (Teece et al., 1997). The dynamic capabilities have been defined by

> "The firm's processes that use resources—specifically the processes to integrate, reconfigure, gain and release resources—to match and even create market change. Dynamic capabilities thus are the organizational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die."
>
> (Eisenhardt & Martin, 2000, p. 1107)

The resource-based view theory considers resources and competencies as static, meaning that they can be addressed as stationary at a certain time frame and will also remain so over a period. The main point is that when firms are having resources that are valuable, rare, inimitable, and non-substitutable, it enables these firms on developing value enhancing strategies that are not easily copied by competing firms (Barney, 1991; Wernerfelt, 1984). However, in the current era of dynamic economy, there is the need for firms to build up new capabilities or competencies for sustaining such competitive advantage (Teece et al., 1997). Dynamic capabilities thus are the organizational processes or strategic routines by which firms develop new configuration for updating resources as per the time changing market requirements. Such dynamic capabilities require that organizations establish processes that enable them to change their routines, services, products, and even markets over time. Initially, to cope with market forces, the market-based view concept, subsequently the focus shifted to the resource-based view. Finally, to respond to challenges of the ever-changing globalized world, the concept of Dynamic Capabilities became a well-accepted theory.

The dynamic capabilities approach examines competitive advantage in the globalized environment of rapid market change. In such dynamic marketplaces, where the competitive environment is rapidly changing, managers of firms need to develop capabilities embedded in the firm which are based on sequences of path dependant learning in order to achieve periods of competitive advantage (Teece et al., 1997). Dynamic capabilities are strategic, hence organizational processes like product development are strategic decision-making which create value for firms by manipulating resources that are inherent with. Author Sidney Winter (2003) perspective of dynamic capabilities, is as a process of extending, modifying, or creating new capabilities. The key differential between ordinary capabilities and those that are dynamic is that dynamic capabilities are linked with change and more particularly, changing the resource base of a firm (Winter, 2003).

The dynamic capabilities approach is especially relevant today when global competitive forces are changing the industrial landscape. Consequently, ways of achieving competitive advantage are changing fast. As such, firms need to have timely strategies, flexible infrastructures, and an ability to utilize resources and coupled capabilities through innovate ways (Teece et al., 1997). Therefore, in contrast with traditional resource-based view assumptions, competitive advantages gained in the dynamic marketplace may be based on capabilities, which have greater homogeneity and substitutability across firms. Competitive advantages achieved through dynamic capabilities are therefore based on the ability to change the resource base of the firm as defined by Helfat et al. (2007). This means dynamic capabilities alter resource bases by creating, integrating, recombining, and releasing resources (Eisenhardt & Martin, 2000). The dynamic capabilities view (DCV) have been tightly coupled with a dynamic or rapidly changing environment (Teece et al., 1997).

Additionally, Teece’s dynamic capabilities view conception evolved to a disaggregation of capacities. So, (Teece, 2007) divides dynamic capability into three types: sensing, seizing, and reconfiguring. Meaning that DC’s can be disaggregated into the capacities to sense and shape opportunities and threats, to seize opportunities, and to maintain competitiveness by reconfiguring a firm's assets (Teece, 2007).

One recent research topic derived from the dynamic capabilities' theory is the networking capability. Mitrega et al. (2012) propose the concept of networking capabilities as "the complex organizational capability oriented towards managing business relationships along all main relationship life-cycle stages" (Mitrega et al., 2012, p. 739). In this article, the authors propose that the networking capability exists and is measurable. Hence representing an important factor that significantly influences firm performance. Moreover, this study develops and tests a measurement model of the networking capabilities that is consistent with a grounding in the resource-based view of the firm, specifically the dynamic capability view of the firm. The paper concludes with a discussion of the findings, its implications, and limitations of the study (Mitrega et al., 2012).

Mitrega et al. (2012) defined the three components of networking capability. The relationship initiation capability (RIC – a set of activities and organizational routines which are implemented at the organizational level of the focal company to initiate business relationships for the benefit of the company); the relationship development capability (RDC – a set of activities and organizational routines which are implemented at the organizational level of the focal company to develop, manage and strengthen, business relationships for the benefit of the company) and the relationship termination capability (RTC - comprises the company´s capability to select unfavourable business relationships, and the company's capability to discontinue relationships with unfavourable patterns), (Mitrega et al., 2012).

This research aims to contribute to the existing managing in business relationships existing literature, providing a capability model derived from a behavioural viewpoint (Mitrega et al, 2012). The authors of this study conclude that "firms see conflict with customers generally extremely critical, while conflict with suppliers becomes particularly pertinent with increasing dependency of the buyer" and that "despite the costs associated with switching suppliers, firms are less sensitive to conflict as long as they have relatively strong positions with respect to their suppliers" (Mitrega et al., 2012, p. 748).

In terms of actionable prescriptions for managerial practitioners, the findings in this study relate to the fact that business networking and business relationships are a key asset for company's competitive advantage and performance. Therefore, firms need to understand the processes, routines and capabilities required to manage as a direct implication to business relationships through networking activities aimed at specific relationship stages (Mitrega et al., 2012).

2.1.1. Critical Appraisals and Reviews

Through this comprehensive review, an interesting critical appraisal of the resource-based view theory done by Richard Priem and John Butler, came across (Priem & Butler, 2001). These authors examine the resource-based view theory (Barney, 1991) in terms of theory, method, empirical evidence, and operational validity.

Examining the resource-based view in terms of theory, Barney's definitions indicate that additional conceptual work is needed if the foundation of the RBV is to meet the lawlike generalization standard. The underlying problem in the statement "that valuable and rare organizational resources can be a source of competitive advantage" (Barney, 1991, p. 107) is that competitive advantage is defined in terms of value and rarity, and the resource characteristics argued to lead to competitive advantage are value and rarity. Instead, the characteristics and outcomes must be conceptualized independently to produce a synthetic statement (Priem & Butler, 2001).

Another, appraisal from Priem and Butler (Priem & Butler, 2001) regarding Barney's concept (Barney, 1991) and the logic of the RBV is that "value is the fundamental component determining the extent of competitive advantage. If a firm consistently generates value greater than that generated by other firms in its industry, it must have at least one rare resource. If a firm has rare resources, however, it does not follow that it will generate value greater than that of other firms in its industry (Priem & Butler, 2001).

The resource-based view theory has developed as a series of related propositions that seek to explain the relationship between a firm's resource endowment and its performance and growth. However, it has not generated clear unambiguous hypotheses in the manner of more narrowly conceived theories of firm behaviour or even transaction cost economics. Priem & Butler (2001) discuss the practical difficulties arising in the RBV methodologies.

On the operational side, one fundamental question for strategy researchers would be the utility of the RBV in developing practical management tools in the form of actionable prescriptions for practitioners. As per Priem & Butler (2001) critical appraisal, advising practitioners to obtain rare and valuable resources in order to achieve competitive advantage and, further, that those resources should be hard to imitate and non-substitutable for sustainable advantage, does not meet the operational validity criterion (Priem & Butler, 2001). Prescription regarding competitive advantage itself, however, still is hindered because the criteria for value in the RBV remain, at present, in an exogenous "black box" (Priem & Butler, 2001).

From the methodological issues side, the multiple studies of resources and firm performance vary substantially in terms of the methodology employed and the way the RBV research is designed. Rouse & Daellenbach (1999) question the strong bias towards quantitative research methods suggesting that such a methodology is not appropriate for RBV research in general. The researchers suggest that the nature of advantages in organizations should be firm based and complex and, as such, qualitative and field-based methodologies such as case studies are much appropriate.

Barreto (2010), writes a seminal article where he reviews and critical assesses the key conceptual and empirical articles on dynamic capabilities published in the leading management journals and a corresponding frame of recommendations for future research. The main motivation of this author for this seminal article was the growing literature on the topic, which, along the years has been providing successive and distinct definitions for this theory and that the dynamic capabilities view have been subject of some important criticism.

One of the most discussed topics within Barreto (2010) article are the outcomes of the dynamic capabilities' theory. Early theorists assumed from its beginning the direct relationship from the dynamic capabilities and firm's performance (Teece et al., 1997). This view is also shared with seminal author Makadok (2001), that also theorized the dynamic capabilities view a causal mechanism by which firms create economic profit. Contrasting with (Eisenhardt & Martin, 2000, p. 1106) view that reiterated, "dynamic capabilities are necessary, but not sufficient, conditions for competitive advantage". In their seminal paper, these authors add that a long-term competitive advantage does not rely on dynamic capabilities themselves but on the resource configurations created by the dynamic capabilities and on "using dynamic capabilities sooner, more astutely, more fortuitously than the competition” (Eisenhardt & Martin, 2000, p. 1117). Another critical appraisal on this topic of the dynamic capabilities view referred in Barreto (2010) article, comes from author Zott (2003), who similarly argued that there is not a direct link between dynamic capabilities and firm performance; dynamic capabilities may influence performance through modifying a firm’s bundle of resources or routines.

Barreto (2010), demonstrates that the dynamic capabilities view is not yet a theory, “I show why the approach is not yet a theory, and I offer some suggestions to guide future efforts to achieve such goal” (Barreto, 2010, p. 270). Hence, Barreto (2010) conceptualizes an alternative definition for dynamic capabilities based on past research. This definition of dynamic capabilities houses old and new suggestions within the field and in other hand tries to overcome some of its limitations.

> “A dynamic capability is the firm’s potential to systematically solve problems, formed by its propensity to sense opportunities and threats, to make timely and market-oriented decisions, and to change its resource base.”
>
> (Barreto, 2010, p. 271).

Barreto (2010, p. 271) concludes that “no dimension alone can represent the construct”. Hence his proposed definition is itself a multidimensional construct as it refers to four distinct but related dimensions or facets (i.e., the propensities to sense opportunities and threats, to make timely decisions, to make market-oriented decisions, and to change the firm’s resource base) treated as a single theoretical concept (Barreto, 2010).

From the operationalization side, Barreto (2010) suggests that researchers should not engage the aggregate construct (dynamic capability) but also the multidimensional constructs. Hence, Barreto (2010) also suggests that for future research, a firm’s dynamic capability should be considered as a simple sum of its four dimensions (assigning equal weights to each dimension) or as a multiplicative nonlinear function of these dimensions (Barreto, 2010).

Regarding the relation between the dynamic capabilities and performance, one major issue on this field as already referred, Barreto (2010) suggests that researchers “should recognize that the kinds of relationships to be explored crucially depend on the nature of the definition of dynamic capabilities used in the analysis" (Barreto, 2010, p. 274). However, Barreto (2010) suggests that an indirect link between dynamic capabilities and performance should be explored. As he states, "perhaps because of the strong emphasis initially put on the direct link to performance, those suggestions remained largely unexplored" (Barreto, 2010, p. 275).

Hence, Barreto (2010), concludes that future research should explore not the direct relation between dynamic capabilities and firm's performance or rents, but between dynamic capabilities and intermediate outcomes and between the intermediate outcomes and performance. Furthermore, this author states, "Even more importantly, future work should attempt to simultaneously address these two research goals in the same study." (Barreto, 2010, p. 276).

The seminal review and critical appraisal from Shilke et al. (2018) synthesize the insights from research and reviews the current state of knowledge of ten years since Barreto (2010) compilation. Moreover, Shilke et al. (2018) article, aims to go beyond current knowledge identifying significant literature gaps, unresolved issues and to address suggestions for future dynamic capabilities research.

The starting point of Shilke et al (2018) study was the conceptual background, where it is defined two broad categories for firm capabilities, the operational capabilities (directed toward maintaining and leveraging the status quo in terms of the scale and scope of activities, businesses, product lines, customer segments) and the dynamic capabilities (directed toward strategic change), (Shilke et al., 2018). Hence, they define dynamic capabilities as:

> "Dynamic capabilities can be considered a distinct subset of organizational capabilities; specifically, they are those capabilities that can effect change in the firm's existing resource base (and the associated support system such as the firm's organizational and governance structure), its ecosystem and external environment, as well as its strategy."
>
> (Shilke et al. 2018, p. 393).

Moreover, Shilke et al. (2018) refers to firm's capabilities, including dynamic capabilities, the capacity to carry out activities in a "practiced and patterned manner" (Shilke et al. 2018, p. 393).

This seminal study from Shilke et al. (2018), as referred, start the review and assessment of the literature from the year 2008 as Barreto's (2010) seminal piece ended in 2007. The review of the current state of dynamic capabilities starts with the theoretical foundations: the dynamic capabilities definitions, theoretical assumptions and theoretical integration. After, they integrate the various findings of the studies into an organizing framework that identifies the primary influences on, characteristics of, and outcomes of dynamic capabilities. This review shows that the study of this subject has progressed to a level which the literature comprises not only conceptual research but also empirical work on antecedents and consequences of dynamic capabilities, as well as moderators and mediators (Shilke et al., 2018).

After this review, Shilke et al. (2018) suggest future directions for dynamic capabilities research. In the same way, they start with the theoretical foundations: the dynamic capabilities definitions. Shilke et al. (2018) reflect that not every form of change is evidence of a dynamic capability as they are context dependent. Hence, suggest special attention between the object of study and the definition of dynamic capabilities as it limits the extent to which a research study can advance the understanding of the dynamic capabilities. Moreover, and regarding the theoretical assumptions, one area suggested for further elaboration was concerning the stance on managers' rationality. To what extent managers are boundedly rational and under what circumstances can they be expected to deviate from full rationality? (Shilke et al., 2018).

From the theoretical integration point of view, the authors suggest that, following the trajectory of the openness and flexibility to integrate other knowledge areas that the dynamic capabilities provide, would be important to further develop the framework and advance the current state of art.

Regarding the dimensionalization item from Shilke et al. (2018) framework, these authors suggest that, as traditionally researchers situate dynamic capabilities at organizational level of analysis, research on supply management has indicated the opposite. That dynamic capabilities act at the interorganizational level of the supply chain system, "an intriguing idea that we find worthy of greater research attention" (Shilke et al., 2018, p. 417). Regarding the antecedent's topic (Shilke et al., 2018), these authors refer the need to know more about how different types of networks and network positions may shape dynamic capabilities. Moreover, on the consequences item, Shilke et al. (2018) reflect on the amount of evidence found on their review about the link between dynamic capabilities and performance outcomes suggesting that the study of such consequences will and should remain at the core of future inquiry. Shilke et al. (2018), reiterate that "a key aspect that sets the dynamic capabilities perspective apart from other literatures on change is its strong orientation toward explaining competitive advantage. Therefore, we expect many future studies to have some type of performance measure as their dependent variable" (Shilke et al., 2018, p. 419). On the mechanisms topic, Shilke et al. (2018) suggest that other than the usual resource change as mediating variable, adding the environmental should worth greater attention from the research on the dynamic capabilities topic. Finally, on the moderator's item of the dynamic capabilities framework presented by Shilke et al. (2018), it is suggested by the authors that forthcoming research should integrate the effect of dynamic capabilities on variables handled as moderators, such as organizational size, culture, structure, strategy, and other capabilities (Shilke et al., 2018).

Shilke et al. (2018), critical appraisal, conclude their seminal article by suggesting on research methods as they recommend using mixed-methods research methodology would allow for a simultaneous theory extension and testing. So far, most studies on dynamic capabilities rely on either qualitative or quantitative approaches but merging the two in a single investigation would significantly increase insight into the operational and the comprehensive role of dynamic capabilities (Shilke et al., 2018).

Forkmann et al. (2018) article is an extensive review and critical appraisal on capabilities in business relationships and networks. Hence, this review is focused on capabilities that provide firms to effectively manage business relationships and networks. Through the last years, capabilities in business relationships started to be an important area of development in industrial marketing research and on developing the dynamic capabilities theory (Mitrega et al., 2012; Forkmann et al., 2018).

In this study, the authors aim to review the current state of literature relating to capabilities in business relationships and networks in order to identify its gaps. They provide guidelines regarding future research directions and in doing so, contribute to the current state of art by providing a foundation for theory consensus creation (Forkmann et al., 2018).

Business relationships theorize how firms can manage such relationships such as buyer-supplier, supplier portfolio, demand chain integration, or the overall network (Forkmann et al., 2018) Actually, business relationships management require specific abilities including, for example, addressing customer requirements that can be met with the current resource base. Current literature, consider that dynamic capabilities allow firms to use business relationships to create, extend or modify its resource base. Including “the capacity to address changed customer requirements that necessitate an altered resource base” (Forkmann et al., 2018, p. 5). Hence, the resource base adjustments are essential due to context dynamics can it be threats, opportunities, both or are ambiguous. These changes can be from internal or external origin i.e., from the firm itself, from business relationships, from the embedding business network, or from the wider environment (Forkmann et al., 2018).

2.1.2. Operationalising RBV and DCV of the firm

One can conclude the dissatisfaction with the traditional strategic management tools as a framework for creating and sustaining competitive advantage. As the main cause of difficulty in operationalising the RBV and DCV is its high level of abstraction. Through the review of Priem and Butler's critical appraisal on the resource-based view of the firm theory (Priem and Butler, 2001), researchers often mention, but have rarely addressed questions related to the operationalisation of the resource-based view theory. Therefore, operationalisation formalises the theoretical concepts into applicable models and guidelines for strategy formulation and decision-making process for practitioners and managers (Ford & Mahieu, 1998).

From the reviewed critical appraisals, one of the main difficulties suggested was to clearly identify the sources of sustained competitive advantage. Ford & Mahieu (1998) was one of the very first attempts to operationalise the resource-based view theory. In their research, they refer the absolute need to operationalise the RBV because of its inherent high level of abstraction. "This makes it difficult for practitioners to recognise which resource-based strategy will lead to sustainable advantage (Ford & Mahieu, 1998).

In their attempt to operationalise the RBV theory, Ford & Mahieu (1998) evaluate all the operative resource-based models through four characteristics: they should provide guidelines to identify and select valuable resources, portray the resources' intrinsic endowment dynamics, depict how managerial policies affect resource management and describe the ability to trace consequences of potential strategies over time. They conclude that none of the analysed models embody all four characteristics required (Ford & Mahieu, 1998).

Ford & Mahieu (1998) operationalise the resource-based view theory in five steps embodying three levels of analysis: the firm's environment, the firm, and resources. Those three levels encapsulate and structure the four necessary conditions for operationalisation, as referred before (Ford & Mahieu, 1998). The five-step methodology consists of:

> "Step 1: List valuable resources: Based on data collected through an environmental and internal resources appraisal we explicitly list the resources which contribute the most to strategy formulation.
>
> Step 2: Sketch resource charts: We draw resource behaviours over time to describe the development of resources and to pinpoint interactions within the resource system. The degree to which each resource can be managed estimated.
>
> Step 3: Draw key-resource maps: Resource charts are used to describe each system's relationships, thereby making it possible to describe the overall resource system. Feedback structures are identified.
>
> Step 4: Identify resource strategic plans and managerial policies: We explicitly formulate the management mental models and policies as the basis for understanding how human decision-making processes affect resources endowment.
>
> Step 5: Develop system model which can explicitly formulate relationships between resources, trace the scale of change and test alternative managerial policies and strategies as a basis for improvement."
>
> (Ford & Mahieu, 1998, p.4).

Actually, Ford & Mahieu (1998) describe an effective way of operationalising the resource-based view of the firm using the described five steps and three levels of analysis as guidelines for the development of a useful system model to design and analyse strategy alternatives. Nevertheless, these authors consider that quantifying intangible resources still consists of a challenge This attempt on operationalising the resource-based view theoretical concepts and ideas was successfully accomplished. "This helps fill an important gap in the strategic management field concerning explaining how RBV theory can be developed and implemented rather than what RBV theory should consist of. System dynamics plays a major role in operationalising this process" (Ford & Mahieu, 1998, p. 14).

Ford & Mahieu (1998) was not the only study addressing the issue of operationalisation the RBV theory. Scott Newbert (Newbert, 2008) tested the RBV hypothesizes at a conceptual level. This author published an empirical study (Newbert, 2008) examining the relationships between value, rareness, competitive advantage, and performance. Results from conceptual level studies do provide insight in what attributes resources and capabilities must own to improve a firm's competitive position (Newbert, 2008). These are the same attributes, that authors George Day and Robin Wensley (G. Day, R. Wensley, 1988) emphasize the importance of the correct diagnosis. Newbert (2008) introduces the need to predetermine which characteristics of resources and capabilities ought to be correlated with competitive advantage and/or performance. Even if a given resource may have the potential to produce a valuable service, that service will remain buried until deployed through a relevant capability. Therefore, even if a resource (or a capability) might have potential value, its value can only be realized when it is combined with a matching capability (or resource). Moreover, the more valuable the firm's resource-capability combinations, the greater the advantage it will enjoy because of their exploitation.

This empirical study (Newbert, 2008) synthesizes most of the guidelines from the seminal RBV theorists. Newbert (2008) tests the following hypothesizes directly derived from Jay Barney seminal work (Barney, 1991):

> "Hypothesis 1: The value of the resource-capability combinations that a firm exploits will be positively related to its competitive advantage."
>
> (Newbert, 2008, p. 748)
>
> "Hypothesis 2: The rareness of the resource-capability combinations that a firm exploits will be positively related to its competitive advantage."
>
> (Newbert, 2008, p. 749)
>
> Hypothesis 3: A firm's competitive advantage will be positively related to its performance.
>
> Hypothesis 4: A firm's competitive advantage will mediate the relationship between the value of the resource-capability combinations that the firm exploits and its performance.

> Hypothesis 5: A firm's competitive advantage will mediate the relationship between the rareness of the resource-capability combinations that the firm exploits and its performance.
>
> (Newbert, 2008, p. 750)

After finding support for Hypothesis 1 and Hypothesis 2 one can conclude that the value and rareness of a firm resource-capability combinations contribute to its competitive advantage, hence contributing to its performance. In this study (Newbert, 2008), by inclosing the independent variables in terms of resource-capability combinations (as opposed to individual resources or capabilities) correctly captures the dynamics by which resources and capabilities have long been argued to contribute to competitive advantage (Newbert, 2008).

As per Priem and Butler critical appraisal (Priem & Butler, 2001), one of the fundamental questions for strategy researchers would be the utility of the RBV in developing practical management tools in the form of actionable prescriptions for practitioners. The finding that a competitive advantage is related to the combination of valuable, rare resources and capabilities might be useful in the way in which managers make decisions to alter their firms' resource/capability bases (Newbert, 2008).

On the support basis for Hypothesis 3, Newbert's study (Newbert, 2008) finds evidence on the idea that a competitive advantage via the implementation of a resource-based strategy is an important means by which a firm can improve its performance (Newbert, 2008).

Concluding, author Scott Newbert was able to find that competitive advantage fully mediates the rareness-performance relationship, it appears that to increase any performance gains from its resources and capabilities, a firm must first achieve the competitive advantages that outcomes from their combined exploitation. Hence, improving performance is not a direct function of the value or rareness of a firm's resource-capability combinations but rather of the advantages it creates from their exploration (Newbert, 2008). Firms need to deploy those resources and capabilities to which they do have access but through new and different combinations such that they are able to reduce costs and/or respond to environmental conditions (Newbert, 2008).

Furthermore, (M. Terziovski, 2010) investigates the innovation practice and its performance implications in small and medium enterprises (SMEs) in the manufacturing sector under the resource-based view framework. In this investigation, Terziovski (2010) theorizes that SMEs are analogous to large firms with respect to the way that innovation strategy and formal structure are key drivers of their performance. Additionally, he concludes that the improvement of SMEs' performance is related to the increasing degree to which they mirror large manufacturing firms with respect to formal and structural strategy, and to the extent of recognition of how innovation culture and strategy are closely aligned through the innovation process.

Moreover, Lin & Wu (2013), explored the combination of the RBV theory with the Dynamic Capabilities view (DCV). As referred before, Teece, Pisano, and Shuen (1997) proposed the concept of DCV to address the important role of capabilities to build, integrate and reconfigure resources to cope with a highly unpredictable environment. Consequently, in situations involving dynamic and fast-changing environments, DCV explains firm competitiveness more effectively than RBV (Lin & Wu, 2013). Lin & Wu (2013) also stated that when combining the RBV theory with the DCV, strategic decisions become increasingly complex because the classification and selection of resources are both important. So, Lin & Wu (2013) tried to understand the role of dynamic capabilities under the RBV framework, examining the types of resources that are most crucial to be transformed into performance through dynamic capabilities, and the types of dynamic capabilities which have the strongest effect in mediating resources on performance. (Lin & Wu, 2013).

This study uses the approach of Teece et al. (1997), that defines firm dynamic capabilities as the capabilities of a firm to integrate learn and reconfigure internal and external resources. Internal resources generally represent the resources possessed by the firm itself, while external resources can be obtained through cooperative alliances and acquisitions (Lin & Wu, 2013). Likewise, this study considers Dynamic capabilities as a transformer for converting resources into enhanced performance. Because of the characteristics of VRIN resources (Barney, 1991), the dynamic capabilities can effectively extract the competitive combinations from them to improve firm performance (Lin & Wu, 2013).

The analytical results of this investigation demonstrate that VRIN resources can enhance firm performance, while non-VRIN resources have only an insignificant influence (Lin & Wu, 2013). Moreover, this study also concludes that, the correlation between resources and dynamic capabilities, for the VRIN resources positively affect the development of all three types (integration, learning, and reconfiguration) of dynamic capabilities. In contrast, non-VRIN resources do not significantly affect the development of dynamic capabilities.

Lin and Wu (2013) conclude this study by suggesting that the competitive advantages result not only from accumulation of VRIN resources, but also from the development of dynamic capabilities, particularly dynamic learning capability (Lin & Wu, 2013). Strategic management should consider RBV and DCV as a combination, instead of considering them as separate (Lin & Wu, 2013).

As already referred, the DCV theory states that firms which can sense and seize fresh opportunities and then reconfigure their capabilities and resources, according to the environmental change, as well as recognised opportunities, are able to establish and maintain their competitive advantages (Teece, 2007).

The developed model (Teece, 2007) divides dynamic capability into three types: sensing, seizing, and reconfiguring. As previously described, several studies in the last few years (e.g. Barreto, 2010; Shilke et al. 2018), including systematic reviews and metanalyses, have highlighted that this area of study falls short when it comes to describing the conceptual consequences (Peteraf et al., 2013) and providing robust empirical evidence (Barreto, 2010).

The study of Breznik, et al. (2018) is one of the rare reports building on carefully selected case studies of firms which can stay competitive in the IT industry and investigating several capabilities of the firm as dynamic capabilities.

Moreover, on this study, Breznik, et al. (2018) have employed Teece's (2007) conceptual typology of dynamic capabilities in order to study the exploitation of firm capabilities as dynamic capabilities. This research fosters the development of the dynamic capabilities view towards empirical evidence. Therefore, this study focuses on dynamic capabilities through detailed cross-case studies of firms operating in an unstable environment. Teece (2007) describes how deployment of capabilities can be explored through sensing, seizing and reconfiguring capabilities. Such a perspective enables this study (Breznik et al., 2018) to better understand the logic behind the DCV. It is proposed that managers have an important impact on the exploitation of firm capabilities as dynamic capabilities.

This study (Breznik et al., 2018) provides evidence for further development of the dynamic capabilities view. First, (Breznik et al., 2018) employed Teece (2007) conceptual typology of dynamic capabilities in order to study the exploitation of firm capabilities as dynamic capabilities. Breznik et al., (2018) have shown how deployment of capabilities can be explored through sensing, seizing and reconfiguring capabilities. Such a perspective enables scholars to better understand the logic behind the DCV. Consequently, Breznik et al., (2018) propose that managers have an important impact on the exploitation of firm capabilities as dynamic capabilities.

2.2. Design as a Process for Product Development

One of the constructs for the present literature review is Design as a process for product development. Hence, this chapter intends to define a theoretical framework for Design as a language that requires processes. In this way, an extensive analysis and review of different processes is made as a global strategy for product development. It is also described some definitions of Design and its purpose, as well as perceived some of the boundaries of the different processes. It is presented the definition of product itself, the design process concept and discussed some of the most representative model maps for processes.

Since the background of the present research is the automotive industry, a specific emphasis is given to the Advanced Product Quality Planning (APQP), the Design process of the automotive industry. With this overview, it is possible to understand how design is embedded through the development of new projects all through the automotive supply chain of suppliers.

Additionally, it is presented a classification framework for design capabilities for the automotive industry suppliers and the idea of the development of suppliers through the evolution of design activities. These specific Design capabilities will later be crossed with the already introduced dynamic capabilities.

2.2.1. Definition of Product

The Collins English Dictionary (Collins, 1987) defines product as "something that is produced and sold in large quantities, often as the result of an industrial process" (Collins, 1987, p. 1145). So, a question emerges from this definition, what is to produce?

The concept of production is intricately linked to the concept of work. Karl Marx demonstrates it as being a process that takes place between man and nature (Marx, 1975). This same author suggests as being intentional activity whose purpose is the production of valuable and useful objects, it is the appropriation of natural elements. It is a general condition of material exchanges between man and nature, a permanent natural condition in human life and thus independent of any social form of that life, or rather, similar to all its forms of society (Marx, 1975).

It is possible to realize that the concept of product is somewhere between the result of the activity of work (production) and the utensil, object, material of execution of this activity. Thus, this intentional activity, resulting from the appropriation of natural elements, as Maurice Godelier explains in his contribution to the Einaudi Encyclopaedia (Einaudi, 1986) is "an organized direct or indirect series of actions on nature in order to detach some of its elements from their immediate links within its conditions of existence, their environment and using them in the material reproduction of individuals and their reciprocal relations, their social relations, their society" (Einaudi, 1986, p. 15) and concludes by classifying it, "The detached elements become useful to man either in their immediate natural form (locally consumed collection products without cooking or other preparation) or after various changes of shape and state which lead them to the final form in which they are usable and become consumables" (Einaudi, 1986, p.15).

Therefore, man interacts with nature, by means which are primarily his own, namely his physical and intellectual capacities. The act of producing is nothing more than the combination of material elements and ideas - the know-how - the technique. Author Karl Marx also noted that "just as the natural organism, head and hands do not subsist without each other, the labour process unites intellectual and manual activity" (Marx, 1975, p. 621).

Finally, about man's relation with nature, man does not limit himself applying his own strength, but also by interposing material objects - utensils - between himself and the object of his work. Thus, Marx (1975) breaks down the work process into three elements: 1) the activity of the individual according to an objective or work itself; 2) the object on which it carries out its activity; 3) the means.

Thus, the object and the means of work exist, as Maurice Godelier explains, “by its function in a process” (Einaudi, 1986, p. 16). In other words, “An object produced according to a given work process becomes the raw material of another”, which can be transformed into its form and state, before being a consumable object (final product) or as a tool. Similarly, Marx (1975) states, “The characteristic of the product, the raw material or the working environment is linked to the value of usability, according to the function that the object plays in his work process and its relative position in it; changing its relative position alters the outcome” (Einaudi, 1986, p. 16). Finally, work is then the resulting impetus in a product. Work is the consequence of the activity of production in which the object and the means of labour are means of production and at the same time products.

2.2.2. Definition and Historical Background of Industrial Design

Design is mainly a phenomenon of the twentieth century. Author Bernhard Bürdek states in his work, "Since the early 1980's Design has been experiencing a global boom. Propelled to dizzy new heights worldwide by the rise of the postmodernist movement, starting at the end of the 1970's, and especially by the Memphis group of the early 1980's, Design will continue to soar well into the twenty-first century. Corporations and institutes across the world recognize the strategic value of Design and are busy cultivating it to a high degree of perfection" (Bürdek, 2005, p.7).

It was not until the second half of the nineteenth century that the function of industrial design began to develop. According to author Tomás Maldonado, "Industrial Design is usually understood as the design of objects for industrial manufacture, that is to say, by means of machines, and in series" (Maldonado, 2009, p. 11). Additionally, this same author deconstructs his own definition, exposing its ambiguity, "For example, it cannot pinpoint the difference between the activity of the industrial designer and the activity traditionally developed by the engineer" (Maldonado, 2009, p. 11).

It was not until 1913 when the commissioner of the United States of America patent office amended the regulations to protect property in Industrial Design and has officially introduced the term Industrial Design "The phrase was used clearly as a generic description for the distinguishing form of products, as distinct from their function" (Lorenz, 1991, p. 10).

Industrial Design finds its roots in the separation between Design and production which occurred by means of the industrial revolution. In other words, the design and manufacture of a product were no longer manufactured by the same person, as it was previously, "until then the craftsman who designed an object usually also made it, either himself or with the help of his workshop apprentices" (Lorenz, 1991, p.10). However, by 1907 in the city of Munich, was founded the Werkbund. The Werkbund was a society that integrated artists, craftsmen, industrialists, and journalists with the purpose of improving mass produced goods, through the cooperation between industry, arts and crafts, education, and advertising. Both lines of thought were represented at the Werkbund: standardization of product on one hand, artistic expression of the individual on the other. One of its main dogmas was the existence of the absolute standard of good form.

Architect and designer Peter Behrens, one of the founders of the Werkbund, begins a long collaboration with AEG, the great German company of electrical products, as artistic director. This architect starts developing a line of products for this brand, its graphic image, and the design of its headquarters building.

In fact, the Werkbund left a colossal mark on European design and in 1919, the Staatliches Bauhaus was founded, an organization whose impact is still echoed today. Directed initially by Walter Gropius and later by Mies van der Rohe (who had worked in Peter Behrens' studio), the Bauhaus helped develop a series of innovative theories for Design. In addition to the mere functionality of the products, Bauhaus conveyed to his students the importance of geometry, precision, simplicity, and economy, providing intellectual foundations to more than half a century of practice of Architecture and Design.

By this time, the United States of America was experiencing a deep economic crisis, leaving the promising industrial society in a slump of unemployment and recession. However, it is during the third decade of the 20th century that the young American industry reacts to the great depression, forging a new and original cultural identity. The image of the machine, the fascination with speed and the explosion of the automobile industry, give rise to a style; the first authentically American style: The Streamline. Criticized by the European modernist movements for being a mere futile expression, a symbol of the relation between production and consumption, streamline in Europe was seen as the product of wild materialism and commercial efforts combined with a trivial artistic advertising. Maldonado notes, “Ultimately, this is the birth of styling, that is, that genre of industrial design seeking to make the product superficially attractive, often to the detriment of its quality and convenience, seeking its artificial aging instead of prolonging its enjoyment and use. All in all, a wasteful program for a society that, at that moment, had little or nothing to waste” (Maldonado, 2009, p. 46).

One of the first companies to realize that it needed something to overcome the crisis, would have been General Electric, which at the beginning of the second decade of the 20th century created a department of Product Styling. Thus, many other companies quickly realized that the way a product looked in an advertisement would be a key element in the way it communicated with the public and consequently its acceptance.

Despite the resistance of Henry Ford who, citing himself in the work of Maldonado, “An automobile is a modern product, and should be built not for represent anything but to be able to deliver a service for which it was conceived” (Maldonado, 2009, p. 45), has been overtaken by General Motors' Alfred Sloan, on learning the power of making, on a yearly basis, small formal and decorative changes to the models of GM’s automobiles, commonly known as restyling.

Post-war Europe once again urged Bauhaus founded values of the good form with the support of organizations such as the British Council of Industrial Design or even the German Hochschule für Gestaltung in Ulm. However, European consumers were eager for innovative products and did not understand the cultural values that the Good form suggested. Raizman reveals in his work, “Yet for many consumers, the “good design” model was not understood as a universal set of standards that raised general cultural awareness or instilled responsible democratic values” (Raizman, 2010, p. 257). Only in the early 1960s, during the post-war European economic recovery and with the increase of the entrepreneurial competition, is that the Industrial Design begins to play a role of relevance, within the heavy hierarchies’ decision makers of the companies. One of the companies that followed the Good form dogmas was Braun, hiring one of his most brilliant graduates: Dieter Rams.

Only a very limited number of European designers have been able to influence product design within the companies. To join the 'superstars', namely Dieter Rams in Braun, first, and Marcello Nizzoli, Ettore Sottsass and Mario Bellini at Olivetti. Only a few consultants such as Kenneth Grange or John Chris Jones have been able to influence the product development process.

After the radical and politicized 1960’s only in 1971 author Victor Papanek writes the seminal work ‘Design for the Real World’ echoing the universality of the Design, right in the opening of his work “All Men are designers. All we do, almost all the time, is design, for design is basic to all human activity" (Papanek 2011, p. 3). According to Papanek, "The most important skill a Designer can bring to their work is the ability to recognize, isolate, define, and solve problems" (Papanek, 2011, p. 163). In Papanek's perspective, the conscious and intuitive attitude of creating order can be considered an act of Design. Papanek himself suggests two examples, such as the organization of a desk or the search for a solution to achieve peace for world's armed conflicts.

Design is a language that requires processes. However, the main function of Design is to solve a problem. Simon (1996) argues that "The engineer, and more generally the designer, is concerned with how things ought to be in order to attain goals, and to function" (Simon, 1996, p. 4). Papanek (2011) refers that Design must be available to people. It cannot be centered, in the designer itself. That is, designers can not focus their work on personal problems but rather on human needs in general.

More recently, Bryan Lawson corroborates Papanek's idea, "Design cannot be practiced in a social vacuum. Indeed, it is the very existence of the other players such as costumers, users and legislators which makes design so challenging. Merely working for yourself can be seen more as an act of creating art in a self-expressionist manner" (Lawson, 2006, p. 237). Finally, Design should thus place total focus on human needs and should perceive the user as the central pillar of its development. However, in the 1980s, there was a movement of Design, with an opposite direction style to the functionalism of Ulm and Papanek's approach to ecological and social consciousness. In the sense of overcoming the doctrine of functionalism, postmodernist movements attempt a metamorphosis of Design with art.

Despite this form of thought, in the case of the much-criticized Italian group Memphis, it should be recognized that Art and Design are two areas that do not come as separate. As Design should be understood as a symbiosis between Art and Science. During the Design practice there are strong logical approaches, characteristic of the universe of science, but also great intuitive approaches, which have links with art. In this way, the difference between Design and Art is its purpose: object of creation, which also separates it from Science, as Lawson states: "Unlike scientists who describe how the world is, designers suggest how it might be" (Lawson, 2006, p. 112).

Tomás Maldonado proposed a definition of Industrial Design that was adopted by the International Council of Societies of Industrial Design (ICSID). This demonstrates his thinking, “Industrial design is an activity that consists of determining the formal properties of industrially produced objects. It is understood by formal property not only the external characteristics but also, and above all, the functional and structural relations that make the object a coherent unit, both from the point of view of the producer and the user. While the exclusive concern for the outer features as a desire to make it appear more attractive inevitably mask its constructive weaknesses. The formal properties of an object - at least as I understand it - are always the result of integration of various factors, functional, cultural, technological, or economic. In other words, while the external characteristics refer to anything that appears to be a strange reality, that is, something detached from the object and not developed in symbiosis with it, the formal properties, on the contrary, constitute a reality that corresponds to its internal linked and developed organization” (Bonsiepe ,1992, p.37).

With this definition, Maldonado understands Design in different dimensions, such as the technological structure of countries, with different levels of industrialization, the socioeconomic context, the complexity of the product, and the greater or lesser degree of dependence on traditional craft objects.

Finally, another no less important factor in the definition of Design is the awareness of all parties involved in the process. It is essential that the designer can transmit to all stakeholders his vision. The designers act, according to Lorenz “as catalysts in the development of the common product imagination for the management team” (Lorenz, 1991, p. 23).

Similarly, Bryan Lawson builds a definition of Design that corroborates this view, “We do not see designing as problem solving in the traditional sense of that phrase. We do not see designing as directional activity that moves from problem through some theoretical procedure or solution. Rather we see it as a dialogue, a conversation, a negotiation between what is desired and what can be realized” (Lawson, 2006, p. 272).

Likewise, Brigitte Mozota reveals this point of view, when she states that “The creative process must internally apply technologies, concepts, and production methods and externally satisfy the needs of a large environment of users and stakeholders” (Mozota, 2003, p. 18). In the specific field of Industrial Design, IDSA - Industrial Designers Society of America suggests the following definition: “Industrial design is the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of user and manufacturer” (Mozota, 2003, p. 3).

The role of the Industrial Designer does not exclusively concern to the formulation of a solution. It must respond to questions of optimization, value and formal appearance and fundamentally act as a catalyst, in order to find a balance between the stakeholders involved in the problem.

2.3. The Industrial Design Process

2.3.1. Definition and Historical Background

The post-war period and the need for a new impetus in the industrialization of the world forced academics to dedicate their research to the problematic of the process for the Design activity. This question was mainly focused on the systematization of a process that would guarantee a methodology for the development of the industrial product. However, the approach to an institutionalization of process for Design would have been controversial. Some scholars have opposed this type of approach, arguing that the practice of Design should be free, in creation and not placed from a strictly logical point of view.

As already referred Design is a language that requires processes. Therefore, it is possible to segment a continuous flow on different stages creating a process. Thus, constraining the process in the flow between the characterization of an opportunity or problem until the ideal solution is found. Papanek (2000), in his seminal work Design for the Real World, states, “The planning and patterning of any act toward a desired, foreseeable end constitutes the design process” (Papanek, 2000, p. 322). Kathryn Best (2006) corroborates the following by speaking of the design process as a “series of methods that are put together to suit the nature of each design project or question” (Best, 2006, p. 112).

John Chris Jones, in his work Design Methods, argues that the goal of studying processes of Design and demonstrating them is to clarify the work process developed by designers. The methods for Design are nothing more than attempts, to make public the thought of the designers and externalize the process of Design (Jones, 1992).

Therefore, Jones (1992) characterizes the process of Design by systematizing it, “includes the three essential stages: analysis, synthesis and evaluation. These can be described in simple words as 'breaking the problem into pieces', 'putting the pieces together in a new way' and 'testing to discover the consequences of putting the new arrangement into practice” (Jones, 1992, p. 63).

The three major steps to systematize the process of Design that Jones (1992) presents are nothing more than the steps that designers have become accustomed to in the exercise of their profession. The analysis phase is simply the deconstruction of a problem as soon as it is posed. It is here that we study all the constraints that involve the problem, researching all possible alternatives and the goals and objectives are defined. The second phase, synthesis, is the generating phase of possible solutions to solve the problem. The last phase, evaluation, is where the solution is tested and its performance against expectations is evaluated (Jones, 1992).

Although John Chris Jones (1992) presented a linear theoretical model, the practice of Design tells us that it does not correspond to reality. The process of Design is a non-linear process, although, continuous. It is a process with advances and setbacks, self-feeding, in search of the best solution (iterations). The fact that there is a setback in a certain stage does not mean something negative, but rather the understanding of the perception of lack of information or, simply, the realization that the solution achieved does not respond in the best way to the defined problem. Bryan Lawson, in his How Designers Think, refers (Lawson 2006, p. 35): “Even more sobering is the experience common to all designers, when they show possible solutions to their clients only then will the clients see that they have described the problem badly”.

Brigitte Borja de Mozota, in her work Design Management, is surgical on the problem of non-linearity in the process of design, “Design knowledge has a tacit nature, and instead of presenting the design process as a vertical, sequential model, it might be wiser to represent it as a wheel” (Mozota, 2003, p. 18). It thus becomes clear that this process must be represented in a circular and non-linear way in order to accentuate its recurrent nature. Brigitte Borja de Mozota's description is central to future representations of the designers' process work model.

2.3.2. Classification of Design Process Models

Describing the processes of design is, as already referred, a challenging task to map as well as to describe the relationships between models concerned with its different aspects.

Many attempts have been used to frame discussions of such literature were made (Lawson, 2006, Cross, 2001, Jones, 1992, Bonsiepe, 1992), including those of discipline, nationality of origin, and historical development of form. Reflecting many other aspects of design research, however, such frameworks seem as diverse and difficult to relate as the models they describe (Clarckson & Eckert, 2005).

As Lawson (2006) points out, however disparate they may seem, the backbone remains common, “The common idea behind all these ‘maps’ of the design process is that it consists, of a sequence of distinct and identifiable activities which occur in some predictable and identifiable order.” (Lawson, 2006, p. 33). Nigel Cross (2001) describes the common concern, “includes the study of how designers work and think, the establishment of appropriate structures for the design process, the development and application of new design methods, techniques and procedures, and reflection on the nature and extent of design knowledge and its application to design problems” (Cross, 2001, p. 53).

Moreover, it is discussed two classification schemes: abstract approaches and procedural approaches. Procedural approaches have a more tangible nature than the abstract theories, typically incorporating a larger number of phases and focusing on a specific audience and/or industry sector (Finger & Dixon, 1989).

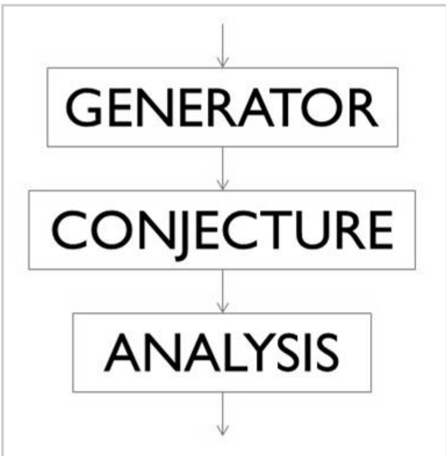
2.3.2.1. Abstract Approaches

Hillier et al. (1972) referred the conjecture-analysis theory to reflect the thought that a designer would pre-structure a problem in order to solve it. By doing it he will use the existing knowledge and previous experiences to influence the nature of the solution. This idea shapes the principle of the solution-oriented models of design. These models are therefore considered to be a more realistic description of the designer's thinking process than their problem-oriented counterparts (Clarckson & Eckert, 2005).

The Darke (1979) model (Figure 2) is an example of a solution-oriented model following observations of the architectural design practice. Moreover Darke (1979) presents a generator-conjecture-analysis model where a new conceptual element is the primary generator “a broad initial objective or small set of objectives, self-imposed by the architect, a value judgement rather than the product of rationality” (Darke, 1979, p. 37). So, the designer does not start by studying an explicit list of problem factors and objectives to be met by the design, but rather tries to reduce the set of possible solutions to a smaller class which is more manageable. This enables further clarification of the design requirements, against which a generated solution is then tested as well as further improvements to be made.

Figure 2

Darke model diagram

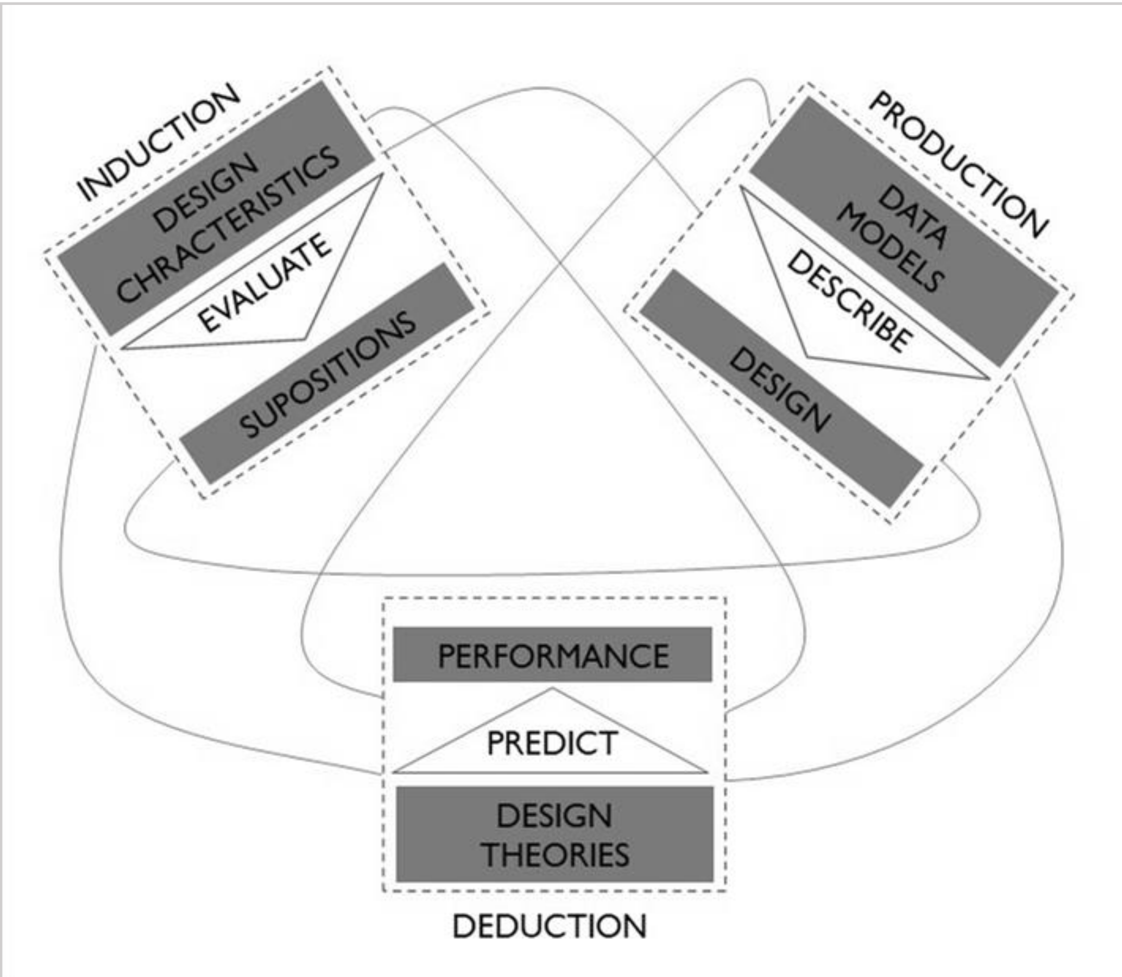


Note. Source: adapted from Darke (1979)

A more radical design process model was presented by March (1984), (Figure 3). This model is solution-oriented focused, which is the nature of design thinking. March (1984) argues that the inductive and deductive forms inherent in anyone's reasoning only apply, respectively, to the evaluation and analysis phases present in most models. However, March (1984) also argues that the synthesis phase is the one that most relates with the designer and is the one that does not represent a way of own reasoning. This author refers to this action as "productive reasoning" and creates a Design process model based on this idea which he calls PDI (Production - Deduction - Induction).

Figure 3

March model diagram

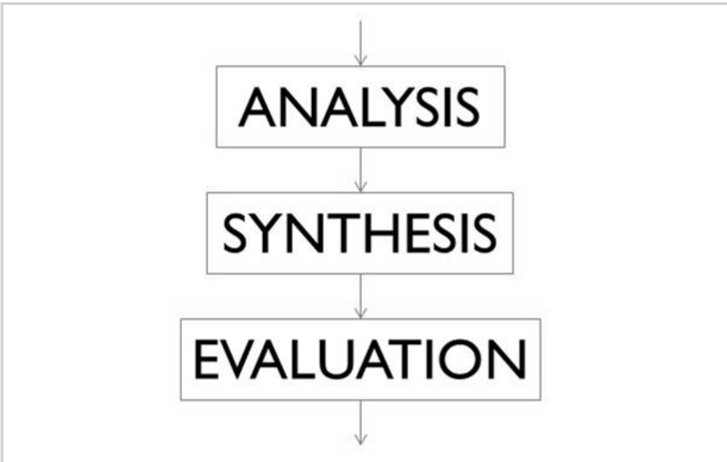


Note. Source: adapted from March (1984)

In contrast, the problem-oriented models are essentially linear, as typified by the description given by Jones (1992). The descriptive model of Chris Jones (1992) shows three steps: analysis, synthesis and evaluation (Figure 4). Jones (1992) expresses the analysis phase as the exploration and understanding phase of the problem. The synthesis phase, as the phase where all the hypotheses are evidenced and the evaluation phase as the selection phase of the solution that most effectively responds to the problem. Jones (1992) makes the correspondence of these three stages as the phase of divergence, the transformation phase and the convergence phase.

Figure 4

Chris Jones model diagram

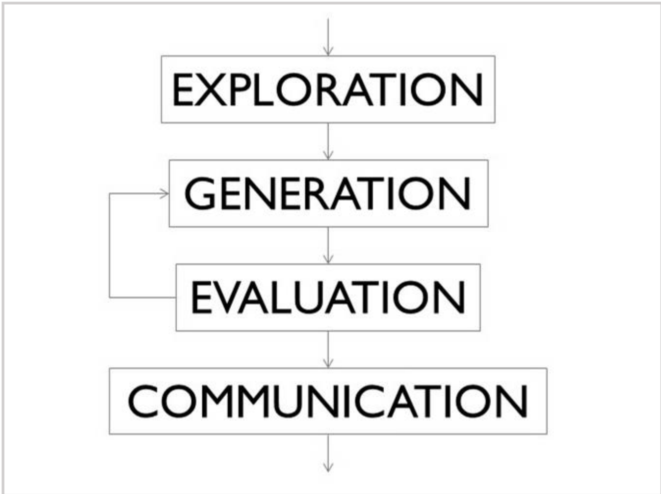


Note. Source: adapted from Jones (1992)

Based on the Jones (1992) model, Nigel Cross (Cross, 1994) also shows a descriptive model with four phases (Figure 5). This author reveals that the Design process goes through exploration, generation, evaluation and communication. The Cross (1994) model puts the initial emphasis on exploring the ill-defined problem, proceeding to a solution-generating phase. It continues through a phase of evaluation of these same hypotheses, followed by a communication phase where the most effective solution is communicated to clients or other stakeholders. Cross (1994) designates a feedback, between evaluation and generation steps, in order to guarantee an iterative process that optimizes the final solution. Cross (1994) model is a strong leap from Jones (1992) model since it introduces the idea of a feedback between the generation and evaluation steps. Hence, this iterative process is a convergent phase.

Figure 5

Nigel Cross model diagram

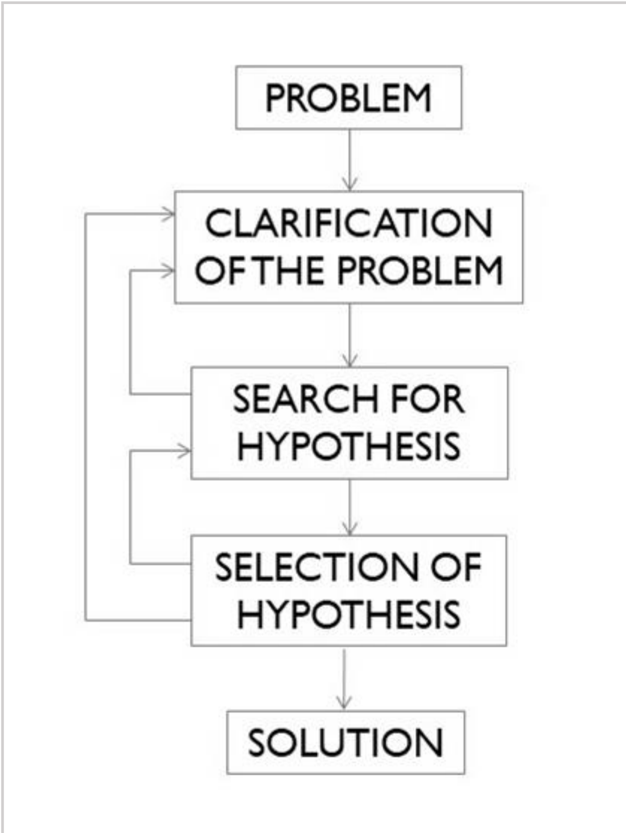


Note. Source: adapted from Cross (1994)

Ehrlenspiel (1995) presents a similar model to Cross (1994), supporting the recurrent nature of the Design process (Figure 6). Ehrlenspiel (1995) focus, like Jones (1992), that the area where the hypotheses are generated is of a divergent nature, however, the selection phase of the hypotheses has a much more convergent character. What this model adds, fundamentally to that of Cross (1994) and Jones (1992), is the possibility of facing the hypotheses with the initial problem, before proceeding to a final solution. Moreover, the Ehrlenspiel (1995) model feedbacks the generation/evaluation steps from Cross (1994) model with the problem generation step. Either the problem is generated by a need or a customer briefing, the confrontation with the problem and the need of its clarification is an evolution from the other (Jones 1992, Cross 1994) presented models. However, the Ehrlenspiel (1995) model lacks further development and detail about the solution step.

Figure 6

Ehrlenspiel model diagram



Note. Source: adapted from Ehrlenspiel (1995)

The presented process models refer to a generic description of the design practice, a high-level approach of a conceptual representation. The objective of these abstract models is not to detail the process of designing but rather give a conceptual framework for the design professional.

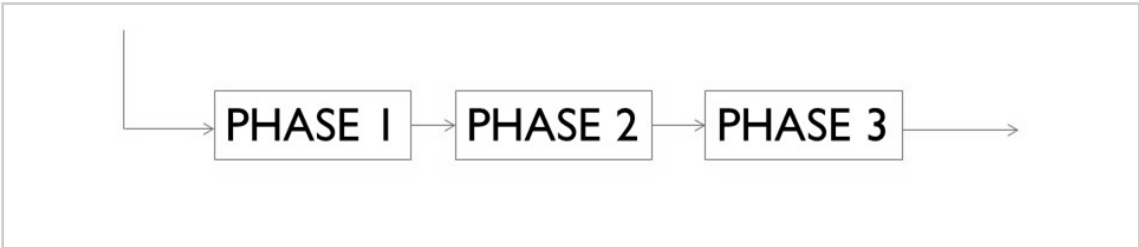
The practical applicability of such approaches is described rather colourfully by Lawson (2006) as "Knowing that design consists of analysis, synthesis and evaluation will no more enable you to design than knowing the movements of breaststroke will prevent you from sinking in a swimming pool" (Lawson, 2006, p. 322).

2.3.2.2. Procedural Approaches

Procedural approaches have a more tangible nature than the abstract theories and models previously discussed, typically incorporating a larger number of phases, and focusing on a specific audience and/or industry sector. Such literature is commonly categorised as follows (Finger & Dixon, 1989).

Figure 7

A descriptive model diagram

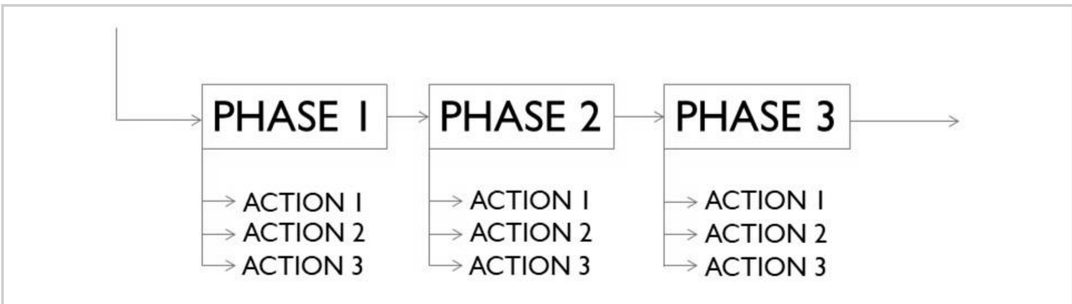


Note. Source: own

It is possible to describe two types of models, descriptive and prescriptive. The descriptive model (Figure 7) translates the general steps in the flow of the design process in a specific order. They are simplified representations of the process but do not present a methodology to be developed at each stage.

Figure 8

A prescriptive model diagram



Note. Source: own

The prescriptive model (Figure 8) are essentially detailed representations of the descriptive models. They are attempts of methodological descriptions to improve the efficiency of a given design process.

Moreover, the classification of approaches as descriptive or prescriptive is of limited practical use. Therefore, it is necessary to consider the following distinction of scope in procedural approaches:

- Models, which refer to a description or prescription of the morphological form of the design process.
- Methods, which prescribe systematic procedures to support the stages within a model.

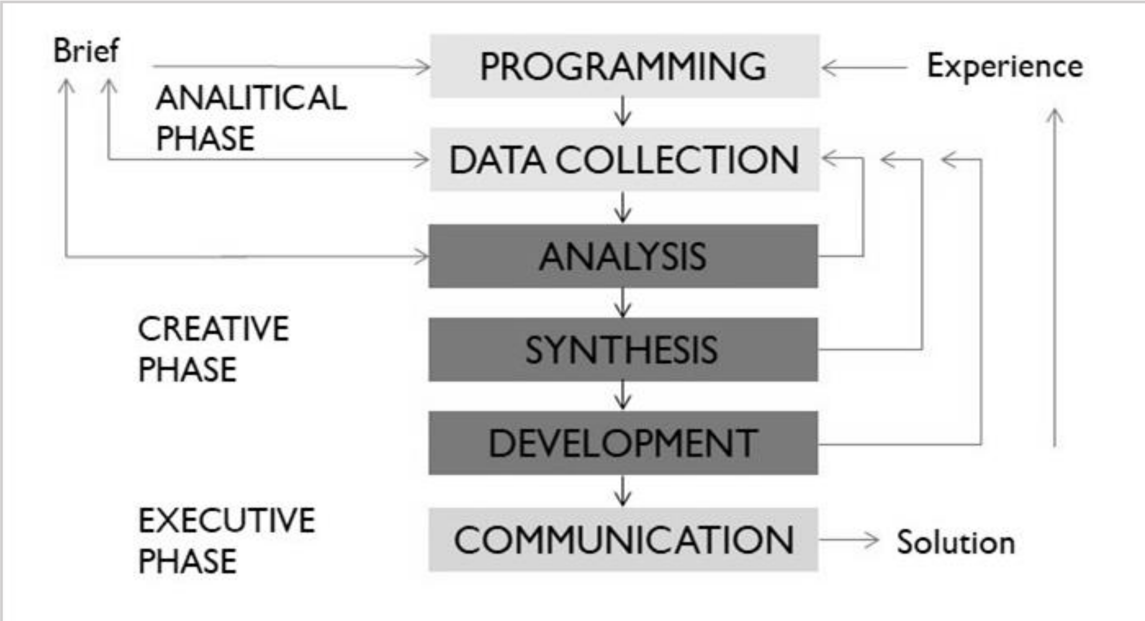
The subsequent sections will describe that models and methods are often entangled, with the stages of each model being dependent upon the methods from which it is composed (Clarckson & Eckert, 2005). Moreover, the difficult issue of classification from prescriptive vs descriptive and model vs method will not be further discussed. The approaches are classified by focus, with literature falling between the following:

- Design-focused, which supports the generation of better products by the application of prescriptive models and methods to the design process (e.g., Pahl and Beitz, 1996).
- Project-focused, which advocates approaches to support or improve management of the design project, project portfolio or company (e.g., Hales, 2004).
- Engineering-focused, which supports the manufacturing process of products and production support equipment design (e.g., Eggert, 2005).

2.3.2.2.1. Procedural Approaches - Design-focused Literature

Figure 9

Bruce Archer model diagram



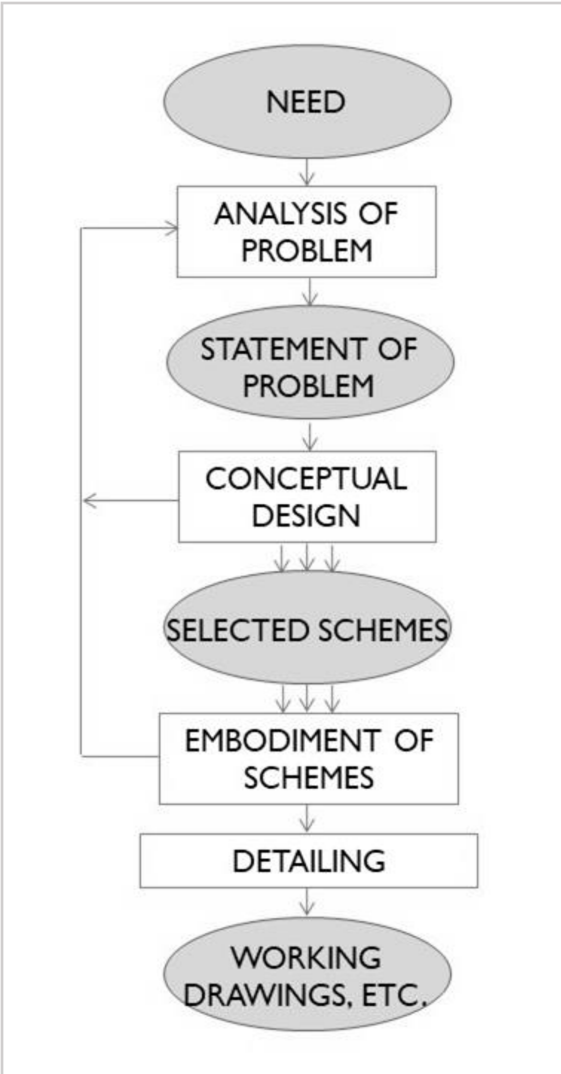
Note. Source: adapted from Archer (1965)

Bruce Archer (1965) developed a relatively complete and conceptual model (Figure 9) in an attempt to describe non-linear processes. Archer (1965) identifies six activities inherent to the Design process, grouping them in three different phases, analytical, creative, and executive. Within the analytical phase, Archer identifies Programming as the step that must establish the crucial problems to be addressed and which should define an action strategy to be developed. Following the stage of Data Gathering where all relevant research for the project should be done. Collecting, sorting, and keeping information. In the third stage, the Analysis should identify the subproblems as well as to determine the specifications of the result and reformulate the program if necessary. In the fourth activity, the Synthesis is the key stage to develop the appropriate solutions and proposals. In the fifth stage, the Development, prototypes of the possible solutions are generated, and studies are carried out to validate the proposals. On the sixth and final activity, Communication, the final documents for manufacturing are prepared. And eventually, Archer sums up (Cross, 2000,

p. 36) “The Design process is thus a creative sandwich. The bread of objective and systematic analysis may be thick or thin, but the creative act is always in the middle”.

Figure 10

French model diagram



Note. Source: adapted from French (1999)

French (1999) suggests a model based on activities such as: the analysis of the problem, the conceptual design, embodiment of schemes and later detailing. This model (Figure 10), as referenced by authors Clarkson & Eckert “is based on design practice observed in industry” (Clarkson & Eckert, 2005, p. 42). The French (1999) model not only demonstrates the different steps of the designer's work, but also the corresponding result he allegedly obtains from each of them. In the diagram presented, the rectangles represent the activity to be developed and the ellipses the result achieved (output). According to this model, the process begins with the observation of a market need, which is then analysed. The result of this activity is the correct description of the problem, without any kind of ambiguity. Subsequently, it results in the formulation of a list of requirements that the product must meet.

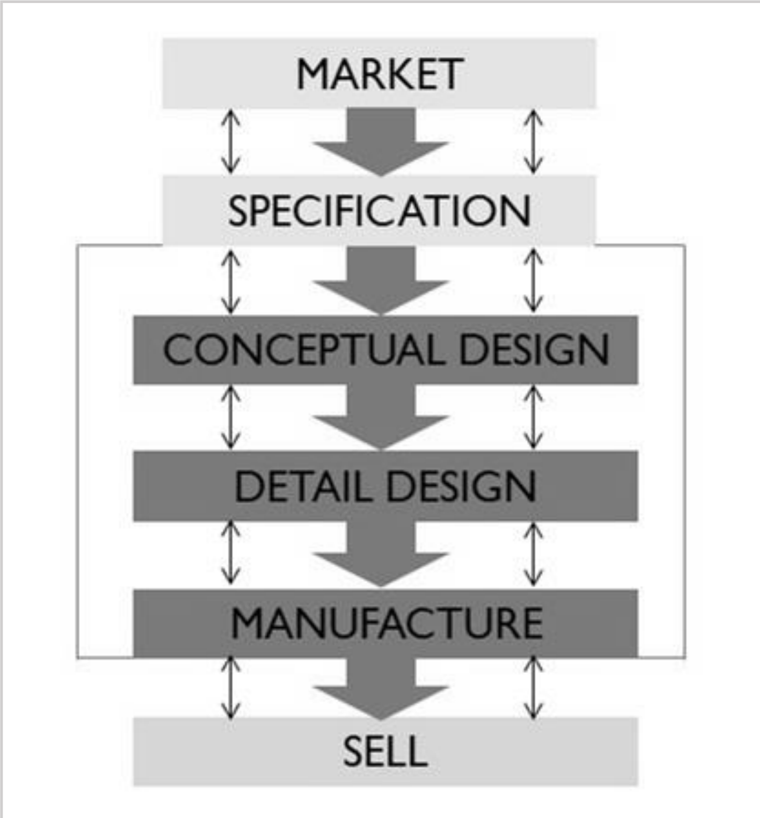
During the Design phase, different concepts are generated, each representing a set of possible options for solving the problem. Subsequently, these schemes are transformed into concrete representations, allowing the evaluation and comparison of the different concepts, culminating in a choice that is worked out in detail.

As the Design process models have become more detailed, their application has been questioned, such as, the design of a successful product is subject to an integration of different design methods with different engineering areas.

In fact, Stuart Pugh (1991) suggests a Design process model based on interaction, experimentation, and validation (Figure 11). Pugh studied the concept of Total Design incorporating the whole process. From the detection of an opportunity, through the needs of users, to the marketing of the product. Pugh (1991) points out this concept as “the systematic activity necessary, from the identification of the market/user need to the selling of the successful product to satisfy that need—an activity that encompasses product, process, people and organisation” (Clarckson & Eckert, 2005, p. 48).

Figure 11

Pugh model diagram



Note. Source: adapted from Pugh (1991)

Through the Pugh diagram it is possible to perceive the bidirectionality between the various stages of the Design process. The information produced, because of the interactions between each of the different phases, must circulate freely in all directions.

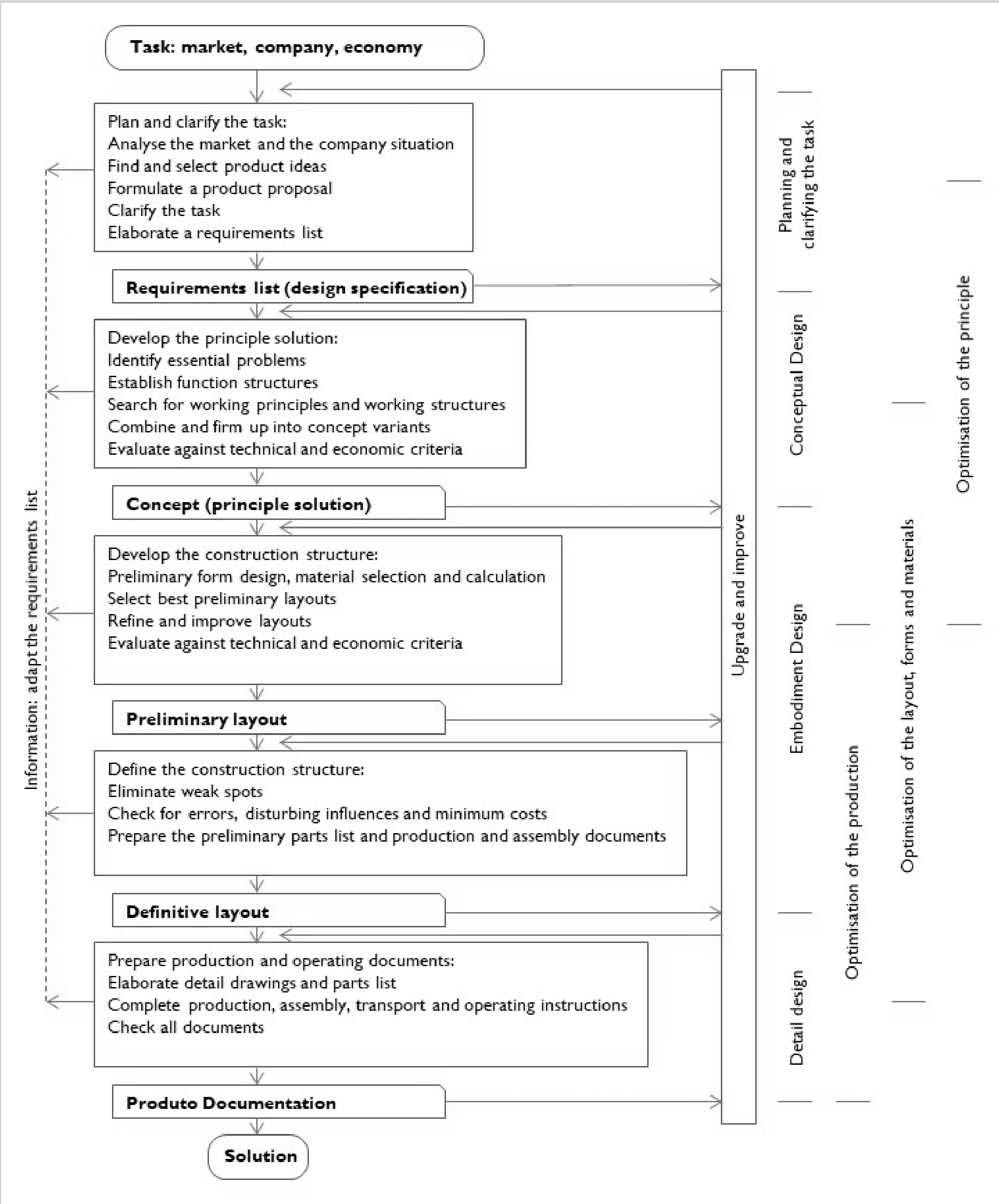
Perhaps the most well-known process model would have been the one proposed by Pahl and Beitz (1996) for the mechanical design (Figure 12). Each of the four phases of the process are intrinsic to certain work steps that consider strategic guidelines for the development of the design. The authors of this model argue that compliance with the prescribed model ensures that no detail is overlooked during the design process, improving the work schedule, and resulting in more optimized solutions.

The great uniqueness of the Phal and Beitz (1996) model is that, after a phase of clarifying the problem, a phase of exhaustive collection of information on the requirements to which the solution is to respond is introduced. In the conceptual design phase, the operating structures are established as well as the principles of the good solution. Subsequently, a phase of Design, where the Designer, from the concept, determines shapes and volumes and subsequently develops a product or technical system. Finally, a phase of detail, where the final forms, finishes, textures, materials, dimensions, and final designs for production are decided and outlined. Regarding this model, Clarkson & Eckert (2005) state “Pahl and Beitz argued that the most complicated challenge in any Design process - or the most resilient solution by systematic methods - is the creative leap between problem definition and the design of a solution” (Clarkson & Eckert, 2005, p. 44). Therefore, in the literature of mechanical design and supporting this problem, emphasis is given to the understanding of the relations between the form and function of physical structures and mechanisms.

Based on Pahl and Beitz model (Phal & Beitz, 1996), the Professional Society of Engineers - Verein Deutcher Ingeniure (VDI) has developed the VDI 2221 model - Systematic Approach to the Design of Technical Systems and Products. (Figure 13). The model suggested by the VDI suggest that all stages of the process are evaluated and analysed according to the results of the previous step. A concern to consistently validate the Design process in each of its stages. In this way, the model is concerned with systematizing the analysis and understanding of the problem by segmenting it into several sub-problems and finding sub-solutions to, in the end, combine them in order to meet a single solution.

Figure 12

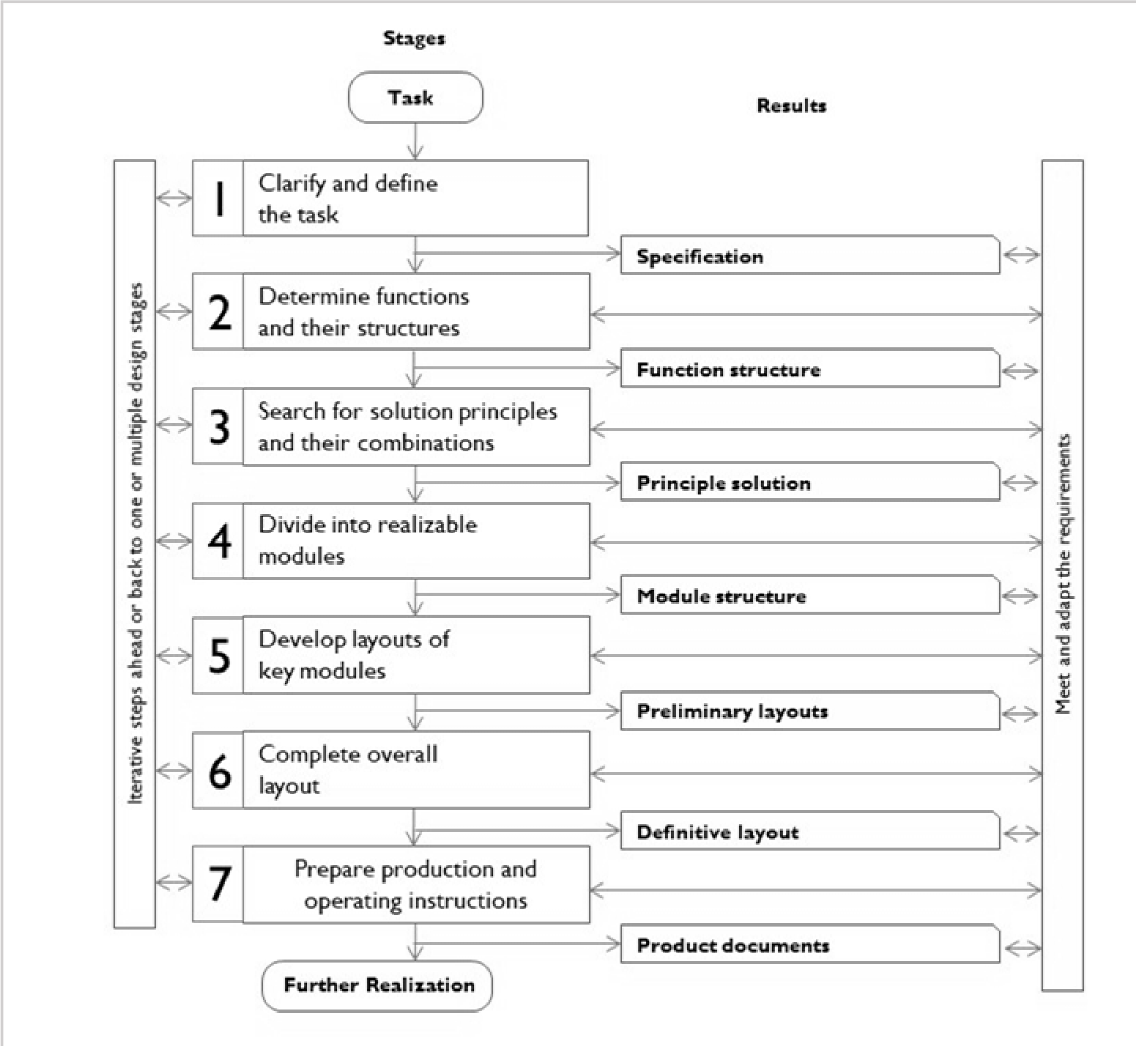
Phal and Beitz model diagram



Note. Source: adapted from Phal & Beitz (1996)

Figure 13

VDI 2221 model diagram

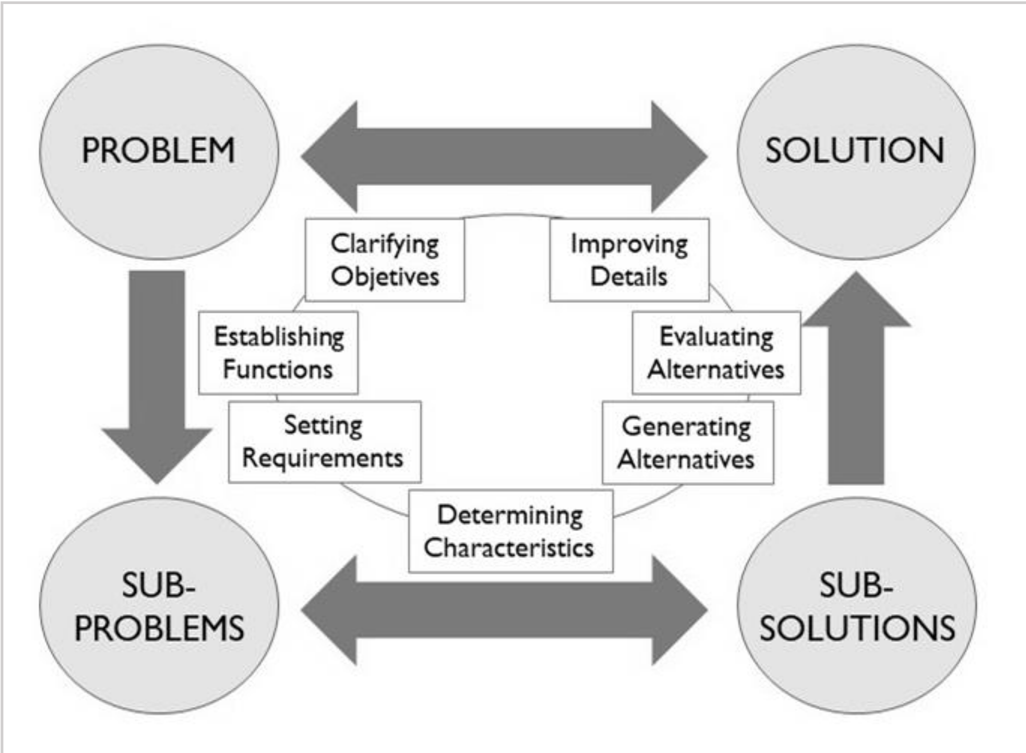


Note. Source: adapted from VDI (1985)

In an attempt to summarize the multiple existing models and attempting, at the same time, to focus on an overall view of the Design process, Nigel Cross (2000) presents an integrated model (Figure 14). Cross (2000) reveals, through his description, that the designer explores, develops the problem and the solution simultaneously. Cross argues that “This model attempts to capture the essential nature of the design process, in which understanding of the problem and of the solution develops together or co-evolves” (Cross, 2000, p. 41).

Figure 14

Nigel Cross model diagram

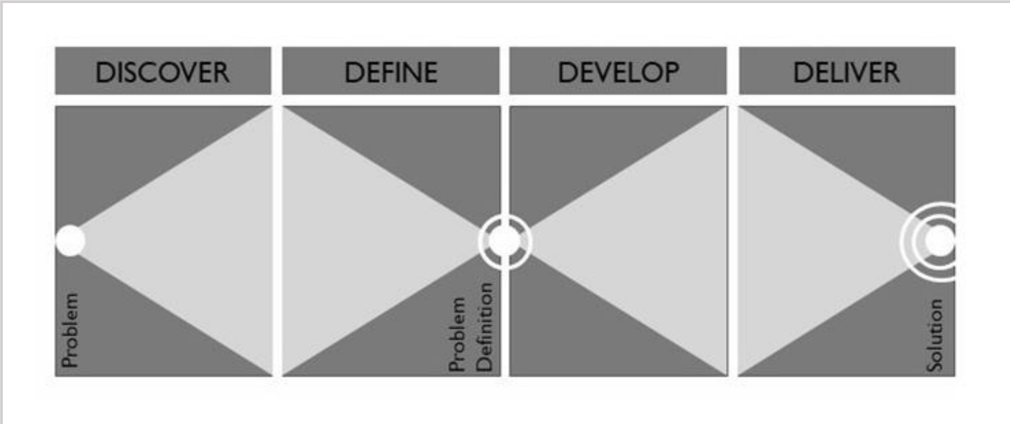


Note. Source: adapted from Cross (1994)

The double diamond model developed by the Design Council (2007) is divided into four distinct phases: discover, define, develop, and deliver (Figure 15). The triangular shapes represented in the diagram not only assume divergent and convergent stages of the design process but also the various modes of thought that the designer must acquire.

Figure 15

Double Diamond model diagram



Note. Source: adapted from Design Council (2007)

Discover, the first stage of the process, begins with an idea or with the identification of the problem based on the needs of the users. At this stage, a market study, the potential user, and information gathering should be carried out in order to create a cognitive support of the boundaries of the problem. The second step, define, is a convergent step, to define the problem. For this, it is necessary to align all the previously collected information within the business areas. This phase includes program development, project management and feasibility assessment. Owing to this, it is possible to correctly evaluate the feasibility of the project.

Afterward, the development stage begins, including the processes of idea creation, design of proposals, multidisciplinary work, prototypes, testing and evaluations. Again, a divergent process where the whole team develops different solutions. The last step, the delivery stage, includes testing and validation of the product or service developed in the previous phase. It is therefore a convergent step for the final solution.

The double diamond model is quite complete and transverse to different design and product types or design services. During the study developed by the Design Council, eleven companies worldwide were consulted, among them Alessi, Lego, Microsoft, and Sony, which helped to validate the functionality of this model (Design Council, 2007).

2.3.2.2.2. Procedural Approaches - Project-focused Literature

The project-focused literature emphasis on understanding the context of the design process, including such cost-related activities as product planning, sales, marketing, and risk management. Therefore, project-focused literature emphasis on product development as opposed to product design, defined by Lorenz (1991) as the development of a current or new business activity around a new product. In fact, understanding the interactions between new product development and business is considered to be one of the keys to success (Clarckson & Eckert, 2005).

The integration of firm personnel and firm disciplines in the product development process was proposed by Ulrich & Eppinger (2000) which define product development as "an interdisciplinary activity requiring contributions from nearly all the functions of a firm; however, three functions are almost always central to a product development project: marketing, design and manufacturing" (Ulrich & Eppinger, 2000, p. 3).

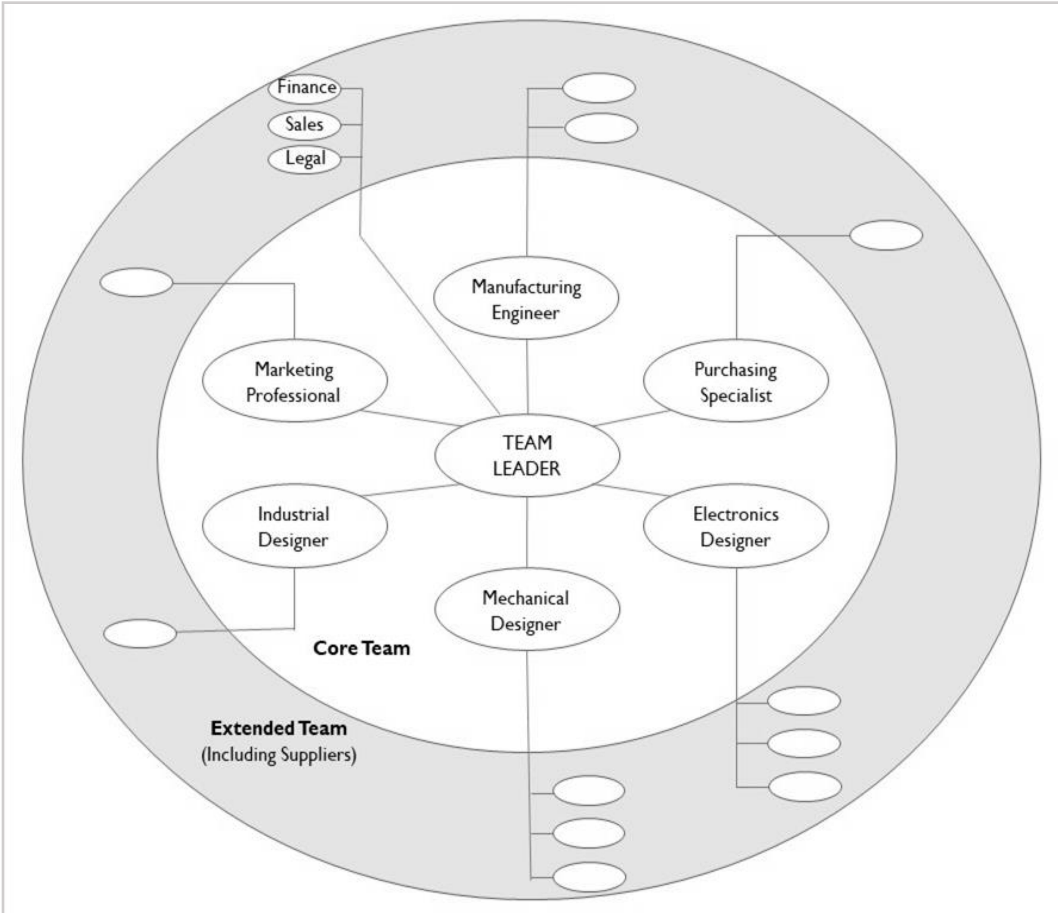
Moreover, for Ulrich & Eppinger (2000), the design function plays de main role in defining the physical form of the product and it includes engineering design and industrial design. The engineering design embraces a broad set of different expertise such as mechanical, electrical and software. On the industrial design side, the expertise roles are from aesthetics, ergonomics, and user interfaces (Ulrich & Eppinger, 2000).

For the manufacturing function, Ulrich & Eppinger (2000) assigns the responsibility for designing and operating the production system in order to manufacture the product (Ulrich & Eppinger, 2000).

Another important outlook from is the composition of a product development team. Ulrich & Eppinger (2000) define a core team and an extended team. The core team, generally small, comprises a team leader, a manufacturing engineer, a purchasing specialist, an electronics designer, a mechanical designer, an industrial designer, and a marketing professional (Figure 16).

Figure 16

The composition of a Product Development Team



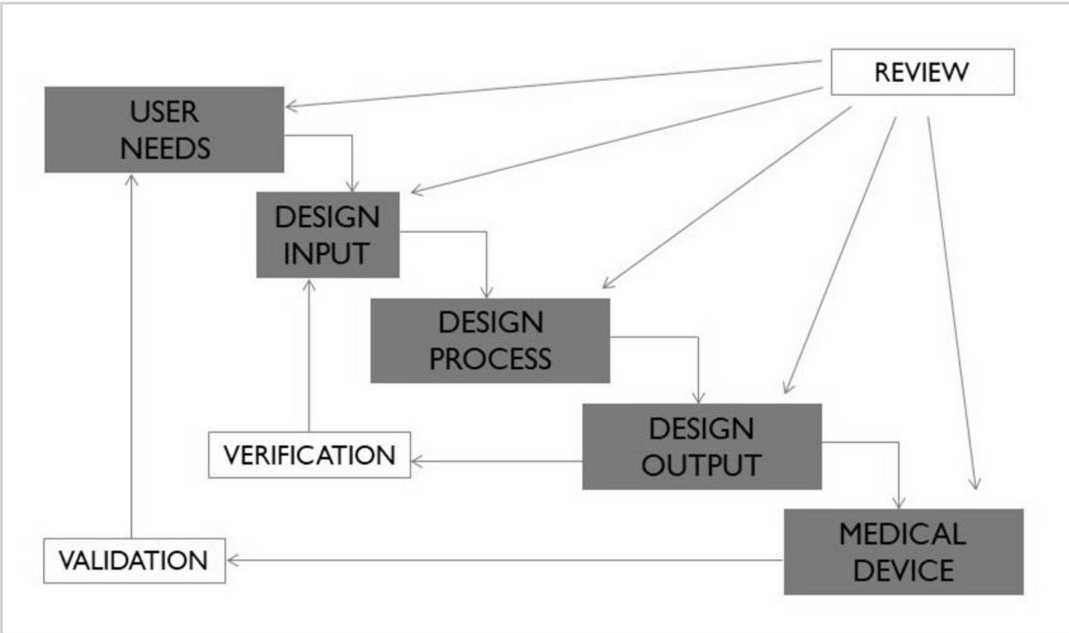
Note. Source: adapted from Ulrich & Eppinger (2000)

Early deep and detailed work analysis should be done in an exceedingly early stage in order to clarify the design requirements. Design processes and models are of little use if at the end of the concept stage, the wrong product is being developed. Manufacturing issues have a strong piece-price impact due to late design changes. Many early design models make little or no mention of manufacturing issues, although most modern methods highlight design for manufacturing concerns as a critical component of the successful design project (Clarkson & Eckert, 2005).

It is of utmost importance to point out the issue of verification and evaluation throughout the Design process in areas of civil liability, such as transportation (including automotive), health and food. A highly effective model in this field was developed by the US Food and Drug Administration (FDA) to promote good Design practices. This model, called the Waterfall Model (Figure 17) clearly shows the important contribution of verification, validation, and revision, in product development for the medical and laboratory industry.

Figure 17

US Food and Drug Administration model diagram



Note. Source: adapted from FDA (1997)

This model is characterized by five steps that are constantly being evaluated by the verification steps, validation, and revision actions. For the success of this model, it is fundamental that at the beginning of the project the validation requirements are very well defined. The validation requirements are fundamental to the good solution that will then be finally verified and checked (Clarkson & Eckert, 2005).

2.3.2.2.3. Procedural Approaches - Engineering-focused Literature

According to the Accreditation Board for Engineering and Technology (ABET), the definition of engineering design is "the process of devising a system, component or process to meet the desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation" (Ertas & Jones, 1996, p. 2).

According to Ertas & Jones (1996), who use the definition of ABET, the concept of engineering design is somehow confused with the Industrial Design as previously defined, in the sense that incorporates the concept phase. However, the main difference, according to this author, is the use of the basic sciences, mathematics, and engineering sciences in the decision process of the Design process.

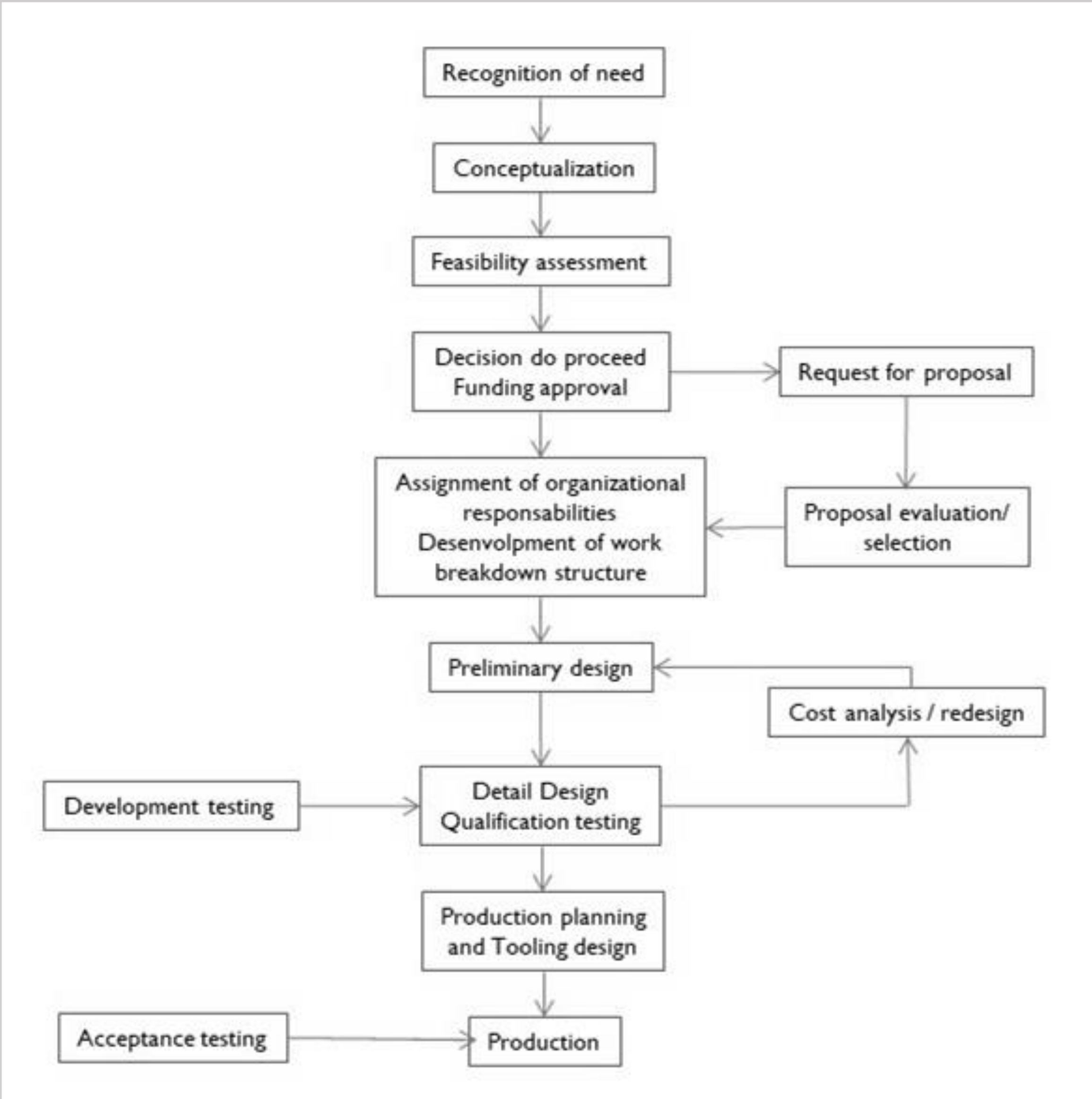
Likewise, Eggert (2005) defines engineering design as being "the set of activities that lead to the manufacture of exciting new products, such as aircraft, automobiles, household appliances and hand tools as well as the construction of new facilities such as refineries, steel mills and food processing plants. It is a pursuit that challenges our analytical abilities and our knowledge of mathematics, the sciences, and manufacturing to find solutions that work the better, last longer, and are easy to maintain or repair" (Eggert, 2005, p. xiii).

This definition discloses a more industrial character of engineering design, that is, as a set of activities whose goal is the manufacture of new products and industrial facilities. It should be noted that Eggert (2005), like Ertas & Jones (1996), evokes scientific, mathematical, and applied engineering knowledge. Showing a tendency for the industrialization of Design using the knowledge of basic sciences, mathematics, and engineering sciences (or science applied to engineering).

The engineering design process model of Ertas & Jones (1996), (Figure 18), illustrates a tendency for the development of product after its conception. That is, a tendency for the evaluation of feasibility, cost analysis and development tests. Stages where the use of engineering tools based on scientific and mathematical models have a strong decisive character for the detailing and industrialization of the concept design.

Figure 18

Ertas and Jones model diagram

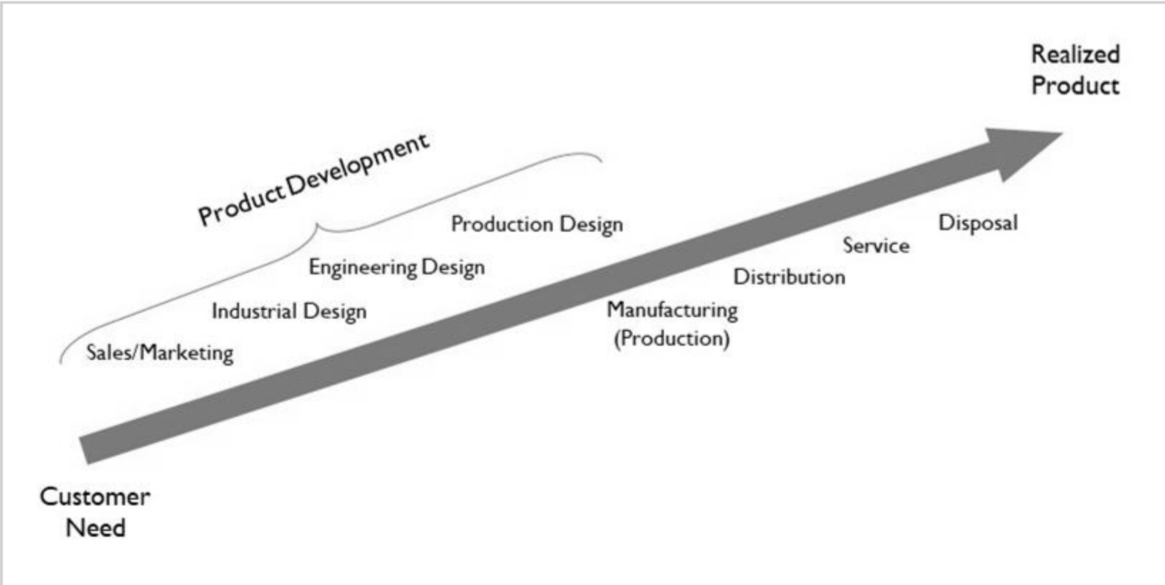


Note. Source: adapted from Ertas & Jones (1996)

Through Ertas & Jones (1996) model, the stages of recognition of need and conceptualization can and are often masked as he recognizes in his work, “the design process can be initiated based on an idea for a solution to an existing or identified need or from an idea for a product or process for which it is thought a need can be generated” (Ertas & Jones, 1996, p. 4). Moreover, “In many projects the "need" is identified by an organization other than the one that will eventually accomplish the effort. This is the case for most projects” (Ertas & Jones, 1996, p. 5).

Figure 19

Eggert model diagram



Note. Source: adapted from Eggert (2005)

Regarding the Engineering Design activities, “result in recommended manufacturing specifications that satisfy the customer’s functional performance requirements and manufacturing constraints” (Eggert, 2005, p. 12). That is, Engineering Design is concerned with making the concept generated by Industrial Design an industrializable product meeting costumer’s specifications and requirements.

Regarding, production design activities “involve the design, fabrication, and installation of production equipment, such as jigs, fixtures, machine tools, quality control instrumentation and material-handling equipment. In some cases, it might involve the construction of a new factory. Production design also considers manual and automated assembly equipment" (Eggert, 2005, p. 12). This quote clearly explains that the function of production design relates to the design of the equipment necessary for the industrialization of the product.

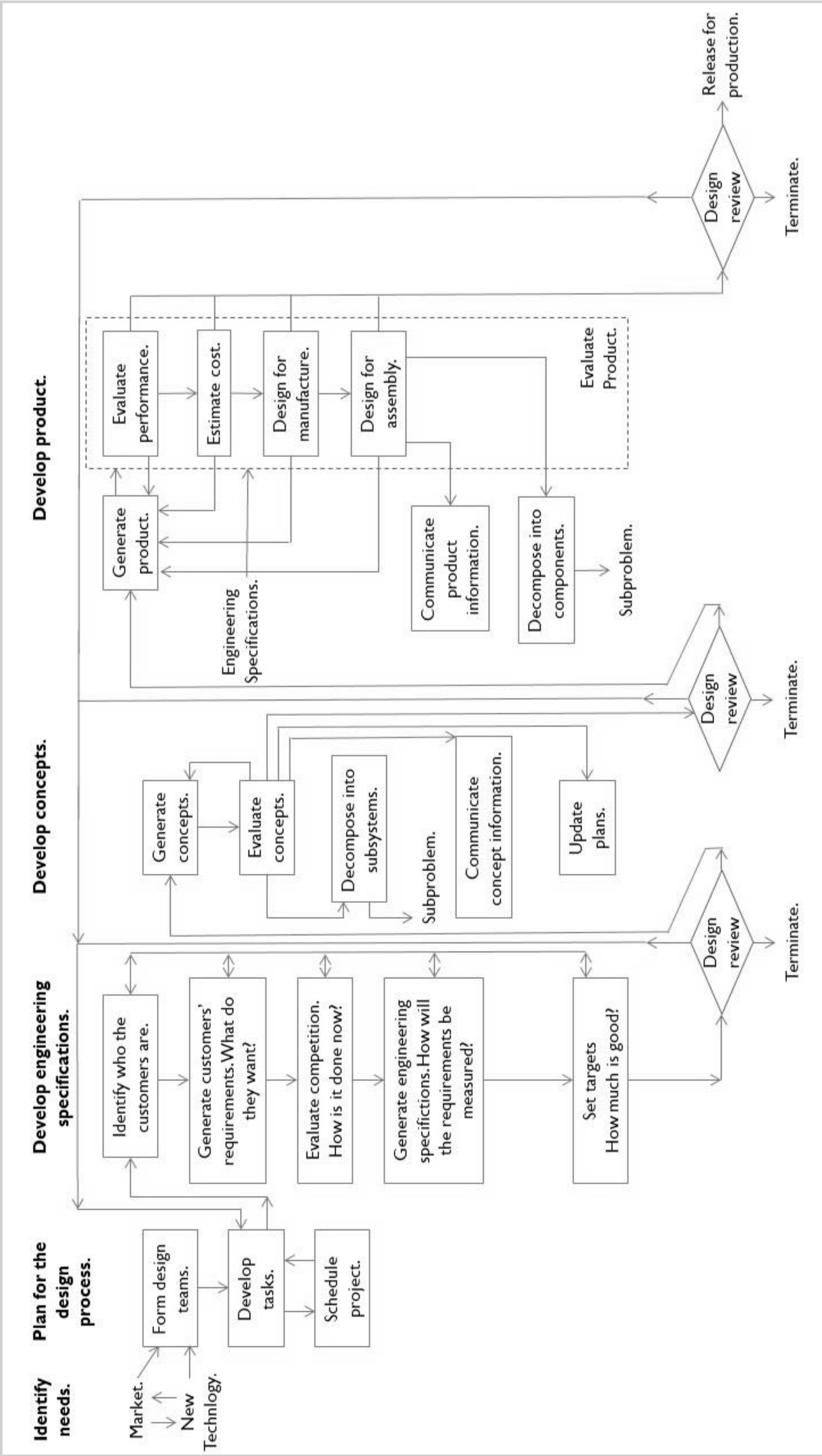
Moreover, it is important to refer that Eggert (2005) includes the sales/marketing, industrial design, engineering design and production design activities under the product development umbrella, "we refer to product development as the collection of activities leading up to, but not including production. Therefore, we can see that product development is more than engineering design. It also involves post design activities such as production planning and the coordination of activities relating to ramping-up of production. Even after the product is launched into the market, engineering design may be involved in making minor improvements for improved performance, safety, or cost reasons" (Eggert, 2005, p. 13).

Ullman (1997) defines the industrial designer as "responsible for how a product looks and how well it interacts with costumers; they are the stylists who have a background in fine arts and in human factors analysis. They often design the envelope within which the engineer has to work" (Ullman, 1997, p. 81). This definition clearly shows that the industrial design function is related to the formal language of the product itself, isolating it from any other function.

As what regards, the design process, Ullman presents a very logical and descriptive model comprising four stages, the identification of needs, planning for the design process, the development of engineering specification, the concept development, and the product development. The focus of this model is clearly on the product development step (Figure 20).

Figure 20

Ullman model diagram

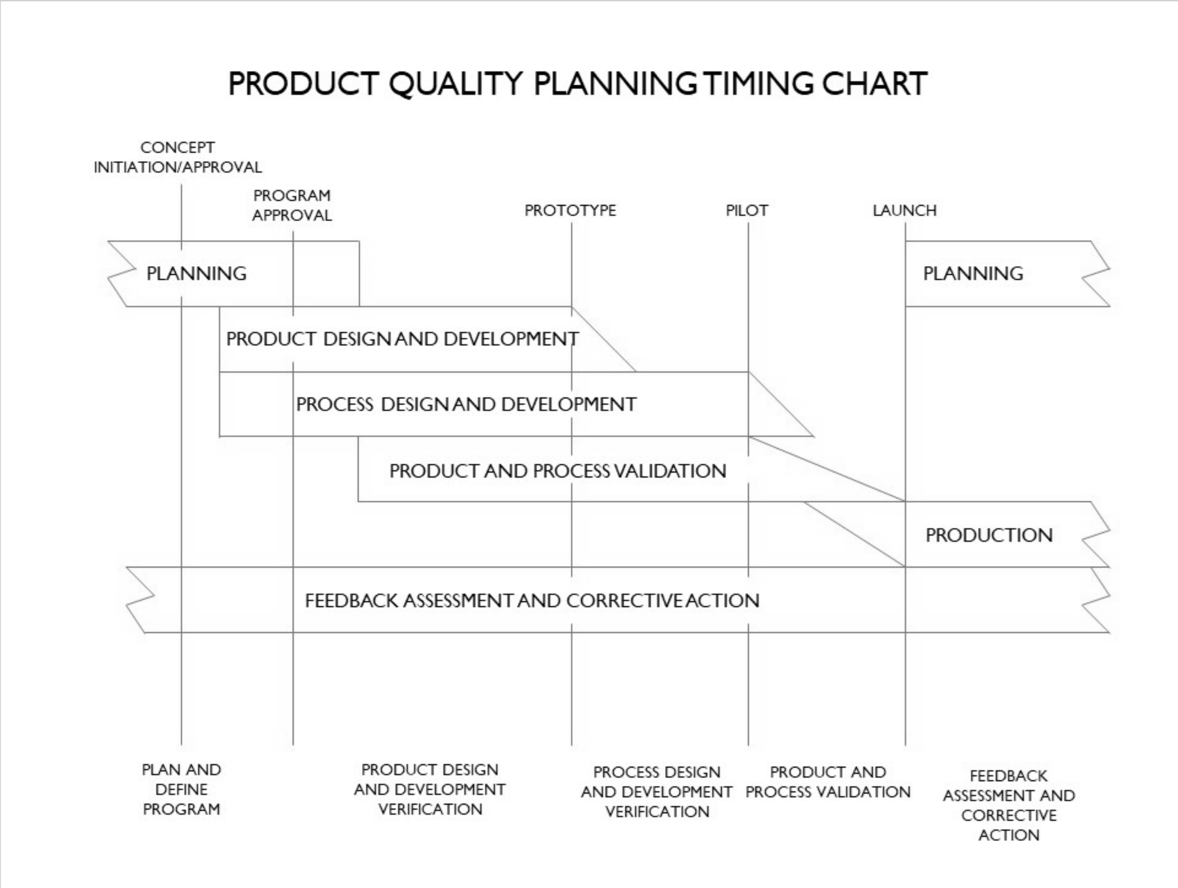


Note. Source: adapted from Ullman (1997)

2.3.3. APQP – The Design Process of the Automotive Industry

Figure 21

APQP planning chart



Note. Source: adapted from IATF (2008)

One of the necessary requirements for the certification for the tier I[2] classification to an automotive supplier is the certification by the standard IATF 16949 [3]. This is a quality standard developed jointly by General Motors, Chrysler, and Ford in 1984 that aims to

[2] Tier 1 supplier: a component manufacturer delivering directly to final vehicle assemblers. Tier 1 suppliers work together with automobile manufacturers to design, manufacture and deliver complex automobile modular systems, such as significant interior, exterior or drive train units. Tier 1 suppliers in turn purchase from tier 2 and tier 3 suppliers.

[3] IATF 16949 is an ISO technical specification aimed at the development of a quality management system that provides for continual improvement, emphasizing defect prevention and the reduction of variation and waste in the automotive industry supply chain and production.

regulate the development and manufacture of products and systems by automotive suppliers.

The IATF 16949 incorporates a proper design process for product development: the APQP - Advanced Product Quality Planning. This process is currently used not only by General Motors (GM), Chrysler (FCA) and Ford but also by other automotive manufacturers who have adapted it to their internal organizational structures. Thus, tier I suppliers are required to follow the APQP procedures and techniques and are consequently regularly audited for compliance with the IATF 16949 standard.

The APQP process serves not only as a guide for the product development process but also as a standardized process for the sharing of results and information between suppliers and customers. The 'gates' between stages, through which each project must pass to be able to follow, are a dual-purpose structure used both for rationalising decisions and for planning. The well-defined deliverables from each stage are convenient documents with which to assess whether a project is likely to succeed, and the timing of these milestones anchors the schedule of the overall development project.

The APQP process specifies three distinct steps: development, industrialization, and product launch. Through these three steps, there are twenty-three major items (deliverables) that will be monitored and must be completed before production begins. These items cover different aspects, such as, the robustness of the design, design tests, specification compliance, production process design, quality inspection standards, process capability, product packaging, product testing and training plan for process operators, among others.

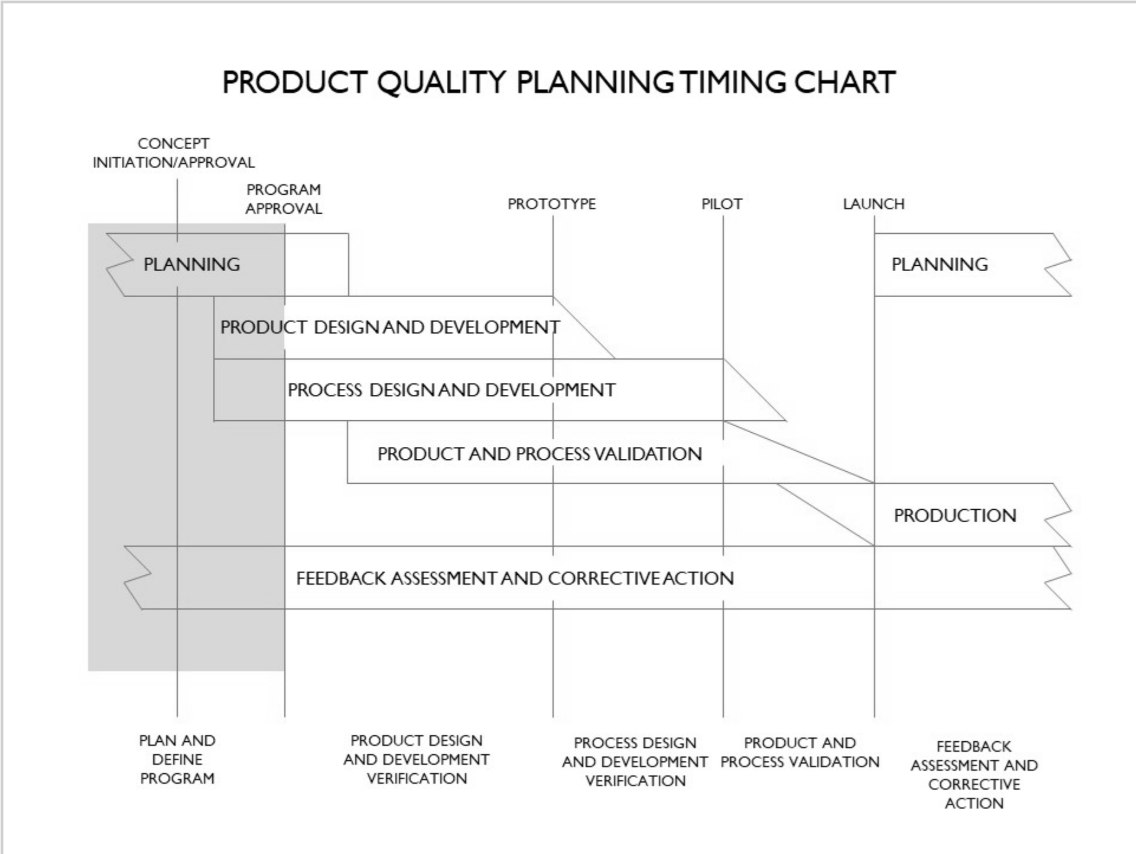
The four goals of the APQP process are: to direct resources to satisfy the customer, to promote early identification of required changes, to avoid late changes and to provide a quality product on time at the lowest cost.

The APQP design process (Figure 21) contemplates five quite distinct steps: planning and defining the scope, product design and development, process design and development, product and process validation, feedback, assessment, and corrective actions.

2.3.3.1. Stage 1 – Plan and Define Program

Figure 22

APQP planning chart – Stage 1



Note. Source: adapted from IATF (2008)

The first stage of the process (Figure 22), planning and defining the scope of the project. The needs and expectations of the costumers should be determined with the purpose of planning and defining a project with the expected. All this preliminary work should be done with the customer in mind aiming to provide a better product or service than the competition. This initial phase of the APQP should be designed to ensure understanding of customer needs and expectations.

The project scope often comes in a form of product specifications and it's a costumer issued document. These specifications (often referred to as the briefing) is the document containing the product definition and specifications, fulfilling several functions: Informs project teams of the customer needs as it provides an evaluation element among possible presented options keeping the focus on the project baseline between different areas and departments (Marcelino, 2008).

Included on the project scope should be the following items:

- **Goals -** This document helps to set clear objectives for the design team, with defined goals that allow the evaluation of results. Goal background may reflect market opportunities and competitive improvements.
- **Information -** In the specifications, the product is placed in a context with the description of its characteristics, variations of its quality through time, product position within brand line. The same should happen compared to competing products. Finally, this chapter should address the description of legal standards and industrial property to be considered.
- **Market -** It is important to describe the market and the final user to whom the product is intended. This description should include the most important needs and characteristics of the market, the motivations for purchasing, problems of use, price levels to be achieved, distribution channels, packaging, communication.
- **Technical specifications** - Technical requirements of the product as to its use, safety, form of production, product life, architecture, dimensions, etc.
- **Production Process -** The production process must be appropriate to the industrial technology installed and know-how available. A product may limit the evolution of the company, or it may create an opportunity to extend specialized technical capabilities. In some cases, the company may not limit herself to the existing production capacities, hence it can subcontract or develop new productive and technical capabilities.

Regarding the project planning, this document (usually attached to the specification) essentially aims to specify the following: definition of the execution times for of each step according to specifications, specification of the task to be performed by each member of the project team and establishment of payment terms and conditions (Marcelino, 2008).

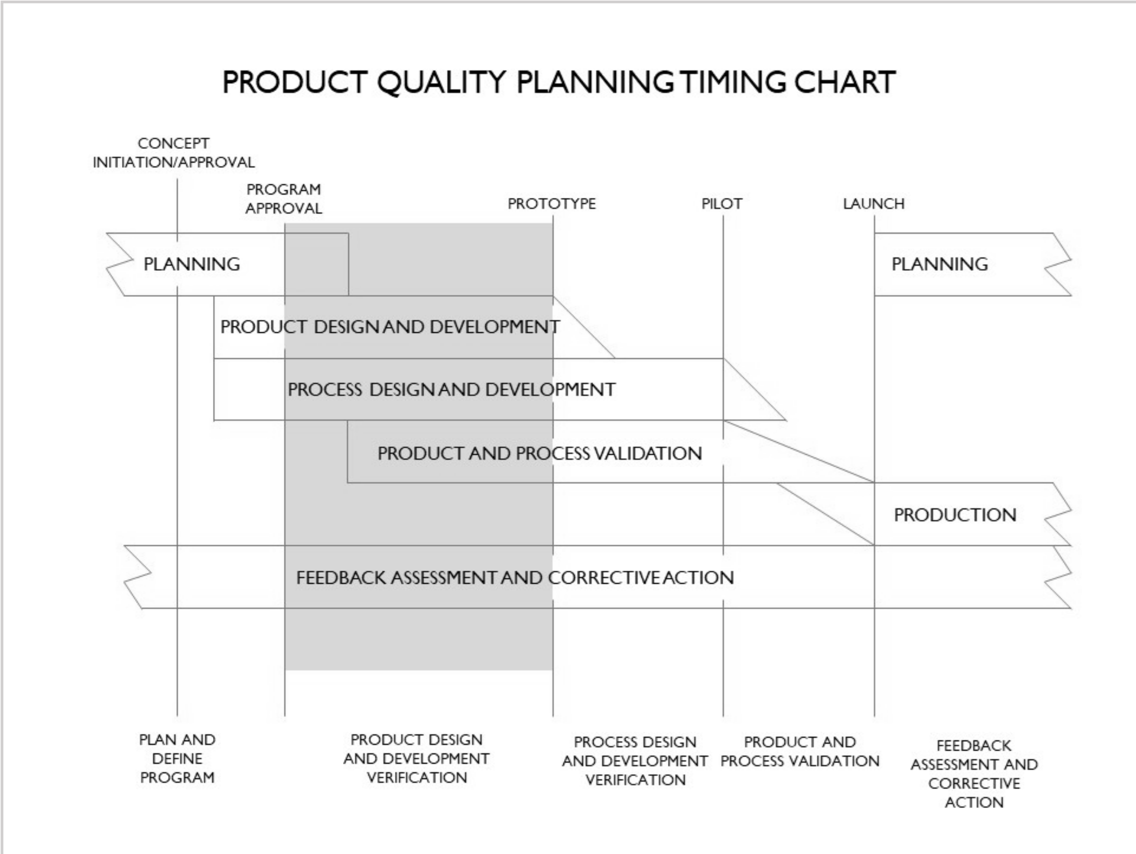
The project planning is also a commitment to meet a certain deadline for the project compliance. This allows execution times to be set for each step and the assignment of everyone to each task. Compliance with this schedule allows the product to be effectively marketed at the right time and on schedule.

It is possible to define some inputs and outputs that uncover the methodology used in this stage. So, as inputs we consider the customer's voice (market research, warranty and quality records and accumulated experience by the team in previous similar projects), business plan, marketing strategy, product database records and reference processes, reliability studies and customer inputs. Outputs from this stage of the process will be project goals, reliability and quality objectives, preliminary material list, preliminary industrial process diagram, preliminary list of special product and process characteristics, product assurance plan and management support to the project. In fact, the outputs of this stage will be the inputs of the second stage of the APQP process.

2.3.3.2. Stage 2 – Product Design and Development

Figure 23

APQP planning chart – Stage 2



Note. Source: adapted from IATF (2008)

The APQP design process advises the product development for its second stage (Figure 23). At this phase, the project team must consider all the factors that impact the process planning, even if the product definition belongs to the customer. It is at the end of this phase that is imperative to include the construction of prototypes to ensure that the product or service meets the objective defined by the voice of the customer on the previous stage. The feasibility of the concept must, necessarily, meet the volumes and timeline of production.

The concept must also have consistency in order to meet engineering specifications, quality, reliability, economic investment, price per part and time objectives. Even if feasibility studies and quality control plans are supported by CAD and CAE technology, the significant characteristics that may require product and process control must be defined, in an analytical way. At this stage, the APQP process is designed to ensure a critical and comprehensive review of engineering characteristics and other relevant technical information. A preliminary feasibility analysis should be done in order to assess the potential problems that may occur during the manufacture of the product.

The product design and development activity does not follow a rigid model: it fits the needs of each project and can be executed in all or part of the necessary constituent phases.

As already referred, the development of a product is usually divided into several phases, as a process, so that costumers and project teams can choose and articulate the degree of development required at each stage and control each investment decision. Thus, design and engineering teams perform different tasks and documentation, independently or simultaneously with other project competencies within the company or externally contracted if needed, continuously converging on the pre-defined planning milestones (Marcelino, 2008).

Author José Marcelino (Marcelino, 2008) advises for the automotive sector that, “Different authors defend different design project methodologies, depending on their experience and specialization. Ulrich & Eppinger (2000), with a closer approach to engineering and industrial design, consider the project divided into six parts: planning, concept development, system-level design, testing and refinement and production ramp-up” (Marcelino, 2008, p. 75).

At this stage of the APQP process – Product Design and Development, the methodology defined by Ulrich & Eppinger (2000), comprises concept development, system-level design, testing and refinement. The concept development includes, firstly, research and information gathering toward the definition of the new product. Also, it can include trends and technology, bionics, sociology, ergonomics and psychology, anthropology, and social sciences in general. Secondly, the concept development comprises the hypothesis materialization of possible problem-solving solutions: the development of concepts based on analysis of customer briefing, technical and productive resources, and platform, enabling the implementation of a product or service.

Regarding the following part of Ulrich & Eppinger (2000) methodology proposed by Marcelino (2008), the system-level design, it includes the development and formalization of the approved proposal. Moreover, the refinement and verification of specifications and constraints of the proposals with greater feasibility and potential approved in the previous part. This part also includes the technical development, as well as preliminary technical studies and product pre-engineering. A functional and chromatic dimensional verification of the product with a respective analysis and adaptation to current regulations is also mandatory. Adaptation of the concept to the production processes. As already stated, these studies are supported by CAD and CAE technology. Also, can comprise, if needed, the execution of physical functional models and or mock-ups.

The following part on Ulrich & Eppinger (2000) methodology is the detail design. This part includes the preparation of the necessary documents for the realization and production of the new product, so that it is clear by the selected productive processes, without distorting the approved concepts. As already stated, these documents are supported by CAD and CAE technology.

After the detail design, comes the testing and refinement part. This phase includes the construction of physical models for product evaluation. This part of the methodology usually runs iteratively until the final product, depending on the tests and validations. Due to the relative uncertainty of the results obtained, one usually uses less expensive methods and tools than those intended by the production (e.g., soft tools). Once a final prototype is approved, the ramp-up for production preparation begins, considering the final tools and processes.

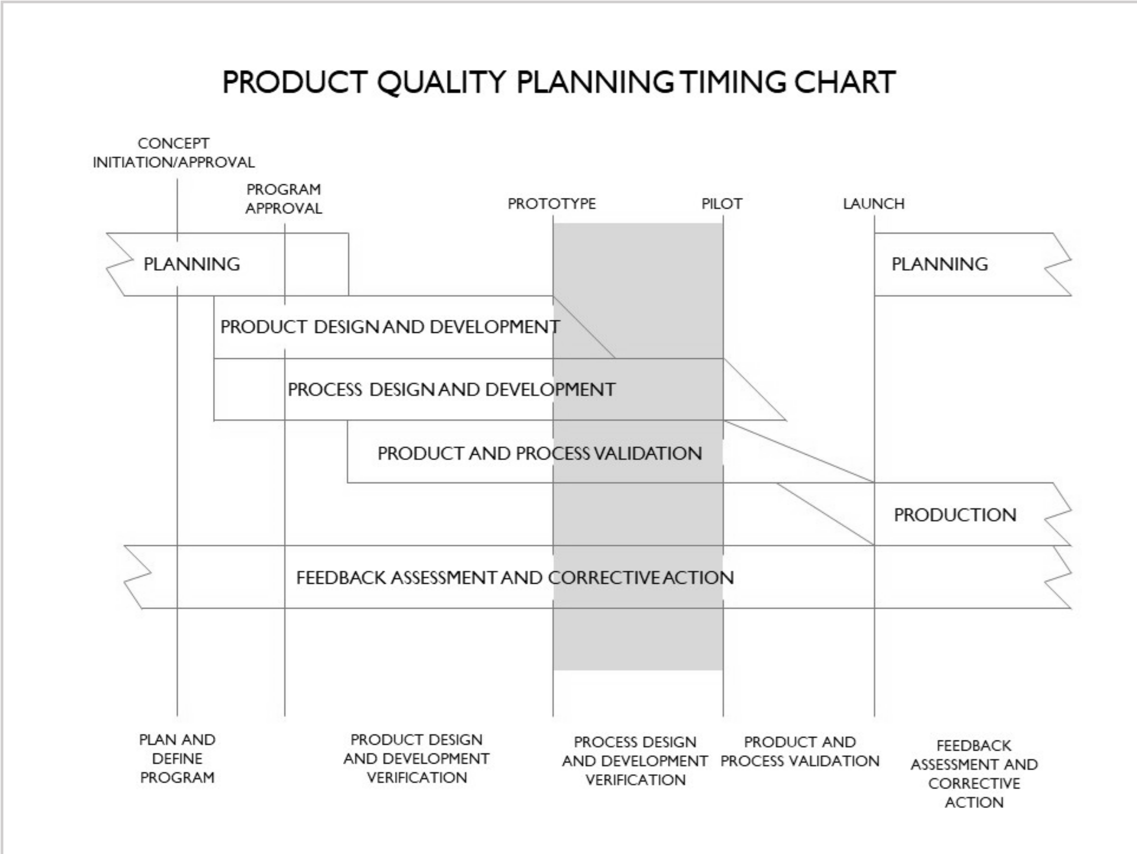
Regarding the last part of the Ulrich and Eppinger (2000) methodology, the production ramp-up, strives to ensure that the project is correctly executed by the production and suppliers. Approval of prototype and first units, production part approval process (PPAP).

Concluding, as outputs of this step, the APQP process advocates, the DFMEA (Design Failure Mode and Effect Analysis), computer aided design (CAD) product definition, design verification, design reviews, prototype build (and corresponding control plan), engineering specifications, materials specifications, and specifications of changes.

2.3.3.3. Stage 3 – Process Design and Development

Figure 24

APQP planning chart – Stage 3



Note. Source: adapted from IATF (2008)

It is in the third step of the ANPQ process (Figure 24) that the manufacturing process is developed and validated in order to obtain a product, according to the customer's requirements. The methodology of this stage of the process depends mainly on the success of the conclusion of the two previous stages. This third stage of the APQP process is designed to ensure the integral development of an efficient manufacturing system. Therefore, the production system must ensure that the requirements, needs and expectations of the customer are met.

Manufacturing processes are used to transform raw materials into products. Processes are used to change the material form as in metal casting, sheet metal bending, or machining. Processes can alter the microstructure and properties of a material such as increasing the yield strength of steel by cold rolling, or heat treatment. Processes can also change the chemical composition of a material such as in chrome plating or galvanized steel.

Manufacturing processes can be categorized (Eggert 2005) as bulk deformation, casting, sheet metalworking, polymer processing, machining, finishing and assembly. The primary manufacturing processes are used mainly to change the material's primary shape or form. The secondary manufacturing processes are used do add or remove geometric features from the basic forms. Tertiary manufacturing processes relate to surface treatments such as polishing, painting, heat treating and joining. Finishing is the preparation of the final surface for aesthetics and protection from the environment. The quaternary manufacturing process is assembly. This is the process of putting together all the product's components before shipping. Products that have subassemblies will have undergone some assembly operations prior to final assembly. Assembly operations can include the handling, insertion, and/or attachment of parts.

Most parts undergo primary, secondary, tertiary, and quaternary manufacturing processes. As a part design develops, a variety of processes are considered. Consequently, some processes are not economically feasible unless significant quantities are produced. Some processes are incapable of producing large part sizes, others cannot produce the desired geometric complexity.

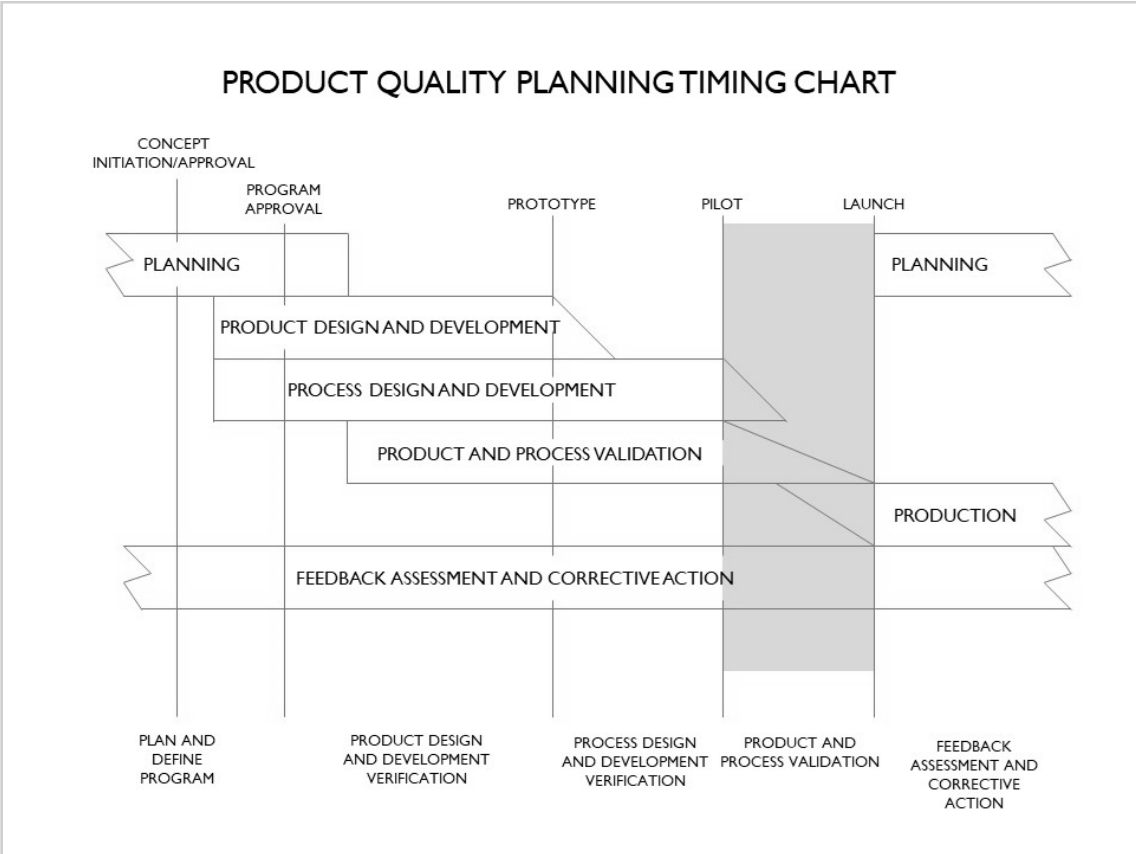
Manufacturing process and materials selection and design occur, as per APQP, in parallel with the product design stage. As more and more information become available, revised costs estimates should be made, ultimately affecting prior decisions. During conceptual development, for example, little is known about part sizes or dimensions. Also, design is an iterative process. During the system-level design some features may be combined to improve functionality, however demanding a specialized manufacturing process or material, not previously considered.

The inputs of this step are the outputs of the following step. As outputs of this stage the ANPQ process demands, packaging specifications, product and process quality system review, process flow diagram, manufacturing process layout, characteristics matrix, PFMEA (Process Failure Mode and Effect Analysis), control plan for pre-series and process instructions.

2.3.3.4. Stage 4 – Product and Process Validation

Figure 25

APQP planning chart – Stage 4



Note. Source: adapted from IATF (2008)

The fourth step of the APQP process (Figure 25) is characterized as the one where the manufacturing process is validated in a production trial run. During this production test, the entire design team must validate that the control plan and process flow chart are being followed, and that the product meets customer requirements. Additional concerns should be identified for investigation and resolution prior to the start of production ramp-up.

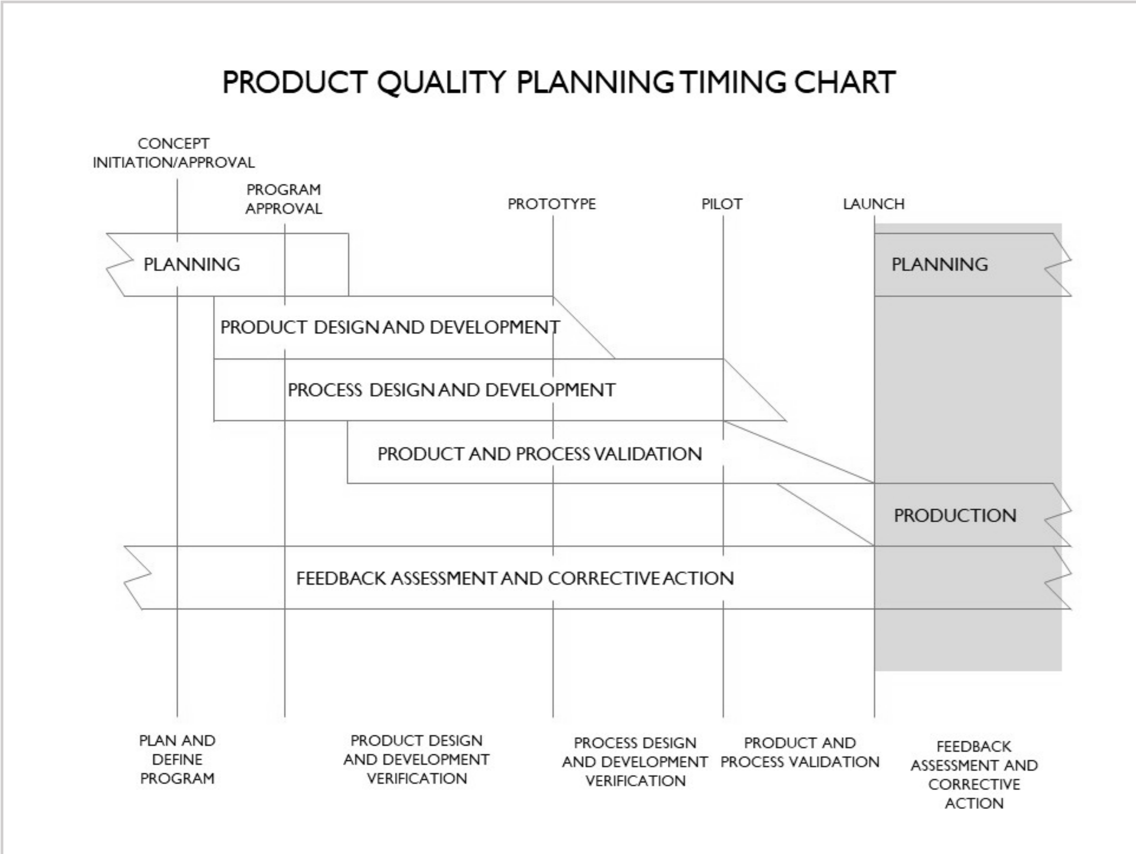
Product and part testing can be divided into three major categories that focus on validating form, fit and/or function (Eggert, 2005). Concerns about form of a part or product relates to its overall appearance, including shape and relative size dimensions. Concerns about fit relate to how precisely the parts are fabricated and how well they fit together in the assembly, or how they fit the user. Finally, parts and products must function, or perform as expected, have an expected duration and be easy maintenance.

As outputs of this step, the APQP process defines, a trial-run production, the evaluation of measurement systems, a preliminary study of process capability, a part production approval, a production validation test, packaging evaluation, production control plan and revision of the quality control plan.

2.3.3.5. Stage 5 – Feedback Assessment and Corrective Actions

Figure 26

APQP planning chart – Stage 5



Note. Source: adapted from IATF (2008)

The APQP process does not end with the installation of the production process validation. The fifth step (Figure 26) contemplates the evaluation of the product and process in full production. It is at this stage that the special and common causes of variation to the characteristics of the manufactured product are observed and evaluated. This is also the phase where the effectiveness of the APQP process is evaluated from the product quality point of view. Meaning that this design process does not end with product and process development. After the start of production, APQP is a quality assurance process throughout the product life cycle. Thus, the production control plan (one of the outputs of the third stage) is the base document for product evaluation at this stage. However, it is still fundamental to use the SPC methodology to characterize and later evaluate the deviations, to the specified requirements, of the special characteristics of the product.

The outputs of this fifth step confirm the underlying idea of the main goal of the APQP Design process, which is to provide a quality product delivered on time, with the lowest possible cost. In effect, the outputs will be, reducing the variability of the final product, customer satisfaction, product delivery on time and the particularly important effective use of the lessons learned/best practices process.

2.3.4. Design Capabilities and Supplier Classification of the Automotive Industry

Asanuma (1989) and Akabane et al. (2016) have defined a classification framework for design capabilities of automotive first and second level suppliers. Asanuma (1989) research paper focus on suppliers' product design capabilities and the idea of the development of suppliers through the evolution of design activities based on supplied drawings to those based on own developed and approved drawings. Moreover, "parts suppliers with product design capability are recognized as suppliers with approved drawings and have a higher probability of receiving big orders with greater value-added from vehicle makers" (Akabane et al., 2016, p. 2).

So, Asanuma (1989) defines a basic criterion for classification as the degree of initiative that a typical supplier of a given category of part can strive in relation to a given core firm (costumer) in the product design and manufacturing stages. Asanuma (1989) calls this variable as "degree of technological initiative" (Asanuma, 1989, p. 19).

Moreover, Asanuma (1989) defines the framework with two axes. A horizontal, where it defines the criterions of classification from the lowest initiative – parts manufactured according to drawings provided by the core firm (customer), to the highest – parts manufactured according to drawings provided by the supplier. On the vertical axis Asanuma (1989) defines the categories (from I to VII) in which a supplier can be classified (Table 1).

Table 1

Classification of Parts and Suppliers According to Degree of Initiative in Design of Product and Process

	Parts Manufactured according to specifications provided by the core firm ("ordered goods")						Parts offered by catalog ("marketed goods")
	Parts Manufactured according to drawings provided by the core firm			Parts Manufactured according to drawings provided by the supplier			
	I	II	III	IV	V	VI	VII
Criterion for Classification	The core firm provides minute instructions for the manufacturing process	The supplier designs the manufacturing process based on blueprints of products provided by the core firm	The core firm provides only rough drawings and their completion is entrusted to the supplier	The core firm provides specifications and has substancial knowledge of the manufacturing process	Intermediate region between IV and V	Although the core firm issues specifications it has only limited knowledge concerning the process	The core firm selects from a catalog offered by the supplier
Example	Small parts assembled by firms offering assembly service	Small outer parts manufactured by firms offering stamping service	Small plastic parts used in dashboard	Seat	Brakes, bearings, tires	Radios, electronic fuel injection systems, batterys	

Note. Source: Asanuma (1989, p. 16)

At the stages of I to III, because parts suppliers do not have product design capability, they basically manufacture parts based on the drawings (supplied drawings) provided by their costumers, this is the case of second and third level suppliers. On the other hand, at stages IV to VI, parts suppliers with product design capability prepare drawings by themselves, and manufacture parts with the approval of their costumers (approved drawings). As previously stated "Asanuma formularized the progress of parts suppliers according to the development stage of product design capability moving from supplied drawings to approved drawings" (Akabane et al., 2016, p. 3).

Moreover, Akabane et al. (2016), based on Asanuma (1989) table (Table 1) proposed some changes in order to accommodate the details of his investigation. So, he states that the designation of the main variable is too broad as a concept and includes process design capability. Moreover, Akabane et al. study, handles process design capability separately and limits the classification criteria of product design capability only as the degree of participation in the preparation of drawings. Hence, classification stages were adjusted (Akabane et al., 2016). Table 2 presents those changes relatively to Table 1.

Table 2

Development Stage of Product Design

Type of Drawings	Supplied drawings			Quasi approved drawings		Approved drawings
	1	2	3	4	5	6
Classification criterion	Correct understanding of supplied drawings	Requesting for changes in supplied drawings	Proposal for improvement in supplied drawings	Approved drawings partially available	Approved drawings available	Predominantly approved drawings
Supplied / Approved drawings	Supplied drawings 100%	Supplied drawings 100%	Supplied drawings 100%	Supplied drawings more than 80% (Approved drawings below 20%)	Approved drawings 20% to 50%	Approved drawings more than 50%

Note. Source: Akabane et al. (2016, p. 8)

The initial stage (1) is where suppliers correctly understand supplied drawings from their costumers and are able to process and produce parts accordingly. Thus, suppliers unable to do it reasonably will not be able to receive orders. In the second stage, suppliers might be able to request changes to supplied drawings although they work with 100% supplied drawing from their customers. This means that these suppliers fully understand the characteristics of their own production facilities as well as their employees can purpose those changes. Stage three is where suppliers can make proposals in order to improve quality or productivity. The crucial difference between stage two and three is “while the former is derived from the ‘ease of works for them, the latter is the proposal ´to seek merit not only for themselves but for their clients. Stage four is the first stage where suppliers are capable of some degree of product design. Meaning that suppliers can initiate the works based on approved drawings. According to the increase of work based on approved drawings, their stage develops from four to six. After stage six, the supplier may carry out direct transactions with vehicle makers" (Akabane et al., 2016, p. 7).

Similarly, Akabane et al. (2016) defines a framework of five stages in order to handle process design capability separately. Table 3 presents Akabane et al. different stages of classification for Process Design capability.

Table 3

Development Stage of Process Design

Process improvement	Process design dependent on clients	Optimization of partial process design			Optimization of whole process design
	1	2	3	4	5
Classification criterion	Process design is dependent on clients	Autonomous improvement of a part of processes & manufacturing equipment	Self-design of jigs & utensils	Self-design of Manufacturing Equipment & Molds	System design of connection of production processes & manufacturing equipment

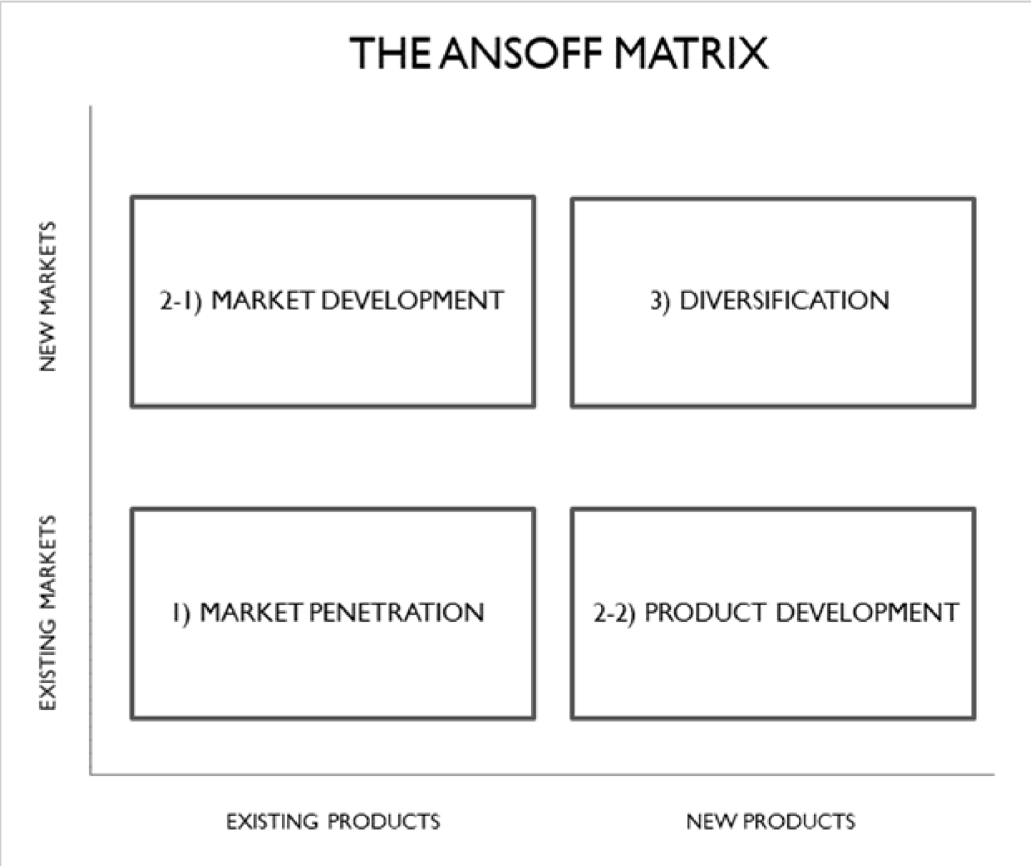
Note. Source: Akabane et al. (2016, p. 9)

The first and initial stage is where customers give full instructions in terms of process design. Next stage (2), parts suppliers take the initiative on designing processes, so they proactively adjust on production layout lines or improvements on manufacturing equipment. Stage three and four are the stages where the supplier is able to self-design jigs, utensils, some specific manufacturing equipment and tooling. The final stage (5) is where the supplier can optimize the total flow from receiving raw materials to processing, production, inspection and up to product shipment (business process) as a hole (Akabane et al., 2016).

Akabane et al., (2016) consider through the Ansoff's growth matrix (Table 4) that sales of existing products in an existing market as the initial stage, and sales of new products in a new market as the developed stage. Therefore, Akabane et al., (2016) set the development stage of domain design (Table 5) as 1) sales of sales of similar type of parts (technology) to small number of clients, 2-1) sales of similar type of parts (technology) to many clients, 2-2) sales of different type of parts (technology) to small number of clients, 3) sales of different type of parts (technology) to many clients (Akabane et al., 2016).

Table 4

Ansoff Growth Matrix



Note. Source: adapted from Ansoff (1970)

Table 5

Development Stage of Domain Design

Diversification of domain	Dependence on Similar type (technology)		Diversification to different type of parts (technology)	
Classification criterion	1) Sales of similar Type of parts (technology) to small number of clients	2-1) Sales of similar type of parts (technology) to many clients	2-2) Sales of different type of parts (technology) to small number of clients	3) Sales od different type of parts (technology) to many clients

Note. Source: Akabane et al. (2016, p. 10)

Moreover, Akabane et al., (2016) consider the existence of challenges in the pathway of domain design development as the transition phases from 2-1) to 3) and/or 1) to 2-2), both of which are complemented by diversification of parts (technology). Therefore, the diversification of parts (technology) requires significant investment in human resources and industrial equipment (Akabane et al., 2016).

3. Introduction to the European Automotive Industry

3.1. Economic Weight

The automotive industry is one of Europe's major industries (European Commission, 2005). It contributes about 6,1% to the total European manufacturing employment (Source: EUROSTAT - 2017) and 17% of total manufacturing output (Source: EUROSTAT - 2018). It produced 20% (Source: ACEA - 2018) of total global motor vehicle production and 21% of total global passenger car production. The total value of exports was about €138.4 billion (Source: ACEA - 2018) corresponding to approximately 6,4 % of total GDP of EU-28 (Source: ACEA – 2018). The value of the automotive industry comes, from a large extent, from its relations within the internal and international economy. The automotive industry in the EU-28 is highly concentrated, Germany accounting for close to half of the total value added. In addition to Germany, also Sweden, and France, as well as the Czech Republic, Slovakia and Hungary express a focused knowledge in automotive manufacturing.

As the automotive industry is not characterized by a high-tech industry, it is a major driver of new technologies and the dissemination of innovations throughout other markets and industries. Thus, almost 20 % of all research and development (R&D) in manufacturing is undertaken by car manufacturers. Its close links with many other manufacturing sectors (such as chemicals, plastics, electrical and electronic parts, etc.) contribute to the rapid diffusion of new technologies. Moreover, the industry is an important demand source for innovations from other industries, including high-tech sectors such as Information and Communication Technologies (ICT). Finally, the automobile is one of the most valuable consumer goods in terms of total household expenses (European Commission, 2005). Consequently, demand for motor vehicles is highly correlated with the general business cycle (next to housing).

3.2. Industry Profile

The automotive industry can be described by a complex network of large internationally owned manufacturers, suppliers and a high number of small and medium sized companies meeting the criteria of component suppliers.

The following definitions are used throughout this text:

- **An Original Equipment Manufacturer (OEM)** is a company that manufactures and/or assembles the final product. In other words, while a car made under a brand name by a given company may contain various components, such as tires, brakes or entertainment features which are manufactured by different suppliers, the firm responsible for the final assembly/manufacturing is the OEM.
- **Tier 1 supplier -** a component manufacturer delivering directly to final vehicle assemblers. Tier 1 suppliers work together with automobile manufacturers to design, manufacture and deliver complex automobile modular systems, such as significant interior, exterior or drive train units. Tier 1 suppliers in turn purchase from tier 2 and tier 3 suppliers.
- **Tier 2 supplier -** These companies produce value adding parts in the minor sub-assembly phase. Tier2 suppliers buy from tier 3 and deliver to tier 1.
- **Tier 3 supplier -** A supplier of engineered materials and special services, such as rolls of sheet steel, bars and heat and surface treatments. Tier 3 suppliers rank below tier 2 and tier 1suppliers in terms of the complexity of the products that they provide.

The described levels reflect the automotive supply chain base, which is structured like a pyramid. On top of this structure is the OEM. Below the carmakers are a small number of Tier 1 suppliers that sell parts directly to carmakers. Tier 1 suppliers in turn purchase materials from Tier 2 suppliers, who purchase from Tier 3 suppliers, and so on down the supply chain (Klier & Rubenstein 2008).

For a supplier, being awarded as tier 1 by an OEM, one of the major requirements is the International Automotive Task Force (IATF) - 16949 standard compliance, is independent of its size (e.g., number of employees, sales volume, etc) and product portfolio range. The close localization of the production sites of OEM's assembly units, represents a logistical advantage that can be a heavy decision factor as it satisfies the Just-in-Time (JIT) concept.

As Taiichi Ohno explains the JIT concept in its seminal work, "With the possibility of acquiring products at the time and in quantity needed, waste, unevenness, and unreasonableness can be eliminated, and efficiency improved. Toyoda Kiichiró, father of Japanese car manufacturing, originally conceived this idea which his successors then developed into a production system. The thing to remember is that it is not only "in time" but "just in time." Just-in-time and automation constitute the two main pillars of the Toyota production system" (Ohno, 1988, p.123).

Moreover, the geographical location of suppliers' plants considerably influences its relationship with the OEMs. Hence, the JIT concept models industry attributes, its players, stakeholders, and geographical location.

The European Automotive Industry concept used in this text comprises the production of passenger vehicles, light commercial vehicles, heavy-duty vehicles, as well as the manufacture of single components and modules. The automobile is a complex product, formed by several components as well as technologies. Such, that it is almost impossible to differentiate as modular or integral in its whole. Automotive engineers and industry managers began to pay attention to modular concepts in the early 1990s, following a past logic of unbundling production activities to be carried out by suppliers (Macduffie, 2013).

Industry's definition of a 'module' is of a large piece of physically adjacent components produced as a subassembly by a supplier and then installed in a single step in an OEM assembly plant. Examples are the instrument panel; the front end; seats; and the rolling chassis (Macduffie, 2013).

Modularity has been traditionally defined based on the notion of product architecture, or according to Ulrich (1995): "(1) the arrangement of functional elements; (2) the mapping from functional elements to physical components; (3) the specification of the interfaces among interacting physical components" (Ulrich, 1995, p. 420).

According to Frigant (2016, p. 913): "Product architecture is described as being modular when (1) the overall product results from the assembly of different subassemblies (modules) that are functionally autonomous and independent, and when (2) the subassemblies are interconnected by previously defined interfaces whose role is crucial insofar as—once they have been defined—it becomes possible to modify the modules (and even to substitute them) without having to change the overall product architecture."

A modular product's design consists of creating an embedded hierarchy of parts ranging from a global system to simple components and including modules (called modular subsystems), Simon (1962).

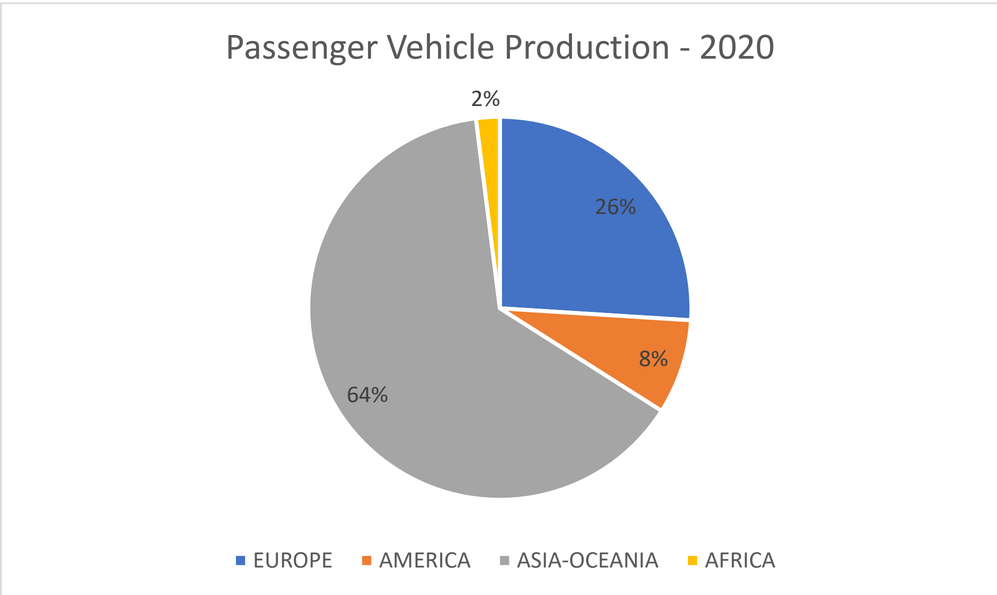
Concluding, the notion of interfaces (and the effectiveness of defining them on an early stage of the development process) is generally accepted in our time (Frigant, 2016). At the same time, this led to a great improvement in design methods (Cabigiosu, Zirpoli, & Camuffo 2013). Its current target is to reduce time-to-market, increase reliability, and enable certain forms of carry-over. The automotive product system was profoundly redesigned and turned into a nested hierarchy of subsystems (AutoBusiness-SSBS 2004; Sako 2003). All things considered; it is generally accepted by researchers that nowadays the automotive industry has taken the concept of modularity in its own specific way. Even if this modularity concept does not entirely fit on Ulrich's (1995) sense of the term, several mechanisms implementing a degree of organizational influence exist within this singular appropriation (Frigant, 2016).

3.2.1. Manufacturers

As already referred, global vehicle production consists of passenger cars, commercial vehicles, and buses. Concerning the production of passenger cars for the world market, Asia-Oceania leads with a share of 64% of world production, followed by Europe with 26% and America with 8% (Source: OICA - 2020), (Figure 27). The leading car manufacturer is the Volkswagen Group, followed by the Toyota Group, Renault-Nissan-Mitsubishi, Hyundai, General Motors, Ford, Honda, PSA and Daimler Group respectively (Figure 28). Within Europe (EU-28), Germany has the highest production share (28%), followed by Spain (17%), France (13%), and the Czech Republic (9%) (Source: OICA - 2020), (Figure 29).

Figure 27

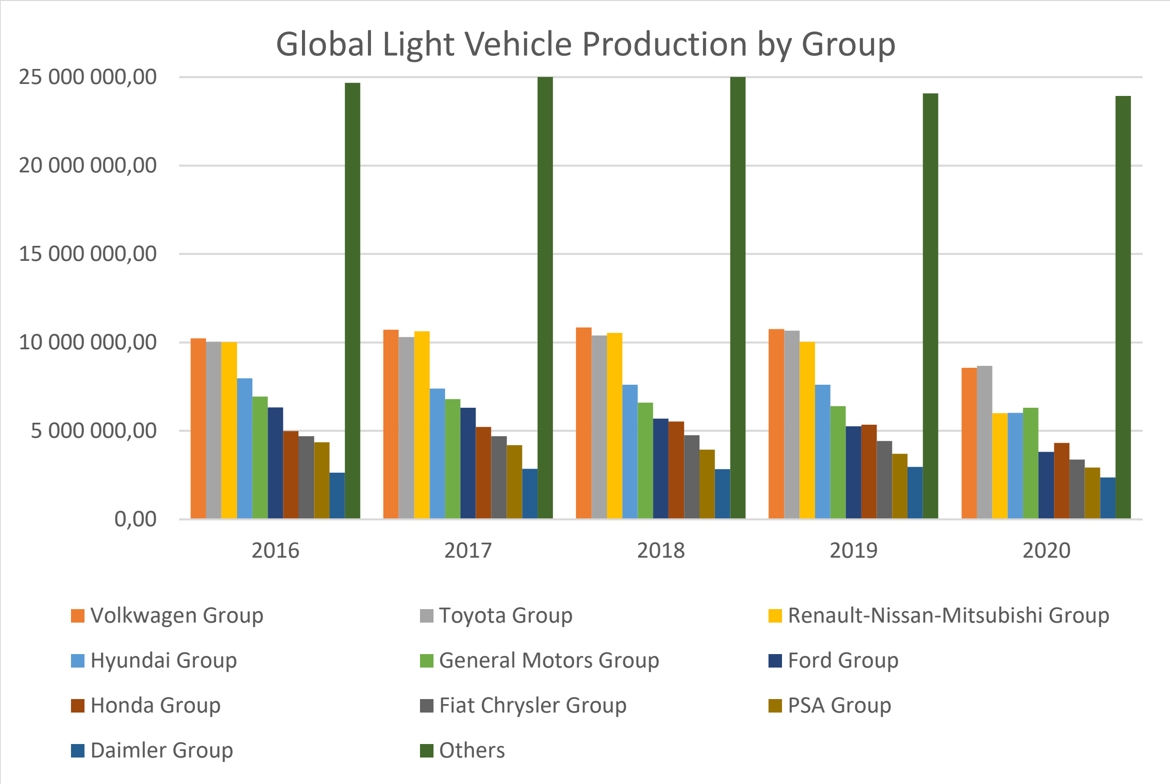
Global Passenger Vehicle Production (2020)



Note. Data accessed from OICA (https://www.oica.net/category/production-statistics/2020-statistics/)

Figure 28

Global Passenger Vehicle Production by OEM (2020)

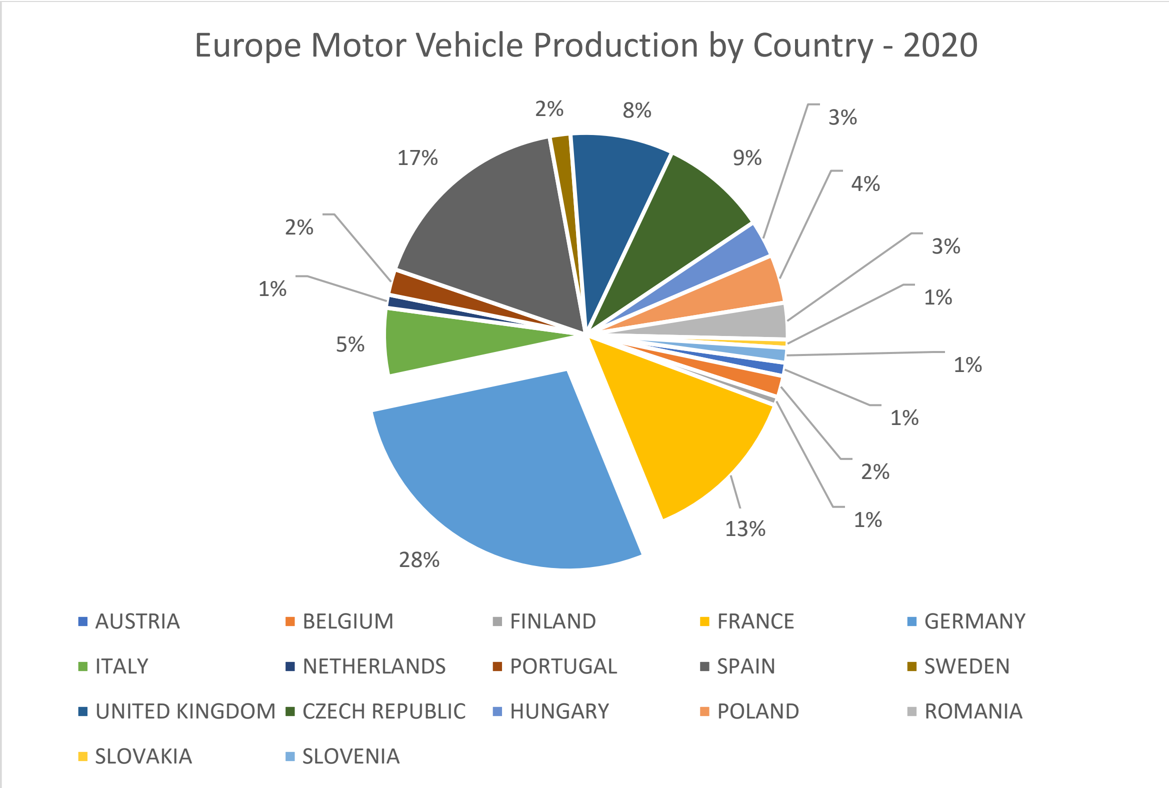


Note. Data accessed from OICA (https://www.oica.net/category/production-statistics/2020-statistics/)

Also, the light commercial vehicles sector is dominated by the big three: America, Europe, and Asia Oceania (Figure 30). In contrast to the car sector, America takes the biggest share of the market with 59% of total production volume, followed by Asia-Oceania with 27%. Europe is number three with just 12% (Source: OICA – 2020). One reason for the strong positions of America and Asia are the long distances in countries such as the USA, Brazil, China, or India.

Figure 29

Europe Motor Vehicle Production by Country (2020)

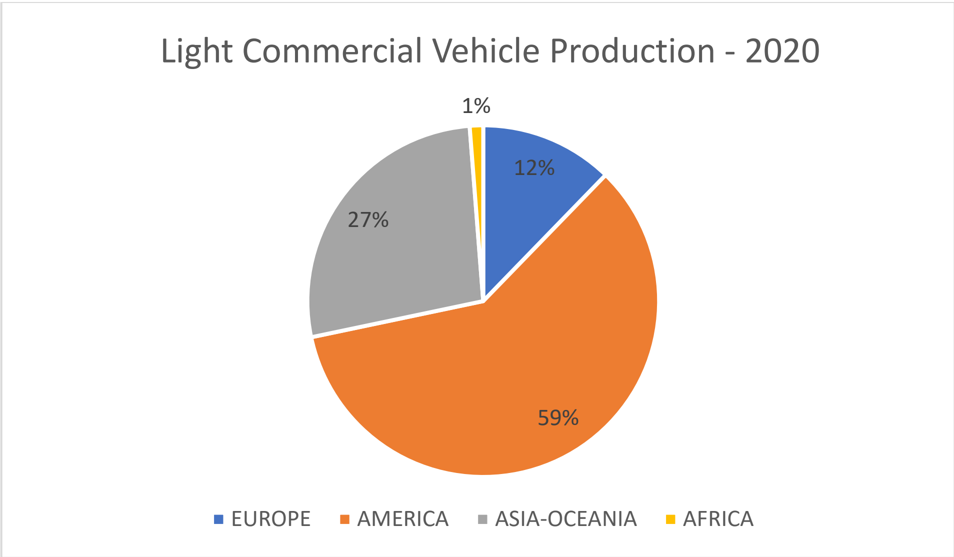


Note. Data accessed from OICA (https://www.oica.net/category/production-statistics/2020-statistics/)

In comparison to cars and trucks, the bus sector (including minibuses and coaches) reveals a different picture. This market is strongly dominated by Asian manufacturers (Figure 31). The region of Asia-Oceania and China in particular, constitutes a huge market for buses. China has a share of 70 % of output i.e., a production volume of more than one hundred thousand and three units in 2020 (Source: OICA – 2020). Number two in this market is India with a share of 22%. Interestingly, the Russian Federation steps ahead of European countries to be number one in this market with a share of 30%. The Western European countries, headed by Poland and the Czech Republic, trail behind.

Figure 30

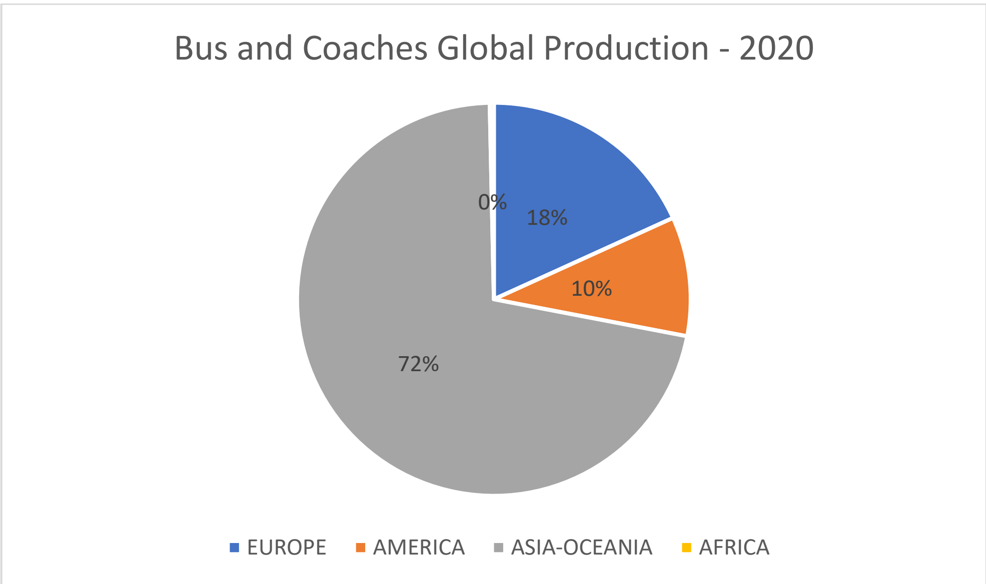
Global Light Commercial Vehicle Production (2020)



Note. Data accessed from OICA (https://www.oica.net/category/production-statistics/2020-statistics/)

Figure 31

Global Bus and Coaches Production (2020)



Note. Data accessed from OICA (https://www.oica.net/category/production-statistics/2020-statistics/)

3.2.2. Suppliers

The supplier industry represents a vital element of the automotive sector. The dramatic changes in the value chain of the automotive sector mean that manufacturer and supplier partnerships are now indispensable. Suppliers are assuming more and more responsibility for different parts of the value chain, even the lion's share in some cases. This trend is expected to continue. Thus, there will be at least four sources of opportunities for future growth in the supplier industry:

- Access to new markets, e.g., China and Russia,
- Increased vehicle value, e.g., Industry 4.0 (digitalization) and electrification,
- Development of light weight and new materials,
- Benefits from manufacturers' outsourcing strategies, e.g., EV's powertrain are not core business to OEMs.

Table 6

Top Ten Global Automotive Suppliers (2019)

SUPPLIER	REVENUE MN. EUR
1. Robert Bosch	47.000
2. Continental	44.478
3. Denso Corp.	43.307
4. Magna International Inc.	35.169
5. ZF Friedrichshafen	33.597
6. Aisin Seiki Co.	32.012
7. Hyunday Mobis	29.378
8. Bridgestone	24.230
9. Michelin	24.135
10. Valeo	19.477

Note. Source: Data accessed from OESA (https://www.oesa.org/)

These developments will necessitate major inputs in terms of manpower, R&D expertise, and financial resources, if suppliers want to be able to accompany manufacturers at their assembly plants all over the world. All the top 10 suppliers are internationally operating firms with a turnover of at least $ 330 billion (Table 6).

The top ten supplier companies (Table 6) fall into four geographical groups dominated by the US, Germany, France, and Japan. There are traditional links between US OEM and US first tier suppliers, French OEMs, and French first tier suppliers, and between German OEMs and German first tier suppliers. As a rule, Japanese OEMs prefer to use suppliers from their own conglomerates. These traditional links are in decline. OEM globalisation tends to favour larger suppliers, resulting in increasing mergers and acquisitions (M&A) activity in this sector.

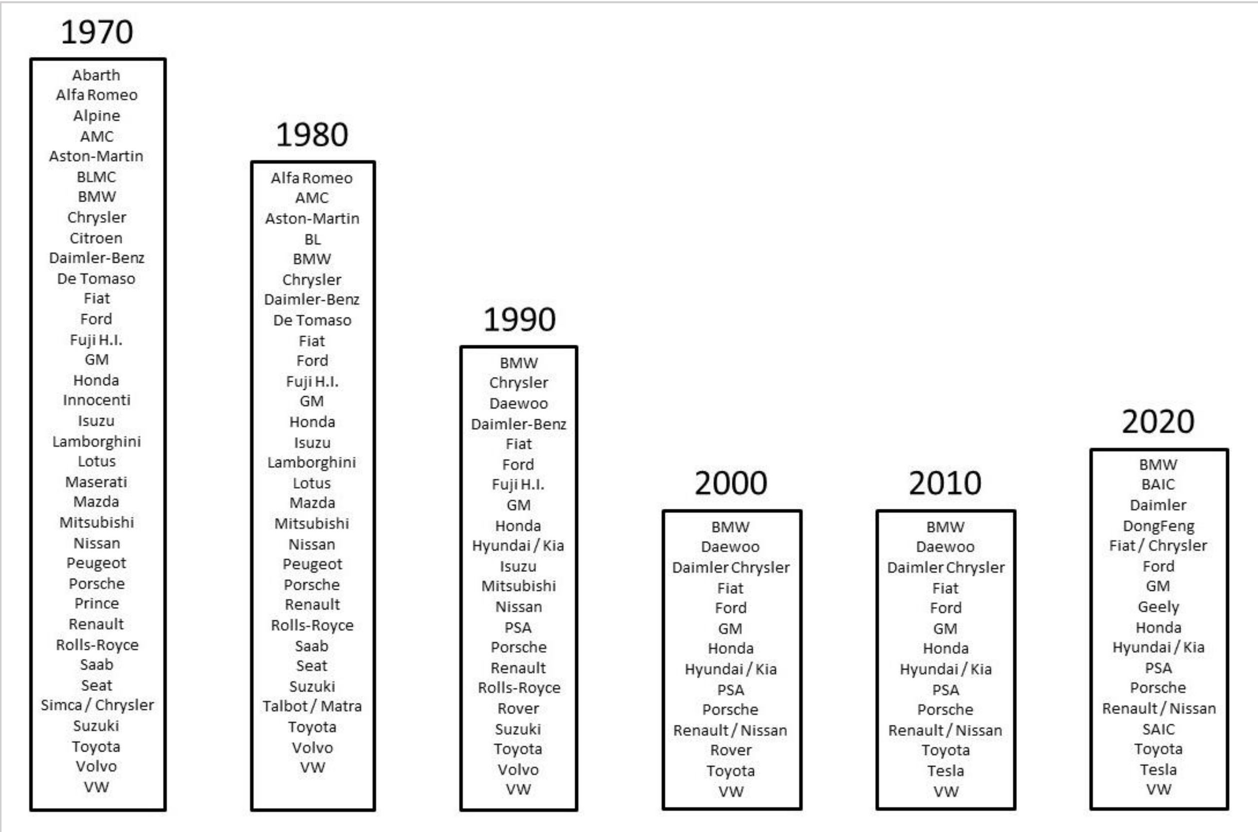
3.3. Consolidation and Restructuring

3.3.1. Manufacturers

Mergers and acquisitions have radically restructured the industry during the last decades. These developments have accelerated in the last decade with the opening to international competition of new and increasingly important markets such as Eastern Europe, China, and Russia.

Figure 32

Timeline of Automotive Industry Restructuring



Note. Source: adapted from European Commission (2008)

The search for scale[4] and scope[5] economies by large manufacturers and the difficulty for smaller ones to sustain the investment race have led to an ever-decreasing number of independent manufacturers in the market. Figure 32 represents the reduction trend from 36 manufacturers in 1970 to 14 in 2000 and a new raise from China manufacturers to 2020.

Additionally, despite the decline in the number of car manufacturers, competition in the regional, local, and niche markets has increased as larger companies are now present in all of them. M&A have played an important role in the process by giving instant access to regions and niche markets and continue to do so. Therefore, manufacturers have transformed themselves from automobile companies to automobile groups.

[4] Economies of scale are the cost advantages that companies obtain due to their scale of operation, with cost per unit of output decreasing with increasing scale.
[5] Economies of scope are efficiencies formed by variety, not by volume. In economics, the word *economies* is synonymous with cost savings and the word *scope* is synonymous with broadening production/services through diversified products.

3.3.2. Suppliers

A similar change is taking place also within the supplier industry, in the need for more product responsibility, larger innovation capabilities and global production.

Moreover, links within the automobile industry go far beyond equity deal as each of the following types of linkage is quite common: joint venture, interchange or buy-off of products; marketing or distribution agreement, technology or R&D agreement, and assembly agreement.

Manufacturers preserve a complex network of several such links, both among themselves and with their tier 1 suppliers, by which they manage their organization hence the strategic control of the whole value chain. This is of utmost prominence, especially in mature markets such as Western Europe where customers expect additional enhancements from vehicle manufacturers but are not willing to pay higher prices. Therefore, product innovations should be financed with an increased efficiency along the value chain which includes component suppliers as well after-sales-services (European Commission, 2005).

Future innovations in vehicle manufacturing will be intricately linked with electronics and software control systems. These innovations must be associated with the traditional mechanical automobile components and battery electric vehicles development. The conventional component supplier or new entrants in the sector will take over these new value-added activities. The outcome will be that more R&D activities (e.g., Design and Engineering) will shift to them. Consequently, the OEMs are trying to ensure his added value share with cost pressure on the component supplier and cost optimisation on the side of their retail business. Current tier 1 suppliers must assure R&D capabilities to OEM's, risking being out of business.

In the 1980s, the modern passenger car consisted of up to 10,000 different parts. The special knowledge of vehicle manufacturers concerned the management of the complexity of the production process, which required co-ordinating up to 2,500 suppliers (Womack, Davies & Jones, 1991). This was a time when suppliers were regarded as commodity suppliers rather than strategic partners in innovation. American manufacturers like General

Motors (GM) purchased 70 percent of their parts from own production which required considerable innovation capabilities and capital lockup.

At the beginning of the 1990s, the pressure to innovate and to cut costs led to a reduction of manufacturing tasks to its core – final assembly. In Germany, the share of the vehicle manufacturer in total automotive value added declined from 18 % in 1995 to 12,8 % in 2001. Similar declines were registered for the UK (about –5,9%), Italy (about –5,3%), Spain (-3,8%) and France (-2,1%). Only in Sweden did the vehicle manufacturers' share in the total value added of the automobile industry increase. Simultaneously, the number of employees declined in the automotive industry as a whole, whereas within the supplier industry employment and gross value added increased (European Commission, 2005).

Moreover, as the modularization idea was being developed for production, it was a short move until OEMs top management start to think about outsourcing design responsibilities similarly. Automotive groups sought the allocation of design tasks to suppliers, under the frame of 'module design', as already referred, to tap their specialized knowledge. Also, suppliers welcomed these approaches as well as instigated them, seeing 'module design' to take on higher value-added activities (Macduffie, 2013).

These changes have not reduced the complexity of the process of vehicle manufacturing, but rather have relocated the tasks along the value chain. Some suppliers started to take the responsibility for larger modules. The assignments of first tier suppliers not only include the manufacturing of module, the just-in-time delivery to vehicle assembly factories and the management of second and third tier suppliers, but also the related R&D. Furthermore, half of the total R&D activity of the automobile industry in the last twenty years has been carried out by first and second tier suppliers. All in all, OEMs kept the control of manufacturing and R&D in the areas of engine, transmission, and car body. So, through the last twenty years, first tier suppliers started to develop a close partnership in the innovation and production process of vehicle manufacturers and acting like true product design and development partners.

The modular revolution has led to the emergence of mega suppliers (Donovan, 1999) who have captured most of the top of the pyramid (Frigant 2009). Through this lens, the only firms capable of satisfying OEMs demands today are large companies. The current supply chain plot leaves no room for small firms (SMEs) in the pyramid’s first tier, relegating them to the second tier and often lower (Klier & Rubenstein, 2008; MacDuffie, 2013).

All things considered, mega suppliers’ emergence clearly required changes in firms’ boundaries. Eventually, this meant that small businesses (SMEs) had no place at the top levels of the supply pyramid. Three of the cumulative mechanisms generated by this process led to radical transformations in the present selection. First, to become module suppliers, companies had to develop new competencies (in R&D, components integration, managing their own supply chains, etc.). To win the modularity race that everyone took part in around the turn of the century, suppliers engaged in more and more M&As in an attempt to build up the competencies they needed to design and produce modules (AutoBusiness-SSBS, 2004).

3.4. Innovation and Competitiveness

Innovation and R&D activities are central to competitiveness. The ability of firms to compete in foreign and home markets depends crucially on innovative products that can be produced and sold at attractive prices. In the short run, productivity and labour costs are important competitiveness factors. In the long run, the ability of firms to innovate and invest in R&D take over as crucial determinants of competitiveness (European Commission, 2005).

There are prominent differences in Europe. Taking Germany for example it is the most expensive country with labour costs per hour (within the automotive industry) of 9 % above the US in 2020. Labour compensation per hour worked is below US and Japan in all other European countries - labour costs in Portugal are about 30 % of the US level. The high labour costs in Germany endanger its competitiveness unless they are matched by an above average labour productivity.

Unit labour costs relate labour costs to the value of production. Unit labour costs crucially depend on the composition of automotive industry, generally higher in the supplier industry than in car assembly. However, they are also affected by the degree of outsourcing. Unit labour costs have been traditionally low in France, Korea, Ireland, Netherlands, Belgium, and Spain. However, different rationales. In Belgium, unit labour costs are low despite of high labour cost per hour because of a high labour productivity and an above average use of intermediate inputs from outside the automotive industry. Also, in the Netherlands, France, and Spain high labour productivity helps to keep unit labour costs below average. Germany has seen a strong decline in labour unit costs which is primarily caused by increased outsourcing. This is reflected in the increase of the share of labour costs in value added (European Commission, 2005).

Skilled workers, such as designers and scientists are key actors in the generation, rapid dissemination, and utilisation of know-how. In most European countries' employees classified as Human Resource in Science and Technology (HRST) count for about 25% of all employees in services and manufacturing and in almost every European country this share is growing (European Commission, 2005).

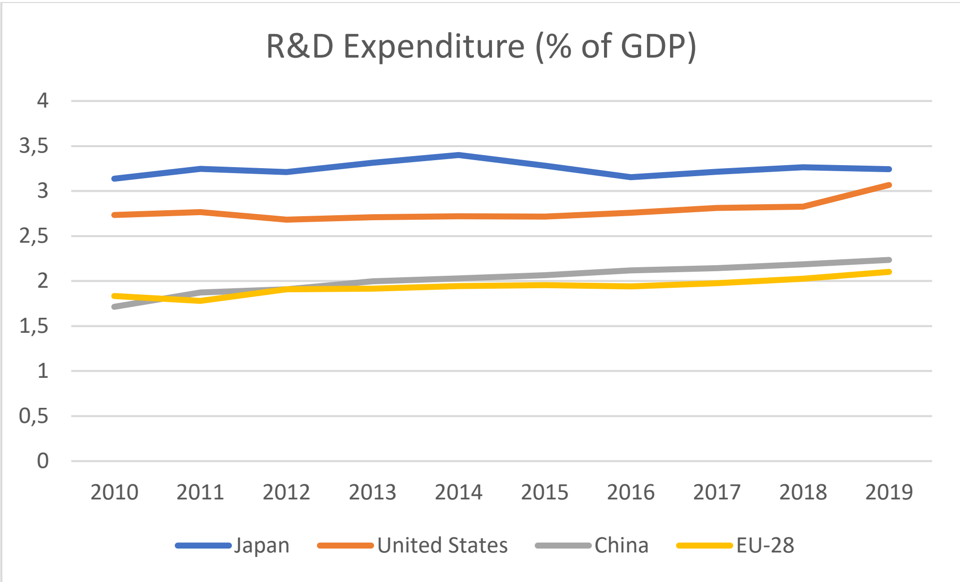
The later mentioned structural and organisational changes of the last twenty years that went through the automotive industry have had implications for human resource management and have led to an important division of the labour force in the automotive industry. The share of low skilled occupations has been reduced to a minimum, resulting in a considerable decline in this category of jobs. Low-skilled labour in car factories was replaced or outsourced to other companies. High-skilled labour became more valuable and an asset for firms. Being the case for R&D, engineering, industrial design, and other knowledge-intensive tasks.

Moreover, a parallel development took also place on the supply side. Suppliers of high-quality products and services, based on high-skilled workers, stabilised their market position. Suppliers providing ubiquitous products and services lost their market position and were substituted by global sourcing.

As to what relates, in the industrial sector, technological R&D is crucial for innovation activity and an important factor in determining technological performance and competitive advantages. In Japan, the US, the EU-28 and China, R&D expenditure account respectively for 3,2%, 2,8%, 2,0% and 2,2% of gross domestic product (GDP) (Source: OCDE – 2018). High-tech industries account for 40 % to 45 % of manufacturing business enterprise R&D, medium-high-tech industries for about 45 %, and medium-low-tech and low-tech industries for 10 % to 15 % (European Commission, 2005). Moreover, EU's share increased between 2010 and 2018, from 1,8% to 2,0% corresponding to a 9,5% increase (Figure 33).

Figure 33

Global R&D Expenditure (2010 -2019)



Note. Data accessed from OCDE (https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm)

Moreover, company level wise, relating the annual growth rate of R&D expenditure of the top 300 international companies to absolute R&D expenditure levels evokes interesting perceptions. In particular, 'IT hardware', 'automobiles & parts' and 'pharmaceuticals & biotechnology' constitute the top three sectors in terms of absolute R&D expenditure levels (European Commission, 2005). Therefore, these numbers evoke that the automotive sector is one of the few sectors where European based multinationals have a competitive edge compared to the other regions.

Technical progress, competitiveness and innovation are based on research and development. But even in R&D intensive industries, R&D is only one but essential core of all innovation activities. Innovation means in this context the development and economic exploitation of new or improved products and services, and the optimisation of business processes. Innovation continuously redefines markets and opens new sectors of economic activity. It concerns every industrial sector, especially the automotive industry (European Commission, 2005).

Technological innovation in the automotive industry is still above the average of the manufacturing sector. Hence, the second- and – to a lesser extend – third-tier suppliers need to innovate to stay in the market. Cost pressures in small supplier companies have increased and some companies have had to stop their innovating activities for financial reasons (European Commission, 2005).

Firms have their own innovation strategies and following different directions. Consequently, one strategy is to develop inhouse R&D and to combine in-house activities with additional R&D undertaken by external partners. Another strategy is technology transfer through the acquisition of new equipment and machinery. For companies with less internal and/or external R&D, the purchase of equipment, imitation and learning by doing could be, undoubted, one of the most valuable innovation strategies. Therefore, these companies invest in trial production, training and tooling combining it with process design and product design.

Blending mass production with the complexity of the automobile (as well as other transportation products) makes the failure risks related to radical innovations extremely high. Therefore, processes and products are developed incrementally. In-house R&D activities and product development are the main sources of technical progress.

3.5. Challenges and Opportunities for the European Automotive Industry

As production volumes rise, especially in Asia, OEMs should manage by building a strong local supplier base, implementing an improved supply chain, and strengthening supplier capabilities. The demanding improvement on green mobility mean that suppliers will develop greater significance concerning the amount of value they can add, particularly for the continuously improving of the Internal Combustion Engine (ICE) but also for the various electrified powertrain options Battery Electric Vehicle (BEV), Plug-In Hybrid Electric Vehicle (PHEV), Hybrid Electric Vehicle (HEV) and Fuel Cell Electric Vehicle (FCEV).

Conventional ICE powered vehicles have been optimized throughout automotive history within the development of engine control systems, downsizing and lightweight of parts and automatic transmissions. However, there are the long-term options of a full range of electric powertrain alternatives, and these are not core competencies of most OEMs. Therefore, OEMs will need technological and logistical support to manage the long-term transition from ICEs to Electric Vehicles (EV) or the production volume increase of ICE-based vehicles with electrified powertrain solutions such as PHEVs or HEVs, with increasing adoption to be expected beyond 2020, given tighter regulation requirements and continuous technological development. However, OEMs may well ponder placing themselves long-term in the design of electric motors and/or manufacturing and development of battery packaging and integration. Moreover, electronics and software will play a dominant role in vehicle innovation specially for suppliers' role. Approximately 90 percent of automotive innovations in 2012 featured electronics and software, especially in active safety and In-Vehicle Infotainment (IVI) options (McKinsey, 2013). Since those are key capabilities for the long-term, it will be decisive for OEMs to consider solutions like developing "vertical partnerships" with their preferred suppliers. Therefore, allowing OEMs to cut R&D costs while developing and implementing new features faster on the market.

The evolution to the modular product architecture had a primary impact compounded by the increasing strength of the design function, given the fact that a leading aim for many OEMs has been to delegate more and more R&D and design tasks. In turn, this has had two effects: higher R&D costs that are partially supported by customers themselves, and innovation rents that can be taken by suppliers capable of designing exceptionally innovative modules. This explains why innovation has become, more than ever, a strategy that mega suppliers use to differentiate themselves and tie in OEMs (Frigant, 2016).

In the automotive industry, innovations are incremental by nature. Innovations usually affect elements that are peripheral to the global and/or emerging system for premium automobile models, before being disseminated across more common models as part of a marketing strategy. Therefore, an innovation process of this sort leaves much room for SMEs (Frigant, 2016). Considering radical innovations such as electric vehicles, mega suppliers seem to also play a key role by means of deals and joint ventures with carmakers (Vitali, 2012). Large suppliers refuse to invest in certain areas that seem too distant from their core competencies. Indeed, many components have had to be invented or re-invented for specific automotive uses (Vitali, 2012). Thus, depending on their specific trajectory, large suppliers will not necessarily develop all the human and material resources that they require. Some of these will then be offered by other companies from other sectors, although if such companies consider the profit opportunities insufficient, SMEs will also have a chance to enter the market and fill the top of the pyramid gaps (Dodourova & Bevis, 2012).

There are six strategic fields of action that should be thoroughly assessed by automotive suppliers when considering transformation initiatives towards mid and long-term timeframes seeking to achieve the top of the pyramid (Deloitte, 2017):

- Product portfolio shifts: Match product offering with demand in growing component clusters (e.g., electric vehicle platforms).
- Collaboration and platform strategies: Accelerate developments and share risks through partnerships (e.g., split development costs through multiple suppliers).
- Consolidation and scaling strategies: Seek economies of scale by consolidating volumes of losing component clusters (e.g., as the ICE development will decrease its long-term development, scaling strategies towards the electric vehicle (EV) specific clusters should be defined).

- Location strategy review: Re-focus production locations according to future market and customer demand (e.g., relocating production sites to new or to be developed EVs platforms assembly plants).
- Digitization for cost leadership: Establish an integrated digital supply chain for next level cost optimization (e.g., implementation of industry 4.0 along the value stream).
- Talent for future business demands: Create a forward-thinking talent model that considers changing requirements (e.g., investment on skilled workers, designers, and scientists as key actors in the EVs new generation).

3.6. Incomplete modularity – A strategic opportunity for SMEs

Supply chains were restructured into three levels. The first, featuring mega suppliers, designing, and producing modules, whereas the third was for SMEs who had been relegated to this level because they were being restricted to acting as subcontractors or suppliers of simple small parts. On the other hand, the second intermediate level, was more diversified, featuring actors who were relatively heterogeneous in size and made more or less complex products (Frigant, 2016).

According to Frigant (2016), this "representation is based on three implicit hypotheses: (1) the existence of a strict isomorphism between product architecture and organization, creating a situation where mega suppliers were the only ones with the ability to manufacture modular subsystems (because major competencies were needed, because carmakers would have to be followed abroad, and because mega suppliers were the only parties who could afford to commit the requisite material and immaterial resources); (2) modules became the only parts that the carmakers were buying, turning automobiles into a simple game of Lego; (3) carmakers were characterized by a constant single degree of vertical integration for all the vehicles they assembled and in all of the different factories where they were producing the same vehicles" (Frigant, 2016, p. 916).

If these three conditions were to be true, one would suppose that the whole market of modular parts could be provided exclusively by mega suppliers. Yet, given automobiles' imperfect modularity (Frigant 2011), it is doubtful that these conditions would be entirely fulfilled. Because the automobile product architecture is not completely modular, the carmakers need to buy some elementary parts, to subcontract certain tasks, etc.

All in all, the incomplete nested hierarchy creates spaces of market for small components that other type of suppliers can deliver. As already referred, the degree of vertical integration is not unique, for some plants and some cars so the need to buy nonmodular parts. As the isomorphism hypothesis is a very debatable issue (Campagnolo & Camuffo, 2010), some gaps appear in the pyramid representation. These gaps are spaces in the market that small firms can take over (Frigant, 2016).

Frigant (2016) has conducted a survey study on French SMEs, in a first moment, asking them if they were working for the automotive industry, what they were doing in this field, and at what level of the pyramid were they operating. In a second moment, what services would they fulfil on behalf of the automotive industry. Frigant (2016), used two classifications here, weather they produce simple or complex parts and afterwards whether a research and/or development activity was combined.

As already referred, the traditional pyramidal concept of the supply chain also contains the idea that a clear disconnection exists between the different tiers. The restructuring of the industrial architecture is said to have led to suppliers being clearly positioned at one and only one tier in the hierarchy (Frigant, 2016).

After the survey was concluded, Frigant (2016) has come to findings that support the hypothesis that suppliers' roles are split across the whole of the supply pyramid. However, almost 40% of the surveyed SMEs operate at several tiers simultaneously. Therefore, as Frigant (2016) concludes, "whereas a majority of SMEs taking part in the supply chain intervene on one single tier alone, it is important to avoid the conceptual trap that consists of considering that the pyramid in question has been structured once and for all. Crossover possibilities do exist between different tiers. Many suppliers are simultaneously present on several different supply chain tiers" (Frigant, 2016, p. 922).

The second findings were that the more complex the service being provided, the greater the possibility that the SME in question would be operating toward the top of the pyramidal hierarchy. As Frigant (2016, p. 923) concludes, "the first major distinction here is between complex and simple parts. The former tends to be made by suppliers positioned on the first tier. Adding R&D services increases the probability of becoming a tier 1 supplier, whether exclusively or partially. Conversely, suppliers manufacturing simple parts without R&D activities tend to be situated toward the bottom of the pyramid."

Finally, Frigant (2016) study has also revealed that some SMEs have continued to operate at tier 1 level of the supply chain hierarchy even if they were producing small simple parts made from plastic or metal.

This observation could lead to the fact that OEMs might be purchasing products and services from SMEs who are picking up whatever is left due to the already referred modularity's imperfection. Another possible reason for this conclusion from Frigant (2016) study could be that large suppliers would occupy markets with the highest relative profitability, leaving other markets (considered less profitable) to SMEs.

Another possible reason for the presence of some SMEs operating at the top of the already described automotive supply chain pyramid, could be that these firms are potentially linked to market transformations caused by technological progress (e.g., electrical vehicles). SMEs can get involved in occupying these small areas, because the large firms have difficulties to manage radical innovations (Henderson & Clark 1990, March 1991).

4. Introduction to the Portuguese Automotive Industry

This chapter is structured in six sections, including an introduction. The following is a general overview of the period between the end of World War II and the Renault project. The third is the Renault project, seeking to characterize its main endeavours and their impact, especially regarding the development of component suppliers. The fourth part relates to the period between Renault's investment and the AutoEuropa project. This is a complex and especially important period, evidenced by the adhesion of Portugal to the European Economic Community (EEC), (which has significantly influenced the car manufacturers' strategies of approaching the Portuguese market and created an Iberian automotive manufacturing and trade space). The fifth section will be dedicated exclusively to the AutoEuropa project, from the contract conditions to the induced effects, and its main features. The status of the automotive industry in Portugal and its future challenges will be described in the last section of this chapter, the sixth, focusing on component and systems suppliers. The chapter will conclude with a summary, highlighting the main topics to be considered in the analysis of the smaller companies that shape the main body of the Portuguese automotive cluster which is the focus of this work.

4.1. Introduction

The Portuguese automotive industry history is a direct reflection of Portugal's path into the European integration over the last four decades. Thus, it was the prospect for the full adhesion of Portugal to the European Union (EU), that denotes the great leap in the integration of the automotive sector, with greater added value, in the Portuguese industrial production.

When reviewing the history of the automobile industry in Portugal, it is possible to conclude that it is a reflection from the interaction between two sides: industrial policy and foreign direct investment (FDI). In fact, at all key moments in the evolution of the automotive sector, it can be found, on one hand, the State, defining (or redefining) policies for the sector and attracting or conditioning foreign investment, and on the other, the large automobile groups and assembly companies. As background, guiding these actors, the process of economic integration, from the creation of the European Free Trade Association (EFTA) in 1969 to the current Economic and Monetary Union (EMU) that kicked off in 1990.

In fact, if the first assembly units established the logical evolution of a sector which, especially from 1986 onwards (full EU membership) has made an exemplary quantitative and qualitative leap, it is certain that the industrial policy underlying the previous units at the time did not allow the automotive sector to have a greater influence in the added value of the economy, nor did it stimulate the technological innovation of Portuguese companies.

By that time, trade and economic policies called for import substitutions, hence the industrial strategy for the automotive was based on assembly operations of semi-knocked-downs (SKD) or complete-knocked-downs (CKD), even if it made the product more expensive internally. Manufacturers were not optimizing the efficiency factor in their assembly units, consequently units with questionable viability began to appear as the market was slowly but steadily opening to the more competitive exterior markets. Moreover, because it constituted at that time a mere process of assembling, it did not, as would be desirable, lead to the emergence of a network of component suppliers for the industry. At the very least, small supplier units may have arisen to supply some minor components, with little added value to the internal market and of no major significance to the sector.

With the full integration of Portugal in the European Union in perspective, Renault leads the first large and structured investment of the automotive sector in Portugal in the early 1980's. Moreover, the Portuguese economic and political context had dramatically changed, the French company moved from the mere CKD assembly process to an actual automobile production, already incorporating parts and systems produced in Portugal with significant added value. Then, around this enterprise, emerges for the first time, a Portuguese automotive cluster, an industrial segment dedicated to the production of automobile components and systems. Afterwards, the technology transfer begins to the Portuguese industry as international automotive corporations show interest on starting their operations in Portugal.

Only with the formal adhesion to the EEC, that later became the EU, in 1986, that the Portuguese automotive sector makes a considerable qualitative and quantitative leap. Taking advantage not only of the easier access to foreign markets, but also of the structural and cohesion funds (ERDF and ESF). The automobile components sector quickly became the leading exporter, and even supersedes traditional textiles and clothing industry sector.

This was the time when a possible embryonic automotive cluster starts to emerge in the Portuguese industrial structure. Portugal, for the first time, appeared on the map of car exporters. In fact, the success of this strategy was directly supported by the trade and economic policies of the time, as priority was given to exports and attracting new investments for complementary projects.

From the automobile manufacturers' side, there was also a well-defined strategy where the weight of the Renault project was obvious. Likewise, and with major significance for the Portuguese supplier companies, there has been a real positive performance towards their technological and organizational development, as well as a constructive open policy to the export market and a continuous business dialogue with the global automotive industry.

Since 1990, with the successful integration into the EU and already with the perspective of the EMU, Portugal has attracted a large investment in the automotive sector, led by a Ford - Volkswagen joint venture. This joint venture, the AutoEuropa project, with a true international dimension, has, as expected, a considerable effect on the Portuguese economy. Consolidating the yet embryonic automobile cluster, inducing around it the emergence of a vast constellation of component business units promoted by large international corporations, local entrepreneurs, and joint ventures, promoting innovation by introducing new methods and technologies in Portugal. Furthermore, it also focused on environmental issues and vocational training, developing a depressed region, as was then the Setúbal Peninsula, creating a new and modern infrastructure and, above all, employment. Finally, the project promoted the concept of networking, integrating, and valuing reciprocal knowledge and experiences.

Moreover, another major focus of this project was on R&D activities, which led the automotive components sector to be the first in the country to continually experiment with the new concept of the knowledge economy. Indeed, in the whole business strategy of this huge investment, innovation was the key factor par excellence ensuring its competitiveness. This new dynamic demands no room for passive or static suppliers taking advantage of crystallized business. Therefore, there was a need for dynamic suppliers deeply knowledgeable of the automotive business and its technologies, working at a business level in a vertical and horizontal network and making innovation the everyday tool of their competitive advantage.

When the AutoEuropa project was developed, through the 1990's decade, it was described by an assumed reopening of external markets and by a business strategy of the OEMs with multiple dimensions. On the suppliers' side, a more technological and professional performance was assumed, namely, consolidating competences and responsibilities based on strict compliance with the cost / quality / time triangle. In the same way, new solutions in engineering capacity development were studied as well as taking part in highly valuable supply chains with internal and external companies.

The European integration was undoubtedly the driving force of the automotive cluster in Portugal. Without the European internal market, without EU funds and without the Euro, the sector would hardly have the projection it has achieved. However, it would not be precise in this analysis to not highlight the positive impact of public policy, not only based on a market economy and free enterprise, but also as a driver for technological innovation and for technological and financial partnerships in line with the needs for the development of the automotive sector.

4.2. From the end of World War II to the Renault Project

Although some automobile manufacturers were established in Portugal in the 1930s as for example, Ford in 1933, the starting point for this brief historic review is the World War II. The Portuguese post-war industrialization was late and slow since the Portuguese Government did not want to be included in the Marshall Plan due to political motivations along with Switzerland. Thus, the industrial output growing only after 1952 on the eve of the first government development plan. The end of the war was a decisive milestone for the diffusion of the automobile as a paradigm for a new consumption product need. Moreover, there is a near coincidence between the publication of the Portuguese Capital Nationalization Law and the end of the War, which led to the use of the armed conflict as the starting point for this analysis.

The period defined from the end of the war to the beginning of the implementation of the Automobile Assembly Law, is characterized by the supply of the domestic market through imports and the occurrence of some cancelled initiatives of fulfilling the dream of building a true original Portuguese car. However, there was no consistent public policy regarding the automotive sector, despite the Spanish example of the creation of SEAT, through a license granted by FIAT.

In the fifteen years that followed the end of the war, the Portuguese market was supplied through imports. In addition to customs duties, demand was constrained by indirect taxes such as fuel and vehicle purchases. An exception was made for US vehicles (contingent on shortage of dollars after the war).

Also, Ford Motor Company, started assembling units in Portugal by 1964 when it opened a brand-new factory in the outskirts of Lisbon, Azambuja by Henry Ford II. The first produced model was the Anglia which followed the Cortina and the Taunus.

Already under the second Portuguese development plan (1959-64) three projects were authorized. One of these, is the Portuguese Automobile Factory (FAP). Hence, in 1959, an attempt was made for the development of the automotive industry undertaken "with a lot of patriotism and little professionalism, the construction and commercialization of an economic / family car, the production under license from a major builder" (Féria, 1999, p.10).

The initial developer of the FAP project was José Félix de Mira, a great farmer of the Évora District and for many years the civil governor of that same district.

After land acquisition in the Aveiro district, remarkably close to the current Renault unit, an attempt was made to obtain licensing for the manufacture of such vehicles. However, José Félix de Mira's team quickly realizes that this will be an extremely complex project. It was unthinkable to try a diffusion into a scarce Iberian market, "Central Europe was an impossible goal and the critical mass of mainland Portugal, Adjacent Islands and Overseas Provinces was clearly below the feasibility threshold of a car factory "(Féria, 1999, p. 10), furthermore it is in the early 1960's that a remarkably high rate of citizens begin to exit Portugal in direction of France, Germany and The Netherlands.

The FAP project, by 1963, turns, not to car assembly, but on medium power tractors. However, even getting the license and some support for the manufacture of these vehicles, by 1965, the Portuguese Automobile Factory (FAP) would not be able to carry on the project, "ceasing its existence without ever producing a single car "(Féria, 1999, p. 10).

The failure of FAP's initial project shows, together with the “assembly law”, a breakthrough moment in the history of the automotive industry in Portugal. In fact, it represents the fading of the dream, cherished throughout the 1950s, of the creation of a Portuguese SEAT rival, manufacturing cars under license from a large foreign manufacturer. The failure of the promoted initiatives and the need of imports control, while creating conditions to stimulate industrial activity in the country, together with the recognition of the importance of the automotive industry sector, led for the first time to the launch of a specific public policy for the sector by the Portuguese authorities (Simões, 2000).

Left behind were fifteen years of a market, supplied almost exclusively through imports of already assembled vehicles. The patriotic dream of a Portuguese car manufacturer was nothing but a dream as the only possibility of acquiring industry know-how would be through the theoretically less restrictive mechanism of foreign involvement, as it did not imply the need for direct investment - the license agreement. However, the economic reality prevailed over the desires of a policy oscillating between everything (the Portuguese builder's dream) and nothingness (the absence of an import control policy). Consequently, the future of the automotive industry in Portugal would necessarily have to be from direct investment in production activities by car major automotive manufacturers.

The 1963 year is a milestone since it was the year that the import policy was substituted, and it was also the year of the end of the dream of the Portuguese car. The change of the political orientation was essentially a result of the post-war industrialization ideas of the secretary of state Ferreira Dias, the author of two diplomas that would become law. The first one establishing the limits and conditions for imports of motor vehicles in Portugal and a second one defining that internal demand should be met mainly through the assembly of imported CKD vehicles on national territory. Each manufacturer could only, annually, import up to 75 passenger cars already built. CKD units should be assembled in the country, outside Lisbon, Porto and neighbouring municipalities, integrating local labour and component suppliers, so that the incorporation of internal work force would not be less than 15% of the cost of the complete vehicle (Simões, 2000).

The “assembly law”, as it was called, had two main purposes: reducing imports and promoting the internal industry. Automobile imports were experiencing sustained growth. By this time the automotive sector would represent 18% of total imports. The stimulus from national industry was consistent with Ferreira Dias's concerns, pointing to an attempt to use the automobile as an industrializing industry. Thus the obligation for an internal incorporation of 15%, a modest but realistic number, considering the industrial capabilities of that time (Simões, 2000).

Nevertheless, switching imports for internal production required two possible movements, both based on new direct investments by car manufacturers and / or the internal companies’ investment from the already represented car manufacturers leading to the establishment of assembly units. The first was the transformation of former commercial subsidiaries into productive subsidiaries, developing assembly activities, or even from scratch, in order to benefit from the new supply conditions in the local market. The second led to the reorientation of many of the former representatives, from mere commercial companies to carmakers, acting under the license of the brand-owned manufacturers and their own know-how required for the assembly activities (Simões, 2000).

By the end of 1964, 17 companies had started operations, assembling up to 40 different models (Guerra, 1990). This number is particularly high considering that in 1969 there were just 19 automobile assemblers in the world. It was not until the late 1960’s that the Japanese car assembly companies began their activities in Portugal. As Guerra (1990) pointed out, the international oligopoly of industry rapidly reproduced in a closed market: the main companies adapted to the new situation in order to prevent them from competition taking advantage. The market could not be left to the competitors, so the need to respond quickly to the new rules.

Finally, as there was no automotive industry tradition in Portugal, the existing know-how was low, the market was small and, moreover, it was spread over almost twenty-four assembly units (Simões, 2000). However, not being able to manufacture components by law, the assembly units chose to purchase in Portugal the minimum elements to satisfy the intended national incorporation rate, thus being limited - with some exceptions - to upholstery, other interior components, and quasi commodities. (tires, batteries, glass, floor mats) (Simões, 2000).

In short, the Assembly Law, while evidenced some industrializing spirit, was unable to promote neither an open-market assembly industry nor a worthy component industry cluster. The sentence used by Schmidt & Almeida (1987) best reflects the style that the experience of assembly lines had left: “a not achieved evolution” (Schmidt & Almeida, 1987).

4.3. The Renault Project

In 1972, the Portuguese government made a new trade agreement with the EEC which consequently open the door to a new possible investment from Alfa Romeo to produce its Alfa-Sud model. Negotiations went to establish a joint venture (60% of the Portuguese State and 40% of the Italian brand) to manufacture the new small family-oriented model for the low-income market of southern Europeans.

The aim was to build an integrated factory - engines, gearboxes, and bodywork - with a capacity of around 60,000 units/year (Simões, 2000). Alfa-Romeo's interest was, of course, in the low labour cost in Portugal, to ensure an acceptable vehicle price tag for the southern European market. The incentives provided by the Portuguese Government for the project were basically of fiscal nature and non-financial (Martins, 1983). Nevertheless, there were internal component incorporation goals set for access to the planed benefits. Although, a project of this size, with such a high level of integration, could not rely on the national industry for the supply of parts and components. Once again, the internal industry weakness was unquestionable: few companies with acceptable critical mass could be involved in the project and none (or almost none) were able to meet Alfa-Romeo's quality requirements (Simões, 2000).

The year of 1979 view a new law establishing a fresh framework for the sector, while at the same time preparing industry for the opening of the market to imports from the EEC and creating conditions for what would become the Renault project.

In the meantime, from 1976 onwards and after the Alfa Romeo project failure, the contacts with several manufacturers eventually evolved into closer negotiations with two French companies: the PSA group (Peugeot / Citroën) and Renault. The projects proposed by these companies were discussed and analysed. The Renault proposal was eventually chosen.

Renault's project was more interesting, as it foreseen the manufacturing of engines and gearboxes, while PSA's project only included vehicle assembly and gearbox production. Renault's proposal had a more industrializing focus (Guerra, 1990) and a greater integration of local component suppliers.

As the Renault project went forward, most in-depth negotiations began, involving not only the industrial project itself, but also the conditions (legal framework, infrastructure, economic incentives) - crucial for its sustainability. The Renault project is somehow the beginning of a true automotive industry in Portugal and, more specifically, of a supplier component industry. It opens a new phase for the sector, providing an undeniable reference for studying the influence of foreign investment on the modernization of the Portuguese industry.

On the 13th of February 1980, an investment contract was signed between the Portuguese State and the Régie Nationale des Usines Renault (RNUR) which provided the basic framework for the implementation and development of the so-called Renault project (Simões, 2000).

Excluding Renault's small-scale industrial unit located in Guarda, in the north of Portugal, the project involved the creation of three brand new factories: the Setúbal assembly unit; Cacia's mechanical components factory; and the foundry of Funfrap, also in Cacia, close to Aveiro.

The Setúbal assembly unit was built in the old premises of an already industrial unit - Entreposto. It was the first to start in 1980, with a production rate of 40 vehicles per day (producing the small Renault 5 model) and a work force of about 450 people at the end of that year. It was an essential element for the Renault project, ensuring the assembly of passenger cars for both the internal and external markets. Its peak production was in 1992, when almost 73,000 vehicles were assembled (Simões, 2000).

Cacia's mechanical components factory was installed in the premises of the defunct FAP. According to the contract, it was intended to produce engines and gearboxes, not only to be integrated into the assembled vehicles in Setúbal, but also for export. This unit started up in 1981 and developed rapidly, so that in 1983 it already exceeded the production volumes established in the contract. If the Setúbal assembly unit was initially intended for the internal market, the Cacia unit concentrated on the manufacturing of great value-added components with a higher technological integration (Simões, 2000).

The construction of the foundry was not on Renault's initial plans. However, the idea was to supply the Cacia factory with castings through the Eurofer firm. Funfrap, also located in Cacia, next to the mechanical component unit, started its activities in June 1985. In addition to the engine parts, gearboxes, and water pumps for Cacia, Funfrap was a unit supplying castings to other Renault factories in the Iberian Peninsula.

Concluding, as Féria (1999) points out, the vertical structure created between these three units seemed to make sense within the ideated framework for the Renault project, where the internal market share was combined with exports. Funfrap casted parts to be integrated into the engines and gearboxes to be manufactured by the Cacia mechanical components unit, which would then be incorporated into the vehicles assembled in Setúbal.

During the 1980’s decade, especially until 1987, the Renault project view a surprising increase on installed capacity, production and employment in all group’s factories in Portugal. The growth from 1982 (the year in which Cacia plant started work) was significant for engines and gearboxes, around 36% for the former and 60% for the latter. Vehicle production also showed a positive evolution, from almost 17,000 in 1981 to 28,000 in 1985 and almost 45,000 vehicles in 1989. However, it never reached the 6000 jobs previewed on the initial investment contract. Even though Renault's market share increased considerably from 12% in 1980 to 25% in 1984, remaining substantially constant until 1987 (Simões, 2000).

We can Identify two major turning points that dramatically influenced the Portuguese Renault project. The first, and most important, was undoubted Portugal’s entry to the EEC in 1986. Although market protection for Renault was extended until 1987, it was obvious that this project was in trouble, given that it was largely based on the protection of the internal market. The second was the AutoEuropa project. The exceptional conditions afforded to attract the project to Portugal were regarded by Renault as an inadmissible distortion of competition; hence the case brought by Matra to the EEC authorities.

In 1995, Renault notifies the Portuguese Government of its decision to close the Setúbal assembly plant from 31 December of that year, as well as its intention to disengage from the investment contract. The Portuguese Government's reaction was certainly not the most appropriate, bringing Renault to court for breach of agreement. In doing so, it stressed a conflict and made unfeasible the development of a negotiation that could strike a balance that would safeguard the company in Portugal.

Although the assembly factory had its destiny, Renault took over the entire capital of the engines and gearboxes company, renaming it to CACIA and endowed with legal autonomy. Engine manufacturing was virtually abandoned, and the company became progressively specialized in gearbox production. It was also believed that this too would be gradually abandoned, with the company's future focusing on its mechanical capabilities, manufacturing other parts and components as well as looking for new markets outside Renault’s group. The decision to give autonomy to the CACIA unit is in line with today's industry-wide logic of outsourcing activities, making the former component units independent businesses that must look for new projects and new customers. The same logic led, moreover, to the merger of the foundry units of Renault and FIAT into a joint venture called Teksid, in which the former Funfrap was integrated. This unit had also stopped working exclusively for the Renault group.

The general opinion is that without the Renault project, it would not have been possible to attract AutoEuropa's investment (Vale, 1999; Guterres, 1996; Féria, 1999). Renault's project was crucial for the creation of the basis for a modern automotive industry, especially on the manufacturing of components. In fact, the positive balance of the Renault project is largely due to its effect on the capacity and dynamism of the current smaller component suppliers’ network.

Until the late 1970s, the Portuguese automobile component supplier’s industry was primitive and characterized by an exceptionally large number of small units (many of them more workshops than factories) and dispersed according to the location of the automotive assembly units. Production focused on traditional technology products (mainly metalworking) and quasi commodities (batteries, glass, and tires). The technological requirements placed by the assembly units were limited as the vehicles were intended for the internal market and there was virtually no quality culture. Production was characterised by small batches and low productivity due to the low level of technical incorporation, weak management approaches and the impossibility of profiting from scale economies (Schmidt & Almeida, 1987).

The contractually defined national incorporation goals and the project's own economic imperatives have led Renault to be concerned from the beginning of the project with the selection of potential internal suppliers. Therefore, Renault made an early assessment and selection not only based on demonstrated capabilities, but also on business dynamics and their ability to invest and risk taking. Renault provided initial technical assistance to these companies developing them to accept them in their supplier board, approving their products and production processes.

In this project, Renault played the role of “tutor” which, according to Kojima (1988), external investment should play. Just as important as the direct effect of the project was its indirect influence on the modernization of the component industry, projecting the international competitiveness of a group of Portuguese companies - of which the Simoldes Group will perhaps be the best example as it will be referenced later in this document. The Renault project ended, but its influence remains alive.

4.4. The end of the Renault Project and the new AutoEuropa Project

The EEC membership allowed companies located in Portugal to combine regional integration with business integration, boosting Portugal's role as a component production platform. Labour cost and the absence of trade barriers made Portugal an interesting location for the manufacturing of components, especially those most labour intensives, intended for export to the EU, and particularly Spain. These attractive factors were boosted by economic incentives granted by the Portuguese Government, mostly through the Programa Especifico de Desenvolvimento da Indústria Portuguesa (PEDIP) program.

PEDIP was an economic incentive programs for industrial activity. Nowadays these programs are financed by the EU structural funds. PEDIP, was a simple, effective and unbureaucratic program. It had seven subprograms: Basic and Technological infrastructures; Professional qualification; Investment incentives; Financial engineering; Productivity missions; Quality and industrial design missions; Disclosure, implementation, and control. What most characterized PEDIP was the full adhesion of Portuguese industrialists and their mobilization. PEDIP was finally provided with a total financing of 2000 million euros (at 1988 prices) for five years, with the participation of an additional 500 million from the EEC Structural Funds and 1000 million from the European Investment Bank (EIB), allowing the follow up and support of a Keynesian industrial policy that has greatly benefited the country.

The evaluation studies carried out by the EU and the Portuguese Government, after the conclusion of the program, unequivocally demonstrated the strongly positive impact. Between 1988 and 1993, productivity grew 5% per year in supported companies, foreign investment went from 1% to 5% of GDP per year, unemployment fell from 10.9% to 4.8%. In the five years of implementation, more than 9500 projects were supported by the program (PEDIP, 1994).

Table 7

Main FDI for Component Suppliers, Renault Project Related

YEAR	COMPANY	MAIN INVESTOR	ORIGIN	ACTIVITY
	(A) DIRECTLY RELATED TO THE RENAULT PROJECT:			
1981	DBA Portuguesa, Lda (1)	Bendix	FRA	Brakes
1982	Trecar – Tecidos e Revestimentos, Lda	Trety	ESP	Textiles, mats e soundproofing
	Electricfil Portuguesa, Lda	Electricfil	FRA	Wiring harness
	Jaeger Portuguesa, Lda	Jaeger	FRA	Instrument clusters
	(B) OEM SPIN-OFFS			
1980	Inlan – Ind. Componentes Mecânicos (2)	GM	USA	Engine mounts, brake pads
1981	Cablesa (3)	GM	USA	Wiring harness
1989	Ford Electronics (4)	Ford	USA	Entertainment systems, alarms
1989	Delco Remi (5)	GM	USA	Ignition Systems
	(C) INDEPENDENTS			
1979	Gametal-Metal. Gandarinha, Lda	Bertrand Faure	FRA	Engine mounts, stamped parts
1982	Kromberg & Schubert, Lda	K&S	GER	Electrical harness
1983	Solex Portuguesa, Lda	Solex	FRA	Engine fuel systems
1986	Bertrand Faure Portugal	Bertrand Faure	FRA	Automobile seats and parts for seats
1986	Yazaki Saltano	Yazaki	JPN	Electrical harness
1988	Continental Mabor	U. Technologies	USA	Electrical harness
1990	United Techn. Automotive Portugal (6)	Continental	GER	Tires
1990	Cofap Europa, Lda (7)	Cofap	BRA	Piston Segments

Note.

(1) Changed designation to Robert Bosch Travões, Lda

(2) Changed designation to Delphi-Interior & Lighting Systems

(3) Changed designation to Delphi Packard Portugal, após a fusão com a Reicab. Lda

(4) Changed designation to Visteon Portugal

(5) Changed designation to Delphi-Sistemas de Energia e Controlo de Motor, SA

(6) Acquired by Lear Corporation

(7) Changed designation to Mahle, after Confap being acquired by Magnetti Marelli

Source: Simões (2000)

The ten years between the Renault and AutoEuropa projects correspond to the development of new players in the Portuguese automotive industry: foreign component manufacturing companies, largely export oriented. This movement, together with the conversion of the CKD and SKD assembly lines, translated into the effective integration of Portugal in the European automotive industry network.

This period is characterized by Portugal's proclamation as an international location of automotive component manufacturing units, attracting a significant set of foreign investment projects, strongly geared towards exportation.

The Portuguese companies begun to export consistently to large automobile manufacturers, notably Renault and Opel, benefiting from the established relationships and learning experience gained from their assembly plants in Portugal. However, the export boost essentially involved the installation of foreign investors, attracted by the country's integration into the European Union, lower production costs (namely labour costs) and investment incentives. Component units established in Portugal were no longer driven predominantly by a concern for meeting local value-added requirements, but rather for export within European or Iberian supply chain networks. European integration made Portugal an attractive location for supplying the European market, as part of corporate integration actions, reconfiguring production, and supply strategies (Simões, 1992).

As an example (Table 7), the Ford Electronics and Delco Remi/GM projects were considered the beginning of the turning of Portugal's positioning as a location for the automotive industry, later consolidated with AutoEuropa (Simões, 2000). While benefiting from considerable incentives and employing mostly female staff, these two projects have placed higher qualification and training requirements, applied modern organizational principles, and deployed sophisticated technologies, thus leading to an upgrade in international investments in the automotive sector. The industrial base was gaining consistency over the final decision of the AutoEuropa project.

On the eve of the AutoEuropa project Portugal's integration into the European car industry was completed. All internal and foreign players in the sector recognized that it was no longer possible to support internal market-oriented strategies as the leading movement in the automotive industry pointed to a growing centralization of purchasing on a European scale.

4.5. The AutoEuropa Project

AutoEuropa was the largest foreign investment ever made in Portugal. According to the investment contract signed on 15 of July 1991 between the Portuguese Republic and the automobile manufacturers Ford and Volkswagen (VW), the total investment of the project was expected to be PTE 453 billion, corresponding to incentives granted of about 31% of the total amount investment. This investment is the peak of the foreign investment period in Portugal, allowing Mira Amaral, at the time Minister of Industry, to affirm that the foreign investments made in the industry constituted the construction of a “cluster” in Portugal (Amaral, 1990).

AutoEuropa was formally constituted as a joint venture between Ford and Volkswagen, with equally distributed capital among the partners, to manufacture a new multi-purpose vehicle (MPV) model, to be marketed separately under the names Galaxy (Ford), Sharan (VW) and Alhambra (SEAT).

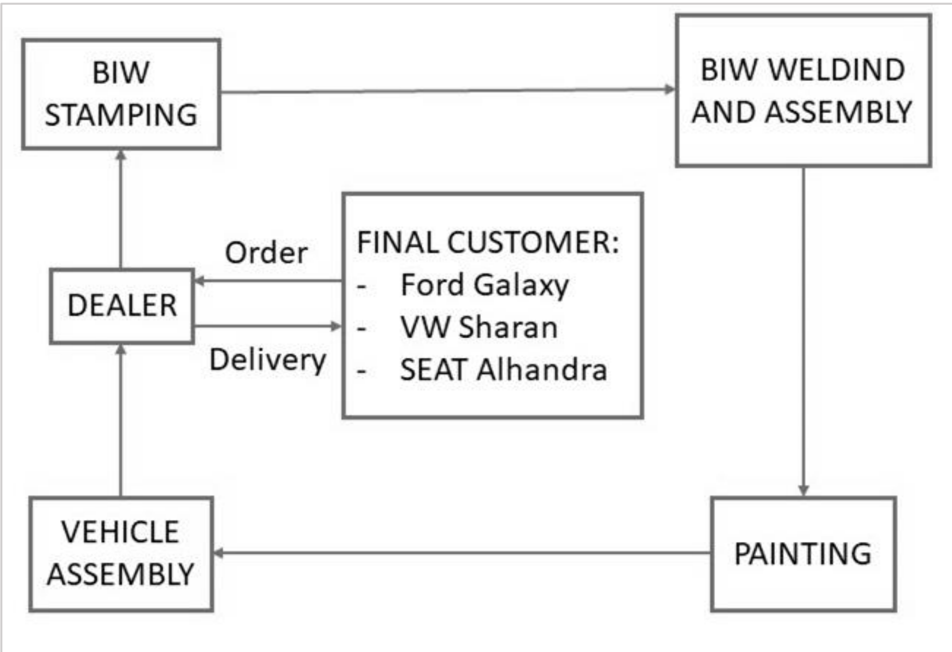
The split responsibility between Ford and VW led to the former having overall coordination of production, procurement and equipment procurement, selection of suppliers, recruitment and training of personnel, and supervision of plant construction. Consequently, VW was primarily responsible for the design and engineering of the new vehicle (Figure 34). This division of tasks was encouraging, allowing for greater involvement of Portuguese component manufacturers, mostly due to Ford's better knowledge of the internal industrial capabilities than VW because of its experience with Azambuja industrial unit and its Ford Electronics subsidiary in Palmela.

Designed from a greenfield, AutoEuropa already incorporated lessons from the Japanese production approach as well as supplier relations (just-in-time, closer cooperation), organization (workplace problem solving, continuous improvement process - Kaizen), human resource management (task rotation, engagement stimulus tools, working groups) and environmental consciousness. Since the beginning of the project there was a concern to create a company culture characterized by responsibility, commitment, and informal relations. A considerable part of the training, as with Ford Electronics, was focused precisely on the processes of socializing and sharing the company's culture.

A national incorporation level of 40% was desired with the specific goal of boosting the Portuguese component industry. Following Matra's complaint, the European Commission interceded, considering the clauses relating to national incorporation to be void because they infringed the European competition rules. As a result, the intentions of national incorporation, which were already difficult to achieve, were no longer legally binding but merely a goodwill.

Figure 34

Structure of AutoEuropa Production Process



Note. Source: adapted from Simões (2000)

4.5.1. The AutoEuropa project and the development of suppliers

The AutoEuropa project in Portugal gave a new impetus to the development of the component industry. (Amaral, 1995, p. 10) states that the AutoEuropa project approval is “a corollary of the joint effort of the administration and the industrial component sector”. Without a slight industrial base in the automotive components sector, the project would not have been possible to achieve. However, it created new possibilities for a qualitative and quantitative improvement of the components supplier industry, for both Portuguese and international companies. In addition to the potential expansion of the businesses of the already established companies, AutoEuropa also brought in new foreign investments, as it was expected to happen.

The initial intent was that the establishment of AutoEuropa would allow for the creation of a value chain that would not only attract the manufacturers loyal suppliers, but also include the qualification of potential national suppliers and the creation of alliances - under the joint ventures or other forms of shared governance - between the latter and foreign companies (Féria, 1995; Amara,l 1995). The idea was to promote an involvement that would stimulate the active involvement of the Portuguese component companies in the project and a movement of strategic alliances between them and the loyal suppliers of the manufacturers, in a logic of developing common advantages.

With a higher manufacturing capacity in relation to the existing vehicle assembly units in Portugal, AutoEuropa was the opportunity to simultaneously merge the existing component supplier network (specifically from Renault and the other assembly units. with a broader perspective of the national “value chain” as GM and Ford) opening new possibilities for expansion. The national incorporation, while being transformed into a gentlemen's agreement with a commitment to “best efforts”, was able to provide a framework for the merging of interests to support the participation of national companies as well as their empowerment.

The Portuguese component industries that expressed interest to be part of the AutoEuropa project were surveyed. Of the approximately 120 installed companies that expressed interest, a significant portion were excluded as they did not meet the minimum requirements to be considered as a potential supplier. The rest were classified into two groups: potential, but lacking substantial adjustments; and with potential, requiring only minor adjustments (Simões, 2000).

During the selection process, the first issues concerned the satisfaction of adequate levels of quality and technological development. Moreover, Ford's requirements were extremely strict, being for many companies a qualitative leap difficult to achieve, as it often translated into the need to rethink the entire organization to meet the desired quality requirements[6]. Another issue, was concerning the scale of the project, requiring significant investments in the expansion of production capacity, and generating situations of possible excessive dependence on a single customer.

It must be referenced that most of these companies were externally owned. In fact, despite all the efforts, the project requirements, a certain suspicion of the capabilities of Portuguese companies and the dimension, technological level and quality weaknesses of Portuguese suppliers led to a high participation in the project of local companies with external capital. Some were already installed in the country, such as Ford Electronics, Indelma or Yazaki Saltano. However, supplying the new unit required foreign investments in local suppliers.

[6] Based on ISO 9001. Currently IATF 16949.

Table 8

Main FDI for Component Suppliers, Autoeuropa Project Related.

YEAR	COMPANY	MAIN INVESTOR	ORIGIN	ACTIVITY
1991	HUF PORTUGUESA	Holsberk & Furst	GER	Locks and Handles
1991	JOHNSON CONTROLS-ASSENTOS	Johnson Controls	USA	Parts and Seat Covers
1992	DALPHI METAL	Dalphi	?	Steering Wheel
	KUPPER & SCHMIDT	Kupper	GER	Metal Parts
1993	SLEM	Barcelonesa de Metals+Solac	ESP+FRA	Metal Storage
	BUNDY, SA	Bundy/TI	?	Plastic Hoses
1994	KENDRION RSL PORTUGAL	Kendrion	?	Handles
1996	BOMORO	Robert Bosch	GER	Locks
	BENTELER		GER	Suspensions
	EDSCHA SCHARWACHTER PORT.	Edscha	GER	Pedal Boxes, HandBrakes and Hinges
	GILLET	H. Gillet	GER	Exhaust Systems
1994	DONNELY HOHE	Donnely+Hohe	USA+GER	Rearview Mirros
1994	CONTINENTAL LEMMERZ	Continental+Lemmerz	GER+GER	Wheels and Tires Assemblies
1994	KAUTEX TEXTRON PORTUGAL	Textron (Kautex) (1)	USA (GER)	Fuel Tank
	PPG BOLLIN & KEMPERr		UK+GER	Coatings
	ROCKWELL GOLDE	Rockwell (Golde) (2)	USA (GER)	Sunroofs
	SIMPKA PLAS		?	Plastic PArts
1993	VANPRO-ASSENTOS, LDA	Johnson Controls+ Bertrand Faure	USA+FRA	Seat Assemblies
1995	HAPPICH DE PORTUGAL	Happich GmbH	GER	Roof Racks

Note.

(1) Acquired by pela Textron in 1986

(2) Acquired by Rockwell Inc, in 1987

Source: adapted from Simões (2000)

The AutoEuropa project, in addition to the large amount of investment it required for the manufacturing unit, it also had a knock-on effect to build up a network of local suppliers (Table 8), leading to a movement of foreign investment in the component industry, especially by German companies. Most of these investments were start-up projects with 100% of foreign capital. However, there were also several cases of interaction between foreign investors and internal companies. AutoEuropa's impact was not only expressed as a way of boosting foreign investment into Portugal. The project also confronted national component companies with new challenges and opportunities, associated with the size of the project and its demands in terms of technology, logistics, organization, and quality.

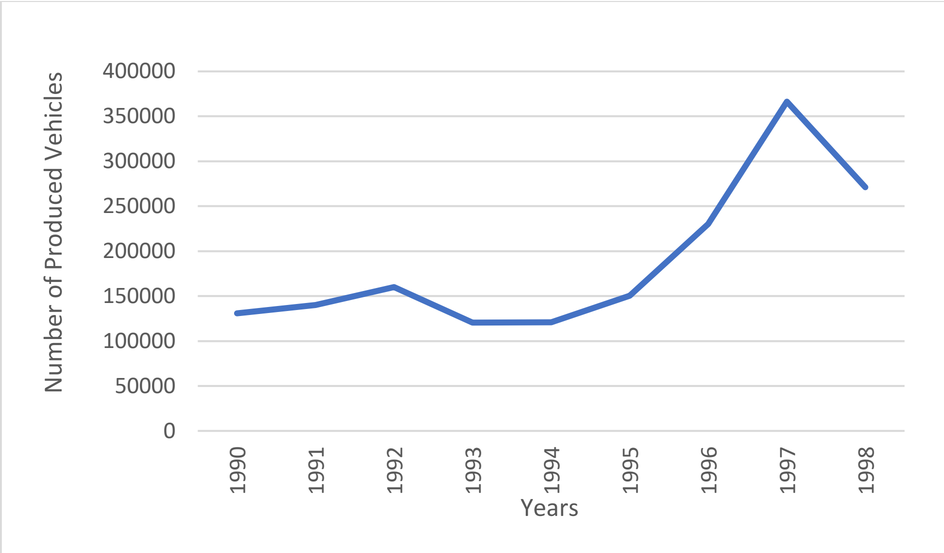
4.5.2. The Auto Europa effect

AutoEuropa gave a strong impetus to the automotive industry in Portugal. This industry, including component assembly and manufacturing, represented in 1997 almost 7% of the Portuguese gross domestic product (GDP) (Veloso et al., 2000). Its weight in exports is quite high, surpassing textiles and clothing as the leading traditional export sector, reflecting a significant change in Portugal international expertise, although this index is still below the organisation for economic co-operation and development (OCED) average. The automotive industry is no longer a self-centred, internal-market sector; on the opposite, it is strongly embedded in the European wide production network and has been, throughout the nineties, a driving force for exports.

In 1998 about 270,000 vehicles (Simões 2000) were assembled in Portugal, including passenger and commercial vehicles, which is almost double the figure registered in 1990, as shown in Figure 35. This increase is due almost exclusively to AutoEuropa, which assembled almost 139,000 vehicles in 1998. In fact, the evolution of the other assembly units was not positive during this period: Citröen (Mangualde) was reducing its production and Ford (Azambuja) was by the time in a standstill situation. Renault's former unit in Setubal eventually closed in 1998. For this reason, the number of passenger cars produced in Portugal declined that year, reversing the upward trend of previous years following the start of production of AutoEuropa.

Figure 35

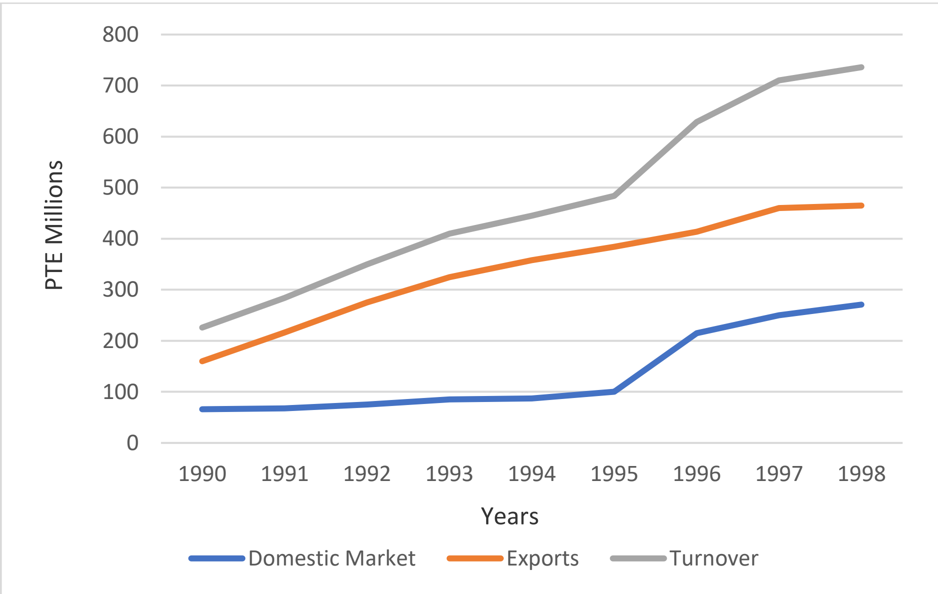
Total Vehicle Production in Portugal (1990 – 1998)



Note. Source: Adapted from Simões (2000)

Figure 36

Component Supplier Industry Evolution (1990 – 1998)

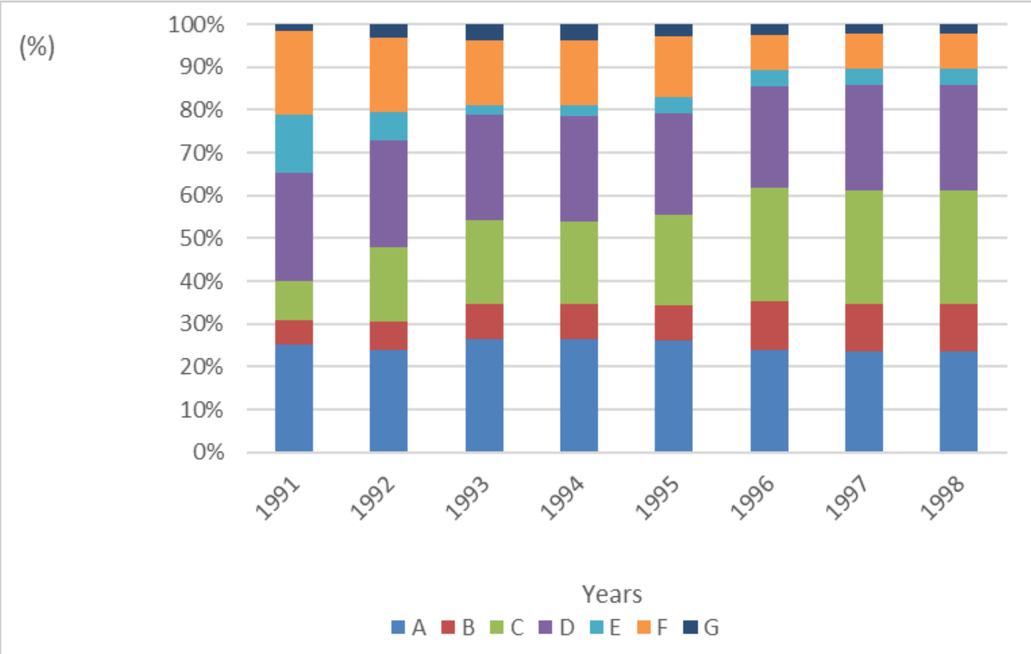


Note. Source: Adapted from Simões (2000)

The evolution of the component industry, shown in Figure 36 clearly shows that in 8 years, between 1990 and 1998, turnover[7] increased from PTE 226 to PTE 736 million, i.e., by a factor of over 3. Interestingly, the growth of the internal market was stronger than exports (310 against 190%), largely reflecting the effect of the AutoEuropa project.

Figure 37

Component Industry Structure Evolution (1991 – 1998)



Note.

(A) – Engine Components, Transmission and Brakes

(B) – Body Trim Components, Suspension and BIW

(C) – Interior Trim

(D) – Electric and Electronic Components

(E) – Tires

(F) – Buses, Trailers and Bodywork

(G) – Others (e.g., Tooling)

Source: Adapted from Simões (2000)

[7] The amount of money taken as sales transacted in a given period.

Although the exports and rents evolution were giving a positive signal and despite the already referred slowdown, the analysis of the rents by activity group, according to the type of parts produced, clearly shows the technological and competitive limitations of the component industry. Figure 37 allows two types of understanding: (i) general characterization of the structure by type of products and (ii) evolution of relative weight.

An overall analysis of the structure from 1998 shows that around three quarters of total turnover is concentrated in three product types: interior (27%), electrical and electronic components (25%) and engine, transmission, and brakes (24%). This structure seems quite unbalanced, with a very heavy weight of often intensive work-intensive activities, as is the case with most electrical components (where wiring harnesses, the most labour-intensive element in the automotive industry, and car radios) and part of the interior components, linked to the textile tradition (Simões, 2000).

Firstly, the extraordinarily strong growth of the interior trim components suppliers stands out, from around 10% in 1991 to 27% in 1998. This behaviour seems to be due to two factors: the commitment of several companies, both (Bertrand and Faurecia) as well as national (TMG, for example) in this sector, taking advantage of links to the textile industry; and the installation of new foreign investments (Vanpro, Johnson Controls, Sommer Allibert), as well as the conversion of some national companies, in the context of the AutoEuropa project. The second standpoint is the increased significance of body and chassis components, which was also largely due to the AutoEuropa effect as it provided new opportunities for metal component suppliers, mostly Portuguese companies. By contrast - groups F (buses, trailers, and bodywork) and E (tires) have lost relative weight, which is due to the difficulties created by old assembly lines and in the case of tires, the closure of a large unit (Firestone). Finally, there is a significant stability in the manufacture of engine, transmission, and brake components (group A) and electrical components (group D). In the first group, the production of engines and gearboxes at CACIA (created, as already referred, in the context of the Renault project) represents about one third of exports.

The given results raise contradictory viewpoints. On one hand, the component industry still heavily marked by labour intensive activities and controlled by foreign capital companies (such as wiring harnesses). In addition, the most technologically demanding product types have not expanded, losing their position as demonstrated by the downgrading of CACIA. plant on the other hand, several Portuguese companies, specifically in metalworking and interior trim, have been showing themselves in the international competitive arena.

The focus on interior trim is a logical decision, in a sense of increasing supply integration (from simple component manufacturers to modular system manufacturers and, at the limit, to modular system integrators), as is the most open area and where stronger synergies could be established at a national level.

4.6. After the AutoEuropa project – into the new millennium

As far as component suppliers are concerned, the main investments made during the nineties were related to AutoEuropa, as already mentioned. The largest investments outside the AutoEuropa network were Lear's acquisition of the former United Technologies Automotive (wiring harness) and the installation of Halla Climate's compressor plant next to Ford Electronics plant in Palmela. Portugal's allure for international component manufacturing groups was reduced, corresponding to a declining phase of Portugal's competitiveness as an international investment location.

For the Portuguese component suppliers the nineties can broadly be broken down into two phases: the first, which ran from 1991 to 1996, was driven by the start of the AutoEuropa project; the second, which began in 1997, was dominated by the internationalization, especially to South America and Europe. In fact, the setting up of AutoEuropa brought, as already mentioned, new opportunities for Portuguese component manufacturers, but it also required an effort to qualification to meet quality, cost, and logistics requirements to win direct or indirect supply contracts for the new unit. The internationalization of companies is linked to their relationships with large clients, manufacturers, or system suppliers, and/or the need to gain dimension. In fact, "the internally established relations created a climate of trust and mutual collaboration that has successively led to the certification as suppliers of multinational groups and in addition their own internationalization movements" (Simões, 1997, p. 57).

On the beginning of the new millennium, the rearrangement of the international automotive industry structure turned to define a context in which most of the Portuguese suppliers became trapped in what can be known as a lock-in position (Camacho, 2001).

From the mismatch between market dynamics (intrinsic to the reconfiguration of the industry) and companies' evolution, a systematic failure could be noticed. The characteristics observed on the Portuguese automotive suppliers on the early 2000's that determined such failure could be listed as follows (Camacho, 2001), the small scale of the companies, lack of product development and product engineering activities and of the necessary organizational environment for the expansion of the innovation processes, weak research and development activities (as well as an inexistent connection to technological infrastructures and universities), internationalization and investment actions non complemented by evolution of key areas of the value chain, weak corporate networking effect, insufficient human resources with suitable qualifications, a demand that (based on the current local market) proves inadequate to the required industry status of the new millennium.

These systemic failure symptoms could produce a lock-in effect, as for the Portuguese automotive supplier's progress would be necessary to act in the upstream areas of the value chain (product development, product engineering and R&D). However, these activities are only possible under a set of circumstances determined by size and clustering. Since the lack of key resources creates negative effects on the upstream and downstream connections of the interdependent system of companies, it became clear the need for a corrective intervention in order to reduce this market bottleneck (Camacho, 2001).

The first decade of the new century was impacted by the development of strategies that strived for an internationalization process of the Portuguese automotive industry suppliers. The P3 Project, the Centro para Excelência e Inovação para a Indústria Automóvel (CEIIA), the Centro de Engenharia e Desenvolvimento de Produto (CEDP), and the Inteligência e Inovação Para o Desenvolvimento da Indústria Automóvel (INAUTO) project were some of the endeavors to develop capabilities on product design, product engineering and R&D.

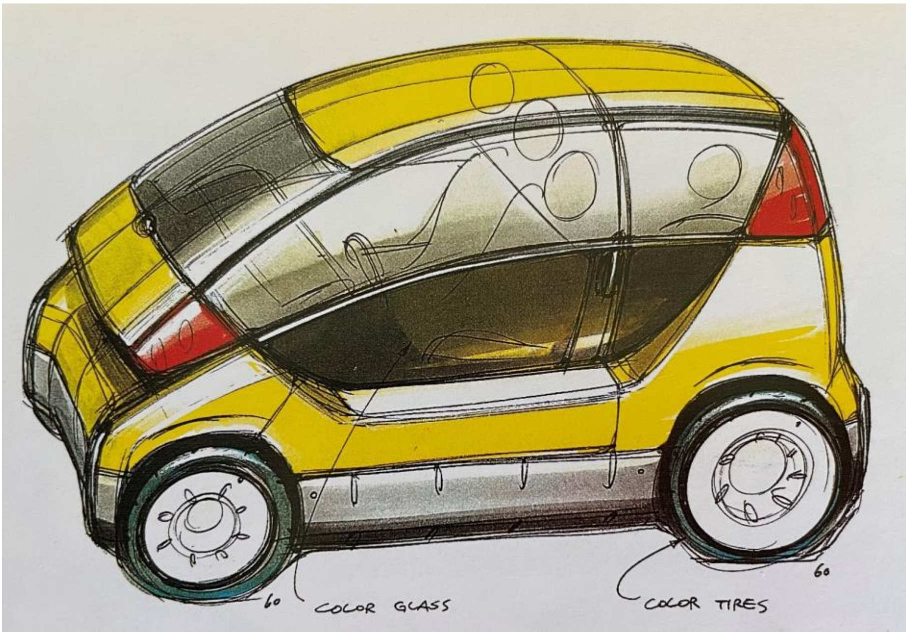
4.6.1. The P3 Project

As already referred, the P3 project was part of an integrated strategy that endeavoured the development of capabilities on product design, product engineering and R&D activities for the national suppliers of the automotive industry.

The P3 Project was Pininfarina's Metrocubo concept car. A small city car that made its debut, as concept car, in September 1999 at Frankfurt Show. Quoting Lorenzo Ramaciotti, general manager of Pininfarina's R&D activities, "The dream of fitting a lot of people into a small space has been pursued since the "prehistory" of automotive design. Think of Dante Giacosa's Fiat 500 or Alec Issigoni's Mini" (Barufaldi, 1999, p16). In fact, the basis for the development of this concept was the creation by Michelin of its run-flat system (RFS) – the PAX System tyres which meant that there was no need to find room for a spare wheel, meaning the entire floorplan area was left free for other purposes.

Figure 38

P3: Early Sketch

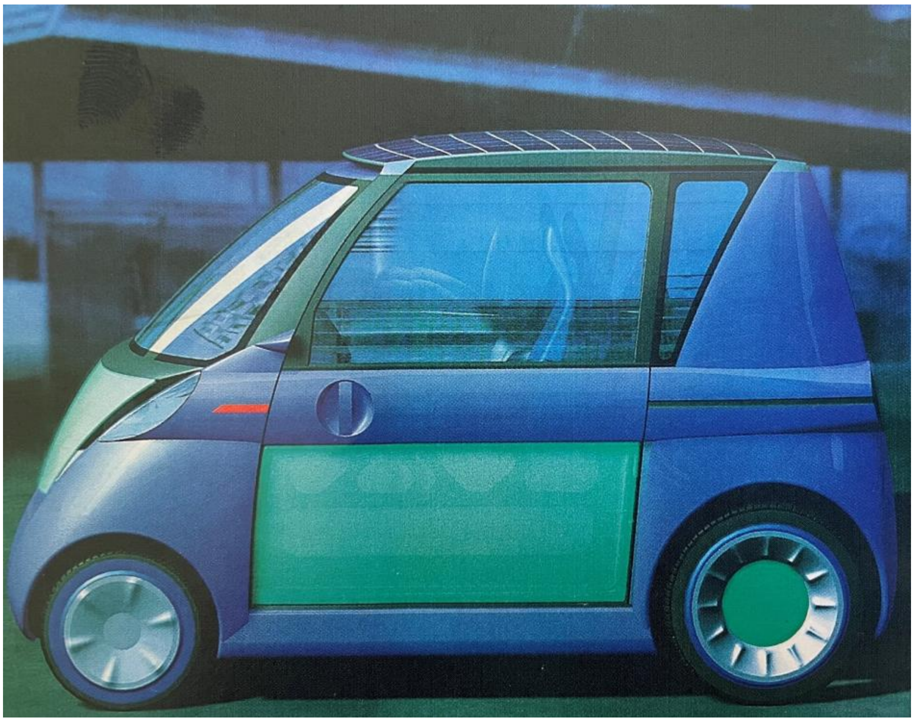


Note. Source: Adapted from (Barufaldi, 1999, p17)

As the PAX System tyres from Michelin were smaller than the traditional type, allowing the designers to adopt a smaller wheel arch which in turn makes it easier to get in and out of the car. Therefore, passengers would get an extra 22% in leg room. This design feature would enable the fit of three front seats. At the rear, and still using the possibilities offered by Michelin's Pax System tyres, the P3 used the extra space inside the wheel to hold the suspension anchorage points, reducing the transversal size of the rear suspension system. Moreover, this solution also meant the possibility to have a lower floor pan on the back, hence the design of a third rear passenger door.

Figure 39

P3: CAS Render



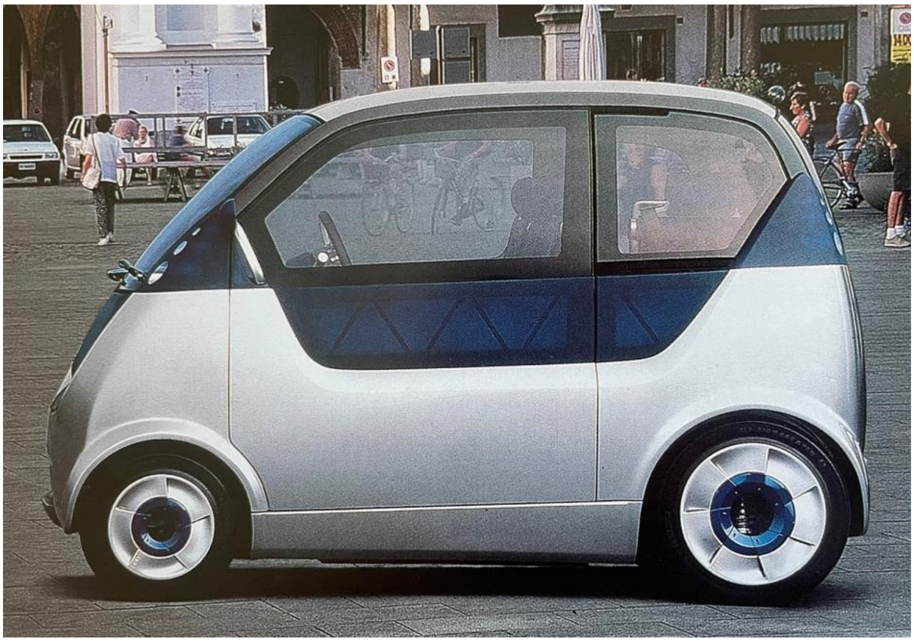
Note. Source: Adapted from (Barufaldi, 1999, p18)

As Pininfarina's Metrocubo concept car an all-electric model, the floor plan structure was designed using extruded aluminium in order to accommodate the batteries. Quoting Lorenzo Ramaciotti, "The floor plan is about 20 cm deep and made of extra-thick extruded sections, so that the side members become bearing structures rounded off by the upper part of the body frame which supports the body-work panels and makes its own, albeit minor contribution to the rigidity of the floorpan" (Barufaldi, 1999, p17).

All this mechanical Design features combined with the modularity of the inside. In addition to the three front seats, two more can be set against the side walls facing inwards. Otherwise, this space could be used in all sorts of different ways. As Lorenzo Ramaciotti explains (Barufaldi, 1999, p18), "We designed the interior as an empty cube, in order to emphasize the spacious, modular character of the cabin (…) you can move all the seats so that nothing remains except the seat slides on the flat floor and a facia that we have made as simple as possible because we didn't want to use complicated shapes interfering with the possible uses of the interior".

Figure 40

P3: Fully Functional Prototype



Note. Source: Adapted from (Barufaldi, 1999, p22)

The modularity presented on the Metrocubo was possible due to the innovative seats. The fully foldable and sliding seats, feature a simple deckchair type aluminium frame which is covered by a special plastic fibre with a soft touch underneath featuring supportive cushions filled with a special gel fitted on the lower-back level of the seat. Moreover, this padding absorbs and distributes stresses ensuring a correct posture for the passengers enhancing its comfort (Barufaldi, 1999).

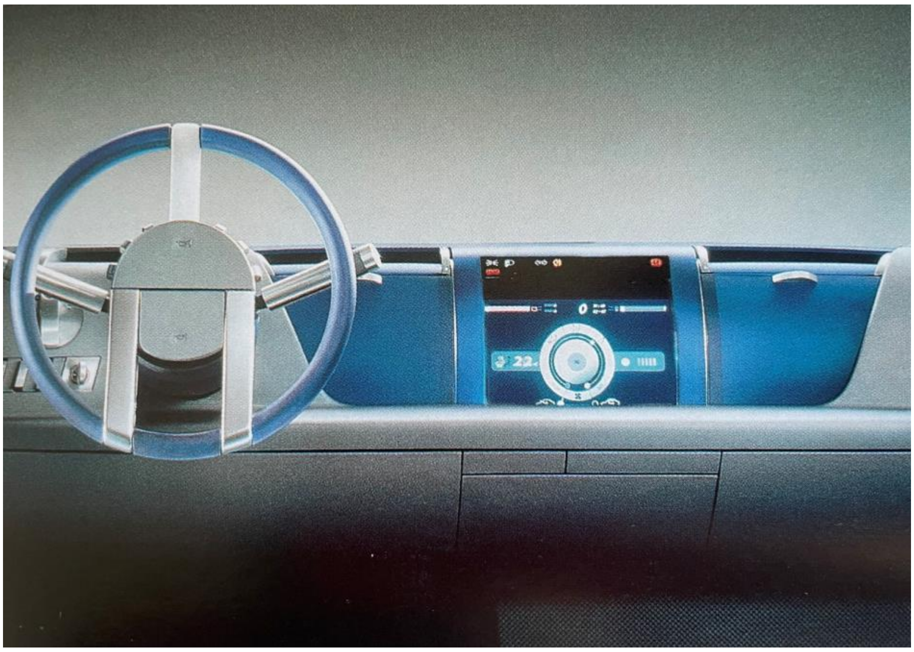
In May 2001 a contract between the Portuguese authorities and the Pininfarina group was celebrated for the development of a new vehicle concept, and eventually to an approach involving an innovative, flexible, modular hybrid powertrain and platform, designed to target different market niches (Camacho, 2001). The P3 project was split in three different stages. Stage one: study and planning; Stage two: Engineering and development; Stage three: industrialization (Selada, 2002).

The multi-disciplinary project team, co-ordinated by Pininfarina Studi e Ricerche S.p.a, involved, on a preliminary stage, the collaboration of universities as the Massachusetts Institute of Technology (MIT, USA), Pennsylvania State University (PSU, USA), Instituto Superior Técnico (IST, Portugal) and, INTELI – Intelligence in Innovation (Portugal). This team had the main goal of developing an integrated knowledge base in areas such as spaceframes and flexible platform design, approaches to systemic urban problems and new vehicle designs, and environmental performance and regulation concerns (Camacho, 2001).

In an innovative approach, the association of engineering firms and national suppliers under the support and encouragement of the Portuguese government, was taking place in order to foster a new cycle in the Portuguese automotive industry, specifically through an increased involvement on the design, development and engineering of automotive products (Camacho, 2001).

Figure 41

P3: Interior Trim Dashboard detail



Note. Source: Adapted from (Barufaldi, 1999, p23)

Moreover, in a reconfiguration phase and compared with other important automotive supplier companies in Europe, Portuguese suppliers did not have enough dimension, technological strength, or local networking supportive environment to compete in a long-standing position. However, with the AutoEuropa project, they have become strong enough to compete and to achieve different costumers, on domestic and international markets. The integration of Portuguese companies in the international supplying networks is effective but their position is “in between”. In this sense, the P3 Project was part of a broadest and coordinated set of actions that includes the launching of institutional platforms to host commercial and R&D projects involving Portuguese and multinational companies (Camacho, 2001).

Figure 42

P3: Modular Seat Concept

Note. Source: Adapted from (Barufaldi, 1999, p23)

The P3 project had the main goal of positioning Portugal as a preferred location for the development of complete automotive programs (design and production) for niche vehicles and small series, creating a necessary work frame for the direct integration of national companies along the entire value chain, thus promoting a new stage of development for the Portuguese suppliers, strongly empowered by the engineering, product development and R&D capabilities as well as increase in the size of these companies (Selada, 2002)

Unfortunately, due to lack of national institutional support, the P3 project was extinguished. However, it left the basis for the current work of CEIIA and CEDP centres.

4.6.2. The CEIIA and CEDP Projects

The CEIIA was created in December 1999 with the goal of enhancing the competitiveness of the Portuguese automotive industry, through supporting the development of technical skills and strategic capabilities of companies, establishing organizational, technological, and economic-financial synergies allowing them to obtain and sustain competitive advantages, as a way of guaranteeing a better positioning in international markets. At the origin of CEIIA, there was a partnership with Pininfarina, for the development of the P3 project (CEDP, 2004).

On December 2002, the CEDP was created with the goal of providing the automotive and aeronautical Portuguese clusters of high-tech content capabilities in terms of product development and innovation of products, according to the global market trend, in articulation with a network of technological consortia, using collaborative work methodologies leading to the promotion of new skills in areas of product engineering and design in companies (CEDP, 2004).

The creation of CEIIA and CEDP were part of a wider strategy that fostered the strengthening of the attractiveness conditions for foreign direct investment, through the improvement of the technological standards in Portugal. The beginning of the activities of these two centres happened before the launch of the P3 project, however, the major goal was to fully support P3’s stage two: development and engineering.

With the sudden end of the P3 project, CEIIA and CEDP centres merged and focused on the support to product development, from concept and design to pre-series. Their portfolio of projects includes partnerships not only with some OEMs and Tier 1 companies but also with Portuguese automotive suppliers and multiple Aeronautical customers.

4.6.3. The INAUTO Project

By the year 2000, CEIIA and the Portuguese authorities, through the Inteligência em Inovação - Centro de Inovação (INTELI), promoted a new project – the INAUTO project. This project aimed to enhance the competitiveness of the Portuguese automotive industry, supporting the development of technical skills and strategic capabilities of companies, establishing organizational, technological, and economic-financial synergies allowing them to obtain and sustain competitive advantages as a way to guarantee a better position in the international markets.

The INAUTO. project was structured in four areas:

- Technological development and optimization of management practices.
- Development of human resources.
- Technology and innovation management.
- Promotion of national industry.

Among the activities of the INAUTO project, there was the “Systemic Characterization of Product Development Processes in the Automotive Industry”, this activity (included in the third specific intervention axis of the project), whose objective was the elaboration of a work frame for the design of strategies, with quality information and prospective analysis, which can be used by any company, or group of companies, to help define their particular strategies, specifically in terms of product development.

The INAUTO project strived to establish a true automotive industry cluster in Portugal, fostering an increase on the technological sector's skills and capabilities. Unfortunately, due to lack of national institutional support, the INAUTO project was abandoned in 2003.

4.6.4. The internationalization of the Portuguese automotive suppliers

As already referred, automotive manufacturers have been progressively outsourcing value chain activities for suppliers, especially for their direct suppliers. The role of these suppliers on the design and engineering of the project requires that the location of at least part of the design activities is in the geographical proximity of customers. In addition, the adjustment of consumer requirements and tastes, the standardization of automobile models, the increasing modularization of components and the consequent reduction of vehicle development times helps explaining the development of the internationalization process of car manufacturers, shown both in the volume and geographical dispersion of the respective direct investments abroad and on the high number of international strategic alliances between manufacturers. The just-in-time supply system, standard in the automotive industry, has required several component suppliers to follow the internationalization process of its customers, especially in the case of components and/or markets whose characteristics do not favour export supply.

The following chapter briefly describes two cases of the internationalization process of two top tier Portuguese supplier companies, the Simoldes Group and the Iberomoldes Group.

4.6.4.1. The Simoldes Group

Taking the case of the Portuguese supplier, Grupo Simoldes, for example. Since its constitution, in 1959, and until the early 1980s, the Group was dedicated to the manufacture of plastic injection tooling, supplying companies of a wide range of industrial sectors. In 1981 Simoldes stepped into the production of plastic injection parts supplying industries whose products incorporated injected plastic components, focusing on one of the most demanding customers - the automotive industry. From the early 1990s, the growing pace of the Simoldes Group accelerated. Thus, the capital investments enhancing production capacity, tool manufacturing and plastic injection technology, both in Portugal and external markets (Lourenço & Sopas, 2003).

Simoldes evolution has been influenced by the external demands of its customers, mainly, the automotive industry, and for the main goal of strengthening customer relations in this industry. The need to follow the automotive manufacturers trends for the vertical disintegration and the outsourcing of activities to specialized suppliers and cross related, largely dictated not only the internal but also the international growth of Simoldes. However, Simoldes' internationalization strategy took an approach to the automotive customers in the two different areas: on one hand, there were capital investments that brought the company's design and product development activities closer to customers; on the other hand, the Group invested on creating production capacity also geographically closer to customers' assembly units (Lourenço & Sopas, 2003).

Moreover, the Simoldes Group greatly benefits from the past learning that has been developed since the early 1980s from a privileged relationship with the Renault group. This manufacturer includes the Simoldes Group in the top ten ranking of best worldwide suppliers, relying on Simoldes know-how for product design, product development and manufacturing processes for the development of its car models in different parts of the world (Lourenço & Sopas, 2003).

During the 1990's Simoldes opened two new units, either in tool making or in injection, hence the MDA unit opened in 1991 and in 1993 Inoplas and IMA units opened. Two years after, Simoldes group opened the injection unit, Plastaze. The opening of these units was particularly important for the next growing step of Simoldes: internationalization (Silva, 2020).

In France, Simoldes opened Simoldes Plasticos and in Brazil, two brand new injection units in Caçapava and Curitiba cities. On the latter, Simoldes opened a new tool making unit - Simoldes Aços Brazil. During the beginning of the millennium Simoldes acquired the toolmakers Mecamolde and Ulmolde (Silva, 2020).

The internationalization did not only happen in the production of moulds and plastic parts, but the expansion of the group also saw the opening of engineering centres in Germany, France, and Spain while in 2003, it opened a new unit in Poland. In 2008, the Simoldes group acquired Pentap and Unipress in Argentina. The Czech Republic saw, in 2015, a new Simoldes plastic injection unit and in 2019 the Kingdom of Morocco was the last one. In 2020 Simoldes Group is scheduled to open a new testing centre. (Silva, 2020)

One of the key factors for the success of the Simoldes Group lies in the blend of tooling construction and plastic injection production. The advantages of this integration outweigh the savings on transaction and range costs. Using their own made tooling to inject plastic parts, made Simoldes took a learning path allowing the company to develop innovative solutions to integrate the design of its tooling and taking part on the design of the parts. Therefore, improving its position on the supplier’s network of the automotive components industry. The design and development cabilities have assured a gradually more active role in the product development process in a close collaboration with its customers.

4.6.4.2. The Iberomoldes Group

Another Portuguese successful case is Grupo Iberomoldes. Founded in 1975, in Marinha Grande, Grupo Iberomoldes currently operates as a holding company for a wide range of companies (16 in total) dedicated to the design and production of precision molds for the plastic industry and die-casting of light metal alloys. Currently the company supplies tooling and plastic parts for the automotive, household appliances, toys, electronics, and packaging industrial sectors (Morais, 2004).

The group has a centre for professional training and technological research - the Instituto de Tecnologia de Moldes - which was formally created in 1986 and has enabled the training of specialized staff in the tooling design and construction. Technological innovation is the driving force of Iberomoldes, as the group was the first European company to apply CAD/CAM technology, as early as 1983, allowing the design and manufacture of parts to be fully integrated through a computer-assisted system. This strategy of progressive innovation is largely responsible for the company's international projection (Morais, 2004).

The Iberomoldes Group has been positioning its activity towards the external market since the early 1980’s as the group implemented a strategy of relocation of its production in two steps.

Firstly, the establishment of technical offices (small companies) abroad that would allow the association with other external companies (Sweden, United Kingdom and Germany). In this case, the main goal of the group is not exactly the development of production units, but rather the implementation of structures able to provide technical assistance to customers on tooling and allowing the implementation of marketing and sales strategies in those geographical areas (Morais, 2004).

Secondly, the Iberomoldes Group has expanded its production abroad, creating autonomous units in Tunisia, Mexico, and Brazil. The Mexico plant as an example, it opened in 1997 with 11 employees. The plant is in a region bordering the United States (Chihuahua), having been a strategic option due to its geographical situation (close to the customer) and by the advantages of low industrialization costs (Morais, 2004).

4.7. The new millennium – The present and future

4.7.1. The Portuguese Automotive Cluster

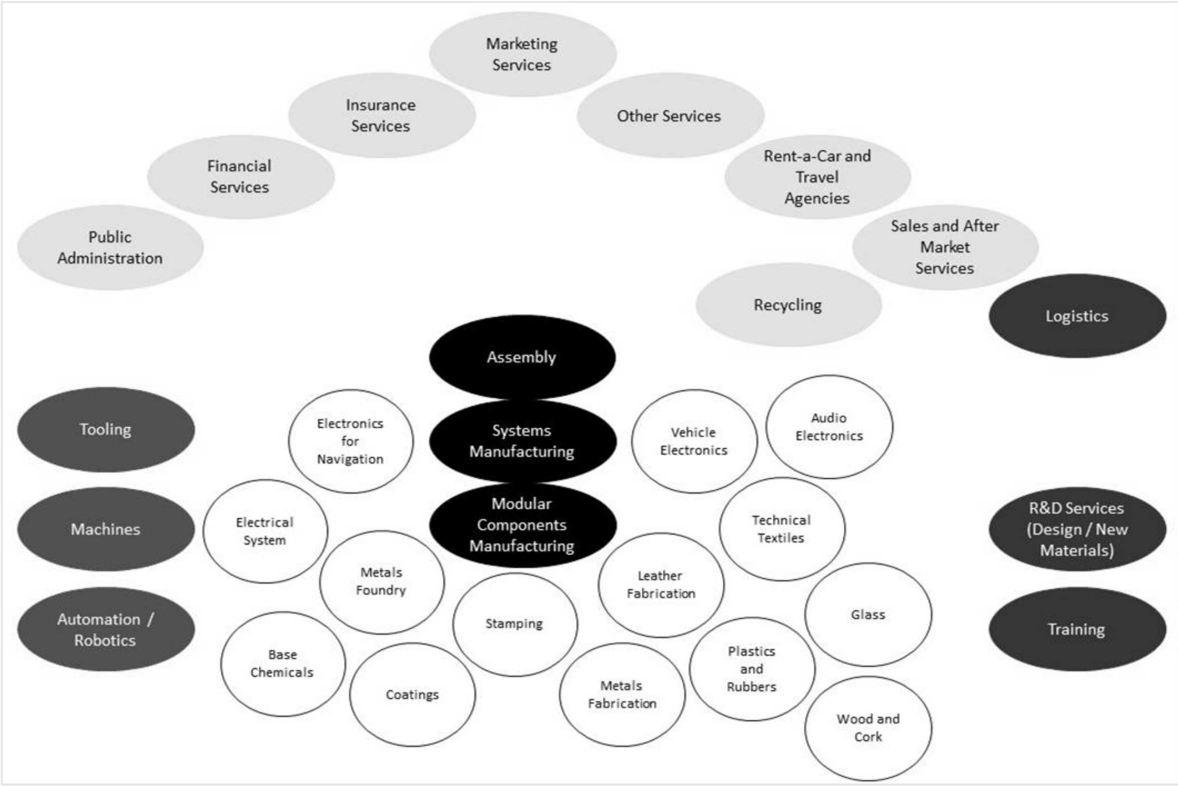
The activities related with the assembly and construction of automobiles and production of components have a strong relationship with a great diversity of activities, upstream and downstream, described not only through a classical logic of production, but also by the growing needs for innovation, as already mentioned, an important element of differentiation in such a competitive market (Lobo & Melo, 2002).

The cluster encompasses the following types of activities (Figure 43):

- Focus (in black) - Set of activities that originates the automobile product or components causally related to its manufacture (essentially, car integration and assembly).
- Input (in white) – Set of activities related to the necessary products to produce the car (products incorporated in the car itself).
- Support (in blue) – Set of activities whose products / services are necessary for the transformation process, whether they are physically incorporated in the final product (specifically, basic equipment used in production, in light blue).
- Complementary (very light blue) – Set of activities related to the final product (focus) or business operation. They are not crucial for the productive process, but they do allow a greater mastery of the chain, especially downstream from the focus (aiming, among other aspects, to provide better individual mobility), although they are also reflected upstream (example of recycling).

Figure 43

The Portuguese Automotive Cluster



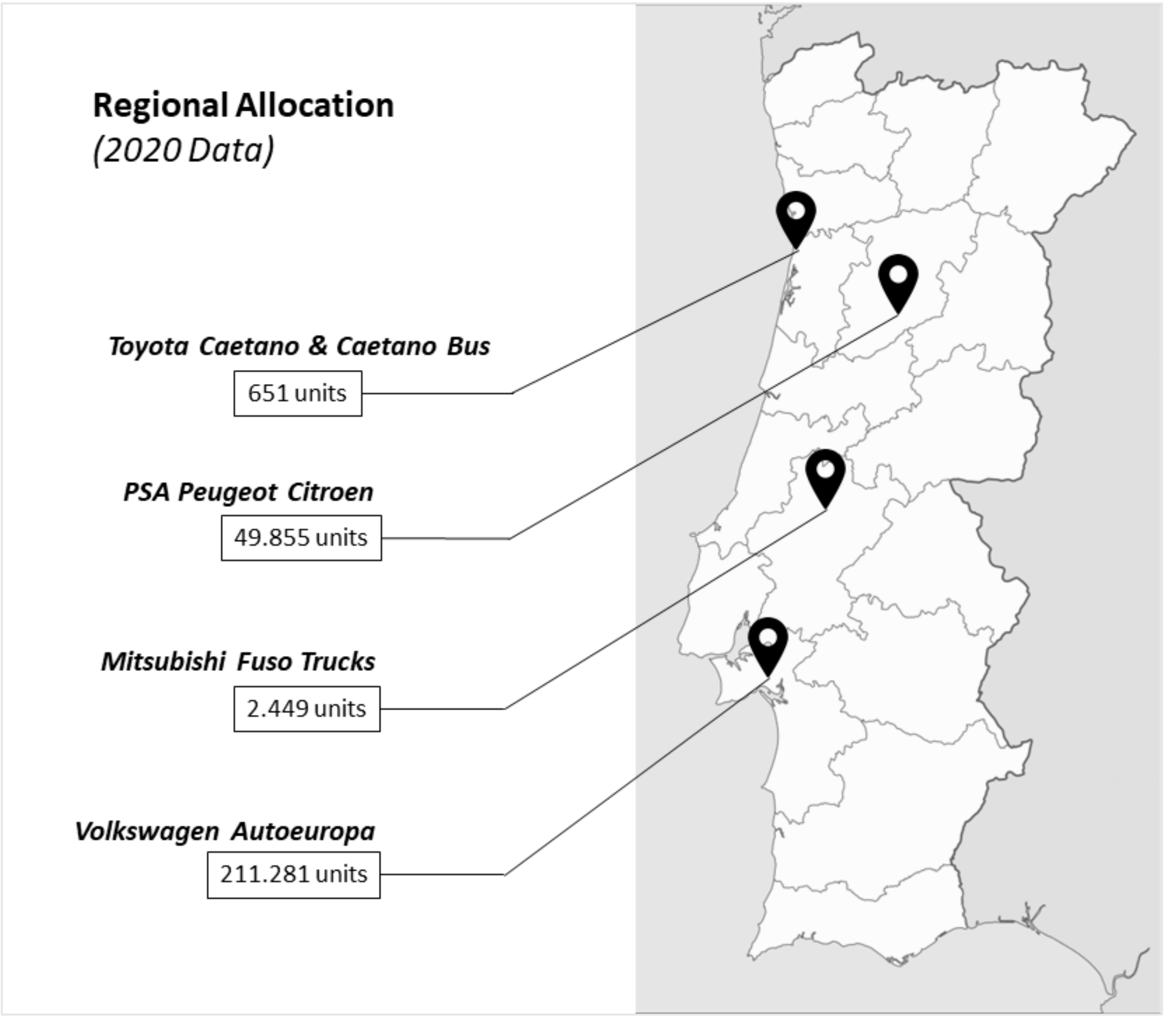
Note. Source: adapted from Lobo & Melo (2002)

These activities are listed on *Classificação Portuguesa das Actividades Económicas, Revisão 3* - 2007, prepared by the National Institute of Statistics (INE) with the collaboration of around two hundred entities, involving the Public Administration, the Social Partners and, occasionally, companies.

Currently, Portugal has five active assembly factories with a workforce of more than five thousand direct and indirect workers (Deloitte, 2018). According to the Organisation Internationale des Constructeurs d'Automobiles (OICA), the total production in 2020 was 264.236 vehicles (Figure 45) through passenger cars, trucks, and buses (allocated by the already referred five active factories from five different manufacturers: PSA, Mitsubishi, Caetano Bus, Toyota, and Volkswagen (Figure 44).

Figure 44

Regional allocation of Portuguese Automobile Production (2020)



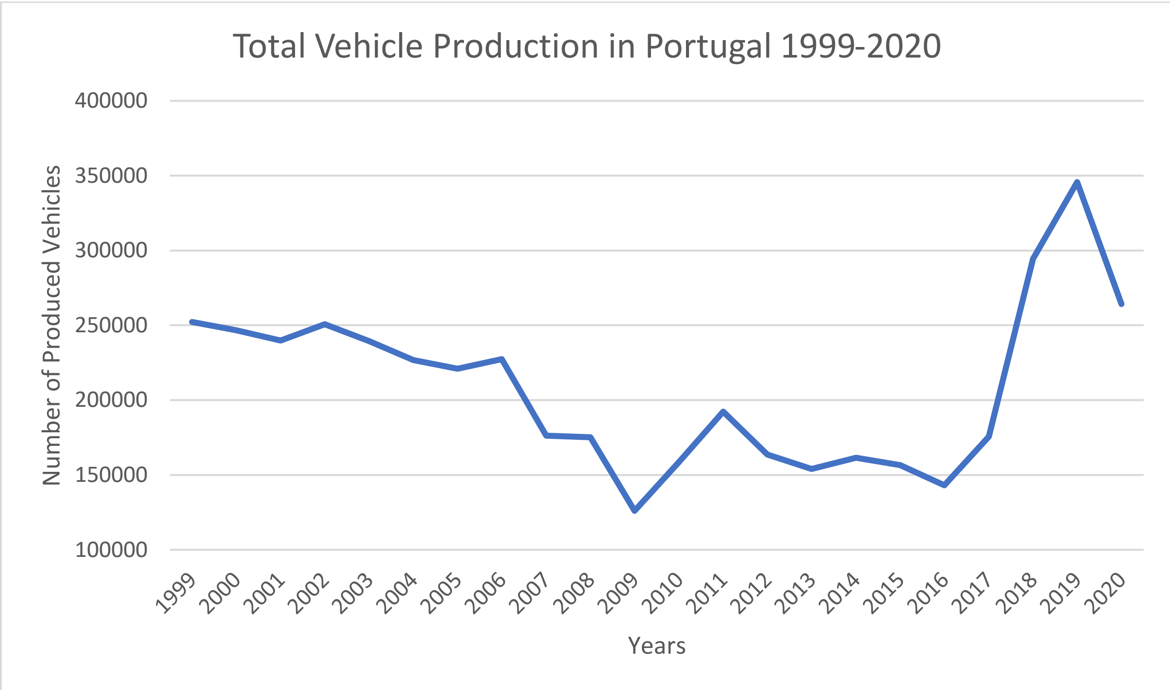
Note. Data accessed from ACAP (https://www.acap.pt/site/uploads/paginas/documentos/81FDCB76-F96A0_1.pdf)

According to the Instituto Nacional de Estatística (INE) there were in 2020, in Portugal, 360 active input suppliers (Figure 40) for the automotive industry, with a business volume of 6,4 billion of Euros (corresponding to 8,6% of the Portuguese GDP). From this number, 98% (6,3 billion of Euros) are export (corresponding to 10,5% of the total Portuguese exportable goods - 2019) (Figure 42).

According to the Associação de Fabricantes para a Indústria Automóvel (AFIA), from the 360 active suppliers in 2018, 32% of the total business volume were from metallic components, 31% were from electronic components and 18% plastics to refer the top three (Figure 46 and 47).

Figure 45

Total Vehicle Production in Portugal (1999 – 2020)

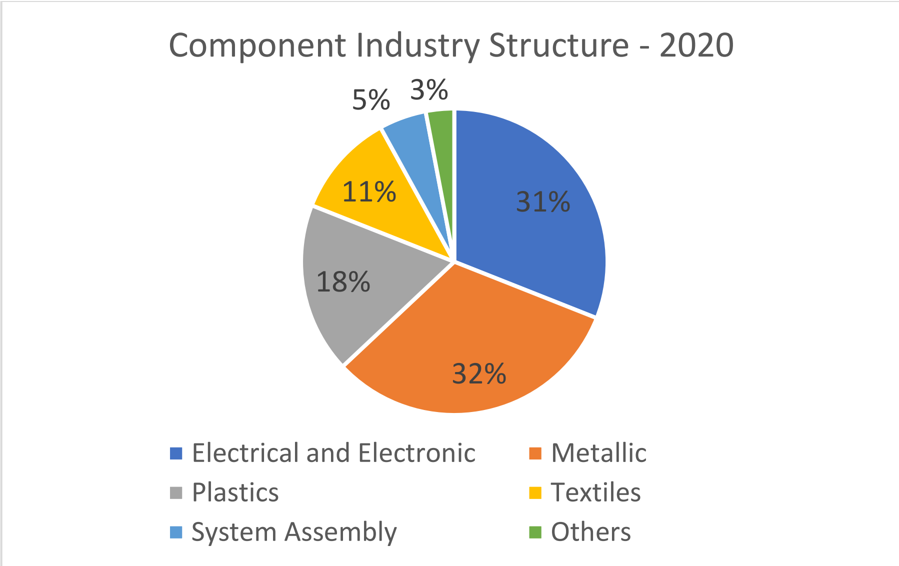


Note. Data accessed from OICA (https://www.oica.net/category/production-statistics/2020-statistics/)

According to INE, the Portuguese automotive cluster has been economically strategic for the country. From 2010 to 2018 (Figure 48) the total exports business volume has had a 58,4% growth.

Figure 46

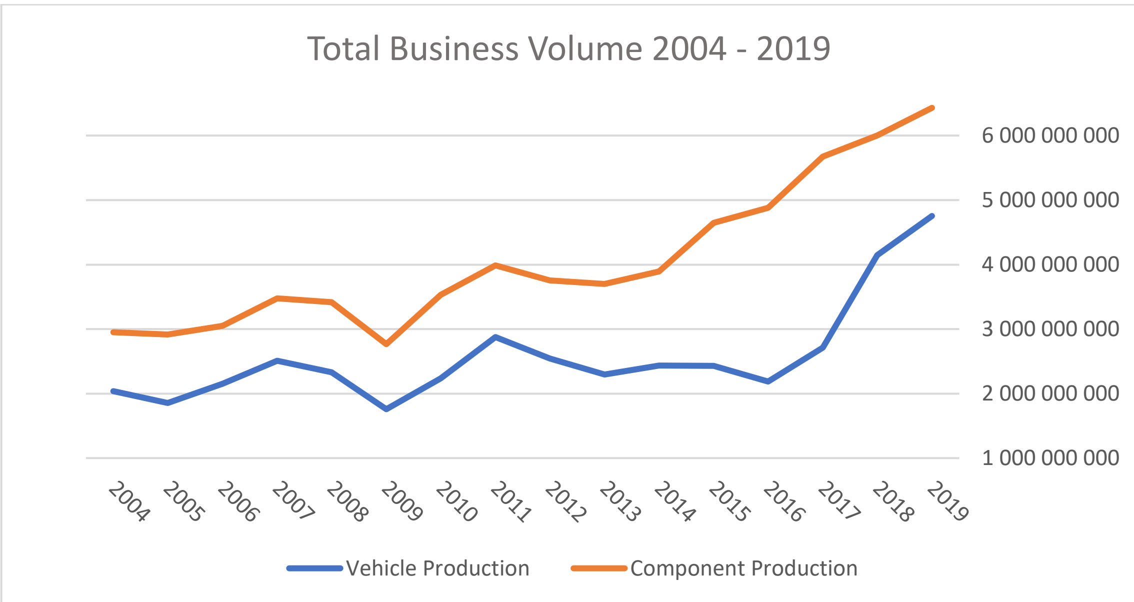
Component Industry Structure (% companies) (2020)



Note. Data accessed from AFIA (https://afia.pt/wp-content/uploads/2020/03/AFIA_AutoComponentsIndustry.pdf)

Figure 47

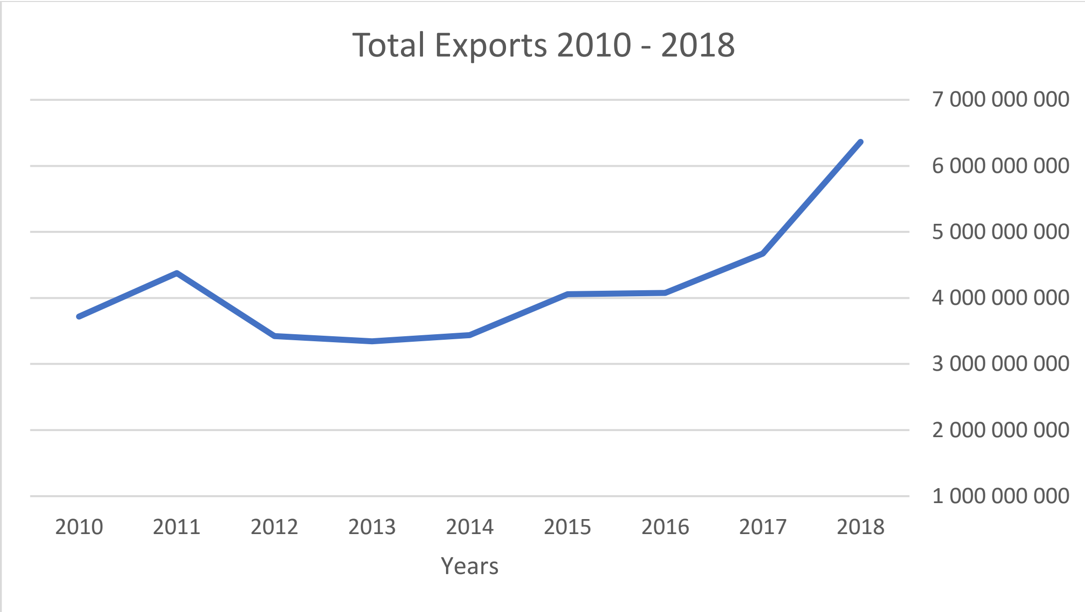
Total Business Volume (EUR) (2004 – 2019)



Note. Data accessed from INE (https://www.ine.pt/)

Figure 48

Exports for Assembly Vehicles and Components (2010 -2018)



Note. Data accessed from INE (https://www.ine.pt/)

Concluding, from what concerns the workforce and job creation point of view the automotive cluster, between 2012 and 2016 has seen a growth of 27%, as well as regarding training which had (in the same period) a growth of 64%. The professional qualification has also seen a 21% growth between 2012 and 2016 as well as wages, that saw a 30% average growth (in the same period), (Deloitte, 2018).

4.7.2. The Future of the Portuguese Automotive Cluster

The future of the Portuguese automotive cluster, specifically suppliers is, as already referred, is interconnected with the upstream and downstream of the value chain, as they are integrated as tier 1, 2, or even 3.

The drivers of change for the industry are common and may affect the industry as a cluster, meaning the full network of value chain. There are three main vectors for driving the change of the industry: market dynamics, Industry 4.0 and new mobility concept trends.

Market dynamics (consumers and OEMs) can directly affect the Portuguese automotive cluster in what concerns its suppliers, through the raise of Spanish automobile production as well Morocco. Moreover, the raise of the Asia-Pacific as consumer has already had a direct effect on the raise of exports for Portuguese suppliers as well as the continuous settlement of Asian OEMs in Europe. Concluding, it can also be referred as a thread, the “Trump” effect for the protectionism of the US industry automotive network.

Suppliers following industry 4.0 will have the advantage of access the potential of new technologies. Adopting a new process technology will have a disruptive effect on the already installed processes and businesses as well as the need for new competencies. This vector fosters the entrance of new suppliers.

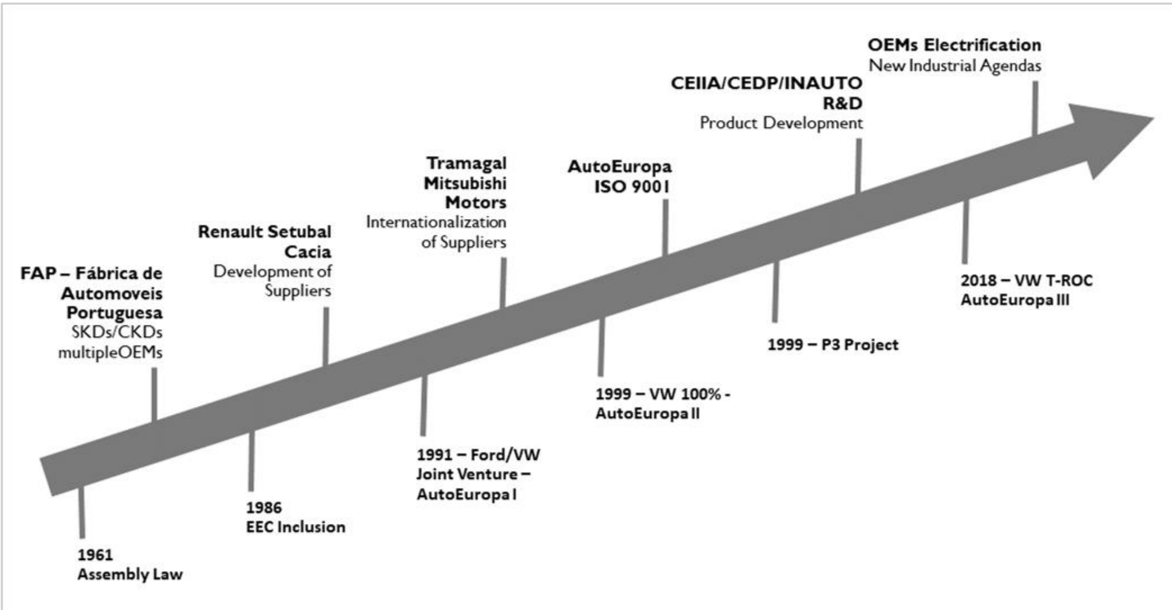
New mobility concept trends will also have a major influence on driving the change of the industry. This will have a strong impact on production volumes per vehicle model as the impact of hybrid models and electric models will tend to diversify the OEM’s portfolios. New materials and components (e.g., connectivity of vehicles) will need to be developed in order to support new concepts as well as the need of increased R&D activities. This vector also fosters the entrance of new suppliers.

So, to respond to the later referred changes, three levels of priorities for the automotive suppliers can be defined (Deloitte, 2018). Priority one should be to increase R&D investment as a driver to launch a new generation of components. Priority two should focus on the development of new business models, development of multi-OEM product solutions, the creation of start-ups for transformational innovation, acquisitions to access new capabilities and develop relationships and networking with new partners. Priority three should focus on the improvement of processes and decrease production costs, attract, develop, and retain talent, raise the number of costumers, develop organizational capabilities, and divest in lower potential businesses (Deloitte, 2018).

Along this chapter, (Figure 49) Portuguese suppliers have had an excellent performance with excellent results. Business volume has had a raising tendency since 2004 as well as OEMs (except for the 2008 crisis). The proposed outcome of this investigation combines with the excellent performance of the Portuguese automotive suppliers in order to further evolve business volume and consequently national exports. Consequently, it is logical to continue providing Portuguese companies in the automotive sector with the necessary tools to make them progress in the value chain.

Figure 49

The evolution of the Portuguese Automotive Industry



Note. Source: own

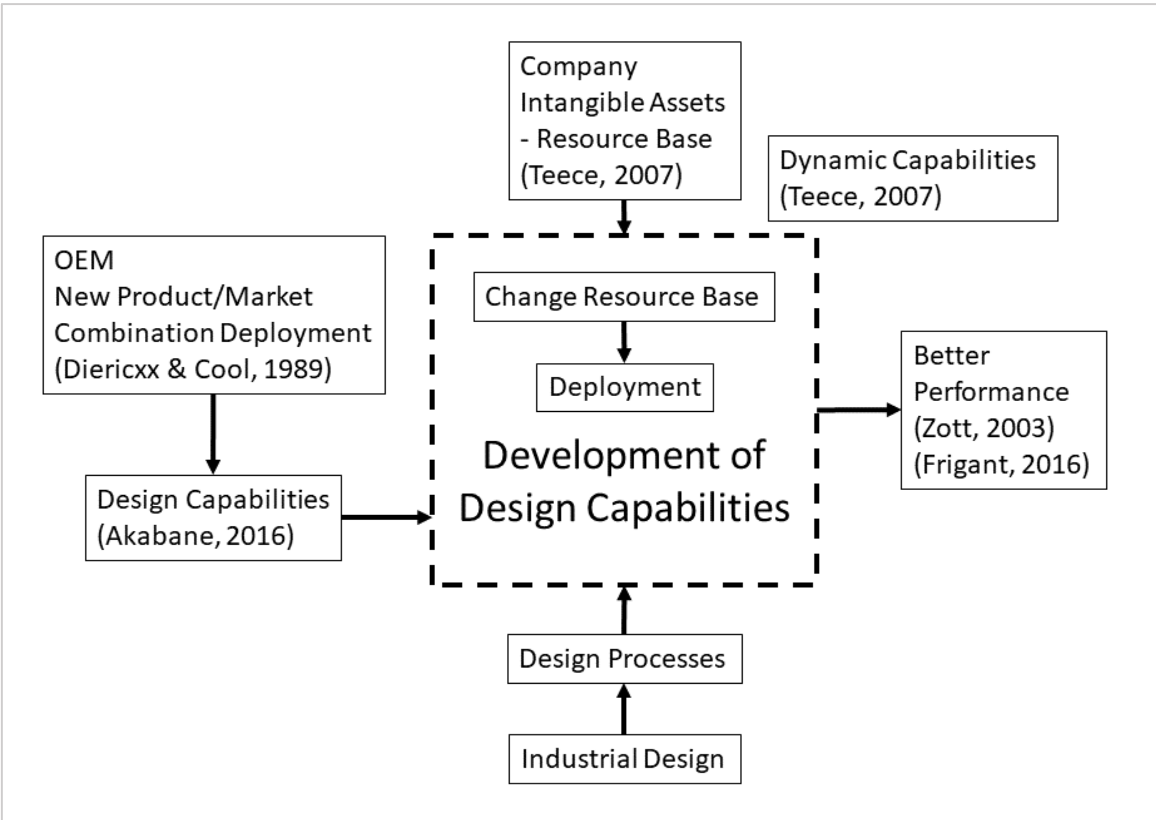
5. The Conceptual Framework

5.1. Building the conceptual framework

> "We define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities thus reflect an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions".
>
> (Teece et al., 1997, p. 516).

Figure 50

The Conceptual Framework



Note. Source: own

Under this umbrella, it is possible to integrate and describe the proposed conceptual framework. Although, as David Teece (1997) refers, it is relatively easy to identify design as a dynamic capability for an organization, but much more difficult to build it into an organization's strategy. However, the dynamic capabilities models of Teece and his colleagues, as well as those of Eisenhardt & Martin (2000), along with an exploratory framework for building design capabilities for the automotive suppliers from Akabane et al. (2016), have contributed to the theoretical framework shown in Figure 50 for building design as a dynamic capability within an organization.

Through their seminal paper (Eisenhardt & Martin, 2000), review the nature of dynamic capabilities and how those capabilities are influenced by market dynamism, and their evolution over time. Hence, new product/market combination as defined by Diericxx & Cool (1989) suggested by OEM's new product development projects, demand a change on company's intangible assets through a reconfiguration of its resource base (Teece, 2007).

As already referred, OEMs continue to control the overall design of the vehicle, as part of the ability to manage the offer portfolio and brand communication. However, the industry has been moving towards an increasing participation of smaller suppliers in product development processes, pushed towards capabilities' development as a requirement to continue competitive in the OEM's suppliers' network (Santos et al., 2019).

The ownership of dynamic capabilities is particularly important to multinational enterprise performance in business environments that reveal certain attributes. The first is that the environment is open to international commerce and fully exposed to the opportunities and threats associated with rapid technological change. The second is that technical change itself is systemic in that multiple inventions must be combined to create products and/or services that address customer needs. The third is that there are well-developed global markets for the exchange of (component) goods and services; and the fourth is that the business environment is characterized by poorly developed markets in which to exchange technological and managerial know-how (Teece, 2007). This is, as already described, the case of SMEs that supply the automotive OEMs.

It is important to distinguish firm capabilities from dynamic capabilities because dynamic capabilities operate on these capabilities and allow them to change and reconfigure in line with the environmental needs (Breznik et al., 2019). Firm capabilities can be viewed as resource base that comprises a bundle of heterogeneous capabilities that each firm deploys and develops individually (Breznik & Lahovnik, 2014).

Akabane et al. (2016) defined a classification framework for design capabilities of automotive first and second level suppliers. However, Asanuma (1989) research paper focus on suppliers' product design capabilities and the idea of the development of suppliers through the evolution of design activities based on supplied drawings to those based on own developed and approved drawings. The design capabilities defined in this framework are: (1) product design capability, (2) process design capability and (3) domain design capability. Moreover, this author concludes that, "parts suppliers with product design capability are recognized as suppliers with approved drawings and have a higher probability of receiving big orders with greater value-added from vehicle makers" (Akabane et al., 2016, p. 2).

These design capabilities are deployed through a design process that should be identical to the already referred VDI 2221 - Systematic Approach to the Design of Technical Systems and Products model (Figure 13) from the Professional Society of Engineers - Verein Deutcher Ingeniure or other. However, this model has been thoroughly adopted by many of the automotive industry suppliers.

"A dynamic capability is the firm's potential to systematically solve problems, formed by its propensity to sense opportunities and threats, to make timely and market-oriented decisions, and to change its resource base" (Barreto, 2010, p. 271), is a noticeably clear definition on how firms develop their dynamic capabilities through changing its resource base. In the case of the proposed framework, firms must show the ability to match their resource base to the design capabilities through a design process by the development of dynamic capabilities.

One of the most crucial relation in the Dynamic Capabilities theory is perhaps the one with performance. Zott (2003) stated that what should be considered is an indirect link between dynamic capabilities and performance. Therefore, dynamic capabilities may change the resource base to a new resource base that may influence new product market positions, which in turn may affect performance (Zott, 2003). This approach is fully consistent with early proposals that dynamic capabilities may be a key antecedent of firms' strategic choices, such as entry strategies, entry timing, or diversification (Teece et al., 1997). Due to the strong prominence initially put on the direct link to performance, those suggestions remained largely unexplored (Barreto, 2010).

Moreover, Barreto (2010), advises:

> "Future research should continue to explore the relationships between dynamic capabilities and intermediate outcomes, on one hand, and between intermediate outcomes and performance, on the other hand, to better assess which dynamic capabilities and intermediate outcomes deserve more attention"
>
> (Barreto, 2010, p. 275).

The proposed framework comprises two outcomes: (1) the propensity to change the resource base to develop design capabilities deploying a design process and (2) a performance outcome. However, this research was neither directed to the performance outcome nor to the networking relations but to the transformations of the resource base.

As already referred, by Frigant (2016), higher value-added projects (higher quality), comprising complex parts, tend to be made by suppliers positioned on the first tier (higher position of the supply pyramid). Adding R&D services increases the probability of becoming a tier 1 supplier, whether exclusively or partially. Akabane (2016) corroborates these findings referring that parts suppliers with product design capability have a higher probability of receiving big orders with greater value-added (higher quality) from OEMs.

5.2. Disaggregating from Dynamic Capabilities Microfoundations

Table 9

Disaggregation of Dynamic Capabilities Into Sensing, Seizing and Reconfiguration Practices

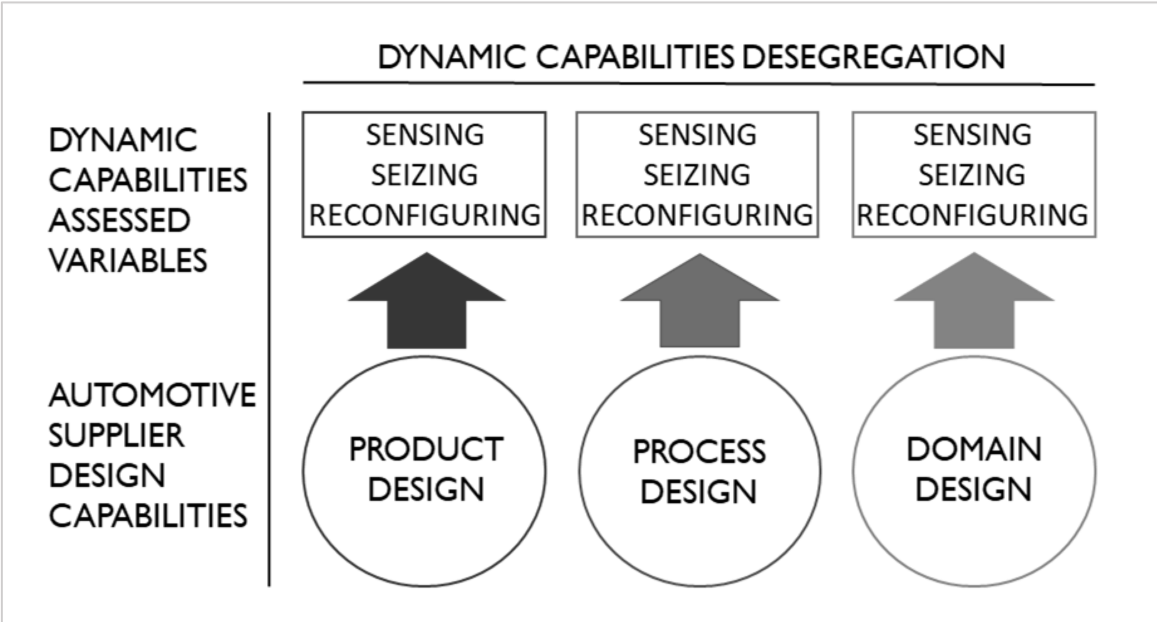
The Composition of Dynamic Capabilities		
(1) Sensing Capability	**(2) Seizing Capability**	**(3) Reconfiguring Capability**
Firms need to explore their internal and external environment in order to identify opportunities.	As soon as opportunities are sensed, they must be addressed through new products, services, processes, etc.	To adress new opportunities, firms need to recombine and reconfigure resources and capabilities as environment changes.
Common practices are: - Identifying new technologies; - Identifying new ideas; - Scanning for new markest / Customers;	Common practices are: - Activities to select the "right" new technology or a business model; - Activities to build commitment and loyalty;	Common practices are: - Activities to stimulate open innovation; - Activities to managing strategic fit; - Deploying knowledge management;

Note. Source: Teece (2007)

Moreover, the presented research framework is constructed on Teece's model of the microfoundations of dynamic capabilities. Teece broke dynamic capability down into three types of capabilities (Table 9) (Teece, 2007): sensing capability (ability to explore the firm's environment in order to identify opportunities), seizing capability (as soon as opportunities are sensed, they must be addressed), and reconfiguring capability (to address new opportunities, firms need to reconfigure their resources). Yet there are differences between sensing and seizing capabilities on one side and reconfiguring capability on the other. The first two encompass relatively basic functions, whereas reconfiguring capability entails greater complexity and might at times require a business model to be fully redesigned (Teece, 2007). The main premise of this breakdown of dynamic capabilities is to shed light on how dynamic capabilities deploy, develop and manifest. In this sense, dynamic capability is a "meta-capability" that transcends an ordinary firm capability (Teece, 2007).

Figure 51

Desegregation of Dynamic Capabilities



Note. Source: own

For analytical purposes, the current study presents how design capabilities can be disaggregated (Figure 51) onto sensing, seizing and reconfiguring capabilities. The following listed practices underpin the each of the design capabilities defined by Akabane et al. (2016).

(1) Product Design Capability

a. Sensing

- Networking activities to gather information about potential Product Development partners/projects, etc. (Breznik et al., 2019)
- Employees closely follow technological development and science and technology in general. (Breznik et al., 2019)
- On-going Benchmarking activities. (Breznik et al., 2019)
- Identifying new materials, architectures, and processes.
- Usability testing and assessment.
- Development of R&D Projects.

b. Seizing

- Using a (or own developed) design process during Product Development activities.
- Selecting the technologies and features that are to be embedded in the product. (Teece, 2007)
- The way in which technologies are to be assembled (architecture). (Teece, 2007)
- How the revenue and cost structure of a business is to be "designed" and if necessary redesigned to meet customer needs through a bill of materials (BOM). (Teece, 2007)

c. Reconfiguring

- Reconfiguring the resource base: new and improved products in line with technological development and market demands. (Breznik et al., 2019)
- Know-how integration. (Breznik et al., 2019)
- Adopting new/improved knowledge and technologies and transforming them into market-oriented solutions (Knowledge transfer). (Breznik et al., 2019)
- Improving the effectiveness of product development processes. (Breznik et al., 2019)

Table 10 resumes the practices that underpin Product Design capability.

Table 10

Practices that Underpin Product Design Capability

Product Design Capability as Dynamic Capability		
(1) Sensing Capability	(2) Seizing Capability	(3) Reconfiguring Capability
Networking activities to gather information about potential Product Development partners/projects, etc. (Breznik et al., 2019)	Using a (or own developed) design process during Product Development activities.	Reconfiguring the resource base: new and improved products in line with technological development and market demands. (Breznik et al., 2019)
Employees closely follow technological development and science and technology in general. (Breznik et al., 2019)	Selecting the technologies and features that are to be embedded in the product. (Teece, 2007)	Know-how integration. (Breznik et al., 2019)
On-going Benchmarking activities. (Breznik et al., 2019)	The way in which technologies are to be assembled (architecture). (Teece, 2007)	Adopting new/improved knowledge and technologies, and transforming them into market-oriented solutions (Knowledge transfer). (Breznik et al., 2019)
Identifying new materials, architectures and processes.	How the revenue and cost structure of a business is to be "designed" and if necessary redesigned to meet customer needs through a BOM. (Teece, 2007)	Improving the effectiveness of product development processes. (Breznik et al., 2019)
Usability testing and assessment.		
Development of R&D Projects.		

Note. Source: own

(2) Process Design Capability

a. Sensing

- Networking activities to gather information about potential Process Development partners/projects, etc. (Breznik et al., 2019)
- Employees closely follow technological development and science and technology in general. (Breznik et al., 2019)
- On-going Benchmarking activities. (Breznik et al., 2019)
- Identifying new materials, architectures, and processes
- Usability testing and assessment
- Development of R&D Projects

b. Seizing

- Using a (or own developed) design process during Process Development activities
- Selecting the technologies and features that are to be embedded in the process. (Teece, 2007)
- The way in which technologies are to be assembled (architecture). (Teece, 2007)
- How the revenue and cost structure of a business is to be "designed" and if necessary redesigned to meet customer needs through a BOM. (Teece, 2007)

c. Reconfiguring

- Reconfiguring the resource base: new and improved products in line with technological development and market demands. (Breznik et al., 2019)
- Know-how integration. (Breznik et al., 2019)
- Adopting new/improved knowledge and technologies, and transforming them into manufacturing process solutions (e.g., industry 4.0)

- Improving the effectiveness of process development processes. (Breznik et al., 2019)

Table 11 resumes the practices that underpin Product Design capability.

Table 11

Practices that Underpin Process Design Capability

Process Design Capability as Dynamic Capability		
(1) Sensing Capability	(2) Seizing Capability	(3) Reconfiguring Capability
Networking activities to gather information about potential Process Development partners/projects, etc. (Breznik et al., 2019) Employees closely follow technological development and science and technology in general. (Breznik et al., 2019) On-going Benchmarking activities. (Breznik et al., 2019) Identifying new materials, architectures and processes Usability testing and assessment Development of R&D Projects	Using a (or own developed) design process during Process Development activities. Selecting the technologies and features that are to be embedded in the process. (Teece, 2007) The way in which technologies are to be assembled (architecture). (Teece, 2007) How the revenue and cost structure of a business is to be "designed" and if necessary redesigned to meet customer needs through a BOM. (Teece, 2007)	Reconfiguring the resource base: new and improved products in line with technological development and market demands. (Breznik et al., 2019) Know-how integration. (Breznik et al., 2019) Adopting new/improved knowledge and technologies, and transforming them into manufacturing process solutions (e.g. industry 4.0). Improving the effectiveness of process development processes. (Breznik et al., 2019)

Note. Source: Own

(3) Domain Design Capability

a. Sensing

- Networking activities are a vital part of gathering information about target markets, customers, etc. (Breznik et al., 2019)
- Employees understand their role within the marketing process. (Breznik et al., 2019)
- On-going industry and competitor benchmarking. (Breznik et al., 2019)

b. Seizing

- Goal-oriented networking activities are a vital part of gathering information about target markets. (Breznik et al., 2019)
- Goal-oriented networking activities are a vital part of gathering information about clientele – additional projects, potential/new customers – new business projects, etc. (Breznik et al., 2019)
- Employees play an active part in marketing activities/processes (especially employees working as business analysts and project managers): recognising the changing costumers' needs. (Breznik et al., 2019)

c. Reconfiguring

- Constantly improving customers' loyalty and satisfaction. (Breznik et al., 2019)
- Constantly establishing, building, promoting, and nurturing long-term partnerships with key customers, partners, employees, and competitors. (Breznik et al., 2019)

Table 12 resumes the practices that underpin Domain Design capability.

Table 12

Practices that Underpin Domain Design Capability

Domain Design Capability as Dynamic Capability		
(1) Sensing Capability	(2) Seizing Capability	(3) Reconfiguring Capability
Networking activities are a vital part of gathering information about target markets, customers, etc. (Breznik et al., 2019) Employees understand their role within the marketing process. (Breznik et al., 2019) On-going industry and competitor benchmarking. (Breznik et al., 2019)	Goal-oriented networking activities are a vital part of gathering information about target markets. (Breznik et al., 2019) Goal-oriented networking activities are a vital part of gathering information about clientele – additional projects, potential/new customers – new business projects, etc. (Breznik et al., 2019) Employees play an active part in marketing activities/processes (especially employees working as business analysts and project managers): recognising the changing costumers' needs. (Breznik et al., 2019)	Constantly improving customers' loyalty and satisfaction. (Breznik et al., 2019) Constantly establishing, building, promoting and nurturing longterm partnerships with key customers, partners, employees and competitors. (Breznik et al., 2019)

Note. Source: own

6. Research Methods and Methodology

6.1. Introduction

The theoretical constructs and context field supported through the literature and the automotive business review leads us to conclude that this is an interdisciplinary research. This research crosses Industrial Design, Strategic Management, with the automotive industries as background field. Likewise, the interdisciplinary approach is the most suitable to work on complex problems for which no single discipline possesses the necessary methods on its own to frame or resolve them (Muratovski, 2016). For example, this approach can provide a systematic and comprehensive theoretical framework for the definition and analysis of various social, economic, political, environmental, and institutional factors influencing design. (Muratovski, 2016).

Following the interdisciplinary approach for this research, the most suitable methodology would be to conduct a qualitative research as a case study. As already referred, the nature of the research problem besides being interdisciplinary, it is applied in a dense and complex network as it is in the automobile business. For this reason, qualitative research can become particularly useful when used within a contemporary design practice that deals with complex problems (Muratovski, 2016), as it is in this case. Therefore, the case study is a qualitative research framework that provides the necessary tools for a researcher to study a complex phenomenon by using a variety of data. This phenomenon can be any situation, occurrence, or a fact that is observed to happen (Muratovski, 2016). The phenomenon is studied in-depth for a defined period and within a set context (Muratovski, 2016).

Moreover, qualitative researchers collect numerous forms of data from a wide range of sources and examine this data from many angles. Therefore, it can be said that the purpose of qualitative research is the construction of a rich and meaningful picture of a complex and multifaceted situation.

According to the definition given by Robert Yin (2009) and Muratovski (2016), the accomplishment of case studies is the most appropriate research strategy for the object of the present study. This choice is supported and explained for the following reasons:

a) Because it is the most appropriate strategy for "how", "what" and "why" questions, seeking explanations or exploring development paths.
b) Because it considers the crucial role of pattern and context in the search for knowledge and ensures the ability to deal with a large set of potentially explanatory variables.
c) “case studies, like experiments, are generalizable to theoretical propositions and not to populations or universes. In this sense, the case study, like the experiment, does not represent a ‘sample’, and in doing a case study, your goal will be to expand and generalize theories (analytical generalization) and not to enumerate frequencies (statistical generalisation)” (Yin, 2009, p. 15) The aim of the research is to expand and generalize explanatory theories, within the framework of analytical generalization, and not to enumerate frequencies of events, in which case statistical generalization would be contemplated.
d) Supported by a theoretical framework and methodological clarification, case studies can be important sources for the enrichment of knowledge about the object of analysis.
e) By adopting a broad definition of the research, the case study integrates sources of information of quantitative and qualitative characteristics and of different nature to establish the explanatory link.

In the most elementary sense, the research design is the logical sequence that connects the empirical data to a study’s initial research questions and, ultimately, to its conclusions. Colloquially, a research design is a logical plan for getting from here to there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions. Between “here” and “there” may be found several major steps, including the collection and analysis of relevant data (Yin, 2009).

As a summary definition, another textbook has described a research design as plan that “guides the investigator in the process of collecting, analyzing, and interpreting observations. It is a logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation” (Nachmias & Nachmias, 1992, p. 77-78).

6.2. Components of Research Designs

For case studies, five components of research design are especially important (Yin, 2009):

a) A study's questions.
b) Its propositions if any.
c) Its unit(s) of analysis.
d) The logic linking the data to the prepositions; and
e) The criteria for interpreting the findings.

a) Study's Questions

The initially proposed study's question are as follows and relate with the thesis title:

Q1: Why Design matters for smaller companies in the automotive industry?

Complementary questions, related do the main question (in why, what, and how format):

Q2: Why automotive firms choose to have design capabilities?
Q3: How automotive firms develop design capabilities?
Q4: What paths automotive firms took to develop design capabilities?

b) Study's Propositions

The research questions are sufficiently directed for the research, therefore there are no defined propositions.

c) Study's Unit of Analysis

This third component is related to the fundamental problem of defining what the "case" is. According to (Yin, 2009), the unit of analysis can be some event or entity other than a single individual. Case studies have been done about decisions, programs, the implementation process, and organizational change.

For this case, it will be defined as an organizational change since it is considered that the dynamic capabilities will be the firm's potential to change its resource base in order to solve problems, formed by its propensity to sense opportunities and threats (Barreto, 2010).

The unit of analysis should be related to the defined initial research questions. Each unit of analysis and its related questions and propositions would call for a slightly different research design and data collection strategy. Moreover, if the unit of analysis is a small group for instance, the persons to be included within the group must be distinguished from those who are outside (the context) (Yin, 2009).

To meet the present study's purpose, it was selected three performing SMEs from the Portuguese Automotive cluster according to the following criterion.

(1) the firm is an SME; (2) the firm must have been active in the market for over 10 years; (3) the firm must be established in Portugal, have local owners (have an independent capital structure); (4) the firm's programmes and business orientation should be comparable (integrated on the automotive supply chain network); and (5) the firm must be willing to participate.

The choice for the defined criteria is related to the described background of the study. As before mentioned, the network of the Portuguese automotive industry suppliers is mostly characterized of local owned SMEs that are established for more than 10 years (most developed through the Autoeuropa project). Moreover, the independent capital structure means that, the firm itself is able to change its own resource-base and that they are not introduced by an international company that establishes its procedures globally.

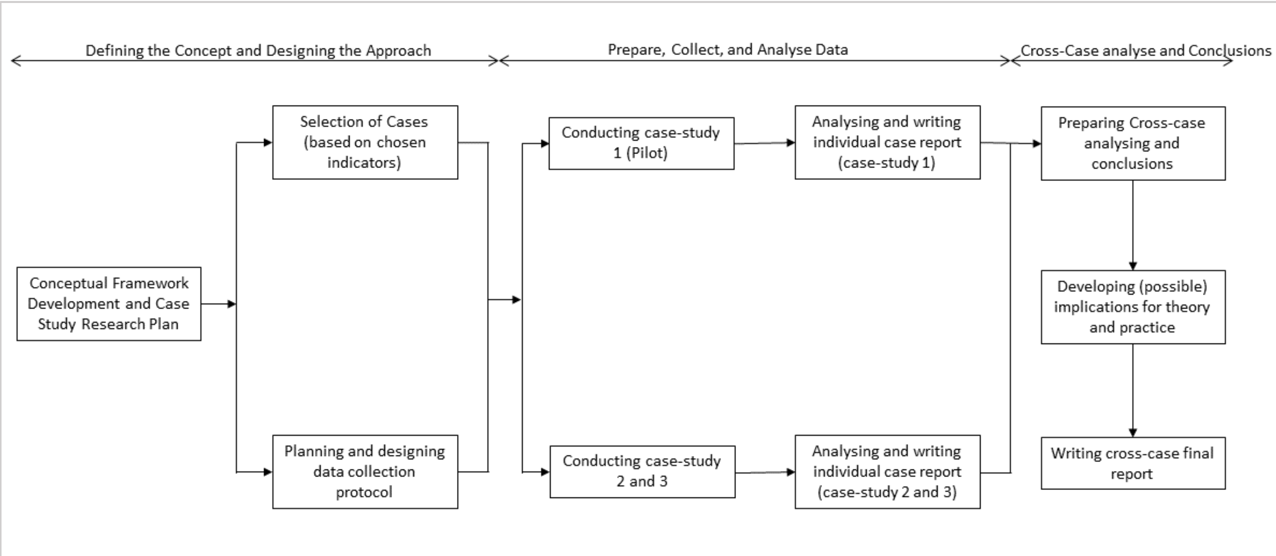
The selected three case study firms seem to represent an appropriate sample for cross-case analysis, particularly when looking for and identifying common patterns and differences concerning the use of dynamic capabilities.

d) Linking Data to Propositions

Oral and written invitations to take part in the research were sent to the chosen firms. After, meetings were arranged to describe the study's goals and data collection methodology. The qualitative nature of the current study and the related potential benefits and deficiencies were explained, also noting that it would thus be more resource-intensive and time-consuming when it came to collecting and (re)analysing the data. The analysis of the acquired data required three phases (Yin, 2009): (1) the analysis and report of individual cases; (2) the analysis and report of cross cases; and (3) the conclusions and implications of the cross cases for both theory and practice (Figure 52).

Figure 52

Developed Protocol for the Case Study



Note. Source: adapted from Yin (2009)

The choice for a multiple case study approach (Eisenhardt & Graebner, 2007; Yin, 2009) for the research design, as already referred, can be justified by the exploratory nature of the present research, as well as detailed interviews from 2020 and 2021, as a way to gather empirical data.

Multiple-case designs have distinct advantages and disadvantages in comparison to single-case designs. The evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust (Herriot & Firestone, 1983).

The recommendations and measures set out by Rouse et al. (1999) were used since they might be interpreted as supporting guidelines for research into resource-based in a specific industry. For the cases proposed, it was considered the processes involved in R&D, sales and marketing, and strategic management. Therefore, three questionnaires were formulated for the main respondents: R&D&I managers, general managers, and marketing/sales managers related to the defined practices that underpin each capability (product design, process design and domain design).

e) Criteria for Interpreting a Study's Finding

The fact that the candidate, author of this thesis is an expert with eighteen years of experience in the automotive industry has helped to understand the subject matter better and carry out the research at a deeper level. Additionally, for each case, the data were then triangulated with additional secondary sources (financial and annual reports, internal firm documentation, various published materials, and public databases) to reduce bias in the qualitative research. Also, literature is continually cross-referenced in line with the inductive research approach.

For categorizing and coding the data, it will be employed thematic analyses/networks (Stirling-Attride, 2001), together with the process of coding (Rubin & Rubin, 2005; Saldaña, 2009). The thematic analysis/networks are web-like sketches that summarize the main themes constituting a piece of text. “The thematic networks technique is a robust and highly sensitive tool for the systematization and presentation of qualitative analyses” (Stirling-Attride, 2001, p. 385). A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence capturing, and/or evocative attribute for a portion of language-based data. For this study, the data consists of interview transcripts (Saldaña, 2009).

The transformation or quantitizing of qualitative data for a study is a very debatable topic (Saldaña, 2009). Assuming that quantitative and qualitative research are two separate approaches to inquiry, it is possible to achieve comparable types of results when each approach examines the same data set. Therefore, the scale used for this study was an array of three variables: strong, moderate and weak. This choice serves the purpose for the case study of three companies, although can be directed to future research developments

The thematic networks are presented in this document annexes.

6.3. Criteria for Judging the Quality of Research Designs

Moreover, Robert Yin (2009) defines the criteria for judging the quality of research designs. This author defines four tests with the objective of the quality of an empirical research. Because case studies are one form of such research, the four tests also are relevant to case studies (Yin, 2009). For the proposed research, Table 13 lists the four tests and relates them with this specific case study tactics to be used as well as a cross-reference to the task / phase of research when the tactic is to be used (Yin, 2009).

Table 13

Developed Case Study Tactics for Four Design Tests

Test	Case Study Tactic	Task / Phase of research in which tactic occurs
Construct Validity	a) Multiple companies queries b) Interviews to more than one person and different hierarchical positions c) Inquired persons to review draft case study report d) Well established hypothesis to develop a strong chain of evidence	a) Three Firms selected for multiple-case study design b) Interviews designed for different hierarchical positions c) Case-study draft reports to be review by inquired persons before publication d) Hypothesis established on research design
Internal Validity	e) Do pattern matching by choosing the adequated cases and by the prior definition of consistent variables that can characterize a pattern f) Do explanation building developing a narrative combining theoretical prepositions and qualitative and quantitative data g) Characterize rival explanations for stronger strategic positioning and efficiency; h) Develop Logic Models that characterize and analyze the multiple case studies including the collection of data on rival explanations	e) Well defined indicators for choosing case-study firms for consistency of variables and pattern characterization f) Included in final Cross Case-study reports g) Literature Review: Critical Appraisals and Reviews h) Matching empirically observed events to theoretically predicted events included on the cross-case report
External Validity	i) Finding on literature review case studies of different industries for comparising j) Well developed link with theoretical explanation k) Use replication logic in multiple case studies	i) Included on Literature review j) and k) Developing logic models matching empiricallly observed events included on cross-case report
Reliability	l) It will be designed and used a case study protocol and a standard questionaire as a way to maximize the standardization of data collection; m) The same kind of documentation will be analysed for the development of the case study database;	l) Included on the research design and interviews; m) For each case, the data were then triangulated with additional secondary sources (documents) to reduce bias in the qualitative research

Note. Source: adapted from Yin (2009)

6.4. Case study Protocol

This procedure is especially desirable if the research is based on a multiple-case design, which is the case (Yin, 2009). The protocol is more than a questionnaire or instrument. It is a major way of enhancing the reliability of the case study research and is meant to guide the researcher in carrying out the data collection from the multiple-case study.

According do Yin (2009), a case study protocol should have the following sections:

a) An overview of the case study project (objectives, issues, and relevant readings about the investigated topic).
b) Field procedures (presentation of credentials, access to case study "sites").
c) Case study questions (the specific questions needed to collect data, "table shells" for specific arrays of data and the potential sources of information for answering each question).
d) A guide for the case study report (outline, format for the data, use and presentation of other documentation).

Consequently, the defined topics will be structured as follows:

A. Introduction to the Case Study and Purpose Protocol

1. Case study questions, hypotheses, and propositions
2. Theoretical framework for the case study

B. Data collection Procedures

1. Names of sites to be visited, including contact persons
2. Data collection plan (covers the type of evidence to be expected, including the roles of people to be interviewed, the events to be observed, and any other documents to be reviewed when on site)
3. Expected preparation prior to site visits (identifies specific information to be reviewed and issues to be covered, prior to going to site)

C. Outline of Case Study Report

1. Format for the data
2. Use and presentation of other documentation

D. Case Study Survey and Interview Questions (see APPENDIX – Table A to D)

7. Case Study Pilot Report – Veneporte

7.1. Introduction

Figure 53

Veneporte Institutional Logo

Note. Source: Indústrias Metálicas Veneporte, S.A.

Veneporte (Figure 53) is a Portuguese small and medium-sized enterprise (SME) company dedicated to the development, production, and distribution of a full range of exhaust systems modules. From catalytic converters (KAT) to particulate filters (DPF), selective catalytic reduction (SCR) filters, silencers, and tubes. Veneporte is an automotive global supplier that operates in three different markets: Original Equipment Manufacturer (OEM), Original Equipment Supplier (OES) and Independent Aftermarket (IAM).

Established in 1966, with the productive activity beginning in 1967, Veneporte has its headquarters and main production unity located in Águeda, Aveiro district, Portugal, in a 25000 m2 of covered shop floor area. The first owner was a Portuguese immigrant from Venezuela, thus the first part of the name “Vene”.

During the 1970’s decade, Veneporte saw an important growth mainly due to the protectionism that the Automobile Assembly Law gave. So, it enabled Veneporte to be the supplier of almost all the OEMs installed in Portugal by that time. It was also in this decade that Veneporte started the tubes production, not only to be incorporated in the production of exhaust system modules but also to be sold to other products and applications.

The 1980's decade was, as already stated, evidenced by the adhesion of Portugal to the European Economic Community (EEC), (which has significantly influenced the car manufacturers' strategies of approaching the Portuguese market and created an Iberian automotive manufacturing and trade space). Veneporte saw a strengthening of the networks with the different OEM customers already installed in Portugal. However, the opening of the European trade space, suggested a greater exposure to competitors, meaning a lot of concerns to the company.

In the beginning of the 1990's, the company was in trouble due to an exceptionally low profitability, hence the shareholder structure was completely changed. Having been acquired by six entrepreneurs from the region of different industrial activities, a sort of business pool was created to carry out the acquisition of the company and thus maintain the supply chain (to the other firms that belonged to them), which would otherwise be interrupted.

Through this way, the installed capacity to produce metal tubes was ensured through an important restructuring plan implemented, with particular emphasis on the improvement of facilities and equipment, but also on the reorganization of the different processes. It is important to note that Veneporte's business structure by that time was only 30% in the automotive area and 70% for the general metalworking industry with tube manufacturing. From then on, the automotive sector was once again given dynamism, being today 100% of the Veneporte market.

As a direct effect of the different investments made and the new company's strategy, in 1996, Veneporte was successfully awarded a quality assurance certification according to the ISO 9002:1995 standard. Later, in 1998, the society was officially a corporation.

Into the first decade of the new millennium, Veneporte sustained significant growths in its activity. In 2003 obtained the certification of its quality management system, according to the EN 9001:2000 standard. Additionally, the 2004 year was marked by a crucial strengthening of the company's internationalization process, as well as the growth of its costumer network with OEMs like the Fiat group, Mitsubishi, and Toyota. Also, during this year, the company saw a shareholder restructure as most of the capital was concentrated in only three entities. Moreover, in the following year of 2008 the company was granted tier 1 supplier for IVECO.

In 2009, Veneporte was nominated as PSA official supplier for the OES market, as well as for its integrated network of aftermarket sales and shops, EUROREPAR. Also, in this year, another important customer entered on Veneporte's portfolio: Volkswagen. The company started supplying the Polo and Golf projects. Also, at the end of 2009, it was celebrated the official supplying agreement to GAU Group – France, a genuine parts company, increasing the vast IAM market portfolio of the company.

The start of the second decade of the new millennium was evidenced by the beginning of new projects with Mitsubishi also as tier 1. In 2011, the company was awarded a certification according to the ISO/TS 16949 standard, achieving a strong credibility with all its established costumer network.

In 2012, Veneporte saw the acknowledgement from a PSA award, as a recognition of its performance, as well as its excellent logistics achievement. During this year, Veneporte took the decision to invest on the development and production of a catalytic converters range, expanding the company's business possibilities.

During the 2013 year, the company achieved the VW group quality certification, according to the VDA6.3 standard. Moreover, through 2014, the company continues to invest on the product develop of its catalytic converters and silencers range, as well as the beginning of the particulate filters range development.

In 2020, 100% of shareholders capital was concentrated in one entity which is the current Chief Executive Officer (CEO), Mr. Abílio Cardoso.

With a capital amount of €2.983.680, Veneporte closed the 2020 year with a sales amount of €11.501.231.

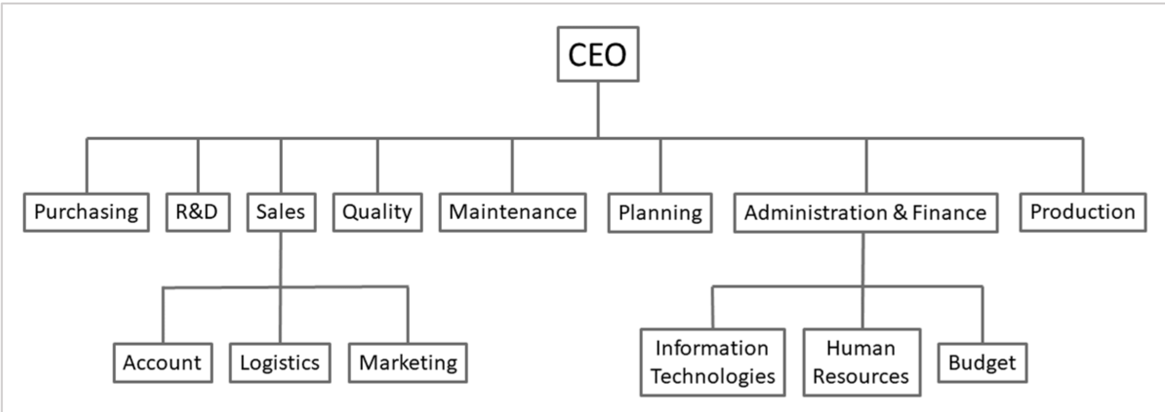
7.2. Organisational Structure and Supply chain position

The organisational structure of Veneporte is a typical functional organisation (Figure 54), currently with 180 employees including internal, external, direct, and indirect. As Veneporte is a tier 1 automotive supplier the current standard category is IATF 16949, therefore the company is familiar and employs all the automotive quality tools such as total quality management (TQM), quality functional deployment (QFD), 5s, Failure Mode and Effects Analysis (FMEA), and Just in Time (JIT).

Veneporte is a tier 1 automotive supplier for all the delivering products for the OEM/OES market.

Figure 54

Veneporte Organizational Chart



Note. Source: Indústrias Metálicas Veneporte, S.A.

7.3. Markets and Product Range

Markets

Veneporte is committed to the development, production, and distribution for three main markets, the OEM, OES and IAM. These three markets have different characteristics even if the product and technology is the same. Veneporte works as tier 1 supplier for the OEM market meaning delivering state of the art technology, high quality standards and just in time kind of distribution.

The OES market requires that Veneporte must deliver as tier 1 supplier, although it does not imply the necessity of product develop therefore not delivering state of the art technology since the models are not in production anymore.

The IAM market does not have the full characteristics of the normal supply chain for the automotive network. Although the after-market products are to be assembled on cars, the technology level of the product and the quality must match the original part from the OEM. This is the main reason that form the market strategy lenses, Veneporte unequivocally needs to be a tier 1 supplier so it can have access to product characteristics and standards as a way to replicate on the product range do be marketed into the IAM.

7.3.1. Product Range

Veneporte product range is typified by two main business domains, hot and cold which unfold into five technological families, catalytic converters (KAT) to particulate filters (DPF), selective catalytic reduction (SCR) filters, silencers (SIL) and tubes.

a) Catalytic Converters

A catalytic converter (KAT) is an exhaust emission control device which reduces toxic gases and pollutants in the ICE exhaust gas, into less-toxic pollutants by catalysing a redox reaction (an oxidation and a reduction reaction). The catalytic converter is an antipollution key-device, and one of the most important components in the exhaust system, mainly due to its effect on the emission’s reduction and in the correct operation of other engine components.

Figure 55

An Example of a Catalytic Converter

Note. Source: Indústrias Metálicas Veneporte, S.A.

Moreover, the first general introduction of catalytic converters was in the United States automobile market as a way to comply with the U.S. Environmental Protection Agency's stricter regulation of exhaust emissions. Most gasoline-powered ICE vehicles launched in 1975 are equipped with catalytic converters.

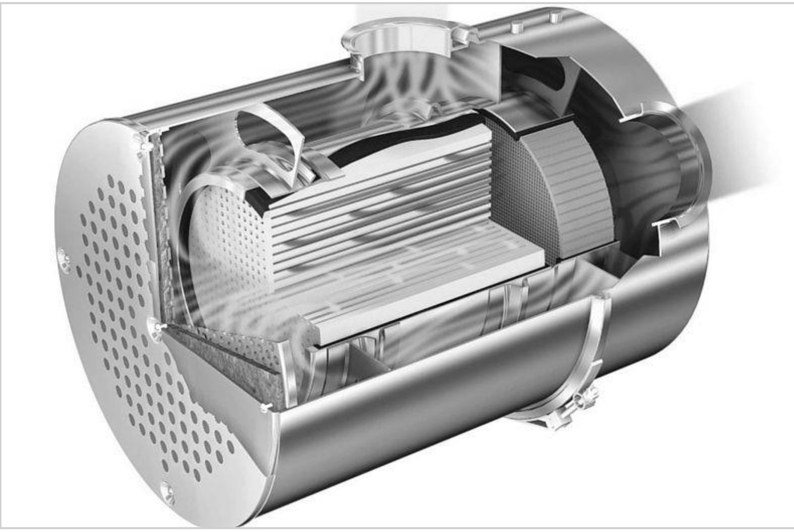
The catalytic converter contains a coted core with noble metals (Platinum, Palladium and, Rhodium), which converts the toxic gases coming from the combustion, hydrocarbons (HC), nitrogen oxides (NOx) and carbon monoxide (CO), through chemical reactions, into mild substances for the atmosphere and human beings, such as steam (H2O), carbon dioxide (CO2) and diatomic nitrogen (N2) – the monolith.

Veneporte's range of catalytic converters are 100% certified to UNECE regulations, covering most of the European car park lot and it is developed considering the specifications of each automobile brand and model. Consequently, the environmental performance is identical to the OEM products, ensuring the fulfilment of all current legal requirements.

b) Particulate Filters

Figure 56

An Example of a Diesel Particulate Filter



Note. Source: Indústrias Metálicas Veneporte, S.A.

The particulate filter is a device that retains solid particles created by the incomplete combustion in ICEs. These particles of reduced size, called nanoparticles, are extremely harmful to human beings and the environment. In the first phase, the particulate filters were solely designed for diesel vehicles – Diesel Particulate Filters (DPF). However, with the increased need for reducing the pollutant gases emissions, is it now possible to find particulate filters also in gasoline vehicles – Gasoline Particulate Filters (GPF).

Moreover, current wall-flow particulate filters have from 85%, approaching 100% soot removal efficiencies. Current technology filters (cordierite, silicon-carbide or metallic) are designed to burn off the accumulated particulates either passively using the engine high temperature to do so, this usually occurs during extra-urban travel. Or by active means. The latter technique is accomplished in one of two ways:

- by engine programming to run (when the filter is full) in a mean that elevates exhaust temperature by opening and closing the exhaust valve allowing for higher temperatures to reach the filter.
- by using an extra fuel injector in the exhaust stream injecting fuel to react with a catalyst element, hence burning off accumulated soot in the DPF filter.

Veneporte's particulate filters range is 100% certified to UNECE regulations as each product is developed according to the specification of each OEM and individual model. Whether they are silicon carbide (SiC) or cordierite technology, Veneporte's particulate filters functional performance is extremely high and widely recognized in the independent aftermarket (IAS) as well as fully complying with the current strict European legal regulations.

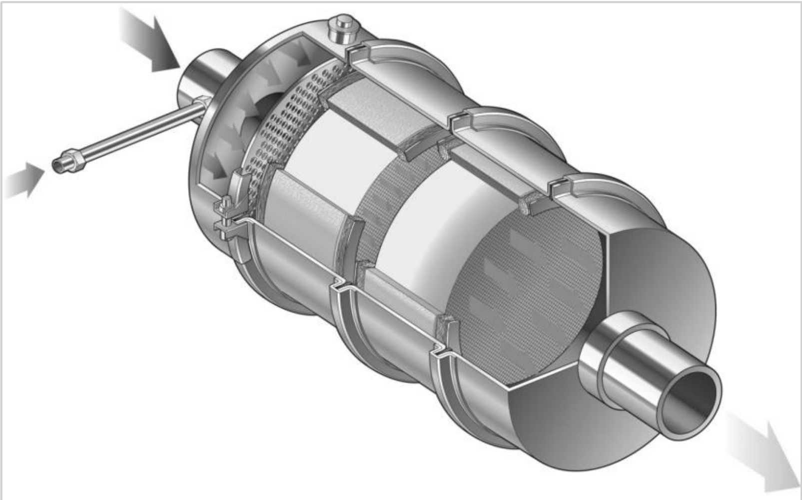
c) Selective Catalytic Reduction Filters

The Selective Catalytic Reduction (SCR) filters are the most advanced automotive emission control systems available today. They can be found in vehicles from the year 2014 on and, adoption is essential to meet the European emission requirements by the EURO 6 standard.

The SCR system is an efficient solution capable of reducing NOx emissions by about 90%. SCR is a means of converting nitrogen oxides, also referred to as NOx with the aid of a catalyst into diatomic nitrogen (N2), and water vapour (H2O). A reductant, typically anhydrous ammonia, aqueous ammonia, or a urea compounds solution (AdBlue - aqueous solution of urea formed by 32,5% pure urea and 67,5% demineralized water), is added to a stream of flow or exhaust gas and is absorbed onto a catalyst. As the reaction drives toward completion, carbon dioxide, CO2 is produced.

Figure 57

An Example of a Catalytic Reduction Filter



Note. Source: Indústrias Metálicas Veneporte, S.A.

SCR systems are now the preferred method for meeting EURO 6 diesel emissions standards for heavy trucks, and for cars and light commercial vehicles. In many cases, emissions of NOx and PM (Particulate Matter) have been reduced by upwards of 90% when compared with vehicles of the early 1990s.

d) Silencers

A silencer or muffler (SIL) is a device for reducing the noise released by the exhaust of an ICE. It is principally a noise-deadening device forming part of the exhaust system of an automobile.

Moreover, silencers are installed within the exhaust system of most ICEs. The silencer is designed as an acoustic device to reduce the loudness of the sound pressure created by the engine by acoustic quieting methods. The noise of the exhaust gas exiting the engine at high speed is decreased by a series of sections and chambers lined with roving fiberglass insulation and/or resonating chambers harmonically tuned to cause destructive interference, in which opposite sound waves cancel each other out.

Figure 58

An Example of a Silencer

Note. Source: Indústrias Metálicas Veneporte, S.A.

An unavoidable side effect of the noise reduction is the restriction of the exhaust gas flow, which creates what is called the back pressure phenomenon, decreasing engine efficiency. Silencers should provide operation with the engine back pressure, allowing the maximization of its performance and the reduction of its own consumption.

7.4. Field Work

The case study of Veneporte followed scrupulously the defined research design. Hence, all the methodology used for the investigation for the case study was constructed to answer the initial study's questions.

Moreover, to meet the study's purpose, Veneporte was selected according the defined five indicators, (1) the firm is an SME; (2) the firm must have been active in the market for over 10 years; (3) the firm must be established in Portugal, have local owners (have an independent capital structure); (4) the firm's programmes and business orientation should be comparable (integrated on the automotive supply chain network); and (5) the firm must be willing to participate.

Oral, and written invitations were sent to Veneporte, particularly to the CEO, Mr Abílio Cardoso (acting also as sales manager) and to the R&D Manager, Mr. Luís Pinho. After, meetings were arranged to describe the study's goals and data collection. The qualitative nature of the study was explained as well as the potential benefits and deficiencies also noting that it would thus be more resource-intensive and time-consuming when it came to collecting and (re)analysing the data.

For the proposed case, it was considered the firms' processes involving R&D, sales, and strategic management. Therefore, three questionnaires were formulated for the main respondents: R&D manager, general manager, and sales manager related to the defined practices that underpin each defined capability (product design, process design and domain design).

The target respondents of the interviews, which were narrative in nature, informal recorded (with consent) and subsequently transcribed, were primarily the R&D manager of Veneporte which constituted our research focus and the general manager. The corresponding interviews took place between 04/12/2020 and 22/01/2021 with Mr. Luís Pinho and Mr. Abílio Cardoso respectively. Intended for categorising the data and coding, it was employed thematic analyses/networks (Stirling-Attride, 2001), together with the process of coding (Rubin & Rubin, 2005; Saldaña, 2009).

The current case study report was sent for approval to the correspondents at Veneporte and was subject to positive comments as exceptionally reliable. Thus, the report was approved in 15/06/2021.

7.5. Empirical Data and Analysis

7.5.1. Quantitative Data Analysis

7.5.1.1. Products and Services Characterization

According to Frigant (2016), complex parts tend to be made by suppliers positioned on the first tier of the automotive network supply chain. The supply chain position of the case studied company is key, together with the level of complexity of each supplied product.

For the current case study it is defined as simple parts, single supplied components (tubes). For complex parts it is defined as supplied modules (KAT, DPF, SCR and SIL). Table 14 shows the current production percentage breakdown of level of part complexity for each market (for OEM, OES and IAM markets, Veneporte acts as tier 1 supplier).

Table 14

Current Year to Date (YTD) Production Percentage Breakdown of Level of Complexity for Each Market

	OEM	OES	IAM
Simple Parts	1,7	2,6	23,5
Complex Parts	0	2,8	69,4

Note. Source: Indústrias Metálicas Veneporte, S.A.

To assess the level of product design (table 2) and process design (table 3) involved for each level of part complexity, it is used the framework developed by Akabane et al. (2016). As already referred, Akabane et al. (2016), defines the framework with two axes. A horizontal, where it defines the criterions of classification of the degree of participation in the preparation of drawings. On the vertical axis it is defined the categories (from 1 to 6) in which a supplier can be classified.

Table 15 and 16, show the classification from the data gathered at Veneporte related to product design and process design of current YTD development projects. Therefore, it is possible to understand that product design wise, Veneporte has a high level of development, since almost 100% of the projects are fully Veneporte responsibility to develop. Process Design wise, the results show that Veneporte is also responsible for the design of manufacturing equipment as jigs and tooling molds.

Table 15

Level of Classification of Product Design of Current Percentage YTD Development Projects According to Akabane et al. (2016)

	Classification Level of Product Design					
	1	2	3	4	5	6
Simple Parts					1,5	
Complex Parts						98,5

Note. Source: Indústrias Metálicas Veneporte, S.A.

Table 16

Level of Classification of Process Design of Current Percentage YTD Development Projects According to Akabane et al. (2016)

	Classification Level of Process Design				
	1	2	3	4	5
Simple Parts				1,5	
Complex Parts				98,5	

Note. Source: Indústrias Metálicas Veneporte, S.A.

Likewise, regarding the development stage of the domain design it is used the framework defined by Akabane et al. (2016) based on Ansoff (1970) growth matrix. As referred Ansoff's growth matrix has two axes. The vertical is the market axis, and the horizontal is the products axis. Akabane et al. (2016) defines a horizontal axis where it defines the criterions of classification of the degree of product/market diversification and on the vertical axis it is defined the categories (from 1, 2-1, 2-2 and 3) in which a supplier can be classified.

Table 17

Number of Current Development Projects per Market, Business Domain and Type of Part

	COLD		HOT	
	TUBES (SINGLE PARTS)	SILs (COMPLEX PARTS)	KATs (COMPLEX PARTS)	DPFs (COMPLEX PARTS)
OEM	1,6	0	0	0
OES	0	0	0	0
IAM	9,3	31,8	25,6	31,8

Note. Source: Indústrias Metálicas Veneporte, S.A.

Through the analysis of this data Table 17, it is possible to conclude that there is a clear strategy of product diversification on the IAM market. However, from table 14, it is also possible to understand that Veneporte is present on all three markets but heavily on IAM. Through Akabane et al. (2016) domain design classification table, Veneporte is at level 3 (Sales of Different type of parts to many costumers), meaning that from Ansoff (1970) matrix it is a clear diversification business strategy.

7.5.2. Qualitative Data Analysis

7.5.2.1. Manifestations of Development of Design Capabilities

As a way to understand the logic behind the DCV, the desegregation from the dynamic capabilities microfoundations by Teece (2007) was deployed in a sense that a dynamic capability is a “meta-capability” that transcends an ordinary firm capability (Teece, 2007). For analytical purposes, the current study was based on the desegregation of the design capabilities into sensing, seizing and reconfiguring capabilities. The following tables (Table 10, Table 11, and Table 12) list the practices that underpin each of the design capabilities defined by Akabane et al. (2016).

For a clearer insight of how Veneporte develops capabilities as dynamic capabilities, its manifestations in sensing, seizing and reconfiguring capabilities are presented regarding design capabilities. The, design capability and the role of managers have been recognised as a key component in developing dynamic capabilities.

With the aim of determining dynamic capabilities level of deployment, namely weak, moderate, and strong, each capability was viewed as containing sensing, seizing, and reconfiguring capabilities (Table 9). This classification of the level of deployment, was an output of coding the interviews according to the defined practices underpinning, product design, process design and domain design (see APENDIX – TABLE E, F, and G).

At Veneporte, the level of deployment of design capability is at a remarkably high level. Accordingly, Veneporte is an example of how dynamic capabilities can be successfully deployed and developed. A deeper investigation of the manifestations of design capability allows us to present some of the practices and activities that undergird the design capability in Veneporte.

7.5.2.1.1. Product Design Capability

Sensing Capability

As defined by Teece (2007), sensing capabilities relate to the ability of firms to explore their internal and external environment in order to identify opportunities. Teece (2007) defined as common practices for recognizing the sensing capability, identifying new technologies, identifying new ideas, and scanning for new markets and costumers.

Based on Teece (2007) common practices, it was defined the practices that underpin the sensing capability for the Product Design capability as a dynamic capability. These are: networking activities to gather information about potential Product Development partners and projects (Breznik et al., 2019), employees closely follow technological development and science and technology in general. (Breznik et al., 2019), on-going benchmarking activities. (Breznik et al., 2019), identifying new materials, architectures and processes usability testing and assessment and, development of R&D projects.

Under these lenses, Veneporte shows a strong level of deployment. They show a strong connection with R&D development partners, either universities, external laboratories, lower-level suppliers, or even other tier 1 suppliers. Veneporte considers that networking is so important that the different areas of networking are intrinsically linked to the design process.

Regarding on-going benchmarking activities, Veneporte engages frequently on benchmarking activities, which involve the acquisition and analysis of products from direct competition and tearing them. Moreover, the way in which technologies, materials and processes are identified usually comes from briefings for OEM project request for quotation (RFQ) processes.

In these RFQs, there are OEMs that, in addition to the volumetry of the assembly environment and engine specifications details (referring the technology specification to the supplier) and others (more mature) that give the specifications of the finished product. In addition to the opportunity to win the project, the latter case gives Veneporte an opportunity to technologically match the existing global supplier panel.

Veneporte engages in R&D projects in order to diversify the company's portfolio regarding its product range.

Seizing Capability

Seizing capabilities relate to the ability of firms to address opportunities as they are sensed, through new products, services, or processes, Teece (2007). Teece (2007) defined as common practices for recognizing the seizing capability, activities to select the “right” new technology or business model and activities do build commitment and loyalty, (Teece 2007).

Based on Teece (2007) common practices, it was defined the practices that underpin the seizing capability for the Product Design capability as a dynamic capability. These are: using (or own developed) design process during product development activities, selecting the technologies and features that are to be embedded in the product (Teece, 2007), the way in which technologies are to be assembled – architecture (Teece, 2007) and how the revenue and cost structure of a business is to be “designed” and if necessary redesigned to meet customer needs through a bill of materials (BOM) (Teece, 2007).

Under these lenses, Veneporte shows a strong level of deployment of seizing capabilities. Concerning the use of a design process Veneporte, based on IATF 16494 standard, developed its own design process using its internal documentation in order to better reflect its process.

One of the features that has an important impact on the architecture of the product, hence on the design, are the DPF filters and the monoliths. As, these components are especially important in the final technical definition of VENEPORTE products, the bechmarking and R&D activities and a close relationship with some of the tier 2 suppliers are exceptionally crucial. Veneporte integrates the acquired knowledge of their benchmarking activities and networking activities with their strategic partners (such as laboratory entities and universities) in the architecture of their products within the existing know-how.

Regarding the use of a structured BOM and the way it integrates a cost structure of the product, Veneporte uses a default spreadsheet that, by default includes all the components that a typical product architecture normally contemplates, as well as the list of industrial processes classified by cost centers. Purchasing components are included in this spreadsheet. Subsequently, it is sent to the commercial department for validation.

Reconfiguring Capability

Reconfiguring capabilities relate to the ability of firms to recombine and reconfigure resources and capabilities as environment changes in order to address new opportunities Teece (2007). Teece (2007) defined as common practices for recognizing the reconfiguring capability, activities to stimulate open innovation, activities to manage strategic fit and the deployment of knowledge management, Teece (2007).

Based on Teece (2007) common practices, it was defined the practices that underpin the reconfiguring capability for the Product Design capability as a dynamic capability. These are: new and improved products in line with technological development and market demands. (Breznik et al., 2019), know-how integration. (Breznik et al., 2019), adopting new/improved knowledge and technologies, and transforming them into market-oriented solutions (Breznik et al., 2019) and finally improving the effectiveness of product development processes. (Breznik et al., 2019).

Under these lenses, Veneporte shows a moderate level of deployment of reconfiguring capabilities. Concerning the process of reconfiguring, implementing and adapting the product design activities, Veneporte’s top management has a share of interference in the programming of the activities of the design process. This interference comes on a weekly basis, identifying new needs that are prioritized not according to the product development and R&D projects scheduled timeline. One of the big gaps in the R&D department of Veneporte is precisely the deficient structuring of the prioritization of activities. However, the design team has a dynamic capacity to adapt and admirably reinvent, and they manage to do so, unfortunately sacrificing some important deadlines. Which is a significant price to pay.

On what relates adopting new/improved knowledge and technologies, and transforming them into market-oriented solutions, Veneporte is successful in applying the outputs of the R&D and Benchmarking activities in association with its product development partners and considers that otherwise it would not be possible to obtain a successful product on the market.

There is an internal key process indicator (KPI) that is followed by the different levels of management which contemplates the number of hours of design activities by developed projects and acts as a gauge to improve the effectiveness of product development processes. This is the only activity of Veneporte that evidences the continuous improvement of product development processes. It is a moderate level of deployment.

Finally, Veneporte considers that there is a major flaw in the design process in what relates to knowledge retention, failing on documenting the know-how acquired during the development of its products.

7.5.2.1.2. Process Design Capability

Sensing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the sensing capability for the Process Design capability as a dynamic capability. These are: networking activities to gather information about potential Process Development partners and projects (Breznik et al., 2019), employees closely follow technological development and science and technology in general. (Breznik et al., 2019), on-going benchmarking activities. (Breznik et al., 2019), identifying new materials, architectures and processes usability testing and assessment and, development of R&D projects.

Under these lenses, Veneporte shows a moderate level of deployment. Veneporte considers that networking is relatively unimportant in the sense that it has all the necessary know-how for the design process, however, the company uses its panel of suppliers for maintenance and purchase of machines or subcontracting some services, therefore Veneporte is in an area with a strong and intense industrial presence in the field of metal transformation.

There are no benchmarking activities regarding tooling or process machinery nor the process of identifying new materials or manufacturing processes through it. Veneporte considers that there is not much innovation in this area due to the design of the parts being very similar from product to product.

Moreover, Veneporte does not have R&D projects related to its process design capability.

Seizing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the seizing capability for the Process Design capability as a dynamic capability. These are: using (or own developed) design process during process development activities, selecting the technologies and features that are to be embedded in the process (Teece, 2007), the way in which technologies are to be assembled – architecture (Teece, 2007) and how the revenue and cost structure of a business is to be “designed” and if necessary redesigned to meet customer needs through a BOM (Teece, 2007).

Process design wise, Veneporte uses their own design process which is, in the case of tooling, a mechanical design process. The tool's layouts are initially established through the design of a strip of sheet metal from which the form and function of the dies and punches are developed. Materials and architecture of die tools are consequently selected according to the materials and geometry of the part to be produced (or processed). No benchmarking activities related to process design capability are carried out.

Finally, Veneporte seizing capability for the process design capability is considered to be moderate.

Reconfiguring Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the reconfiguring capability for the Process Design capability as a dynamic capability. These are: new and improved products in line with technological development and market demands. (Breznik et al., 2019), know-how integration. (Breznik et al., 2019), adopting new/improved knowledge and technologies, and transforming them into manufacturing process solutions (e.g., industry 4.0) and finally improving the effectiveness of process development processes. (Breznik et al., 2019).

The product design and process design team are the same. Thus, as the planning is changed, the team is reconfigured according to the prioritization (often by the top management) and the emerging needs. This is considered a moderate evidence of a reconfiguring capability, since the team is able to reconfigure itself from product to process design, alas top management share of interference in the planning of the activities of the design department.

Since the same team share product design and process design resources, the internal KPI which reveals the number of hours of product development activities by developed projects, includes the product design and process design. This evidence is considered moderate, since there should be a segregation of both activities in order to have a clear way to improve the effectiveness of the process development processes.

Likewise, Veneporte considers that there is a major flaw in the design process in what relates to knowledge retention, failing on documenting the know-how acquired during the development of its products and processes.

7.5.2.1.3. Domain Design Capability

Sensing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the sensing capability for the Domain Design capability as a dynamic capability. These are: networking activities to gather information about target markets and customers (Breznik et al., 2019), employees understand their role within the marketing process (Breznik et al., 2019), On-going industry and competitor benchmarking. (Breznik et al., 2019).

Under these lenses, Veneporte shows a strong level of deployment. As to what relates to the networking activities in order to tap new opportunities, concerning new markets and costumers, Veneporte has a different action for the OEM/OES and IAM markets. For the OEM/OES market, new opportunities are captured through request for quotes (RFQs) by customers in which Veneporte competes. Regarding the IAM market, it is through the distribution network, that new business opportunities are induced, such as new ranges (associated with new EU legislation), or new products.

Veneporte considers that, there are interesting opportunities in the OEM/OES market in the short term. However, from a solid and effective point of view, and having already made some negotiations for 2021, it is the IAM business market where Veneporte feels that there are more opportunities.

These opportunities are sensed through the benchmarking of the market environment. For the OEM and OES markets, an analysis is made of what are the opportunities or potential business opportunities in the customer portfolio in relation to what would be the capacity (design and production) that Veneporte is able to provide within a project related to its competitors. Concerning the IAM markets, Veneporte performs a market-to-market analysis, not only regarding the type of product range sold, but also of what new references might be introduced (most sought after by the market and which Veneporte does not have available in its portfolio), price positioning, evaluation of competition (regarding price/quality) and approval related to EU legislation.

Seizing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the seizing capability for the Domain Design capability as a dynamic capability. These are: networking activities as a vital part of gathering information about target markets. (Breznik et al., 2019), goal-oriented networking activities as a vital part for gathering information about clientele – additional projects, potential/new customers – new business projects (Breznik et al., 2019), and employees play an active part in marketing activities/processes (especially employees working as business analysts and project managers) recognising the changing costumers' needs. (Breznik et al., 2019).

The process of recognising the "right" opportunities as a way of developing the seizing capabilities within the domain design capability, is a task of the sales team responsible for the follow-up of the customers portfolio. After doing a pre-analysis of the opportunity, the sales team present it to the top management, therefore giving or not approval for a technical pre-study.

Moreover, Veneporte considers that the markets where it has been able to fit most of the opportunities is in the IAM market. However, Veneporte is currently competing for an OEM project of relevant economic and strategic interest. This strategic placement reflects the path the company has taken so far. The fact that Veneporte does not exclusively work for the OEM/OES market, ends up giving other opportunities due to the characteristics of Veneporte's product, taking advantage of the capacity and flexibility of the resources to maximize results.

Additionally, Veneporte considers costumers' needs when developing its business strategies. Therefore, if it is not paying attention to the needs of strategic customers, a significant part of the business could be lost.

Finally, it is considered that Veneporte has a strong seizing capability deployment.

Reconfiguring Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the reconfiguring capability for the Domain Design capability as a dynamic capability. These are: constantly improving customers' loyalty and satisfaction. (Breznik et al., 2019), constantly establishing, building, promoting and nurturing longterm partnerships with key customers, partners, employees, and competitors (Breznik et al., 2019).

The customer retention rate for the last five years at Veneporte is about 90% on all three markets, OEM, OES and IAM, a reflect of costumer's loyalty and satisfaction.

Veneporte is currently in a long-term partnership with a direct competitor for a market entrance strategy, one of the largest players in the world (tier 1). The Veneporte product range is being supplied directly as product range for this partner.

Additionally, along with competitors, Veneporte has been continuously working with universities, R&D institutions, suppliers, and distributors demonstrating a strong tendency to partnership through a diverse range of stakeholders. This competence is a strong evidence of the reconfiguring capability.

7.6. Case Summary

According to Yin (2009), the case study evidence analysis is one of the most underdeveloped and most challenging aspects of undertaking case studies. The analytical tool to be used is the explanation building due to the explanatory nature of the present case study (Yin, 2009).

Therefore, the explanation building will take place in a narrative form reflecting some theoretically significant propositions and connecting them through the results of the level of the design capabilities deployment evidenced through the case study.

The pyramidal supply chain organization directly impacts the nature of the firms involved in the automotive industry. The automobile modular architecture led to the emergence of mega suppliers who have captured most of the pyramid's first tier (Frigant, 2009). Through these lenses, the only firms capable of satisfying carmakers' demands today are large companies – mega suppliers. Consequently, leaving no room for SMEs in the pyramid's first tier, relegating them to the second tier and often lower.

These mega suppliers were able to trigger three main mechanisms that led them to build barriers for the entry of new actors such as SMEs. They managed to develop new competencies (in Design, components integration, own supply chains management). Also, carmakers encouraged follow sourcing (when a single module supplier is chosen to supply all the carmaker factories manufacturing one and the same model) requiring a global presence. Finally, mega suppliers were able to innovate using modular architecture to incorporate more and more technology and functionalities (Frigant, 2009).

Through Frigant (2016), it became evident that the incomplete modularity of the automobile architecture created a strategic opportunity for SMEs (as there is not a strict isomorphism between product architecture and organization, modules are not the only parts that OEMs buy, and OEMs are not characterized by a constant single degree of vertical integration throughout the assembly of its vehicles).

Therefore, SMEs are still able to rise to the top tier of the supply chain provided they develop specific capabilities to strategically position them accordingly and overtake the barriers built by the mega suppliers. The development of Design capabilities fosters the rise of SMEs to the top of the established pyramid.

Veneporte is a Portuguese SME dedicated to the development, production, and distribution of a full range of exhaust systems modules. It operates at the top of the automotive network supply chain pyramid as tier 1 supplier.

This SME fits on the referred gap partially due to historical reasons concerning the protectionism that the Automobile Assembly Law gave during the post war period until the full EEC adhesion. It enabled Veneporte to be the supplier of almost all the OEMs installed in Portugal by that time. It was also in this decade that Veneporte started the tubes production, not only to be incorporated in the production of exhaust system modules but also to be sold to other products and applications.

Currently, Veneporte is acknowledged as a relevant market player due to its investment on Design capabilities that led to its state-of-the-art product range portfolio reflecting its strategic market positioning.

For an insight of how Veneporte develops capabilities as dynamic capabilities, it is presented the research results for its manifestations in sensing, seizing and reconfiguring capabilities regarding its design capability.

Design capabilities and the role of managers have been recognised as a key component in developing dynamic capabilities. Design capability as a dynamic capability is a capability by which the level of deployment of sensing, seizing and reconfiguring capabilities is at in Veneporte at high level. Veneporte is an example of how design, as a dynamic capability can be successfully deployed and developed. A deeper investigation of the manifestations of the design capability fosters leads to present some of the practices and activities that undergird design capability at Veneporte.

Design capability is the ability to sense, seize and reconfigure in product design, process design and domain design activities. Veneporte shows a strong ability on the full range. Regarding the sensing capability, the use of effective communication and networking with all stakeholders, enables managers to sense opportunities inside and outside the firm. Moreover, these skills allow them to receive and collect the right information at the right time. The general manager and R&D manager at Veneporte are able to systematically sense their environment, not simply observe it.

At Veneporte, the ability to seize the right opportunities is a result of the firm's business model as being a tier 1 supplier for the automotive network. Gathering the information and knowledge that enables the firm to recognise opportunities is primarily a result of its networking activities and long-term and trust-based partnerships with customers, suppliers, universities, employees, and other partners.

However, recognising opportunities by itself might not be enough, as they must be further developed. After the opportunities are recognised as potential opportunities, they must be exploited through a recombination of the firm's resource base.

As already referred, Veneporte has its own design process based on IATF 16494 (from APQP). As this feature is an incredibly important seizing ability that enables the firm to recognize the needs of recombining its resource base, it is not enough to establish a strong reconfiguration capability.

The deficient structuring of the prioritization of activities, as there is no program management, is one of the biggest gaps in the R&D department of Veneporte, since top management has a significant share of interference in the programming of the activities of the design process.

On what relates adopting new/improved knowledge and technologies, and transforming them into market-oriented solutions, Veneporte is successful in applying the outputs of the R&D and Benchmarking activities in association with its product development partners, which is considered to be a strong evidence of the reconfiguring capability.

Through the proposed conceptual framework it was acquired that one of the most crucial relation in the Dynamic Capabilities theory is perhaps the one with performance. Zott (2003) acknowledged that what should be considered is an indirect link between dynamic capabilities and performance. Dynamic capabilities may change the resource base to a new resource base that may influence new product market positions, which in turn may affect performance (Zott, 2003). Moreover, this approach is fully consistent with early proposals that dynamic capabilities may be a key antecedent of firms' strategic choices, such as entry strategies, entry timing, or diversification (Teece et al., 1997). However, due to the strong prominence initially put on the direct link to performance, those suggestions remained largely unexplored (Barreto, 2010).

The case with Veneporte evidences these theories. The development of Design capabilities, evidenced through the deployment of sensing, seizing and reconfiguring capabilities in product design, process design and domain design activities, foster the relation with OEMs for a tier 1 positioning strategy on the automotive supply chain. This strategical positioning enables a technology advantage for another market - the IAM.

Moreover, Veneporte desires to have a direct and technological relation with the OEMs in order to further develop the IAM market as way of obtaining a technological competitive advantage. The development of Design capabilities as a Dynamic capability has an indirect link with performance, however, is key to a business strategy as technological advantage. Therefore, in accordance with the biggest sales share of Veneporte, that is from the IAM market.

8. Case Study Report – KLC

8.1. Introduction

Figure 59

KLC Institutional Logo

Note. Source: KLC - Indústria de Transformação de Matérias Plásticas, Lda.

KLC is a Portuguese small and medium-sized enterprise (SME) dedicated to the development, production, and distribution of a full range of plastic parts and modules for the automotive, medical, and healthcare, consumer electronics and industrial markets.

Thus, KLC is a custom moulding company with thorough experience and know how in plastic part decoration and assembly of parts for high end applications such as automobile interior trim. KLC's core business is the production and supply of part assemblies mainly for the automotive industry and consumer electronics. KLC's greatest added value relies in its flexibility and quality consistent to all production processes and practices as is IATF 16949 certified.

KLC was established in 1993, from a direct invitation by the German firm Keune & Lauber GmbH to Mr. Pedro Colaço (hence the initials KLC) to start an operation in Portugal for the assembly of plastic parts that were initially produced (injected) in Germany and later to return to Germany. Subsequently, KLC gained skills and, in 1997, started its own production of injected plastic parts. Later, KLC expanded the production of plastic parts, specifically for mobile phones, an activity that remained until the year 2000. It was by this time that production began to shift to the automotive industry, as the market to produce mobile phones in Europe fell into decay. This shift from two completely different market domains was already a sign of a strong capability of reconfiguration of its resource base. This capability will later be the subject to investigation for this case.

Thus, by 2001, KLC started the production of injected plastic parts for the automotive industry. It was also by this time that KLC decides that, in addition to plastic injection, it should add more value to its production as the plastic injection parts market for the automotive industry was starting to be relatively saturated. KLC invested in a painting line, for a major project of a car radio panel for the BMW model 5 (E39 series). Subsequently, investments were made in all other assembly processes (such as welding), always pursuing the strategy of increasing added value to produce parts and modules as part of the strategical position of KLC. This strategy came with the development of process design capabilities that allowed KLC to have its own research and development projects with a strong network of partners, positioning itself as a specialist for the production of decorative plastic parts for automotive interior trim and In-Vehicle Infotainment (IVI) modules.

In 2016, the break with the German partner occurs due to divergences in the company's market strategy, aiming to leave the automotive industry. The shareholding of the German partner is sold to Pedro Colaço, who until today holds 100% of the company's share capital and is the current General Manager.

With a capital amount of €105.000, KLC closed the 2020 year with a sales amount of €12 Million.

8.2. Organisational Structure and Supply chain position

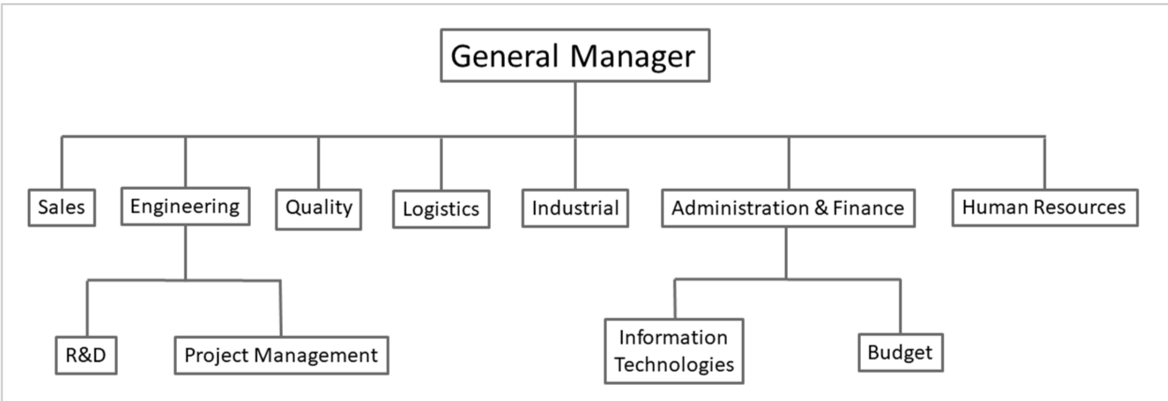
Towards exceeding the levels of quality required by its customers, KLC strives to ensure a quality focused environment towards quality. The approach to quality is done regularly through GEMBA[8] as a way to assure and exceed costumers' requirements promoting the development of continuous improvement. As KLC is a tier 1 and 2 automotive supplier the current standard category is IATF 16949, so the company is familiar and employs all the automotive quality tools such as total quality management (TQM), quality functional deployment (QFD), 5s, Failure Mode and Effects Analysis (FMEA).

The organisational structure of KLC is a typical functional organisation (Figure 60), currently with 240 employees including internal, external, direct, and indirect.

KLC is a tier 1 and 2 automotive supplier for all the delivering products for the automotive market.

Figure 60

KLC Organizational Chart



Note. Source: KLC - Indústria de Transformação de Matérias Plásticas, Lda.

[8] The Gemba Walk is an opportunity for firm staff to stand back from their day-to-day tasks and walk the floor of their workplace to identify wasteful activities. Developed by Taiichi Ohno.

8.3. Markets, Product Range and Technologies

8.3.1. Markets and Product Range

KLC is committed to the development, production, and distribution for four main markets, the Automotive (as tier 1 and 2), medical and healthcare, consumer electronics and industrial applications. These four markets have different characteristics even if the product is the same. However, a completely different level of technology is used for the automotive market where most of the complex parts and added value are produced.

KLC works as tier 1 and 2 supplying the automotive market meaning delivering state of the art technology, high quality standards and just in time kind of distribution.

KLC’s automotive product range is characterized by the production of single parts and assembly parts. Assembly parts do have a higher integration of technology, namely in the surface treatment, e.g., painting. KLC is an experienced partner in the supply of interior decorated automotive parts, namely instrument clusters, In-Vehicle Infotainment (IVI), knobs and Switches.

KLC supports customers and their projects from the tooling concept stage, done in the perspective of optimized part production with reduced costs, provides packaging solutions and ensures reliability and quality in the product supply. At the core of the process design capabilities of KLC is an early integration in the development process and a simultaneous work with the customer at the concept of the component for an optimal industrialization of the product.

The location of KLC, at Marinha Grande, in the heart of the Portuguese polymer injection tooling manufacturing cluster, is an advantage with a strong positive effect on the project management hence on the success of the final product.

8.3.2. Technologies

a) Polymer Injection

The polymer injection process equipment is state-of the-art at KLC; so it is correctly adjusted to produce each particular part. KLC's production team uses the latest process methods that adapts to customers' requirements for different technologies such as one, two or three shot (1K, 2K, 3K), in-mould labelling (IML) and in-mould decoration (IMD).

KLC's tooling know how is employed in the product design stage, with its technical team providing inputs that aim for an enhanced production process for an improved plastic part, optimising de process design process.

Figure 61

An Example of a Typical Interior Trim Painted Simple Part.

Note. Source: KLC - Indústria de Transformação de Matérias Plásticas, Lda.

b) Decoration

Paitining

KLC has three automated painting lines prepared for the application of water based and solvent based materials, pre-cleaning, conventional and UV curing. KLC has experience in the production of matt, high gloss, and metal look finishing parts.

PVD Coating

Physical vapor deposition (PVD) is a method of vacuum deposition which can be used to produce thin films and coatings. PVD is characterized by a process in which the material goes from a condensed phase to a vapor phase and then back to a thin film condensed phase. KLC leads the PVD process technology as a clean chrome plating by vacuum sputtering, producing environmentally friendly, high resistant and economical parts.

Figure 62

An Example of a Typical Interior Trim Complex Part.

Note. Source: KLC - Indústria de Transformação de Matérias Plásticas, Lda.

Laser engraving / Pad printing / Silk screening

KLC employs state-of-the art laser engraving process with vision detection technology. Moreover, KLC's Pad printing (tampography) process can print up to 4 colours. Silkscreen and hot foil are other decorative processes also developed by KLC.

Assembly

The final assembly process of components into modules is performed either in automatic or semi-automatic assembly lines. Process technologies like ultrasonic and vibration welding, heat staking, gluing and mechanical press fit are developed by KLC. Furthermore, each assembly stage is visually monitored.

8.4. Field Work

The case study of KLC followed scrupulously the defined research design. Therefore, all the methodology used for the investigation for the case study was constructed to answer the initial study's questions.

Moreover, to meet the study's purpose, KLC was selected according the defined five indicators (1) the firm is an SME; (2) the firm must have been active in the market for over 10 years; (3) the firm must be established in Portugal, have local owners (have an independent capital structure); (4) the firm's programmes and business orientation should be comparable (integrated on the automotive supply chain network); and (5) the firm must be willing to participate.

Oral, and written invitations were sent to KLC, particularly to the General Manager, Mr Pedro Colaço (acting also as sales manager) and to the R&D Manager, Mr. Pedro Pires. After, meetings were arranged to describe the study's goals and data collection. The qualitative nature of the study was explained as well as the potential benefits and deficiencies also noting that it would thus be more resource-intensive and time-consuming when it came to collecting and (re)analysing the data.

For the proposed case, it was considered the firm's processes involving R&D, sales, and strategic management. Therefore, three questionnaires were formulated for the main respondents: R&D manager, general manager, and sales manager related to the defined practices that underpin each defined capability (product design, process design and domain design).

The target respondents of the interviews, which were narrative in nature, informal recorded (with consent) and subsequently transcribed, were primarily the R&D manager of KLC which constituted our research focus and the general manager. The corresponding interviews took place between 11/03/2021 and 25/03/2021 with Mr. Pedro Colaço and Mr. Pedro Pires respectively. Intended for categorising the data and coding, it was employed thematic analyses/networks (Stirling-Attride, 2001), together with the process of coding (Rubin & Rubin, 2005; Saldaña, 2009).

The current case study report was sent for approval to the correspondents at KLC and was subject to positive comments. Consequently, the report was approved in 21/04/2021.

8.5. Empirical Data and Analysis

8.5.1. Quantitative Data Analysis

Products and Services Characterization

According to Frigant (2016), complex parts tend to be made by suppliers positioned on the first tier of the automotive network supply chain. The supply chain position of the case studied company is key, together with the level of complexity of each supplied product.

For the current case study it is defined as simple parts, single supplied components (single parts). For complex parts it is defined as supplied sub-assemblies (assembled parts). Table 18 shows the current production percentage breakdown of level of part complexity per level of supply chain for each market (for automotive markets, KLC currently acts only as tier 2 supplier). Additionally, production volume for the Automotive corresponds to 92% at KLC, while other markets (medical, electronics and industrial) correspond to 8%.

Table 18

Current Year to Date (YTD) Production Percentage Breakdown of Level of Complexity for Each Market

	Automotive	Others (Medical/Electronics/Industrial)
Simple Parts (Single Parts)	40	70
Complex Parts (Assemblies)	60	30

Note. Source: KLC - Indústria de Transformação de Matérias Plásticas, Lda.

To assess the level of product design (Table 19) and process design (Table 20) involved for each level of part complexity, it is used the framework developed by Akabane et al. (2016). As already referred, Akabane et al. (2016), defines the framework with two axes. A horizontal, where it defines the criterions of classification of the degree of participation in the preparation of drawings. On the vertical axis it is defined the categories (from 1 to 6) in which a supplier can be classified.

Table 19 and 20, show the classification from the data gathered at KLC related to product design and process design of current YTD development projects. It is possible to understand that product design wise, KLC has a low level of development, since the level of product design for 100% of the projects are only proposals for improvement in supplied drawings. It does not make sense for this case study to assess product design capabilities at KLC. On the scope of Process Design, the results show that KLC is 100% responsible for their process with some projects already at industry 4.0 level with system design of connection of production processes and manufacturing equipment. KLC have a R&D department fully dedicated to process design and development.

Table 19

Level of Classification of Product Design of Current Percentage YTD Development Projects According to Akabane et al. (2016)

	Classification Level of Product Design					
	1	2	3	4	5	6
Simple Parts			20			
Complex Parts			80			

Note. Source: KLC - Indústria de Transformação de Matérias Plásticas, Lda.

Table 20

Level of Classification of Process Design of Current Percentage YTD Development Projects According to Akabane et al. (2016)

	Classification Level of Process Design				
	1	2	3	4	5
Simple Parts				10	10
Complex Parts				70	10

Note. Source: KLC - Indústria de Transformação de Matérias Plásticas, Lda.

Likewise, regarding the development stage of the domain design it is used the framework defined by Akabane et al. (2016) based on Ansoff (1970) growth matrix. As referred Ansoff's growth matrix has two axes. The vertical is the market axis, and the horizontal is the products axis. Akabane et al. (2016) defines a horizontal axis where it defines the criterions of classification of the degree of product/market diversification and on the vertical axis it is defined the categories (from 1, 2-1, 2-2 and 3) in which a supplier can be classified.

Table 21

Percentage Breakdown of Parts per Market, Business Domain and Type of Part (Technology)

	Simple Parts (Single Parts)		Complex Parts (Assemblies)	
	Injection	Painting/Decoration	Injection	Painting/Decoration
Automotive	95	5	10	90
Others	1	0	1	0

Note. Source: KLC - Indústria de Transformação de Matérias Plásticas, Lda.

Through the analysis of the data in Table 21, it is possible to conclude that there is a clear strategy of product diversification on the Automotive market through painting and decoration technology processes.

It is also notable that the biggest percentage of complex parts delivered to the automotive tier 1 suppliers have painting and decoration technology incorporated. This reflects the development of a highly specific technology fostering a strategic positioning of a high added value market domain such as the automotive interior trim and In-Vehicle Infotainment (IVI).

Additionally, from table 21, it is also possible to understand that KLC is present on all markets but heavily on Automotive (automotive current share 92% of production, while other markets share is 8%). Through Akabane et al. (2016) domain design classification table, KLC is at level 2-2 (Sales of Different type of parts and technologies to a few costumers), meaning that from Ansoff (1970) matrix it is a clear product development business strategy.

8.5.2. Qualitative Data Analysis

8.5.2.1. Manifestations of Development of Design Capabilities

As a way to understand the logic behind the DCV, the desegregation from the dynamic capabilities microfoundations by Teece (2007) was deployed in a sense that a dynamic capability is a “meta-capability” that transcends an ordinary firm capability (Teece, 2007). For analytical purposes, the current study was based on the desegregation of the design capabilities into sensing, seizing and reconfiguring capabilities. The following tables (Table 10, Table 11, and Table 12) list the practices that underpin each of the design capabilities defined by Akabane et al. (2016).

For a clearer insight of how KLC develops capabilities as dynamic capabilities, its manifestations in sensing, seizing and reconfiguring capabilities are presented regarding design capabilities. Design capability and the role of managers have been recognised as a key component in developing dynamic capabilities.

With the aim of determining dynamic capabilities level of deployment, namely weak, moderate, and strong, each capability was viewed as containing sensing, seizing, and reconfiguring capabilities (Table 9). This classification of the level of deployment, was an output of coding the interviews according to the defined practices underpinning, product design, process design and domain design (see APENDIX – TABLE H, and I).

At KLC, the level of deployment of design capability is at a relative high level, even if the product design capabilities were low. Accordingly, KLC is another example of how dynamic capabilities can be successfully deployed and developed. A deeper investigation of the manifestations of design capability allows us to present some of the practices and activities that undergird the design capability at KLC.

8.5.2.1.1. Process Design Capability

Sensing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the sensing capability for the Process Design capability as a dynamic capability. These are: networking activities to gather information about potential Process Development partners and projects, employees closely follow technological development and science and technology in general, on-going benchmarking activities, identifying new materials, architectures and processes usability testing and assessment and, development of R&D projects (Breznik et al., 2019).

Through these lenses, KLC shows a Moderate level of deployment. KLC considers that networking is critical throughout its business domain in a sense that believes that it cannot be isolated from the world but must live with all the knowledge network around it, such as the competition, suppliers, customers, in short, all the stakeholders that form the complex network that is the automotive industry.

KLC explores this complex network firstly, through a direct relation with its partners. Secondly by research, online research, published scientific articles and related literature. Thirdly, through links with universities and R&D centres. Finally, KLC believes that sharing experiences with other business partners is essential for the development of networking. However, KLC does not have a defined strategy for a planned networking process.

Moreover, presently the company is involved in R&D projects with Universities and customers (University of Minho, University of Coimbra, and Bosch) in the research field of coating recyclable materials. KLC also believes that all its suppliers are also partners, therefore it considers that it is the only way it makes sense to create long-term relationships.

Most of the process development design and R&D team are part of engineering national associations and are actively following technological development and science and technology in general through most employees follow and are interested in science and technology in general by subscribing to magazines and publications related to design and engineering, process wise.

KLC permanently promotes and demands on-going benchmarking activities on the scope of process design as for tooling and machinery to the design team. The company considers that the knowledge acquired through benchmarking, and subsequently implemented through the design process, brings advantages in terms of reducing the process design development time as identifying new materials, architectures, and manufacturing processes for its designs. However, it was not shown evidence of a systematised practice.

As already referred, KLC is currently developing a project in the research field of recyclable materials for polymer coatings. Likewise, KLC is also developing more projects in this same area of automotive interior decoration. These projects have the close collaboration of the University of Aveiro and the University of Coimbra.

Seizing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the seizing capability for the Process Design capability as a dynamic capability. These are: using (or own developed) design process during process development activities, selecting the technologies and features that are to be embedded in the process, the way in which technologies are to be assembled – architecture and how the revenue and cost structure of a business is to be “designed” and if necessary redesigned to meet customer needs through a BOM (Teece, 2007).

KLC does not follow an established design process for its process design and development activities. However, it can map its own process and follow it. The fact that it does not follow a pre-established or that has not a defined process design does not mean that intuitively does not follow its own. Nevertheless, the lack of evidence found on the use of a process design shows that this capability is still in a development stage of a systematized process that can led to a better workflow throughout the realization of its projects by the team.

Despite, the fact that a design process is not implemented throughout the company, and due to the small structure of the R&D team, all the members, individually, have the capability to gather personal skills, hence being able to follow a design process with the support of its manager.

The selection of technologies and features to be embedded in the process design are the result of the defined specifications of the product design and the approved budget for the project. Moreover, KLC integrates the knowledge acquired by the benchmarking activities through brainstorming exercises with the project teams during an initial phase of the design process.

Although there is a BOM structure at KLC, it is a document that currently has a basic structure and has little in-house use. There is no evidence of how design changes are reflected in the development phase through a BOM and into the cost structure of the process.

Summing up, KLC seizing capability for the process design capability is considered to be moderate.

Reconfiguring Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the reconfiguring capability for the Process Design capability as a dynamic capability. These are: new and improved products in line with technological development and market demands, know-how integration, adopting new/improved knowledge and technologies, and transforming them into manufacturing process solutions (e.g., industry 4.0) and finally improving the effectiveness of process development processes. (Breznik et al., 2019).

At KLC the process of reconfiguring, implementing, and adapting for the process design development starts with a planning through a bar chart that illustrates the project schedule. This chart lists the tasks to be performed on the vertical axis, and time intervals on the horizontal axis. Thus, process design and R&D activities are not started without an exhaustive planning of all activities.

Moreover, this planning is built based on the APQP process and subsequently all process design activities are adapted according to the specifications of the product for which the process is to be designed.

Since the program management share the same manager as the R&D team, there is little or no interference from top management or other departments on the design process. The reconfiguration of the team occurs through a planned approach. KLC considers itself to be remarkably successful on embedding the new knowledge (e.g., acquired from R&D activities, benchmarking) in its process design activities.

The process design and development activities effectiveness are measured through several KPIs linked to different stages (gates) of the design and R&D processes. The improvement of the process design and development effectiveness is done through annually defined goals. However, there are no evidence of the systematic use of a document or a process to retain knowledge and know-how for future projects.

Summing up, KLC reconfiguring capability for the process design capability is considered to be strong.

8.5.2.1.2. Domain Design Capability

Sensing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the sensing capability for the Domain Design capability as a dynamic capability. These are: networking activities to gather information about target markets and customers, employees understand their role within the marketing process, on-going industry and competitor benchmarking. (Breznik et al., 2019).

Under these lenses, KLC shows a strong level of deployment. As to what relates to the networking activities in order to tap new opportunities, there are three main channels that KLC explores. Firstly, the needs of customers, who may have different domains, for example the resolution of a problem, or information about a new technology that needs to be used and that might not exist, although KLC might be able to develop.

Secondly, benchmarking and marketing studies provided by the different associations that KLC is part of are used, which are considered to be especially useful as they show valuable information such as field research, industry ratios and automotive trends.

Thirdly, business conventions, international and national fairs where the network of contacts expands, and valuable information is exchanged with technological suppliers, industrial partners and competitors.

Therefore, KLC considers that, there is a major transformation in the automotive industry due to electrification of cars. As a result, KLC considers that the percentage, of the technical polymers incorporation in the design of automobiles will increase, not only for economic reasons, but also for technical reasons.

These opportunities are sensed through the benchmarking of the market environment over studies provided by different associations that KLC is part of as referred.

Additionally, KLC considers that the collaboration with the Automotive suppliers and technological leaders in the Automotive industry is extremely important for KLC. Currently, KLC collaborates with a tier 1 supplier (Bosch) and an OEM (Autoeuropa) to develop some innovative concepts of parts in technical polymers.

Seizing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the seizing capability for the Domain Design capability as a dynamic capability. These are: networking activities as a vital part of gathering information about target markets, goal-oriented networking activities as a vital part for gathering information about clientele – additional projects, potential/new customers – new business projects, and employees play an active part in marketing activities/processes (especially employees working as business analysts and project managers) recognising the changing costumers' needs. (Breznik et al., 2019).

The process of recognising the "right" opportunities as a way of developing the seizing capabilities within the domain design capability, is at KLC a non-systematized process.

Therefore, KLC recognizes that it is essential to have differentiating factors and that is why it strives to ensure that the "right" opportunities are the projects that have the greatest possible added value, with innovation being one of them.

Moreover, KLC considers that the market sector where it has been able to fit most of the opportunities is the Automotive market, tier 1 suppliers for interior trim and cockpit modules (instrument clusters, In-Vehicle Infotainment (IVI), knobs, and switches).

Additionally, KLC considers costumers' needs when developing its business strategies. Therefore, if it is not paying attention to the needs of strategic customers, a significant part of the business could be lost, consequently it considers to be the bases for the company business strategy.

Summing up, it is considered that KLC has a strong seizing capability deployment.

Reconfiguring Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the reconfiguring capability for the Domain Design capability as a dynamic capability. These are: constantly improving customers' loyalty and satisfaction, constantly establishing, building, promoting and nurturing long-term partnerships with key customers, partners, employees, and competitors (Breznik et al., 2019).

The customer retention rate for the last five years at KLC is about 100% on all markets, automotive, medical, and healthcare, consumer electronics and industrial, hence a reflection of costumer's loyalty and satisfaction.

KLC is currently in a long-term partnership with a direct competitor for a market entrance strategy.

Additionally, along with competitors, KLC has been continuously working with two universities for R&D projects for the development of painting and decorative processes. This competence is a strong evidence of the reconfiguring capability.

8.6. Case Summary

According to Yin (2009), the case study evidence analysis is one of the most underdeveloped and most challenging aspects of undertaking case studies. The analytical tool to be used is the explanation building due to the explanatory nature of the present case study (Yin, 2009).

Therefore, the explanation building will take place in a narrative form reflecting some theoretically significant propositions and connecting them through the results of the level of the design capabilities deployment evidenced through the case study.

As already referred, through Frigant (2016), it became evident that the incomplete modularity of the automobile architecture created a strategic opportunity for SMEs enabling them to rise to the top tier of the supply chain provided they develop specific capabilities to strategically position them, accordingly, overtaking the barriers built by the mega suppliers.

KLC has developed specific capabilities not on product design, but on process design, granting the access as an extremely specific technology supplier to tier 1 mega suppliers (Bosch, Visteon and Continental). The focus on specific technologies such as painting, PVC coating and pad printing, triggered KLC to a high added value decorative interior polymer injection complex parts that integrate electronic modules supplied by the top three best in class In-Vehicle Infotainment (IVI) companies.

Currently, KLC is acknowledged as a relevant market player due to its investment on Design capabilities that led to its state-of-the-art product range portfolio reflecting its strategic market positioning, even though is not the target is currently not the top of the supply chain pyramid.

For an insight of how KLC develops capabilities as dynamic capabilities, it is presented the research results for its manifestations in sensing, seizing and reconfiguring capabilities regarding its design capability.

Design capabilities and the role of managers have been recognised as a key component in developing dynamic capabilities. Design capability as a dynamic capability is a capability by which the level of deployment of sensing, seizing and reconfiguring capabilities is found at a high level. Accordingly, the KLC case is another example of how dynamic capabilities can be successfully deployed and developed. A deeper investigation of the manifestations of design capability allowed presenting some of the practices and activities that undergird the design capabilities at KLC. The Design capability is the ability to sense, seize and reconfigure in product design, process design and domain design activities. At KLC, the level of deployment of design capability is at a high level, even if the product design capabilities were low.

Regarding the sensing capability, the use of effective communication and networking with all stakeholders, enables managers to sense opportunities inside and outside the firm. Moreover, these skills allow them to receive and collect the right information at the right time. Both the general manager and the R&D manager at KLC are able to systematically sense their environment, not simply observe it.

Although the process of recognising the “right” opportunities as a way of developing the seizing capabilities is at KLC a non-systematized process. However, the firm recognizes that it is essential to have differentiating factors as a strategic positioning for the company business model. Therefore, the “right” opportunities being the projects where the greatest possible added value can be incorporated. Consequently, the development of process design capabilities reflects the referred business strategy.

Nevertheless, recognising opportunities by itself might not be enough, as they must be further developed. After the opportunities are recognised as potential opportunities, they must be developed through a recombination of the firm’s resource base.

As already referred, KLC does not follow an established and systematized design process for its process design and R&D activities however, due to the small structure of the R&D team, all the members, individually, have the capability to gather personal skills, therefore being able to follow a design process with the support of its manager. Moreover, the design activities are not initiated without an exhaustive planning. This planning is built based on the APQP process and subsequently all its deliverables are adapted accordingly.

On what relates adopting new/improved knowledge and technologies, and transforming them into market-oriented solutions, KLC is successful applying the outcomes of the R&D and Benchmarking activities in association with its process development partners, which is considered to be a strong evidence of the reconfiguring capability. However, these activities are not systematized although both managers find it extremely valuable.

The case with KLC evidence theories from different academics that relate the dynamic capabilities with performance (Teece et al., 1997, Zott, 2003, and Barreto 2010). Especially that the dynamic capabilities might change the resource base to a new resource base and subsequently may influence new product market positions, which in turn may affect performance.

The development of Design capabilities at KLC evidenced through the deployment of sensing, seizing and reconfiguring capabilities in, process design and domain design activities foster the relation with specific tier 1 suppliers for an extremely specific product portfolio: interior trim and In-Vehicle Infotainment (IVI). This strategic positioning enables a technology advantage in comparison with other polymer injection firms operating on the automotive market.

Summing up, the development of Design capabilities as a Dynamic capability has an indirect link with performance, however, is key to a business strategy as technological advantage. Therefore, in accordance with the biggest sales share of KLC that is from the Automotive market.

9. Case Study Report – Sodecia

9.1. Introduction

Figure 63

Sodecia Institutional Logo

Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

Sodecia is a Portuguese enterprise company dedicated to the development, production, and distribution of a full range of automotive body systems modules. From Power Train systems to BIW parts and Safety and Mobility systems, Sodecia is an automotive global supplier that operates in two main levels of the automotive supply chain, as tier 1 and 2.

Founded in 1980, in 2020 Sodecia completed its 40th anniversary. Sodecia's growth begins through an internationalization process. This process begins in 1997 with a first acquisition made in Brazil. During this time, Brazil entered an economic recession that caused most of the foreign companies that had internationalized to Brazil in great difficulties, which caused the local production capacity to be substantially reduced. Therefore, Sodecia made a large investment (through a bank loan) not only in the acquisition, but also in the modernization of the production shop floor, the only way out would be to make this process a success. Counter-cyclical projects arose during this period by OEMs Ford and Honda, which, due to the scarcity of supply, used the existing production capacity of Sodecia in Brazil. The success of this operation provided the company with sufficient financial resources not only to settle the loan, but also to invest in new industrial units, continuous refurbishment of equipment and new production technology.

This second trend of internationalization at Sodecia takes place at the time of the economic crisis, in 2008 in a countercyclical trend. Sodecia (that by that time had some financial muscle and know-how in restructuring industrial units) with the goal of, after the acquisition, setting the units to an economically interesting situation, continued its international expansion ambition. Thus, in 2009, the company expanded to Germany, the United States of America and Canada, increasing and diversifying its product offering portfolio. After this countercyclical period of internationalization, Sodecia progressed to India, Africa (South Africa), and Asia (Thailand) following the footprint of its major OEM customers.

The following acquisition strategy was made not only to complement Sodecia's technological skills and portfolio, but with the goal of pursuing the footprint of its main customers, continuously through a sight of increasing and consolidate its position on the supply chain of the Automotive industry.

With a capital amount of €376.000 (Sodecia SGPS), 44 worldwide locations, Sodecia closed the 2020 year with a sales amount of €759 Million.

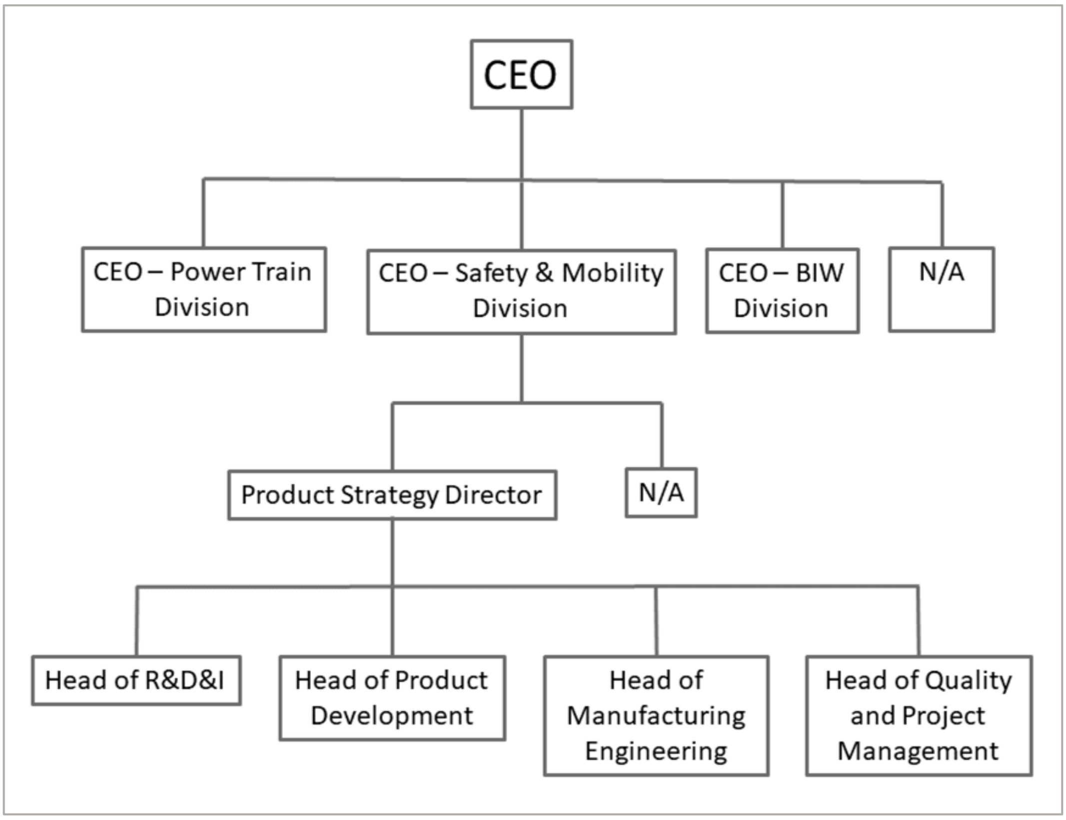
9.2. Organisational Structure and Supply chain position

The organisational structure of Sodecia is a typical functional organisation (Figure 64), currently with 7086 employees including internal, external, direct, and indirect. As Sodecia is a tier 1 and 2 automotive supplier, the current standard category is IATF 16949, so the company is familiar with and employs all the automotive quality tools such as total quality management (TQM), quality functional deployment (QFD), 5s, Failure Mode and Effects Analysis (FMEA).

Sodecia is a tier 1 and 2 automotive supplier for all the delivering products for the OEM/OES market.

Figure 64

Sodecia Organizational Chart



Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

9.3. Markets and Product Range

9.3.1. Markets

Sodecia is committed to the development, production, and distribution for two main markets, the OEM and tier 1 suppliers. These two markets have different characteristics hence the different product domains supplied. Sodecia works as tier 1 supplier for the OEM market meaning delivering state of the art technology, complex parts, using high quality standards and just in time (JIT) distribution.

The tier 1 market requires that Sodecia must deliver as tier 2 supplier, although it does not imply the necessity of product development capabilities, thus delivering already designed products (single parts), but still with the need of process design development capabilities.

9.3.2. Product Range

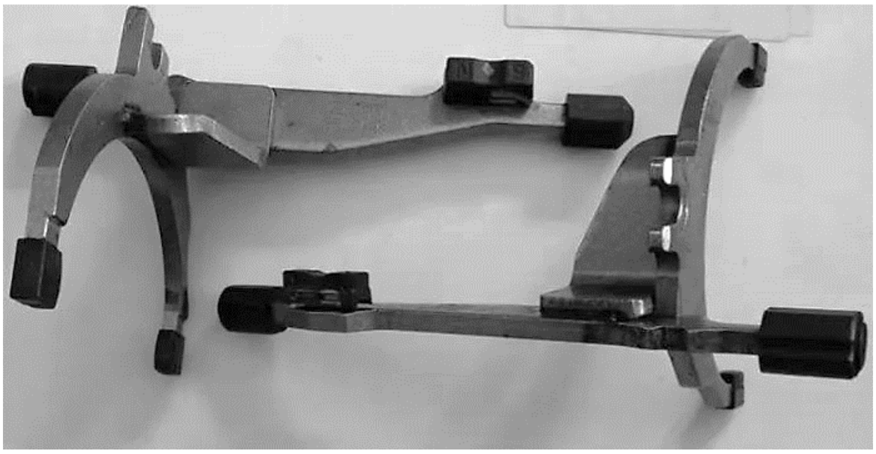
Sodecia product range is typified by three main business domains, power train, body-in-white (BIW) and safety & mobility, which unfold into seven technological families: shift systems (SS), park brakes (PB), BIW parts, cross-car beams (CCB), seat belt height adjusters (SBHA), tie down loops (TDL) and thread extrusions (TE).

Shift Systems (SS)

Sodecia designs, manufactures, and delivers to OEMs, modular gearshifts for dual clutch transmission (DCT) and single clutch transmissions (Figure 65).

Figure 65

An Example of Shift Forks for Single Clutch Transmission



Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

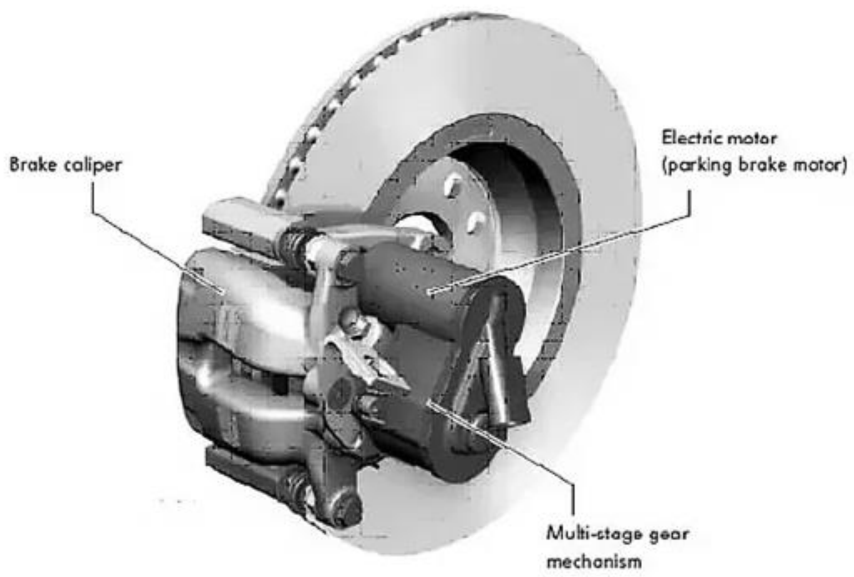
The modular gearshift design allows flexible use in different vehicle models and integrates great synergy effect. Thanks to the use of modern design programs and stress calculations the weight and space optimised gearshift system fulfil the highest quality requirements of OEMs.

Park Brakes (PB)

Sodecia designs, produces, and supplies to OEMs, modular electronic actuated parking brakes, cable-pulling type, and motor on calliper type (Figure 66).

Figure 66

An Example of a Motor on Caliper Electric Actuated Park Brake



Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

The parking brake is a mechanism used to keep the vehicle securely motionless when parked. Parking brakes often consist of a cable connected to two wheel brakes, which is then connected to a pulling mechanism. In most vehicles, the parking brake operates only on the rear wheels. The mechanism may be a hand-operated lever, a straight pull handle located near the steering column, a foot-operated pedal located with the other pedals or electronic actuated.

Current trend is the electronic actuated park brake which removes any hand operated lever from the inside of the car giving more possibilities for the interior design of automobiles.

Body in White (BIW) Parts

Body in white (BIW) is the stage in automobile manufacturing in which a car body's frame has been joined together, that is before painting and before the motor, chassis sub-assemblies, or trim (glass, door locks/handles, seats, upholstery, electronics, etc.) have been integrated into the structure. Body in white parts assembly involves different technologies such as welding, riveting, clinching, bonding, or laser brazing.

Figure 67

An Example of a Complete BIW Car Chassis Frame

Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

Sodecia produces parts to be assembled on the final body frames such as: wheel arches, side members, roofs, rockers, rear floors, rear ends, main floors, front rails, fire walls and doors.

Cross-car beams (CCB)

Sodecia designs, manufactures, and supplies cross-car beam modules as tier 1 to OEMs. It was the product that gave Sodecia the automotive supply chain top position. It is the product which Sodecia has more product design and process design know-how.

Figure 68

An Example of a Cross-Car Beam and Relative Location in the Automobile

Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

The Cross-car beam is a module located in the front part of the automobile, under the instrument panel (IP) and, is typically designed to support the steering column module, airbags, the instrument panel (IP), and other systems differing on the architecture of the car.

The cross-car beam module main function besides the support of the steering system and instrument panel is the absorption of impact energy, reducing the steering wheel displacement in case of a collision, reduction of the overall instrument panel vibration and, to provide a superior stiffness and precision to the steering wheel system and to the overall car.

Seat Belt Heigh Adjusters and Tie Down Loops (SBHA and TDL)

The automotive seat belt height adjuster is a module of the seat belt system which adjusts the shoulder height of the seat belt. It is present mostly for the driver and the front passenger seat of the vehicle. Automotive seat belt height adjuster assembly modules are mounted on a vehicle B-pillar to attach the tie down loop (or D-ring belt) anchorage. The height adjuster assembly can be moved vertically to optimally locate the seat belt and D-ring.

Figure 69

An Example of a Seat Belt Height Adjuster

Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

Sodecia designs, manufactures, and supplies seat belt height adjusters along with their tie down loop anchorage modules as tier 1 to OEMs.

Thread Extrusions (TE)

Thread extrusions are extremely simple parts that require state of art deep drawn hot forming technology. They are often welded or bonded to the automobile frame, usually to the body in white, but can also be found as part of modules or systems.

Sodecia supplies thread extrusions as a tier 2 automotive supplier.

9.4. Field Work

The case study of Sodecia followed scrupulously the defined research design. All the methodology used for the investigation for the case study was constructed to answer the initial study's questions.

Moreover, to meet the study's purpose, Sodecia was selected according the defined five indicators. (1) the firm is an SME; (2) the firm must have been active in the market for over 10 years; (3) the firm must be established in Portugal, have local owners (have an independent capital structure); (4) the firm's programmes and business orientation should be comparable (integrated on the automotive supply chain network); and (5) the firm must be willing to participate.

Oral, and written invitations were sent to Sodecia, particularly to the Product Strategy Director, Mr José Noronha (acting also as R&D Manager). After, a meeting was arranged to describe the study's goals and data collection. The qualitative nature of the study was explained as well as the potential benefits and deficiencies also noting that it would thus be more resource-intensive and time-consuming when it came to collecting and (re)analyzing the data.

For the proposed case, it was considered the firm's processes involving R&D, sales, and strategic management. Therefore, three questionnaires were formulated for the main respondents: R&D manager, general manager, and sales manager related to the defined practices that underpin each defined capability (product design, process design and domain design).

The target respondent of the interviews, which were narrative in nature, informal recorded (with consent) and subsequently transcribed, was primarily the Product Strategy Director of Sodecia which constituted our research focus. The interview took place in 01/04/2021 with Mr. José Noronha. Intended for categorising the data and coding, it was employed thematic analyses/networks (Stirling-Attride, 2001), together with the process of coding (Rubin and Rubin, 2005; Saldaña, 2009).

During the production of this report, there was the need for a second interview as way to further develop the embedded case of the Sodecia's Cross-Car Beam product.

The current case study report was sent for approval to the correspondent at Sodecia and was subject to positive comments. Therefore, the report was approved in 25/05/2021.

9.5. Empirical Data and Analysis

9.5.1. Quantitative Data Analysis

Products and Services Characterization

According to Frigant (2016), complex parts tend to be made by suppliers positioned on the first tier of the automotive network supply chain. Consequently, the supply chain position of the case studied company is key, together with the level of complexity of each supplied product.

For the current case study it is defined as simple parts, single supplied components (BIW parts and Thread extrusions). For complex parts it is defined as supplied assembled modules (Shift Systems, Park Brakes, Cross-car beams and Seat Belt Height Adjusters). Table 22 shows the current production percentage breakdown of level of part complexity for each market. This data is in line with the hypotheses from Frigant (2016) as 100% of complex parts production are supplied as Tier 1.

Table 22

Current Year to Date (YTD) Production Percentage Breakdown of Level of Complexity for Each Market

	Tier 1	Tier 2
Simple Parts (Single Parts)	50	10
Complex Parts (Assemblies)	40	0

Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

To assess the level of product design (table 23) and process design (table 24) involved for each level of part complexity, it is used the framework developed by Akabane et al. (2016). As already referred, Akabane et al. (2016), defines the framework with two axes. A horizontal, where it defines the criterions of classification of the degree of participation in the preparation of drawings. On the vertical axis it is defined the categories (from 1 to 6) in which a supplier can be classified.

Table 23 and 24, show the classification from the data gathered from Sodecia related to product design and process design of current YTD development projects. It is possible to understand that product design related, Sodecia has a high level of development, since 100% of the projects for complex parts are fully Sodecia responsibility to develop, while simple parts projects are built to print with minor proposed changes on the design. On the scope of Process Design, the results show that Sodecia is also responsible for the design of manufacturing equipment as jigs and tooling molds with 20% of the development projects being already designed to industry 4.0 standards.

Table 23

Level of Classification of Product Design of Current Percentage YTD Development Projects According to Akabane et al. (2016)

	Classification Level of Product Design					
	1	2	3	4	5	6
Simple Parts			30			
Complex Parts						70

Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

Table 24

Level of Classification of Process Design of Current Percentage YTD Development Projects According to Akabane et al. (2016)

	Classification Level of Process Design				
	1	2	3	4	5
Simple Parts				10	10
Complex Parts				70	10

Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

Likewise, regarding the development stage of the domain design it is used the framework defined by Akabane et al. (2016) based on Ansoff (1970) growth matrix. As referred Ansoff's growth matrix has two axes. The vertical is the market axis, and the horizontal is the products axis. Akabane et al. (2016) defines a horizontal axis where it defines the criterions of classification of the degree of product/market diversification and on the vertical axis it is defined the categories (from 1, 2-1, 2-2 and 3) in which a supplier can be classified.

Table 25

Current Development Projects per Market, Business Domain and Type of Part in Percentage.

	Power Train		BIW	Safety & Mobility			
	SS (COMPLEX PARTS)	PB (COMPLEX PARTS)	BIW Parts (SIMPLE PARTS)	CCB (COMPLEX PARTS)	SBHA (COMPLEX PARTS)	HDTL (COMPLEX PARTS)	TE (SIMPLE PARTS)
OEM	2	8	0	12	9	9	50
Tier 1	0	0	10	0	0	0	0

Note. Source: SODECIA - Participações Sociais, SGPS, S.A.

Through the analysis of this data Table 25, it is possible to conclude that there is a clear strategy of product diversification on the OEM market. Moreover, there is also a clear shift to automotive interior modules such as the cross-car beams, seat belt heigh adjusters and tie down loops, a clear sign of the future product strategic positioning of Sodecia towards the automotive electrification trend.

From table 22, it is also possible to understand that Sodecia is present on both markets but heavily on OEM. Through Akabane et al. (2016) domain design classification table, Sodecia is at level 3 (Sales of Different type of parts to many costumers), meaning that from Ansoff (1970) matrix it is a clear diversification business strategy.

9.5.2. Qualitative Data Analysis

9.5.2.1. Manifestations of Development of Design Capabilities

As a way to understand the logic behind the DCV, the desegregation from the dynamic capabilities microfoundations by Teece (2007) was deployed in a sense that a dynamic capability is a “meta-capability” that transcends an ordinary firm capability (Teece, 2007). For analytical purposes, the current study was based on the desegregation of the design capabilities into sensing, seizing and reconfiguring capabilities. The following tables (Table 10, Table 11 and Table 12) list the practices that underpin each of the design capabilities defined by Akabane et al. (2016).

For a clearer insight of how Sodecia develops capabilities as dynamic capabilities, its manifestations in sensing, seizing and reconfiguring capabilities are presented regarding design capabilities. Design capability and the role of managers have been recognised as a key component in developing dynamic capabilities.

With the aim of determining dynamic capabilities level of deployment, namely weak, moderate, and strong, each capability was viewed as containing sensing, seizing, and reconfiguring capabilities (Table 9). This classification of the level of deployment, was an output of coding the interviews according to the defined practices underpinning, product design, process design and domain design (see APENDIX – TABLE J, K, and L).

At Sodecia, the level of deployment of design capability is at a high level. Accordingly, Sodecia is an example of how dynamic capabilities can be successfully deployed and developed. A deeper investigation of the manifestations of design capability allows us to present some of the practices and activities that undergird the design capability in Sodecia.

9.5.2.1.1. Product Design Capability

Sensing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the sensing capability for the Product Design capability as a dynamic capability. These are: networking activities to gather information about potential Product Development partners and projects, employees closely follow technological development and science and technology in general, on-going benchmarking activities, identifying new materials, architectures and processes usability testing and assessment and, development of R&D projects (Breznik et al., 2019).

Through these lenses, Sodecia shows a strong level of deployment. Sodecia considers that networking is very important for their business. This is evidenced through the job description of people working for product development and R&D at Sodecia, namely the chief product engineers (focused on the product) and key account managers (focused on the costumer). At the intersection of these two job functions, product design networking is built. Across this way it is possible to articulate a matrix view of the binomial product/customer that reveals the current trends and relevant information for future projects. Consequently, Sodecia has specific strategies for doing planned networking as there are routines in the management model, which organize employees' activities and direct them towards the creation of networking.

Sodecia, has some short-term partnerships for product design with some Universities, however no long-term partnerships have been established.

Regarding the follow-up of science and technology, Sodecia shows weak evidence of capabilities, since there a very limited number of employees members of professional associations and following-up on technological developments and science and technology in general.

Sodecia promotes and demands on-going benchmark activities not only from competitors' products but also for interface parts of the developed product. It is through the benchmarking analysis, the technical specifications of customers and suppliers and, by quality problem solving, that new materials, architectures, and manufacturing processes are identified. Moreover, sensing the needs of current and potential customers is, at Sodecia, done by the networking activities, design-reviews, and product specifications.

In both product design and process design, Sodecia has on-going innovation projects running in parallel with application projects. Sodecia has an R&D department that owns three areas of activity. One of the areas is the generation of knowledge where employees investigate and develop new knowledge and new technical solutions. The second is related to the activity of prototyping and the third to testing. The set of the three areas allows the development of quality loops in which it is possible to conceptualize the solution, design it, prototype build, testing, and provide feedback for each development loop.

Seizing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the seizing capability for the Product Design capability as a dynamic capability. These are: using (or own developed) design process during product development activities, selecting the technologies and features that are to be embedded in the product, the way in which technologies are to be assembled – architecture and how the revenue and cost structure of a business is to be “designed” and if necessary redesigned to meet customer needs through a BOM (Teece, 2007).

Sodecia uses the APQP process under the IATF 16494 standard for both product design and process design. Each new development project at Sodecia is managed by its own process model based on the APQP and which is revised through seven dedicated gates with corresponding checklists and formal approval. This is a strong evidence of seizing capability.

The selection of the technologies and features to be embedded in the product is based on technical and economic criteria. Consequently, the product architecture is defined by the functional analysis of the product and the analysis of the interfaces. However, the integration of the knowledge achieved from the benchmarking activities into the product design has no explicit formalization in a process. Knowledge is available for employees to use it, but there is no formalized process regarding the use of knowledge from benchmarking activities.

Regarding the use of a structured BOM and the way it integrates a cost structure of the product, Sodecia uses a BOM and Bill of Process (BOP) as the costing base for any product at Sodecia. Moreover, design changes in the development phase are reflected through a BOM and into the cost structure as there is a systematic process. Each BOM and each BOP are associated with a certain design level (or engineering level). BOMs and BOPs are supported by a formal register, making it possible to trace any linked documentation.

Summing up, Sodecia seizing capability for the product design capability is considered to be strong.

Reconfiguring Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the reconfiguring capability for the Product Design capability as a dynamic capability. These are: new and improved products in line with technological development and market demands, know-how integration, adopting new/improved knowledge and technologies, and transforming them into market-oriented solutions and, finally improving the effectiveness of product development processes (Breznik et al., 2019).

Under these lenses, Sodecia shows a moderate level of deployment of reconfiguring capabilities. Concerning the process of reconfiguring, implementing, and adapting the product design activities, product design teams at Sodecia are organized by product typology, hence, a product is always developed by the same team with the same supervision. However, there are occasional difficulties with resource capacity management, at that time resources from other teams with fewer working loads are displaced accordingly. This situation is not the norm. Moreover, there are a set of capabilities that are transversal to the entire product line, and this is managed based solely on the basis of available capacity (e.g., finite element method (FEM) analysis).

On what relates adopting new/improved knowledge and technologies, and transforming them into market-oriented solutions, Sodecia is moderately successful in applying the outputs of the R&D and Benchmarking activities in association with its product development partners. One of the evidenced difficulties in Sodecia's product design reconfiguring capability is mainly due to the capacity to capitalize on knowledge. Sodecia is currently moving from a phase in which knowledge is generated and kept its employees so there is the need for a high rate of people retention, to a different phase of knowledge retention through own design guidelines and databases to own technical specifications.

The product design and development activities effectiveness are measured through the on-time delivery of the document deliverables in each milestone. Each project has a timeline, each timeline has milestones, each milestone has a list of deliverables. The effectiveness of each project is measured by on-time deliverables. In terms of efficiency, the number of hours is measured, however it is not possible to compare with a standard to understand whether a given project takes too many hours or a few hours do be accomplished.

9.5.2.1.2. Process Design Capability

Sensing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the sensing capability for the Process Design capability as a dynamic capability. These are: networking activities to gather information about potential Process Development partners and projects, employees closely follow technological development and science and technology in general, on-going benchmarking activities, identifying new materials, architectures and processes usability testing and assessment and, development of R&D projects (Breznik et al., 2019).

Under these lenses, Sodecia shows a moderate level of deployment. Sodecia considers that networking is advantageous and useful, for a further efficient access to information on innovative technologies. It believes that its supplier base regularly provides information about its innovative processes. Sodecia also evaluates suppliers for their innovative capacity.

The process design staff has specific strategies for doing planned networking as there are routines in the management model, which organize employee’s activities focusing them on the creation of networking. The process designers have clear procedures for contacting with suppliers and production units.

Sodecia has long-term partnerships with some key suppliers for tooling and machinery which are frequently benchmarked. This benchmark data, along with costumer technical specifications are key inputs to identify new materials, architectures, and manufacturing processes for the design of the industrial processes.

Moreover, Sodecia does not have R&D projects related to its process design capability.

Seizing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the seizing capability for the Process Design capability as a dynamic capability. These are: using (or own developed) design process during process development activities, selecting the technologies and features that are to be embedded in the process, the way in which technologies are to be assembled – architecture and how the revenue and cost structure of a business is to be "designed" and if necessary redesigned to meet customer needs through a BOM (Teece, 2007).

Process design wise, Sodecia uses their own design process based on the APQP process according the IATF 16944 standard.

As well as the product design development, the selection of the technologies and features that are to be embedded in the design of the industrial processes are based on technical and economic criteria. Moreover, the integration of the knowledge achieved from the benchmarking activities into the process design has no explicit formalization in a standardized process.

Summing up, Sodecia seizing capability for the process design capability is considered to be moderate.

Reconfiguring Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the reconfiguring capability for the Process Design capability as a dynamic capability. These are: new and improved products in line with technological development and market demands, know-how integration, adopting new/improved knowledge and technologies, and transforming them into manufacturing process solutions (e.g., industry 4.0) and finally improving the effectiveness of process development processes (Breznik et al., 2019).

Under these lenses, Sodecia shows a moderate level of deployment of reconfiguring capabilities.

Concerning the process of reconfiguring, implementing, and adapting the process design activities, process design teams at Sodecia are arranged by type of technology used, and it is always the same team per project.

Together with the product design team, one of the evidenced difficulties in Sodecia's process design reconfiguring capability is mainly due to the capacity to capitalize on knowledge. Sodecia considers that there is a major flaw in the design process in what relates to knowledge retention, failing on documenting the know-how acquired during the development of its products and processes.

The process design and development activities effectiveness are measured through a similar process to the one used for the product design activities which is through the on-time delivery of the document deliverables in each milestone of the project.

9.5.2.1.3. Domain Design Capability

Sensing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the sensing capability for the Domain Design capability as a dynamic capability. These are: networking activities to gather information about target markets and customers, employees understand their role within the marketing process, on-going industry, and competitor benchmarking. (Breznik et al., 2019).

Under these lenses, Sodecia shows a strong level of deployment. As to what relates to the networking activities in order to tap new opportunities, concerning new markets and costumers, it takes two different dimensions at Sodecia.

It has a sales dimension that stems from the regular activities of the development and costumer account teams that are in regular contact with customers and their technical-sales teams. Moreover, the second dimension, has a broader dimension at a higher hierarchical level, which has to do with the study and monitoring of the market situation and its trends as well as the strategic activities of customers. Thus, approximately forty-eight meetings are held annually dedicated to the growth of the business with information from the entire geography of the company, which are subsequently filtered in order to direct the strategy by feeding an action plan for this purpose.

Sodecia considers that, there are interesting opportunities in the entire product range for interiors (cross-car beams, tie down loops and seat belt height adjusters). On the other side, where it sees fewer opportunities will be in the product range related to the classic ICE related drivetrain.

Sodecia does not considers a collaboration with the Automotive suppliers, technological leaders in the Automotive industry, even if it is for an entry market strategy. Besides, the installed production capacity is greater than demand, competition is fierce and the protection of know-how, whether from hard-skills or soft-skills, is tougher.

Seizing Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the seizing capability for the Domain Design capability as a dynamic capability. These are: networking activities as a vital part of gathering information about target markets, goal-oriented networking activities as a vital part for gathering information about clientele – additional projects, potential/new customers – new business projects, and employees play an active part in marketing activities/processes (especially employees working as business analysts and project managers) recognising the changing costumers' needs (Breznik et al., 2019).

The process of recognising the "right" opportunities as a way of developing the seizing capabilities within the domain design capability, is achieved through a process of analysis by a transversal team that includes members of the sales team, the product development team, the general directors of the business units and the corporate management teams.

Moreover, Sodecia considers that one area that was qualified to adapt an opportunity was the hot-forming technology, as this was an area where Sodecia was not present. The acquisition strategy was not about the product, but about technology, it was a combination of a technical and investment plan.

Additionally, the success of the cross-car beam product was essentially due to the accomplishment of the sales strategy and the recognition of Sodecia's design capabilities.

Sodecia considers costumers' needs when developing its business strategies. through the analysis of the technical specifications that are received, the analysis of the interfaces and for their interactions in the development phase (for example during the validation, assembly tests, etc.).

Customers take an active part in the innovation process, as they define the technology they want to install on their automobiles. However, they are open to installing innovative technology that is validated. Additionally, this process of developing innovative technology is done in parallel through an R&D project with the customer.

Finally, it is considered that Sodecia has a strong seizing capability deployment.

Reconfiguring Capability

Based on Teece (2007) common practices, it was defined the practices that underpin the reconfiguring capability for the Domain Design capability as a dynamic capability. These are: constantly improving customers' loyalty and satisfaction, constantly establishing, building, promoting, and nurturing long-term partnerships with key customers, partners, employees, and competitors (Breznik et al., 2019).

The customer retention rate for the last five years at Sodecia is of 100% on all markets, OEM and Tier 1, a reflection of costumer's loyalty and satisfaction.

As already referred, Sodecia has no partnerships with competitors, nor for joint R&D projects nor for market entrance strategies, due to the existing high competition environment. Nevertheless, Sodecia has short-term partnerships with marketing studies service providers specialized in collecting and compiling information in a way that is useful for its business.

Sodecia has long-term relationships with all stakeholders, especially with government entities in the regions where Sodecia operates, with its own supplier base and most importantly with financial entities.

Summing up, this evidence reveals a strong reconfiguring capability.

9.6. The Cross-Car Beam product, a case study for Sodecia

Over the development of this case study, it has been identified an embedded case that can eventually improve to validate the initial research question and hypothesis even in a chosen firm that does not entirely fulfil all the initial assumptions. Therefore, it is an example from a company of a different dimension having pursued a distinct strategy on the development of Design capabilities.

Through Frigant (2016) it became apparent that mega suppliers refuse or are unable to fulfil OEMs needs in their fullness. In such a fierce and competitive environment whose structures all seem to benefit mega suppliers, these are essentially incapable of capturing the whole of the market. This hypothesis provides a possible explanation for the diversity of SMEs operating at the top tier, as revealed by Frigant (2016).

The choice of Sodecia for a case study was driven precisely by the fact that, currently this firm has not the dimension of a SME nor a mega supplier (large company). Sodecia ambition is clearly the top of the pyramid's first tier level of the supply chain and becoming a mega supplier.

Also from Frigant (2016), it became clear that the emergence of mega suppliers was done through, (1) development of new competencies (in R&D, components integration, etc.), (2) engagement in mergers and acquisitions in an attempt to build up the competencies needed to design and produce modular assemblies, (3) encouragement of OEMs for follow sourcing, which is when a single module supplier is chosen to supply all of the OEM factories manufacturing one and the same model, and (4) innovation through progressively integrating more technology and functionalities in an endeavour to build barriers to the entry of new actors (Frigant 2016).

The process of internationalization of Sodecia, started with the acquisition of industrial units in Brazil namely in Bahia by the end of the millennium. During this period, Brazil entered an economic recession that caused most of the foreign companies that had internationalized to Brazil in great difficulties, which caused the local production capacity to be substantially reduced.

Due to the geographic closeness and the lack of suppliers sourcing, Ford of Bahia approached Sodecia for the manufacture and supply of a cross-car beam module. The Cross-car beam at Sodecia came about through a partnership with PWO (Progress-Werk Oberkirch AG), proposed by Ford, therefore customer driven. Additionally, the product design would be the responsibility of PWO and the industrialization, production, and logistics of Sodecia.

The cross-car beam appears as an interstice, that allowed Sodecia to supply its first complex assembly module as a tier 1 supplier because no mega supplier was able to capture this part.

Likewise, the development of product design capabilities at Sodecia comes about this time triggered by the first complex module project of Sodecia directly supplying an OEM. Thus, this was the start of Sodecia’s strategy to move away from a built-to-print process for product development in order to move up in the automotive industry's value chain. Increasing the added value of Sodecia's product portfolio, moving up the value chain and subsequently increasing the product portfolio complexity.

It was from the development of the cross-car beam module that Sodecia began to be qualified to demonstrate a set of skills and abilities that later managed to be a supplier of larger and complex modules. The opening of Sodecia's product development centre in 2005 in Portugal, was a way of capitalizing on the know-how acquired in the partnership with the firm PWO and using that knowledge in the development of new products. In this way, it was possible to consolidate the position of specialist in the cross-car beam product, thus being qualified to approach other customers (OEMs).

Summing up, the development of Design capabilities as a Dynamic capability has an indirect link with performance, however, is key to a business strategy as technological and market entrance advantage as evidenced through this embedded case.

9.7. Case Summary

According to Yin (2009), the case study evidence analysis is one of the most underdeveloped and most challenging aspects of undertaking case studies. The analytical tool to be used is the explanation building due to the explanatory nature of the present case study (Yin, 2009).

Therefore, the explanation building will take place in a narrative form reflecting some theoretically significant propositions and connecting them through the results of the level of the design capabilities deployment evidenced through the case study.

As already referred, through Frigant (2016), it became evident that the incomplete modularity of the automobile architecture created a strategic opportunity for smaller companies enabling them to rise to the top tier of the supply chain provided they develop specific capabilities to strategically position them, accordingly, overtaking the barriers built by the mega suppliers.

The case with Sodecia was distinct, due to the fact that has been identified an embedded case that could eventually improve to validate the initial research question and hypothesis even in a chosen firm that does not entirely fulfil all the initial assumptions. Therefore, this would lead to the conclusion that this company has pursued a distinct strategy on the development of Design capabilities.

The development of design capabilities qualified Sodecia to position itself strategically as a tier 1 supplier for the automotive, currently supplying fourteen OEMs.

Sodecia is acknowledged as a relevant market player due to its investment on Design capabilities that led to its state-of-the-art product range portfolio reflecting its strategic market positioning, even though Sodecia is not a mega supplier.

For an insight of how Sodecia develops capabilities as dynamic capabilities, it is presented the research results for its manifestations in sensing, seizing and reconfiguring capabilities regarding its design capability.

Design capabilities and the role of managers have been recognised as a key component in developing dynamic capabilities. Design capability as a dynamic capability is a capability by which the level of deployment of sensing, seizing and reconfiguring capabilities is found at a high level. Accordingly, the Sodecia case is another example of how dynamic capabilities can be successfully deployed and developed. A deeper investigation of the manifestations of design capability allowed presenting some of the practices and activities that undergird the design capabilities at Sodecia. The Design capability is the ability to sense, seize and reconfigure in product design, process design and domain design activities. At Sodecia, the level of deployment of design capability is at a high level.

Regarding the sensing capability, the use of effective communication and networking with all stakeholders, enables managers to sense opportunities inside and outside the firm. Moreover, these skills allow them to receive and collect the right information at the right time. The product strategy director at Sodecia can systematically sense the surrounding environment, not simply observe it.

The process of recognising the “right” opportunities as a way of developing the seizing capabilities is at Sodecia a systematized process because of the firm’s business model. Therefore, this process is achieved through a process of analysis by a transversal team that includes members of the sales team, the product development team, the general directors of the business units and the corporate management teams.

Nevertheless, recognising opportunities by itself might not be enough, as they must be further developed. After the opportunities are recognised as potential opportunities, they must be developed through a recombination of the firm’s resource base.

As already referred, Sodecia has its own design process based on IATF 16494 (from APQP). As this feature is an incredibly important seizing ability that enables the firm to recognize the needs of recombining its resource base, it is not enough to establish a strong reconfiguration capability. Product design teams at Sodecia are organized by product typology, therefore, a product is always developed by the same team with the same supervision.

On what relates adopting new/improved knowledge and technologies, and transforming them into market-oriented solutions, Sodecia is moderately successful applying the outputs of the R&D and Benchmarking activities in association with its product development partners. Such as, one of the evidenced difficulties in Sodecia's product design reconfiguring capability is mainly due to the capacity to capitalize on knowledge. Sodecia is currently moving from a phase in which knowledge is generated and kept by its employees so there is the need for a high people retention rate, to a different phase of knowledge retention through own design guidelines and databases and own technical specifications.

The case with Sodecia evidence theories from different academics that relate the dynamic capabilities with performance (Teece et al., 1997, Zott, 2003, and Barreto 2010). Especially that the dynamic capabilities might change the resource base to a new resource base and subsequently may influence new product market positions, which in turn may affect performance.

The development of Design capabilities at Sodecia evidenced through the deployment of sensing, seizing and reconfiguring capabilities in, process design and domain design activities fosters the relation with specific OEM suppliers for an extremely specific product portfolio: power train and safety and mobility. This strategic positioning enables a technology advantage in comparison with the competing companies operating on the automotive market. Moreover, through Frigant (2016), it is also clear that through the development of Design capabilities at Sodecia, fostering innovation, the increasing incorporation of technology and functionalities on modular products was key in an attempt to build barriers to entry impeding the arrival of new actors as competition is fierce - this was the case of the cross-car beam product.

The development of Design capabilities as a Dynamic capability has an indirect link with performance, however, is key to a business strategy as technological and market advantage. Therefore, in accordance with the biggest sales share of Sodecia that is from the OEM market as a tier 1 supplier.

10. Cross-Case Report

10.1. Cross Case Analysis and Report

As suggested by theory, the Dynamic Capabilities View (DCV) allows firms to react to change. The firms under study operate in the Automotive industry environment, which has seen tough international competition and fast-paced technological changes on the latest years. The results gathered from this study reveal that these firms are effectively developing their dynamic capabilities design related. Consequently, they are qualified to successfully survive in the dynamic Automotive sector.

From the data gathered on table 26, it is possible to understand the differences between the selected case study firms. The year of establishment characterises the historical perspective hence their initial market, product portfolio, level of supply chain and industrial culture. Veneporte was the earliest established studied firm. This firm started as a supplier of mostly all the OEMs established in Portugal during the Automobile Assembly Law period in a complete knocked down/semi knocked down (CKD/SKD) perspective. As to what relates KLC, the firm was established in 1993 a time when the integration of Portugal was being consolidated, direct foreign investments (DFIs) such as Ford/VW AutoEuropa were being intended. The Sodecia firm was established in a period between Veneporte and KLC. This period was already after the automobile assembly law although before the big DFIs. This was a period of the Renault project where most Portuguese automotive firms supplied the French OEM.

Except for KLC, which is an exclusive tier 2 supplier, both Veneporte and Sodecia are tier 1 suppliers (however KLC is awarded tier 1 for VW) and the three case study firms supply both simple and complex parts (simple parts are considered single parts and complex parts are considered assemblies or modules). Also from table 26, it can be noticed that for Veneporte and KLC, the percentage breakdown of level of part complexity is higher for complex products (in case of Veneporte, modules and, in case of KLC, assemblies) showing a clear strategy on the supply of increased value-added parts. As Sodecia is a medium sized company, the percentage breakdown ratio tends for the supply of simple parts as part of a scale economy strategy (although shifting to the supply of complex parts – modules).

Table 26

Selected Indicators and Quantitative Results for 2020.

	VENEPORTE	KLC	SODECIA
General Structure			
Year of Establishment	1966	1993	1980
Capital Amount (2020)	3M	105K	64.5M
Sales Amount (2020)	11.5M	12M	759M
Profit Rate (2020)	N/A	N/A	N/A
Organisational			
Organizational Type	Functional	Functional	Functional
Number of Employees	180	240	7086
Current Standard Level	IATF 16494	IATF 16495	IATF 16496
Years Supplying the Automotive	54	20	41
Quality Tools	ALL	ALL	ALL
Products Supplied	Exhaust System Modules	Decorated Polymer Injected Parts and Assemblies	Power Train / BIW / Safety & Interiors System Modules
Supply Chain Position			
Level of Supply Chain	Tier 1	Tier 1/2	Tier 1/2
Percentage Break Down Tier 1/ Tier 2	Tier 1 = 100%	Tier 1 = 0% Tier 2 = 100%	Tier 1 = 90% Tier 2 = 10%
Products			
Complexity Level of Supplied Products	Simple and Complex	Simple and Complex	Simple and Complex
Percentage Breakdown of level of part complexity	Simple = 27,8% Complex = 72,2%	Simple = 40% Complex = 60%	Simple = 60% Complex = 40%
Level of Product Design per supply level	Simple = 1,5% (5) Complex = 98,5 (6)	Simple = 20% (3) Complex = 80% (3)	Simple = 30% (3) Complex 70% (6)
Level of Process Design per supply level	Simple = 1,5% (4) Complex = 98,5 (4)	Simple = 10% (4) / 10% (5) Complex = 70% (4) / 10% (5)	Simple = 10% (4) / 10% (5) Complex = 70% (4) / 10% (5)
Market and Diversification			
Business Domains	Cold / Hot	Single Parts / Assemblies	Power Train / BIW / Safety & Interiors
Types of Products per Business Domain	Cold = Tubes + SILs Hot = KATs + DPFs	Automotive = Injection + Decorative Others = Injection	Power Train = SS + PB (OEM) BIW = BIW Parts (Tier 1) Safety & Mobility = CCB + SBHA + HDTL + TE (OEM)
Part Complexity per Business Domain	Simple = Tubes Complex = SILs + KATs + DPFs	Single = Injection + Decorative Assys = Injection + Decorative	Single = BIW (Tier 1) + TE (OEM) Assys = SS + PB + CCB + SBHA + HDTL (OEM)
Number of Costumers as Supply Destination	N/A	15	14

Note. Source: Own

The level of product design per supply level is deeply connected with the level of supply chain and the complexity of the supplied parts. So, 98,5% of the supplied complex parts from Veneporte are fully in-house designed. Likewise, for Sodecia, 70% of the supplied complex parts are 100% designed in-house. As for KLC, which is a tier 2 supplier, the level of product design is at simple proposals for improved on supplied drawings, process related.

As for what process design matters, KLC is the leader. This result agrees with the chosen business strategy of developing specific capabilities not on product design, but on process design, granting the access as an extremely specific technology. This focus on specific technologies triggered KLC to a high added value decorative interior polymer injection complex parts production. Moreover, Veneporte and Sodecia also have process design capabilities as for 100% of their parts they design their own industrial process.

Veneporte and Sodecia have a clear diversification strategy. Both develop and produce various parts from each business domain supplying to different costumers. As for KLC firm case, the developed technology is extremely specific for the business domain type of product, therefore, it is a clear product development business strategy.

Moreover, different ways of deploying design capabilities as dynamic capabilities were analysed for all case study firms. As a way of determining the dynamic capabilities level of deployment, such as weak, moderate, and strong, each capability was viewed as containing sensing, seizing, and reconfiguring capabilities, so a cross-case analysis enabled each capability's evaluation. The level of deploying the capabilities was established after comparing the results for each case study firm (Table 27).

As defined, the assessed design capabilities on the case study firms were product design capabilities, process design capabilities and domain design capabilities as per Akabane et al. (2016). One of the first find outs during the research was that managers should take an active role in sensing, seizing and reconfiguring dynamic capabilities. Their commitment could be witnessed by leading by example and vision, and that has a great impact on firm employees.

Table 27

Overview of the Dynamic Capabilities Deployed by the Case Study Firms.

	Case Study Firms		
Capabilities	**Veneporte**	**KLC**	**Sodecia**
Product Design Capabilities			
(1) Sensing	Strong	N/A	Strong
(2) Seizing	Strong	N/A	Strong
(3) Reconfiguring	Moderate	N/A	Moderate
Process Design Capabilities			
(1) Sensing	Moderate	Moderate	Moderate
(2) Seizing	Moderate	Moderate	Moderate
(3) Reconfiguring	Moderate	Strong	Moderate
Domain Design Capabilities			
(1) Sensing	Strong	Strong	Strong
(2) Seizing	Strong	Strong	Strong
(3) Reconfiguring	Strong	Strong	Strong

Note. Source: Own

It is possible to establish that all the interviewed managers are able to sense their environment systematically and not just observe it, mostly for the product design and domain design capabilities. Unfortunately, process design wise, all the case study firms scored a moderate level, even the KLC firm as did not show evidence of a systematised practice. In fact, their sensing capabilities are strongly linked to the ability of networking. In the case of Veneporte, it is considered so important that the different areas of networking are intrinsically linked to their design process. Also strongly linked to the sensing capability are the systematized practices of benchmarking and R&D. Both are particularly strong at Veneporte and Sodecia firms.

The three case study firms, show the ability to seize the right opportunities as an outcome of the firm’s business model. Gathering the information and knowledge that enables the firm to recognise opportunities is primarily a result of its networking activities and long-term and trust-based partnerships with customers and other partners.

Many scholars (Breznik et. al., 2019, Verona & Ravasi, 2003), claim that the basis for the innovation capability deployment is to build dynamic capabilities that allow the continuous and systematic generation and integration of knowledge. The findings on the case study firms investigation clearly show that obtaining and implementing new and improved knowledge and further converting it into market-oriented product designs is one of the main factors of success in the case study firms.

Moreover, findings show that not only the new and improved knowledge can be converted into market-oriented product design, but also on the design of innovative industrial processes. Therefore, deploying design capabilities as dynamic capabilities is crucial for the selected strategy focus of each firm, which in the case of the three selected firms is to rise the added value products they supply.

The case analysis revealed that the sensing capability seem to be more alike and comparable across firms. On the other hand, the seizing and reconfiguring capabilities may differ more. As the results show, all the case study firms systematically sense their environment and even use similar networking techniques. Commonalities in design capabilities, especially by the sensing capability, do exist between the case study firms.

There are more differences when considering the seizing and reconfiguring capabilities. For instance, Veneporte follows its own design process based on IATF 16494 (from APQP). As this feature is an incredibly important seizing ability that enables the firm to recognize the needs of recombining its resource base, on the other hand, KLC does not follow a systematized design process but follow a tailor-made planning for the process design and R&D activities.

Regarding the reconfiguration capability, Veneporte and Sodecia scored moderate due to different reasons. The study was able to understand that there are internal barriers on the reconfiguration capability deployment due to different reasons. Veneporte evidences a significant share of interference in the programming of the activities of the design process.

Moreover, Veneporte considers that there is a major flaw in the design process in what relates to knowledge retention, failing on documenting the know-how acquired during the development of its products and processes.

Table 28

Activities for Developing Design Capabilities as Dynamic Capabilities.

Area	An overview of activities that help develop dynamic capabilities ("positive practices")	An overview of activities that block the development of dynamic capabilities ("negative practices")
Product & Process Design	Networking as a systematic practice to accelerate developments and share risks.	Networking seen as a threat to the existing know-how
	Create a forward-thinking talent model investing on designers as key actors.	Collaborators that do not engage on the automotive business
	Benchmarking as a systematic practice to identify new materials, architectures, manufacturing processes.	
	R&D projects as a way to develop innovative technology.	R&D activities are seen as non profitable, hence a cost to the company
	Develop or follow a design process as the most efficient and systematic way to embedd the knowledge aquired from networking and benchmarking activities.	Rely on managerial directions for product/process development process steps
	Systematize the use of a BOM/BOP as key tool for product/process cost structure.	
	Develop tools for knowledge retention such as design guidelines and lessons learnt.	Rely on "key employees" knowledge
Domain Design	Systematically benchmark market environment and take action accordingly.	
	Considering customers needs as way of developing the right business strategies.	
	Build, promote and nurture long-term partnerships with all stakeholders.	

Note. Source:Own

Likewise, one of the evidenced difficulties in Sodecia's product design reconfiguring capability is mainly due to the capacity to capitalize on knowledge. Sodecia is currently moving from a phase in which knowledge is generated and kept by its employees so there is the need for a high people retention rate, to a different phase of knowledge retention through own design guidelines and databases and own technical specifications.

Through the analysis of the three case studies, it is shown how deployment of design capabilities can be explored through sensing, seizing and reconfiguring capabilities. These lenses enabled a better understanding of the logic behind the DCV. Therefore, like Breznik et. al. (2019), but on a design capabilities perspective, it is proposed that managers have an important impact on the exploitation of design capabilities as dynamic capabilities.

Table28 sums up the activities – positive practices – that can help firms develop their design capabilities as dynamic capabilities, and activities – negative practices – that firms need to minimise on developing their design capabilities as dynamic capabilities. These practices are a result from the comparative analysis of the firms under study.

These results may help managers in realizing the practices in which dynamic capabilities work and provide guidance while seeking to deploy and take advantage of their firm’s design capabilities in the automotive environment.

10.2. Cross Case Conclusions for Theory and Practice

One of the main goals in a multiple-case study is building a general explanation that would fit each individual case, even though the cases vary in their details (Yin, 2009). The objective is creating an overall explanation for the outcomes of the multiple conducted experiments. From the multiple case analysis, it is possible to note that the three studied firms have different approaches on the relation of their design capabilities deployment with their business strategy. Although a pattern was not evidenced due to the detail of each individual firm, it is possible to develop a theory building through an explanatory narrative examining the various facets of a causal argument.

The proposed conceptual framework advises that one of the most crucial relation in the Dynamic Capabilities theory is the one with performance. An indirect link between dynamic capabilities and performance should be considered. The dynamic capabilities can shift the resource base to a new combination that may influence new product/market strategic positions, which in turn may affect performance (Zott, 2003). Moreover, this approach is fully consistent with early proposals that dynamic capabilities may be a key antecedent of firms' strategic choices, such as entry strategies, entry timing, or diversification (Teece et al., 1997). The intention of this investigation is to try to explore the link between the proposed theories to performance.

From the case of Veneporte it was possible to conclude that the development of Design capabilities, evidenced through the deployment of sensing, seizing and reconfiguring capabilities in product design, process design and domain design activities, foster the relation with OEMs for a tier 1 positioning strategy on the automotive supply chain. This strategical positioning enables a technology advantage for another market - the IAM.

Moreover, Veneporte desires to have a direct and technological relation with the OEMs in order to further develop the IAM market as way of obtaining a technological competitive advantage. The development of Design capabilities as a Dynamic capability has an indirect link with performance, however, is key to a business strategy as technological advantage.

Therefore, in accordance with the biggest sales share of Veneporte, that is from the IAM market.

The development of Design capabilities at KLC evidenced through the deployment of sensing, seizing and reconfiguring capabilities in process design and domain design activities, foster the relation with specific tier 1 suppliers for an extremely detailed product portfolio: interior trim and In-Vehicle Infotainment (IVI). Through the development of high-end industrial processes enhanced by R&D projects with their stakeholders, KLC, promotes a specific relation with the very exclusive set of suppliers for automotive interior trim and IVI.

This strategic positioning enables a technological advantage in comparison with other polymer injection firms operating on the automotive market and contrasts with the one from the Veneporte firm. KLC does not aim to the top pyramid of the automotive supply chain as tier 1 supplier but fosters an industrial technological process advantage for supplying a very specific product to an exclusive selection of tier 1 suppliers. Additionally, the development of Design capabilities as a Dynamic capability has an indirect link with performance, however, is key to a business strategy as technological advantage. Therefore, in accordance with the biggest sales share of KLC that is from the Automotive market.

The case with Sodecia was distinct, as already referred, due to the fact that has been identified an embedded case that would help to improve building a general explanation for the multiple-case report, even if this case would lead to the conclusion that Sodecia pursued a distinct strategy on the development of Design capabilities.

Therefore, it was from the development of the cross-car beam module that Sodecia began to be qualified to demonstrate a set of skills and abilities that later managed to be a global tier 1 supplier of larger and complex modules to the largest OEMs. The launching of Sodecia's product development centre in 2005 in Portugal, was a way of capitalizing on the know-how acquired in the partnership with the firm PWO and using that knowledge in the development and improvement of new products. Thereby, it was possible to consolidate the strategic position of specialist of the cross-car beam product, being qualified to approach other customers (OEMs).

Moreover, the development of Design capabilities at Sodecia evidenced through the deployment of sensing, seizing and reconfiguring capabilities in process design and domain design activities fosters the relation with OEMs for an extremely specific product portfolio: power train and safety and mobility. This strategic positioning enables a technological advantage in comparison with the competing companies operating on the same automotive market. Moreover, it is also clear that through the development of Design capabilities at Sodecia, fostering innovation, the increasing incorporation of technology and functionalities on modular products is key on an attempt to build barriers to entry, impeding the arrival of new actors as competition is fierce - this was the case of the cross-car beam product.

Even if the goal of Sodecia was to reach the top of the automotive supply chain pyramid as a tier 1 supplier, the strategic positioning of the design capabilities deployment is much different from Veneporte and KLC cases. If the cross-car beam product was the interstice that triggered the development of design capabilities, now de deployment of design capabilities has a completely different strategic position as an attempt to build competition entry barriers.

From the beginning, the development of Design capabilities as a Dynamic capability has an indirect link with performance, however, is key to a business strategy as technological and market advantage. Therefore, in accordance with the biggest sales share of Sodecia that is from the OEM market as a tier 1 supplier.

As it can be observed a pattern was not evidenced due to the details of each individual firm. It is possible to develop a theory building through explanation of the different facets of the causal arguments. It can be theorised that the development of the design capabilities for the automotive supplier firm case studies is strongly related to their strategic market position and indirectly related to its performance.

11. Conclusions and Recommendations

Why Design matters? Why is it crucial for automotive supply companies to have design capabilities? This question is particularly challenging to answer.

Industrial design is not usually highlighted as a cornerstone skill of most small-scale automotive supply companies. Practice suggests a double bias either in the definition of design, sometimes emphasized as style and associated with carmakers, or in design's role in developing the position of small and medium enterprises in supply networks. Lack of knowledge, and possible misunderstandings, raise barriers to the development of design and its business as well as its professional expansion. This line of reasoning supports the lead research question: why design matters for smaller companies in the automotive industry?

The roles of design and design management capabilities have been explored as strategic resources and core competencies (Borja de Mozota, 2003, or more recently by Muratovski, 2015), emphasizing design's increasingly recognized role. While including design in a larger company's skill set is largely industry status quo, design is not usually listed as a resource among smaller automotive industry suppliers. Design is instead established as a combined process of resources and capabilities due to the highly dynamic environments that characterize this industry. This condition creates the need for a new research approach, integrating the resource-based view (RBV) and dynamic capabilities view (DCV) theories.

11.1. Recalling the Path – The Theoretical Background

Why and How Firms Choose to Adopt Design

Resource-based view (RBV) and dynamic capabilities view (DCV) theories highlight the internal strategic design resources and capabilities a firm possesses that provide a sustained competitive advantage. Internal resources and capabilities determine strategic decisions made by firms to compete in their external business environment. Additionally, a firm's abilities add value in the customer value chain when developing new products and expanding to new markets. When a firm's capabilities are considered superior and create a competitive advantage, the firm has an opportunity to focus on the reconfiguration of its value chain activities and identify other resources and capabilities within the firm's value chain that provide sustained competitive advantages. The RBV highlights the resources and capabilities identified by the firm for the purpose of developing a sustained competitive advantage.

Resources might be considered input that enables firms to carry out their activities. Not all the resources of the firm can be considered as strategic resources or sources of competitive advantage. According to the RBV theory, a competitive advantage occurs only when there is a situation of resource heterogeneity (different resources across firms) and resource immobility (the inability of competing firms to obtain resources from other firms). If the resource is not perfectly mobile (i.e., the resource is not free to move between firms, or if a firm without a resource faces a considerable cost burden in developing, acquiring, or using it, that a firm already using does not), then the resource is likely to be a source of sustained competitive advantage (Barney, 1991). It can be concluded that process combinations – design included - are the most difficult to copy or to move from one firm to another, reinforcing the competitive advantages of companies that are able to master their development.

Dynamic capabilities view (DCV) is the latest perspective to expound upon the resource-based view (RBV) and is recognised as one of the most relevant concepts in the strategic management field. Through this literature review it was acquired that "We define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities thus reflect an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions" (Teece et al., 1997, p. 516).

The definition of DCV has been discussed and reviewed through scholars (e.g., Barreto, 2010), and is still being advanced through research, mainly due to the fact that there is a dearth of evidence on how to apply the DCV model to build and exploit firm capabilities as dynamic.

Therefore, there is a need for analysing the relationship between design (resource) as a competitive advantage for firms and their performance (output). There is also a need for analysing resources and capabilities combination as dynamic capabilities, with the background of an industrial segment, operating on such a complex and dense network as that of the automotive industry. The relationship between design, resources and capabilities, and the industrial and automotive industries can be translated into a DCV strategy model that illustrates the connections between resources, capabilities, competitive advantage, and performance yield, which is one of the main constructs of this study.

Industrial Design – Concept and Interaction Framework

The second construct to be reviewed was design as a framework for industrial product and process development within the automotive industry.

An extensive analysis and review of different processes was made as a global strategy for product development. This analysis describes some of the main definitions of design and its purpose, and additionally identifies some of the boundaries of varying design processes. The definition of product is presented, as is the design process concept, and some of the most representative model maps for processes are discussed.

All the process models examined through the literature review of this research span a diverse and extensive range of design disciplines and problems. Hence, the aim of this review is to gain a balanced perspective. While all the reviewed process models offer insight into the nature of the design process, they are far too general to help with project planning activities or to guide daily decisions made by industrial design professionals.

Although it can be tailored to the specificity of a particular OEM's business model, in the singular context of the automotive industry the Advanced Product Quality Planning (APQP) remains the primary source for the definition of an operative research industrial design concept and, simultaneously, an interaction tool linking the different poles of the supplying network. The product and process design stages are deeply described in an APQP, which is not only a product development process, but also an automotive industry standard process.

The definition of capabilities for product design, process design and domain design integrated on the APQP process for automotive suppliers were also acquired through this literature review. These specific design capabilities will be later disaggregated with the introduction of the DCV micro-foundations theory.

Addressing the “What” Question

Although the "what" question emerged linked to the last research topics, its exploratory basis can only be viable if rooted and balanced on a well-defined environment. Hence, the background of this research is the automotive industry, and there was the need of describing the international automotive system and the Portuguese automotive cluster in detail.

The international automotive system can be structurally described as being densely composed, with a central focus on the supplier’s organizational network. Hence, one could envision a profile of the industry, described in terms of an automobile’s architectural modularity and that architecture’s supply and value chain, shaped as a pyramid. The worldwide production of passenger cars, light commercial vehicles, and bus and coaches is also presented in this research.

The mergers and acquisitions (M&A) that have radically restructured the automotive industry in recent decades have also impacted the supply chain through the reshaping of the size and interrelations of supplier networks and have impacted the core of our research: the automotive industry's resources and capabilities.

The international automotive system's core dimensions were the object of analysis. However, a dynamic model enabling the characterization of small and medium enterprises' progress within the automotive system's structure was still needed. The Frigant (2016) viewpoint, being the most well-known work within this line of research, provided us with a way for modelling paths and opportunity spaces.

Frigant (2016) explores and later theorises about the relation between the automotive supplier's structure and the automobile modular architecture. Frigant (2016) defines three supply levels: the first level features mega suppliers designing and producing modules; the second level is more diversified and intermediate and features relatively heterogeneously sized makers of and made somewhat complex products; the third level contains small and medium enterprises restricted to acting as subcontractors or suppliers of simple small parts.

The three defined levels are based on three hypotheses. The first is the existence of a strict isomorphism between product architecture and organization, creating a situation where mega suppliers exclusively possess the ability to manufacture modular subsystems. The second is that modules became the only parts purchased by automotive manufacturers, turning automobile construction into a simple game of Lego. The third hypothesizes that carmakers can be characterized by a constant single degree of vertical integration for all the vehicles they assemble, in all assembly facilities (Frigant, 2016).

However, as the author theorizes, if the aforementioned three conditions would be true, the whole market of automotive modular parts could be provided exclusively by mega suppliers. Nevertheless, because automobile product architecture is not completely modular (Frigant, 2011), carmakers need to purchase some elementary parts, and must subcontract certain tasks (Frigant 2016).

Because the isomorphism hypothesis is a hotly debated issue (Campagnolo & Camuffo, 2010), some gaps appear in the pyramid representation. These gaps are spaces in the supply chain that create manufacturing opportunities for small firms (Frigant, 2016).

Through his study, Frigant (2016) leads to two conclusions. The first is that many suppliers are simultaneously present on several different supply chain levels (or tiers). The second conclusion is that the more complex the service being provided, the greater the possibility the firm in question would be operating toward the top of the pyramidal hierarchy. Hence, as Frigant (2016, p. 923) concludes, “the first major distinction here is between complex and simple parts. The former tends to be made by suppliers positioned on the first tier. Adding R&D services increases the probability of becoming a tier 1 supplier, whether exclusively or partially. Conversely, suppliers manufacturing simple parts without R&D activities tend to be situated toward the bottom of the pyramid”. According to this viewpoint, it can be summarised that developing and controlling the right resources and capabilities are simultaneously a route to access the direct supply of OEMs (putting a supplier in a better position) and a way to prevent automotive manufacturers from seeking the services of other suppliers by leveraging an entry barrier.

The Portuguese Evolution

The Portuguese automotive cluster is described through a historical perspective, giving a clear view on the cluster’s evolution and value within the Portuguese economy. This perspective also examines sustainable job creation and research and design (R&D) opportunities and capabilities across the Portuguese automotive stakeholder network.

This chapter starts with a general overview of the period between the end of World War II and the Renault project, mainly characterized by an industrial automotive strategy based on assembly operations of semi-knocked-downs (SKD) or complete-knocked-downs (CKD). A mere process of assembling did not (as would have been desirable) lead to the emergence of a network of component suppliers for the industry. Small supplier units may have arisen to supply some minor components, with little added value to the internal market and of no major significance to the sector.

From the perspective of the full integration of Portugal into the European Union, the Renault projects lead the first large and structured investment into the automotive sector in Portugal in the early 1980’s, resulting in a significant impact on the development of component suppliers.

The period between Renault's investment and the AutoEuropa project that came a decade later was characterized by a complex and especially important period which adhered Portugal to the European Economic Community (EEC). Portugal was able to take advantage not only of the easier access to foreign markets, but also of available structural and cohesion funds (ERDF and ESF). The industrial automotive component supply sector quickly became Portugal’s leading exporter, even superseding the traditional textile and clothing industry sector.

Since 1990, with the perspective of the Economic Monetary Union (EMU) and with the successful integration into the EU, Portugal attracted a significant investment in the automotive sector, led by a Ford/Volkswagen joint venture: the Autoeuropa project. This joint venture, with true international dimension, has, as expected, had a considerable effect on the Portuguese economy. New mantels of technological and skilled performance were assumed by Portuguese automotive suppliers. Specifically, Portuguese suppliers consolidated competences and responsibilities, new solutions in design and engineering capability development were created, and Portuguese suppliers began taking part in highly valuable supply chains with internal and external companies.

Currently, Portugal has five active assembly factories with a workforce of more than five thousand direct and indirect workers (Deloitte, 2018). According to the Organisation Internationale des Constructeurs d'Automobiles (OICA), the total vehicle production out of Portugal in 2020 was 264.236 vehicles including passenger cars, trucks, and buses (allocated by the five active factories which belong to five different manufacturers: PSA, Mitsubishi, Caetano Bus, Toyota, and Volkswagen).

In Portugal during the year 2020, according to the Instituto Nacional de Estatística (INE), there were 360 active input suppliers for the automotive industry, with a business volume of 6.4 billion Euros (corresponding to 8,6% of the Portuguese GDP). From this number, 98% (6.3 billion Euros) represent exports (corresponding to 10,5% of the total Portuguese exportable goods in 2019).
According to INE, the Portuguese automotive cluster has been economically strategic for the country. From 2010 to 2018 the total exports business volume has seen 58.4% growth.

A significant part of this growth is driven by companies operating in Portugal as well as small and medium-sized Portuguese companies.

11.2. Research Strategy

The Theoretical Framework

As Teece (1998) refers, identifying design as a dynamic capability for an organization is relatively easy, but building it into an organization's strategy is more challenging. The dynamic capabilities model of Teece, as well as those of Eisenhardt and Martin (2000), along with an exploratory framework for building design capabilities for the automotive suppliers from Akabane et al. (2016), have contributed to the core of the proposed theoretical framework for building design as a dynamic capability within an organization with the characteristics of the ones this study focuses on.

One of the most crucial relationships in the dynamic capabilities view (DCV) theory is perhaps the performance relationship. Zott (2003) confirmed that an indirect link between dynamic capabilities and performance should be considered. Dynamic capabilities may change the current resource base to a new resource base, which may influence new product market positions, which in turn may affect performance (Zott, 2003). This approach is fully consistent with early proposals that dynamic capabilities may be a key antecedent of firms' strategic choices, such as entry strategies, entry timing, or diversification (Teece et al., 1997). Hence, this indirect link to performance will be the output of the proposed theoretical framework. As stated by Zott (2003) and Teece et al (1997), the output performance of dynamic capabilities is extremely hard to measure, as it should be considered an indirect link.

This research framework is constructed on Teece's model of the micro-foundations of dynamic capabilities, which Teece broke down into three types: sensing capability, seizing capability, and reconfiguring capability (Teece, 2007).

The main principle of this breakdown is to clarify how dynamic capabilities can be deployed, developed, and manifested. In this sense, dynamic capability is a "meta-capability" that transcends an ordinary firm capability (Teece, 2007). For analytical purposes, the current study presents how design capabilities can be disaggregated into sensing, seizing and reconfiguring capabilities.

Additionally, Akabane et al. (2016) defined a classification framework for design capabilities of first and second level automotive suppliers. The design capabilities defined in this framework are: (1) product design capability, (2) process design capability and (3) domain design capability. These design capabilities are deployed through a design process. This author concludes that "parts suppliers with product design capability are recognized as suppliers with approved drawings and have a higher probability of receiving big orders with greater value-added from vehicle makers" (Akabane et al., 2016, p. 2).

Methodological Approach

The choice for the most appropriate research strategy was given through Yin (2009), and more recently by Muratovski (2016). Both authors argue that case studies are the most appropriate research strategy for the object of the present study. Hence, the choice for a multiple case study approach for research design, as already referred, can be justified by the exploratory nature of the present research, and justified by detailed interviews gathering empirical data through the years 2020 and 2021.

This choice of research strategy is supported and explained using the following reasoning: it is the most appropriate strategy for "how", "what" and "why" questions seeking explanations or exploring development paths; it considers the crucial role of pattern and context in the search for knowledge and ensures the ability to deal with a large set of potentially explanatory variables. The choice of this research strategy, to quote Yin (2009, p. 15), is reasonable because "case studies, like experiments, are generalizable to theoretical propositions and not to populations or universes. In this sense, the case study, like the experiment, does not represent a 'sample', and in doing a case study, your goal will be to expand and generalize theories (analytical generalization) and not to enumerate frequencies (statistical generalisation)".

The aim of the research is to expand and generalize explanatory theories within the framework of analytical generalization, and not to enumerate frequencies of events, in which case statistical generalization would be contemplated. Supported by a theoretical framework and methodological clarification, case studies can be important sources for the enrichment of knowledge about the object of analysis. By adopting a broad definition of the research, the case study integrates sources of information of quantitative and qualitative characteristics and of different nature to establish the explanatory link.

To meet the present study's purpose, three firms from the Portuguese automotive cluster were selected for analysis. The selected case study firms seem to represent an appropriate sample for cross-case analysis, particularly when looking for and identifying common patterns and differences concerning the use of dynamic capabilities. Oral and written invitations to take part in the research were sent to the chosen firms. When the firms agreed to participate, meetings were arranged to describe the study's goals and data collection methodology. The qualitative nature of the current study and the related potential benefits and deficiencies were explained.

The analysis of the data acquired in this research required three phases according to Yin (2009): the analysis and report of individual cases; the analysis and report of cross cases; and the conclusions and implications of the cross cases for both theory and practice.

11.3. The Final Path – Driving the Research Home

Answering the Research Questions

Because of the author's research and case studies, it is now possible to answer the research questions. The first question asks why automotive firms choose to have design capabilities. According to the evidence collected from the firms the author studied, it is possible to understand the role of the development of design capabilities in each firm: each firm develops its design capabilities according to different product and market strategies. The case with the Sodecia firm, which currently has a conventional approach as a first tier supplier, revealed noticeably clear evidence that Sodecia adopted an initial strategy of developing design capabilities for a quick entry and with strategic positioning for a first tier supplier. Therefore, the answer to the first research question is that automotive firms choose to have design capabilities because design capabilities allow firms to position themselves using a defined business strategy.

The second research question is how automotive firms develop design capabilities. Through the review of the presented case studies, evidence was found suggesting that the development of design as dynamic capabilities for the smaller automotive suppliers' firms is strongly related to their strategic market position and indirectly related to performance. Hence, the development of design capabilities makes sense for a determined product market business strategy. Through the review of the design processes for the automotive industry, the fundamental capabilities to be developed are product, process, and domain design. These three "micro-capabilities" are developed and deployed through research constructed upon the Teece (2007) model of the micro-foundations of dynamic capabilities.

The third research question inquired as to what paths automotive firms took to develop design capabilities. From the case studied firms, it can be deduced that the intended product market determines that a business strategy based on the increase of the added value is necessary. This is a common pattern found on the three case studied firms. This means that the development of design capabilities is necessary to devise high added value products and create complex parts or modules. It was observed that the path to develop design capabilities was established through a process of resource-capability combinations that materialize through the change from a current resource base to a new resource base, influencing a new product market strategic position, which in turn may affect performance.

Regarding the main research question, why Design matters for smaller companies in the automotive industry? after the evidence and conclusions retrieved from the conducted case studies that built this investigation, the author is able to answer positively. The development of design capabilities as dynamic capabilities for the smaller automotive suppliers' firms is strongly related to their strategic market position and indirectly related to performance. For the case-studied firms, the development of design capabilities matters very much. Without design capabilities, these firms' business strategies would be entirely jeopardized.

In addition to answering the research questions, this study makes a wide contribution to the smaller supplier firms navigating this complex automotive industry and to the practice of industrial Design.

Significance and Implications of the Study Findings

One of the main ambitions in a multiple-case study is constructing a general explanation that would fit each individual case (Yin, 2009). Hence, the goal for this research is to create a global explanation for the outcomes of the multiple conducted experiments. From the multiple case report analysis, it is possible to understand that the three studied firms have different approaches to their design capability deployment alongside their business strategy. Although a pattern was not evidenced within the study details of each individual firm, it is possible to develop a theory by building through an explanatory narrative while examining the different aspects of a causal argument. Through the review of the presented case studies, evidence was found to suggest the following conclusion:

The development of design as a dynamic capability for smaller automotive suppliers' firms is strongly related to their strategic product market position and indirectly related to performance.

This conclusion is supported by the evidence found throughout the cross-case study analysis and validates the proposed theoretical framework.

Contributions for Smaller Companies in the Automotive Industry

The contributions for smaller companies in the automotive industry can be split into two groups. The first contribution group suggests developing design capabilities as dynamic capabilities. Through the analysis of the three case studies, it is shown how deployment of design capabilities can be explored through sensing, seizing and reconfiguring capabilities. This analysis enabled a better understanding of the logic behind the dynamic capabilities view (DCV) theory.

A list of suggested positive practices (that can help firms develop their design capabilities as dynamic capabilities) was generated. For product and process design, the following positive practices were suggested: networking as a systematic practice to accelerate developments and risk sharing; creating a forward-thinking talent model investing in designers as key actors; using benchmarking as a systematic practice to identify new materials, architectures and manufacturing processes; using research and development projects as a way to develop innovative technology; developing or following a design process as the most efficient and systematic way to embed the acquired knowledge from networking and benchmarking activities; systematizing the use of a bill of materials (BOM) and bill of process (BOP) as key tool for product/process cost structure; developing tools for knowledge retention such as design guidelines and lessons learned; integrating design and hiring designers as resources and capabilities necessary for the development of new positions; understanding integration as innovative in the approach described in this thesis and not as another resource to perform 2D drafting and 3D modelling.

For domain design, it was suggested the following positive practices: systematically benchmark market environment and take action accordingly; consider customers' needs as a path to develop appropriate business strategies; build, promote and nurture long-term partnerships with all stakeholders.

Additionally, a list of negative practices (which firms should seek to minimise while developing their design capabilities as dynamic capabilities) was presented. Negative practices noted in product and process design include: networking being seen as a threat to existing skills and expertise; retaining collaborators that do not engage with the automotive business; research and development activities being viewed as a cost to the company rather than profitable long-term; relying on managerial direction for product/process development next steps; relying on knowledge of "key employees".

These findings may help managers realize the practices in which dynamic capabilities work best and may provide guidance while firms seek to deploy and take advantage of design capabilities in the automotive industry.

The second group demonstrates the importance of the development of design capabilities for a determined business strategy in the automotive supply chain network. It was found that even if a pattern was not clearly evidenced due to the details of each individual firm, it can be theorised that the development of design capabilities for the automotive supplier firms is strongly related to their strategic market position and indirectly related to performance. This determination may also help managers realize that the development of design capabilities is key for the development of high added value products for the supply of complex parts or modules.

Contributions for the Practice and Education of Industrial Design

Industrial design is not usually highlighted as a cornerstone skill of most small-scale automotive supply companies. Practice suggests a double bias either in the definition of design, sometimes emphasized as style and associated with carmakers, or in design's role in developing the position of small and medium enterprises in supply networks. Moreover, the multiple definitions of Industrial Design (Maldonado, 2009; Lorenz, 1991) suggest that industrial design is not only the design of objects to be produced by means of machines in series, and that industrial design works with a clear distinction between the form of products and their function. A lack of knowledge of the definitions of industrial design, and possible misunderstandings, create barriers to the development of design and its business as well as its professional expansion within smaller automotive firms. Therefore, design is not usually found in smaller supplier firms of the automotive industry as a resource and is instead established as a process in resource-capability combinations due to the highly dynamic environments that characterize this industry.

Industrial design can establish, in firms, a dimension between style and functionality that other professional activities such as engineering cannot. The engineering practice is not focused on product design, but rather on static, dynamic and thermal calculation (applied sciences) of the designed solutions.

It is important to note that the automotive firms' workflow processes are extremely standardized. Nevertheless, this research shows that there is space and opportunity for innovation and shows that the development of design capabilities can take up this gap. Hence, the development of design capabilities can be part of a strategy as an emergent response to opportunities or in an innovative construction path.

In summation, the development of industrial design capabilities, although not the object of the current research strategy, can show how to innovate within or alongside the established norm, and can additionally demonstrate how to advance progress in the gaps within this structured industry. Hence, understanding, developing, and implementing design capability is the most appropriate strategy for smaller companies that have the agility that a mega supplier does not.

This study clearly shows a gap in suitable industrial design educational offerings and the industry's effort to build awareness for the opportunities, recognition, and support among small and medium automotive enterprises. For undergraduate programs, the author suggests incorporation of design for business transformations. For post-graduate programs, the author suggests introducing curricular units (CUs) that ensure adequate training for networks of companies with similar characteristics of the case studied ones, for post-graduates to understand integrating design processes and solutions that exist outside the already referred classic design perspectives.

Limitations of the Study and Further Research

Through these conclusions, it is possible to explore the debate on the value of further investigation on different hypotheses or propositions. The present investigation integrates a multiple case design study compiling three case studies. However, one of the greatest concerns of the case study research is perhaps that the studies provide little basis for scientific generalization. Though scientific facts are hardly based on single experiments, as they are typically based on a multiple set of experiments that have replicated the same phenomenon under different conditions, this tactic was used with the present multiple-case study. Hence, case-studies, like experiments, are generalizable to theoretical propositions and not to populations, as opposed to statistical generalization (Yin, 2009). Representation would be enhanced if more firms would integrate this study, though these three case studies are thought to be a very convincing sample of the small and medium enterprise firms that comprise most of the Portuguese automotive cluster with innovative approach to market positioning and with an emphasis on the exploratory and explanatory paths. Admittedly, the limited time frame and resources for the development of this study has had a significant impact on the size of the case study research sample. The result of these case studies establishes the domain of a new insight which did not previously exist. This knowledge, linking micro developments (in which design is a key factor) to macro changes, creates a starting point for a new and future research phase with an emphasis on more quantitative methods and larger samples.

Also, this knowledge is sought to be disseminated across the academic system through the publication of scientific papers in journals, conferences, and workshops. The results of this research will be shared with the participating firms, and industry-wide dissemination will share the research results with the automotive supply community at industry conferences and workshops. It will be directed to design professional associations and industry associations. Additionally, the dissemination process will also target a selected sample of Portuguese automotive companies suitable to adopt the approach and benefit from its results.

Across Teece (2007), a dynamic capability is a meta-capability that transcends an ordinary firm capability due to the prominence initially placed on the direct link of dynamic capabilities to performance, more exploratory studies are needed. The proposed framework for the present investigation could be used as a meta-model that holds the potential to explore similar industries. As design is not usually found in smaller firms as a resource but established as a process in resource-capability combinations, other domains and industries such as trains, aerospace, computers, mobile phones, and IT would be equally interesting to explore. These industries share a similar logic for organizing product and establishing supply networks. In particular, trains and aerospace often share suppliers.

11.4. Final Considerations

The candidate, author of this thesis, is an expert with almost two decades of experience as an industrial designer for the automotive industry, has helped to better understand the subject matter and carry out research that could answer the formulated case study questions.

During his professional experience through multiple suppliers of the automotive industry, the author always questioned why the automotive firms would want to have design capabilities. The first answers came with more questions: would the automotive firms that own design capabilities have a competitive advantage? Do firms deploying design capabilities earn more just by understanding and using these capabilities?

These questions were the motivation for a journey between industrial design practice and academic research to further develop the modest knowledge related to the deployment of design capability in the small and medium enterprise automotive manufacturing industry. It is with great satisfaction that the author drives home this research contribution to the design discipline.

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Appendix

TABLE A

Questions found in the interviews with the key respondents.

	Subject Areas / Questions	Primary Respondent	Secondary Respondent
1	**Basic information about the case study firm**		
11	**General Structure**	GM	
111	What is the ownership structure? How has it been changed over the past years and why?	GM	
112	What was the year of establishment?	GM	
113	What is the capital amount?	GM	
114	What was the sales amount of last year?	GM	
115	What was the profit rate of the last year?	GM	
12	**Organisational Strucuture**		
121	How is your firm organised (functional, matrix, divisional, process, etc.)	GM	
122	What is the current number of employees (internal, external, direct and indirect)?	GM	
123	What is your current category of Standard (ISO 9001-2008, ISO 14001, IATF 16949, other)?	GM	
124	How many years is the firm working on the automotive industry?	GM	
125	What automotive quality tools do you use? (TQM, QFD, 5s, FMEA, JIT, etc.)	GM	
126	What kind of products or services do you supply for the automotive industry?	GM	
13	**Supply Chain Position**		
131	What level of the of the supply chain pyramid do you work (or different levels)?	GM	
132	What is the percentage breakdown as Tier 1, 2 or 3 (By project and Volume)	GM	
14	**Products and Services Characterization (See Tables A1, B1 & C1)**		
141	What level of complexity are the products that you supply for the Automotive Industry? (Single parts = simple parts / Modules = complex parts)	R&D M	
142	What is the percentage breakdown of level of part complexity for each level of supply (See Table A1)?	R&D M	
143	What is the level of product development involved for each level of part complexity (See Table B1 & B2)	R&D M	
144	What is the level of process development involved for each level of part complexity (See Table C1 & C2)	R&D M	
15	**Market and Diversification (Table D)**		
151	What are your business domains (See Table D1)?	SM	GM
152	What and how many types of technologies do you manufacture per business domain (See Table D1)?	SM	GM
153	What is the single parts or modules ratio per technologies of each domain (See Table D1)?	SM	GM
154	How many costumers as supply destinations (See Table D1)?	SM	GM

Note. Case study research interviews with key respondents – Basic information about the case study firm. Source: own.

TABLE B

Questions found in the interviews with the key respondents.

	Subject Areas / Questions	Primary Respondent	Secondary Respondent
2	**Product Design Capability**		
21	**Sensing Capabilities**		
211	**Networking and partnerships development**		
2111	How networking is important for your business, product design related?	R&D M	GM
2112	In which areas and how do you proceed the networking activities, product design related?	R&D M	GM
2113	Do you have any specific strategies for doing this the so-called planned networking, product design related?	R&D M	GM
2114	Do you have any short-term/long-term partnerships with universities, R&D institutions and if so, why?	R&D M	GM
2115	Have you established any long-term partnerships and why?	R&D M	GM
212	**Follow-up of Science and Technology**		
2121	Are your employees members of diverse professional associations? Which are they?	R&D M	
2122	Do your employees closely follow technological development and science and technology in general?	R&D M	
213	**Benchmarking Activities**		
2131	Do you promote or demand on-going benchmark activities?	R&D M	
2132	How do you identify new materials, architectures and manufacturing processes?	R&D M	
2133	How do you discover the needs of your existing and potential customers/markets?	R&D M	SM
2134	Do you do any usability assessment?	R&D M	
214	**R&D Activities**		
2141	Do you have any R&D projects? If so for what purpose?	R&D M	
22	**Seizing Capabilities**		
221	**Design Process**		
2211	Do you follow the APQP process under the IATF 16949?	R&D M	
2212	Do you follow any Design process for the Product Design and development? If so which one?	R&D M	
2213	How do you select the technologies and features that are to be embedded in the product?	R&D M	
2214	How do you define the architecture of the product?	R&D M	
2215	How do you integrate the benchmarking activities and usability assessment in your product development activities?	R&D M	
222	**BOM and Cost Structure**		
2221	How do you structure a BOM and how does it integrate with the cost structure of the product?	R&D M	
2222	How do you reflect design changes in the develop phase through the BOM and into the cost structure?	R&D M	
23	**Reconfiguring Capability**		
231	**Reconfiguring the Resource Base**		
2311	How does the process of reconfiguring, implementing and adapting the product design development activities takes place?	R&D M	
2312	How successful are you on embedding the new knowledge (e.g. aquired from R&D activities, benchmarking) in your product design activities?	R&D M	
232	**Effectiveness of the product design processes**		
2321	How do you measure the product design and development activities effectiveness?	R&D M	
2322	How do you improve product design and development effectiveness?	R&D M	
2323	How do you retain knowledge and know-how for future projects (e.g. Lessons Learnt, Things Gone Right/Wrong)	R&D M	

Note. Case study research interviews with key respondents – Product Design Capability.

Source: own.

TABLE C

Questions found in the interviews with the key respondents.

	Subject Areas / Questions	Primary Respondent	Secondary Respondent
3	**Process Design Capability**		
31	**Sensing Capabilities**		
311	**Networking and partnerships development**		
3111	How networking is important for your business, process design related?	GM	R&D M
3112	In which areas and how do you proceed the networkig activities, process design related?	GM	R&D M
3113	Do you have any specific strategies for doing this the so-called planned networking, process design related?	GM	R&D M
3114	Do you have any short-term/long-term partnerships with universities, R&D institutions and if so, why (Process Design related)?	GM	R&D M
3115	Have you established any long-term partnerships and why (Process Design related)?	GM	R&D M
312	**Benchmarking Activities**		
3121	Do you promote or demand on-going benchmark activities to tooling and machinery?	R&D M	
3122	How do you identify new materials, architectures and manufacturing processes for building machines and tooling?	R&D M	
313	**R&D Activities**		
3131	Do you have any R&D projects? If so for what purpose (Process Design Related)?	R&D M	
32	**Seizing Capabilities**		
321	**Design Process**		
3211	Do you follow any Design process for the Process Design and development? If so which one?	R&D M	
3212	How do you select the technologies and features that are to be embedded in the design of machines and tools?	R&D M	
3213	How do you integrate the benchmarking activities in your machines and tooling development activities?	R&D M	
33	**Reconfiguring Capability**		
331	**Reconfiguring the Resource Base**		
3311	How does the process of reconfiguring, implementing and adapting the process design development activities takes place?	R&D M	
3312	How successful are you on embedding the new knowledge (e.g. aquired from R&D activities) in your process design activities?	R&D M	
332	**Effectiveness of the process design processes**		
3321	How do you measure the process design and development activities effectiveness?	R&D M	
3322	How do you improve the process design and development effectiveness?	R&D M	
3323	How do you retain knowledge and know-how for future projects (e.g. Lessons Learnt, Things Gone Right/Wrong)	R&D M	

Note. Case study research interviews with key respondents – Process Design Capability.

Source: own.

TABLE D

Questions found in the interviews with the key respondents.

	Subject Areas / Questions	Primary Respondent	Secondary Respondent
4	**Domain Design Capability**		
41	**Sensing Capabilities**		
411	How does the process of sensing, taping new opportunities take place?	GM	SM
412	Are there any areas with more/less opportunities?	GM	SM
413	Do you benchmark your environment? Explain this activity.	SM	GM
414	How important is collaboration with the Automotive suppliers, technological leaders in the Automotive industry? Why?		
42	**Seizing Capabilities**		
421	How does the process of recognising the “right” opportunities/ideas/models take place?	SM	GM
422	On which areas have you been able to adapt most of the opportunities and why?	SM	GM
423	Do you consider costumers’ needs when developing your business strategies? How?	SM	GM
424	Are your customers taking an active part in the innovation process? Explain.	SM	GM
43	**Reconfiguring Capability**		
431	What is your customer retention rate (for the last five years)?	SM	GM
432	Do you have any short-term/long-term partnerships with your competitors (joint R&D, market entrance) and if so, why?	SM	GM
433	Do you have any short-term/long-term partnerships with universities, R&D institutions and if so, why (the level of commercialisation)?	SM	GM
434	Do you have any short-term/long-term partnerships with any other subjects in your environment and if so, why?	SM	GM

Note. Case study research interviews with key respondents – Domain Design Capability.

Source: own.

TABLE A1

Production percentage breakdown of level of complexity for each market

	Tier Level		
	Tier 1	Tier 2	Tier 3
Simple Parts			
Complex Parts			

Note. Source: own.

TABLE B1

Level of Classification of product design of percentage developed projects according to Akabane et al. (2016)

	Classification Level of Product Design					
	1	2	3	4	5	6
Simple Parts						
Complex Parts						

Note. Source: own.

TABLE C1

Level of Classification of process design of percentage developed projects according to Akabane et al. (2016)

	Classification Level of Process Design				
	1	2	3	4	5
Simple Parts					
Complex Parts					

Note. Source: own.

TABLE D1

Developed projects per market, business domain and type of part.

		Domain 1		Domain 2	
	Tier	Simple Parts	Complex Parts	Simple Parts	Complex Parts
Customer 1					
Customer 2					
Customer 3					
Customer X					

Note. Source: own.

TABLE E

Coding process using focused coding methods.

Capability	Components of Dynamic Capability	Examples indicating the development of dynamic capabilities
Domain Design	Sensing	"No que diz respeito ao mercado OEM/OES a apreensão de novas oportunidades é feita através de RFQs por parte dos clientes em que a Veneporte concorre"
		"Relativamente ao mercado IAM, é através dos distribuidores que trabalham com a Veneporte que induzem as novas oportunidades de negócio, nomeadamente novas gamas (associados a nova legislação comunitária), ou novos produtos (binómio produto/gama)."
		"Tendo, no entanto, algumas portas interessantes nos mercados OEM e OES a abrir atualmente. A Veneporte sente algumas oportunidades a curto prazo quer para o mercado OEM quer para o OES. Contudo, do ponto de vista concreto e efetivo, tendo já algumas negociações feitas para 2021, é a área de negócio IAM."
		"Para os mercados OEM e OES é feita uma análise daquilo que são as oportunidades ou potenciais oportunidades de negócio na carteira de clientes face aquilo que é a capacidade que a Veneporte pode aportar ao projecto face aos seus concorrentes."
		"Já no que diz respeito ao segmento IAM é completamente diferente. A Veneporte faz uma análise de mercado a mercado, não só no que diz respeito ao tipo de gama comercializada, como aquilo que poderão ser as novas referencias (mais procuradas pelo mercado e que a Veneporte não tem disponível), posicionamento dos preços, avaliação da concorrência (no que diz respeito ao binómio preço/qualidade) e homologação relativa à legislação europeia."
		"A Veneporte tanto colabora com fornecedores tier 1, como fornecedores de nível mais baixo na cadeia de fornecimento da indústria. Esta colaboração, é de importância fundamental para a Veneporte."
	Seizing	"As oportunidades comerciais são pesquisadas pela parte da equipa comercial responsável pelo seguimento de determinados clientes, que depois de fazer uma pré-análise da oportunidade, apresenta à direção comercial, e a direção comercial dá ou não seguimento para uma pré-estudo técnico "
		"Do ponto de vista de volume de negócio e de crescimento da empresa e onde a Veneporte vê mais oportunidades de crescimento e de um desenvolvimento mais sólido do negócio é no mercado IAM. Contudo, a Veneporte está neste momento a concorrer para um projecto OEM de interesse económico e estratégico relevante."
		"este posicionamento, reflete o percurso que a empresa tem tido, até porque, o facto da Veneporte não trabalhar exclusivamente o mercado OEM/OES, acaba por dar outro tipo de oportunidade face às características do produto da Veneporte, tirando partido da capacidade e flexibilidade dos recursos, maximizando resultados."
		"A Veneporte está sempre muito atenta às necessidades sobretudo dos seus clientes estratégicos em todos os mercados (OEM, OES e IAM)"
		"A Veneporte considera que se não estiver atenta às necessidades dos clientes estratégicos, uma parte significativa do negócio poder-se-á perder."
	Reconfiguring	"É muito elevada nos três mercados. Cerca de 90%. É possível que se tenha perdido cota em alguns clientes, contudo a retenção mantém-se."
		"A Veneporte está neste momento num processo de parceria deste tipo com um dos maiores players mundiais (tier 1). A gama da Veneporte serve de gama de comercialização para o parceiro."
		"A Veneporte está neste momento a terminar a fase de teste do desenvolvimento de um novo produto em parceria com duas Universidades e uma instituição da Universidade de Coimbra integrado no programa de apoio estatal Compete 2020."

Note. Coding process (Domain Design) for Interview with General Manager – Veneporte.

TABLE F

Coding process using focused coding methods.

Capability	Components of Dynamic Capability	Examples indicating the development of dynamic capabilities
Product Design	Sensing	"Sem networking a VENEPORTE não conseguiria desenvolver produtos no nível de qualidade exigido pelas OEM."
		"As diferentes áreas de networking estão intrinsecamente ligadas ao processo de design"
		"Não existem acordos de cooperação “oficiais”, assinados, contudo têm relações muito próximas e de há muito tempo com a Universidade de Aveiro e Universidade de Coimbra."
		"O Gestor da VENEPORTE tem contactos estreitos com professores e investigadores de ambas as Universidades."
		"As atividades de benchmarking são regulares tanto para aferir a oferta em termos tecnológicos como a nível de preços."
		"fazem-se investimentos tecnológicos para aumentar o leque de soluções em termos de design (por exemplo, curvas com geometrias mais complicadas, posicionamento de crivos) e melhoria da eficácia dos processos produtivos."
		"No que diz respeito à parte “quente”, a VENEPORTE está muito dependente dos seus parceiros de R&D (exemplo, laboratórios), para fazer análises às soluções da concorrência."
		"atividades de benchmarking, que passam pela aquisição e análise de produtos da concorrência (tear down dos produtos da concorrência)"
		"Nestes pedidos de cotação existem OEM’s que pouco para além da volumetria do ambiente de montagem e especificações da motorização detalham (remetendo a especificação da tecnologia para o fornecedor) e outras (mais maduras) que dão as especificações do produto acabado. Para além da oportunidade de ganhar o projeto, este último caso, dá uma oportunidade à VENEPORTE de se equiparar tecnologicamente ao painel de fornecedores globais existente."
		"Sim. Com o objetivo de diversificar a área de ação da empresa no que diz respeito à sua oferta em termos de produto."
	Seizing	"Sim, possuímos o nosso, baseado na IATF. Assim, a VENEPORTE, baseado na norma IATF 16494, desenvolveu com a sua documentação interna e espelhando a sua realidade o seu processo de design."
		"Através das atividades de benchmarking e R&D e da relação muito próxima com alguns dos fornecedores da nossa gama de produtos “quente”, ou seja, dos filtros DPF (diesel particulate filter), monólitos (peça que contem os metais nobres para a transformação dos gases nos catalisadores). Estes componentes são muito importantes na definição técnica final dos produtos da VENEPORTE."
		"Partindo da análise da concorrência, ou seja, das atividades de benchmarking, posteriormente e recorrendo a parceiros estratégicos como as entidades laboratoriais e as universidades, integrando-as nas soluções já existente, no know-how existente."
	Reconfiguring	"a gestão de topo tem muita interferência na programação das atividades do departamento de técnico. Quase numa base semanal, a gestão de topo identifica novas necessidades que são priorizadas, não pela gestão do departamento técnico, mas por si. Uma das grandes lacunas do departamento técnico da VENEPORTE é a precisamente a deficiente estruturação da priorização das atividades."
		"Na prática a equipa tem uma capacidade dinâmica de se adaptar e reinventar admirável, e conseguem fazê-lo, mas a custo de 90% das vezes, falhar prazos. Que, é um custo muito grande."
		"A VENEPORTE é bem-sucedida na aplicação dos outputs desses processos (R&D e Benchmarking) em associação com os seus parceiros de desenvolvimento de produto, porque de outra maneira não seria possível obter um produto vendável."
		"A VENEPORTE considera essencial a implementação do conhecimento adquirido nas atividades de R&D e benchmarking no desenvolvimento dos seus produtos."
		"existe um KPI interno que é seguido pelos vários níveis de gestão que contempla o número de horas de atividades de desenvolvimento de produto por projetos desenvolvidos."
		"A VENEPORTE considera que há uma grande falha no desenvolvimento do produto em termos de retenção do conhecimento, em não conseguir documentar o conhecimento adquirido ao longo do desenvolvimento dos seus produtos."

Note. Coding process (Product Design) for Interview with R&D Manager – Veneporte.

TABLE G

Coding process using focused coding methods.

Capability	Components of Dynamic Capability	Examples indicating the development of dynamic capabilities
Process Design	Sensing	"o networking é relativamente pouco importante no sentido em que a VENEPORTE é possuidora de todo o know-how necessário para o processo de design."
		"a empresa recorre ao seu painel de fornecedores para manutenção e aquisição de máquinas novas ou subcontratação de serviços (por exemplo, erosão por fio)"
		"a VENEPORTE está localizada numa zona com forte e intensa presença industrial no ramo da transformação metálica"
		"não há grande inovação nessa área pois as geometrias das peças são muito semelhantes de produto para produto."
		"Não, a VENEPORTE não tem projectos de R&D relacionados com o seu processo de design"
	Seizing	"utilizam o seu próprio processo de design que é um processo, no caso das ferramentas progressivas, de design mecânico. Os layouts da ferramenta são inicialmente estabelecidos através do desenho da banda e a forma e função das matrizes e punções são desenvolvidos a partir daí."
		"Não são feitas atividades de benchmarking relacionadas com o design de processo."
	Reconfiguring	"a equipa de design de produto e de design de processo é a mesma. Assim o planeamento é alterado e a equipa reconfigurada consoante a priorização (muitas vezes por parte da gestão de topo) e as necessidades emergentes."
		"A VENEPORTE não tem atividades de R&D relacionadas com o design do processo."
		"existe um KPI interno que é seguido pelos vários níveis de gestão que são o número de horas de atividades de desenvolvimento de produto por projetos desenvolvidos. Estas horas incluem design do produto e design do processo."
		"A VENEPORTE considera que há uma grande falha no desenvolvimento do produto em termos de retenção do conhecimento, em não conseguir documentar o conhecimento adquirido ao longo do desenvolvimento dos seus produtos."

Note. Coding process (Process Design) for Interview with R&D Manager – Veneporte.

TABLE H

Coding process using focused coding methods.

Capability	Components of Dynamic Capability	Examples indicating the development of dynamic capabilities
Domain Design	Sensing	"Em primeiro lugar as necessidades dos clientes que podem ter vários âmbitos, por exemplo a resolução de um problema, ou informação sobre uma nova tecnologia que necessita utilizar e que pode não existir, mas a KLC pode vir a desenvolver."
		"Em segundo lugar são utilizados estudos de benchmarking e marketing fornecidos por diversas associações que a KLC faz parte que são muito úteis por mostrarem informações valiosas como pesquisas, rácios e tendências."
		"Em terceiro lugar as convenções empresariais, feiras internacionais e nacionais onde se expande a rede de contactos e se trocam informações valiosas com fornecedores tecnológicos, parceiros industriais e competidores."
		"Existe uma grande transformação na indústria automóvel devido à eletrificação"
		"Em consequência, a KLC considera que percentualmente, a incorporação de polímeros técnicos no design de automóveis vai aumentar, não só por razões económicas, mas também por razões técnicas."
		"A KLC considera que esta informação não é necessariamente feita pela empresa pois ela existe e está disponível."
		"a KLC considera que o benchmarking é importante para perceber que há linhas limite e que elas não podem baixar em certos indicadores de performance."
		"É muito importante este tipo de colaboração para a KLC. Atualmente a KLC colabora com um fornecedor tier 1 (Bosch) e um OEM (Autoeuropa) para com eles desenvolver alguns conceitos inovadores de peças em polímeros técnicos."
	Seizing	"Não existe um automatismo na KLC para reconhecer a oportunidade certa."
		"A KLC sabe que é fundamental existirem fatores de diferenciação e por isso tenta que os projetos tenham o maior valor acrescentado possível sendo que a inovação é um deles."
		"Automóvel, interiores, cockpit."
		"A KLC não se imagina a desenvolver uma estratégia de negócio que não levasse em consideração as necessidades dos seus clientes."
		"É a base da definição da estratégia do negócio."
		"Nos projetos de R&D de inovação que a KLC tem com a Bosch e a Autoeuropa, existe uma colaboração dos clientes, contundo num grau que a KLC gostaria que fosse mais desenvolvido."
	Reconfiguring	"100%"
		"A KLC de momento tem um projeto em partnership com um concorrente para market entrance."
		"A KLC está neste momento em consórcio com a Universidade do Minho e Universidade de Coimbra para o desenvolvimento de tecnologia no domínio dos revestimentos."

Note. Coding process (Domain Design) for Interview with General Manager – KLC.

TABLE I

Coding process using focused coding methods.

Capability	Components of Dynamic Capability	Examples indicating the development of dynamic capabilities
Process Design	Sensing	"É fundamental em toda a nossa área."
		"A KLC considera que não pode estar isolada do mundo e sim conviver com toda esta cadeia humana de valor que existe à sua volta como a concorrência, os fornecedores, os clientes, em resumo, todos os stakeholders que forma a complexa rede que é a indústria automóvel."
		"Em primeiro lugar através de contacto direto com os parceiros. Em segundo lugar por investigação, pesquisa online, pesquisa de artigos científicos publicados. Em terceiro lugar com contactos com universidades e centros de R&D. Por último, a KLC considera que a partilha de experiências com outros parceiros de atividade é fundamental para o desenvolvimento do networking."
		"A KLC não tem uma estratégia definida para um processo de networking planeado."
		"Actualmente a empresa está envolvida em projectos de R&D com Universidades e com clientes (Universidade do Minho, Universidade de Coimbra e Bosch) na área de reciclagem de materiais."
		"A KLC considera que todos os seus fornecedores são seus parceiros e só assim faz todo o sentido criar relações de longo termo."
		"Permanentemente."
		"A KLC considera, que o conhecimento adquirido através do benchmarking, e posteriormente implementado através do processo de design, traz vantagens ao nível de redução do tempo de desenvolvimento do design de processo."
		"A identificação de novos materiais e arquiteturas surgem sempre de uma necessidade especifica de cada projeto."
		"Atualmente a KLC encontra-se a desenvolver um projeto na área dos revestimentos."
		"Para além deste projeto a KLC está a desenvolver mais projetos nesta mesma área de decoração de interiores automóvel."
		"Estes projetos têm a estreita colaboração da Universidade Aveiro e da Universidade de Coimbra."
		"Alguns dos colaboradores fazem parte da ordem dos engenheiros."
		"A maioria dos colaboradores seguem e interessam-se por ciência e tecnologia em geral assinando revistas e publicações relativas a design e engenharia."
	Seizing	"A KLC não utiliza um processo de design estabelecido."
		"A KLC, mesmo não tendo o seu processo descrito num documento, consegue mapear o seu próprio processo e segui-lo."
		"Ou seja, são os constrangimentos definidos pelas especificações do design do produto e o budget acordado para o projeto que vão definir o a tecnologia e as características do processo a desenhar."
		"A KLC integra o conhecimento adquirido pelas atividades de benchmarking através dos exercícios de brainstorming nas equipas de projeto durante uma fase inicial do design de processo."
		"Apesar de sempre ter existido uma estrutura BOM na KLC, é algo que atualmente tem um funcionamento bastante rudimentar e é muito pouco explorada internamente."
	Reconfiguring	"Assim as atividades de design de processo e R&D não são iniciadas sem o planeamento exaustivo de todas as atividades."
		"Este planeamento é construído tendo por base o processo APQP e posteriormente todas as atividades de design são adaptadas consoante as especificidades do produto para o qual o processo vai ser desenhado."
		"A KLC considera que o sucesso é total."
		"O Departamento de Engenharia tem vários KPIs ligados a diferentes etapas dos processos de design e de R&D."
		"Esta é feita através de objetivos definidos anualmente."
		"A KLC tem um documento de lessons learnt que já utilizou em alguns projetos."

Note. Coding process (Process Design) for Interview with R&D Manager – KLC.

TABLE J

Coding process using focused coding methods.

Capability	Components of Dynamic Capability	Examples indicating the development of dynamic capabilities
Product Design	Sensing	"Muito importante."
		"Através do modelo organizacional da Sodecia."
		"Existem pessoas que ocupam posições que têm na sua descrição de funções uma responsabilidade de criar e desenvolver esse networking."
		"Os chief product engineers estão focados no networking no que diz respeito a produto e os key account managers estão focados no que diz respeito aos clientes."
		"No cruzamento destes dois temos o nosso networking de produto construído. Porque desta forma é possível ter uma visão matricial do binómio cliente/produto que nos diz as tendências e nos dá informação relevante para os próximos projectos."
		"Existem rotinas no modelo de gestão, que organizam a atividade das pessoas e as direcionam no sentido da criação do networking."
		"Sim, só short-term com algumas Universidades e só product oriented."
		"No que diz respeito a produto não existem."
		"Sim mas um número muito limitado."
		"Menos do que deviam. Só um número limitado de pessoas. Gostaria que houvesse mais."
		"Sim para produto."
		"Pelas especificações técnicas de clientes e fornecedores, pelas análises de benchmarking e pela resolução de problemas de qualidade."
		"Basicamente, e uma vez mais, pelas rotinas de contacto, pelas design-reviews e pelas especificações de produto."
		"A Sodecia tem um departamento de R&D que tem três áreas de atuação."
		"Uma das áreas é a geração de conhecimento onde os colaboradores investigam e desenvolvem novo conhecimento, novas soluções técnicas."
		"A outra área estará relacionada com a prototipagem e a terceira com testes."
		"O conjunto das três áreas permitem fazer os quality loops de desenvolvimento em que é possível conceptualizar a solução, desenhando-a, construir o protótipo da solução, testar a solução e fazer um feedback do loop."
	Seizing	"Sim."
		"Cada novo projeto de desenvolvimento na Sodecia é gerido por um modelo de processo próprio que tem por base o APQP e cuja revisão é feita através de sete gates próprios com check-lists correspondentes e aprovação formal."
		"A arquitectura do produto é definida pela análise funcional do produto e pela análise das interfaces."
		"Não existe uma formalização num processo. O conhecimento está disponível para os colaboradores o utilizarem, mas não existe um processo formalizado relativamente à utilização do conhecimento das atividades de benchmarking."
		"O custo do produto é calculado precisamente com os dados de entrada: a BOM e a BOP (Bill of Process)."
		"São a base de custeio da Sodecia para qualquer produto."
		"Há um processo sistematizado para este tema."
		" Cada BOM e cada BOP estão associados a um determinado nível de engenharia."
		"As BOMs e as BOPs estão suportadas num registo formal, sendo possível fazer a rastreabilidade dos documentos."
	Reconfiguring	"As equipas de design de produto estão organizadas por tipologia de produto e as equipas de design de processo por tipologia tecnológica."
		"Um produto é sempre desenvolvido pela mesma equipa com a mesma supervisão."
		"Contudo, existem pontualmente problemas de gestão de capacidade, e quando os há são deslocados recursos de outras equipas com menor carga. De notar que esta situação não é a regra."
		"Existem um conjunto de competências que são transversais a toda a linha de produtos e essa é gerida com base unicamente na base da capacidade disponível (e.g., FEM)."
		"O problema no departamento de desenvolvimento de produto da Sodecia passa sobretudo pela capacidade de capitalização do conhecimento."
		"Passamos uma fase em que o conhecimento é gerado e é guardado pelas pessoas assim, sinto a necessidade de uma elevada taxa de retenção de pessoas."
		"Através da entrega on-time dos deliverables em cada milestone."
		"Através de testes de validação virtuais ou reais."
		"Basicamente por lessons learnt e melhores práticas. Sendo que lessons learnt é a consequência de things gone right / things gone wrong."

Note. Coding process (Product Design) for Interview with R&D Manager – Sodecia.

TABLE K

Coding process using focused coding methods.

Capability	Components of Dynamic Capability	Examples indicating the development of dynamic capabilities
Process Design	Sensing	"Vantajoso."
		"Relativamente ao processo, e como já foi referido, o networking é vantajoso para um acesso mais expedito a informação sobre tecnologias inovadoras. É só vantajoso porque a nossa base de fornecedores oferece regularmente informação sobre o seu processo de inovação. A Sodecia faz a avaliação de fornecedores também pela sua capacidade de inovação."
		"Existem rotinas no modelo de gestão, que organizam a atividade das pessoas e as direcionam no sentido da criação do networking."
		"os nossos engenheiros de processo têm rotinas de contacto com as unidades de produção e fornecedores."
		"Não."
		"No que diz respeito a processo sim, existem long term com alguns fornecedores chave."
		"Sim."
		"Pelas especificações técnicas de clientes e fornecedores, pelas análises de benchmarking e pela resolução de problemas de qualidade."
		"Não."
	Seizing	"A Sodecia utiliza a metodologia APQP tanto para o design de produto como para o design de processo."
		"Com base em critérios técnicos e económicos."
		"Não existe uma formalização num processo. O conhecimento está disponível para os colaboradores o utilizarem, mas não existe um processo formalizado relativamente à utilização do conhecimento das atividades de benchmarking."
	Reconfiguring	"A equipa de desenvolvimento de processo depende sempre do tipo de tecnologia utilizada, contudo é sempre a mesma."
		"O problema no departamento de desenvolvimento de produto da Sodecia passa sobretudo pela capacidade de capitalização do conhecimento."
		"Passamos uma fase em que o conhecimento é gerado e é guardado pelas pessoas assim, sinto a necessidade de uma elevada taxa de retenção de pessoas."
		"Através da entrega on-time dos deliverables em cada milestone."
		"Através de testes de validação virtuais ou reais."
		"Basicamente por lessons learnt e melhores práticas. Sendo que lessons learnt é a consequência de things gone right / things gone wrong."

Note. Coding process (Process Design) for Interview with R&D Manager – Sodecia.

TABLE L

Coding process using focused coding methods.

Capability	Components of Dynamic Capability	Examples indicating the development of dynamic capabilities
Domain Design	Sensing	"Tem várias dimensões."
		"Tem uma dimensão comercial que decorre das atividades das equipas de desenvolvimento e comercial que estão em contacto regular com os clientes e as suas equipas técnico-comerciais."
		"A segunda dimensão, é uma dimensão mais ampla a um nível hierárquico mais elevado, que tem que ver com o estudo e acompanhamento da situação do mercado e suas tendências assim como dos movimentos dos clientes."
		"Assim são feitas anualmente cerca de 48 reuniões dedicadas ao crescimento do negócio com informações de toda a geografia do grupo que posteriormente são filtradas por forma a direcionar a estratégia alimentando um plano de ações para o efeito."
		"Onde nós vemos mais possibilidade de oportunidades são em toda a gama de produto para interiores (cross car beams, tie down loops e os seat belt height adjusters)."
		"Onde vemos menos oportunidades será na gama de produtos relacionada com o drivetrain do ICE clássico."
		"Sim. A Sodecia faz uma análise regular aos produtos quer de produtos semelhantes da nossa concorrência quer dos produtos que estão na vizinhança dos nossos."
		"Este tipo de estratégia de colaboração não existe no grupo Sodecia."
		"A capacidade instalada é superior à procura, a concorrência é feroz e a proteção do know-how, quer seja das hard-skills quer seja das soft-skills, é muito dura."
	Seizing	"Através de um processo de discussão por uma equipa transversal que engloba membros da equipa comercial, da equipa de desenvolvimento, dos diretores gerais das unidades de negócio e das equipas corporativas de gestão."
		"A área do hotforming era uma área onde a Sodecia não estava presente, a estratégia de aquisição passou não pelo produto, mas pela tecnologia, foi uma conjugação do plano técnico com o plano de investimentos."
		"Nos cross car beams foi basicamente pelo sucesso da estratégia comercial e reconhecimento da capacidade técnica."
		"Sim. Pela análise das especificações técnicas que são recebidas, pela análise das interfaces e pelas interações em fase de desenvolvimento (por exemplo durante os ensaios de validação, de montabilidade, etc)."
		"Sim. Os clientes definem a tecnologia que querem instalar nas suas plataformas. Contudo estão abertos a instalar tecnologia inovadora que esteja validada."
		"Esse processo de desenvolvimento de tecnologia inovadora é feito em paralelo num projecto de R&D com o cliente."
	Reconfiguring	"100%"
		"Não, pelo ambiente de competição existente."
		"Sim, só short-term. Em termos de marketing, a Sodecia contrata prestadores de serviços especialistas em colectar e compilar informação de uma forma que seja útil para o negócio."
		"Sim, temos relações long-term com fornecedores e mesmo com todos os stakeholders, nuns casos mais evidentes do que outros. Mas sobretudo com entidades governamentais das regiões onde a Sodecia opera, com a base de fornecedores da Sodecia, com as entidades financeiras."

Note. Coding process (Domain Design) for Interview with General Manager – Sodecia.