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IDENTIFICAÇÃO DE BARREIRAS NA IMPLEMENTAÇÃO DE METODOLOGIAS ÁGEIS NA INDÚSTRIA AUTOMÓVEL

DANIEL ESTEVES SOARES
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IDENTIFYING BARRIERS IN THE IMPLEMENTATION OF AGILE METHODOLOGIES IN AUTOMOTIVE INDUSTRY

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Daniel Esteves Soares
1130482

Dissertation presented to ISEP – School of Engineering, Polytechnic of Porto to fulfill the requirements necessary to obtain a master's degree in Mechanical Engineering, carried out under the guidance of Doctor Francisco José Gomes da Silva from the department of Mechanical Engineering, and co-supervised by Doctor Sandra Cristina Faria Ramos from the School of Engineering, Polytechnic of Porto, as well as by Doctor Konstantinos Kirytopoulos from the School of Mechanical Engineering, National Technical University of Athens.

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Second supervisor
Sandra Cristina Faria Ramos, PhD
Adjunct Professor, School of Engineering, Polytechnic of Porto - Portugal
Third supervisor
Konstantinos A. Kirytopoulos, PhD
Associate Professor, School of Mechanical Engineering, National Technical University of Athens - Greece
Examiner
Christiane Lucas Tscharf, PhD
Auxiliar Professor, University Institute of Maia - Portugal

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KEYWORDS

Agile Project Management, Agile Methodologies, Barriers, Enablers, Automotive Industry

ABSTRACT

The automotive sector is one of the major contributors for the worldwide economy, not being just a vital element in the economy of the industrialized countries, where motor vehicle production and sales are one of the major impellers of the economy in those countries, but also contributes to the growth of other related activities as metallurgy, plastic/rubber, electronics, textiles, etc. thus empowering the global industrialization. The increasing competitive pressure in the sector led to the "projectivization" of product development processes, through defined concepts and organizational frameworks. However, as projects have grown into more dynamic and complex, consequently the ways of managing them should be reconsidered. Agile Project Management emerged within the software industry, but its applicability is theoretically feasible to any industry. This approach despite permitting to meet the rapidly changing requirements through iterative development, and increasing the process efficiency, the companies also face barriers and challenges in its implementation. Although there is literary evidence of barriers observed in the implementation of Agile Methodologies in software development, there is a lack of bibliographic evidence of barriers observed in the manufacturing sector, and almost null in the Automotive Industry. This survey intended to address a literature gap, identifying barriers in the implementation of Agile Methodologies in the Automotive Industry through a questionnaire survey, categorizing them, and detecting their major source, as well as find possible enablers and recommendations to overcome the identified barriers.

"Organizational", and "Knowledge and technology" barriers were found, through the factor "Improper competency management". It was corroborated the existence of "Institutional" barriers, through the factor "Change predisposition", and its correlation with the "No obligation" barrier. It was also found a correlation between the factor "Absence of immediate quantifiable benefits" with the "Lack of financial support" barrier, fitting these variables into the "Financial" barrier category. "Organizational support" and "Investment in training" were identified as the main enablers for the Agile Methodologies implementation. Lastly, a flowchart was developed to sequence the possible enablers and recommendations to overcome the identified barriers.

PALAVRAS CHAVE

Gestão Ágil de Projeto, Metodologias Ágeis, Barreiras, Facilitadores, Indústria Automóvel

RESUMO

A Indústria Automóvel é uma das maiores contribuições para a economia global, não sendo somente um elemento essencial na economia de países industrializados, onde a produção e venda de veículos motorizados são um dos maiores impulsionadores da economia desses países, como também contribui para o crescimento de outras atividades relacionadas, tais como metalurgia, plásticos e borrachas, dispositivos eletrónicos, têxteis, etc. contribuindo desta forma para a industrialização global. O aumento da pressão competitiva no setor conduziu à estruturação dos processos de desenvolvimento do produto, através da definição de conceitos e hierarquias organizacionais. No entanto, à medida que os projetos se tornam mais dinâmicos e complexos, consequentemente as formas de os gerir devem ser reconsideradas. A Gestão Ágil de Projeto surgiu na indústria do software*, mas a sua aplicabilidade é teoricamente possível em qualquer indústria. Esta abordagem, apesar de permitir alcançar rápidas mudanças nos requisitos através de repetições sucessivas, e aumentar a eficiência do processo, as organizações também enfrentam barreiras e desafios na sua implementação. Embora haja evidência literária quanto às barreiras observadas na implementação de metodologias ágeis no desenvolvimento de software, é escassa a evidência bibliográfica quanto às barreiras observadas no setor da produção, e é praticamente nula na Indústria Automóvel. Este estudo pretendeu colmatar uma lacuna na literatura, através da identificação de barreiras na implementação de Metodologias Ágeis na Indústria Automóvel por intermédio de um questionário, categorizar as barreiras, assim como identificar a sua principal origem, encontrar possíveis recomendações e facilitadores para ultrapassar as barreiras identificadas.*

Foram encontradas barreiras "Organizacionais" e de "Conhecimento e tecnologia", através do fator "Competência de gestão inadequada". Foi corroborada a existência de barreiras "Institucionais", através do fator "Predisposição para a mudança", e a sua correlação com a barreira "Não obrigação". Também foi encontrada uma correlação entre o fator "Ausência de benefícios imediatos quantificáveis" com a barreira "Falta de suporte financeiro", abrangendo estas variáveis na categoria de barreiras "Financial". "Suporte organizacional" e "Investimento em formação" foram identificados como os facilitadores principais para a implementação de Metodologias Ágeis. Por fim, foi desenvolvido um fluxograma de modo a sequenciar os possíveis facilitadores e recomendações para superar as barreiras identificadas.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

AFIA	Portuguese Manufacturers Association for the Automotive Industry
AI	Automotive Industry
AM	Agile Methodologies
APM	Agile Project Management
Cat.	Categories
CBM	Circular Business Models
CPM	Critical Path Method
EUR	Euro
FLD	Finish Latest Date
Hypos	Hypothesis
IT	Information Technology
No.	Number
OEMs	Original Equipment Manufacturers
OICA	International Organization of Motor Vehicle Manufacturers
PERT	Program Evaluation and Review Technique
PM	Project Management
PO	Product Owner
QCT	Quality, Cost and Time
qn	Questions
SDLC	Software Development Life Cycle
SLD	Start Latest Date
SM	Scrum Master
ST	Scrum Team
TPM	Traditional Project Management
UK	United Kingdom
WIP	Work In Progress

List of symbols

%	Percentage

GLOSSARY OF TERMS

Agile Methodology	Any practice or method correlated to the Agile Project Management, that contributes to the execution of a process, and that may employ one or more techniques and tools.
Barrier	Any factor that hinders, affects, or resists to the occurrence of a certain action, resulting in its delay or obstruction.
Enabler	Any factor that facilitates, helps, accelerates, or encourages the event of a certain action.
Kanban	Card or visual sign that promotes the visualization of the system workflow, through columns that represent the states of the work.
Scrum	Single team iterative process framework, used to manage product development, and based on a variety of concepts such as customer feedback, daily scrum meetings, product backlog, sprint backlog, sprints, and delivery-ready after each sprint.
Scrumban	Hybrid framework where teams use scrum as a framework, and kanban for process improvement.

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INTRODUCTION

1 INTRODUCTION

1.1 CONTEXTUALIZATION

The automotive sector is one of the major contributors for the worldwide economy, not being just a vital element in the economy of the industrialized countries, where motor vehicle production and sale are one of the major impellers of the economy in those countries, but also contributes to the growth of other related activities as metallurgy, plastic/rubber, electronics, textiles, etc. thus empowering the global industrialization. In Portugal, the Automotive Industry (AI) has a relevant economy and social importance contributing with 8% for the manufacturing industry employment, 6% for the gross domestic product, and 16% for exportation of tradeable goods.

The outstanding contribution of the AI to the technological advance was the establishment of full-scale mass production, a process characterized by precision, standardization, synchronization, and continuity. The increasing competitive pressure of the market emphasized the ability of industrial firms to improve indicators as quality, cost, and time, and to manage the increasing complexity of products. This took to the “projectivization” of the product development processes even though under rigid, stable, and inflexible capabilities.

The globalization and expanding markets increased the dynamism and complexity of the projects, leading to the shift of Traditional Project Management (TPM) to Agile Project Management (APM). The implementation of Agile Methodologies (AM) could face various barriers, and there is extensive literature regarding this matter in the software development field, where this concept emerged. However, even recognized as a fully adaptable approach to any industry, when it comes to manufacturing the literature background is much less extensive and almost null in the automotive sector.

It is necessary to understand if an industry originally characterized by stable and continuous processes could implement AM, characterized by dynamism and agility. It is also required to comprehend the change predisposition of the companies, and the expected barriers in its implementation to avoid them or decrease their influence. This study aims to address a literature gap identifying barriers in the implementation of AM in the AI, developing for that a questionnaire survey. Firstly, a literature review was performed in order to acquire the necessary background knowledge regarding the proposed subjects, and identify barriers found in other and/or similar industries/sectors that can also be verified in the AI.

1.2 AIMS AND OBJECTIVES

The main aim of this survey is to identify barriers in the implementation of AM in Portuguese AI. Taking into account this main goal, it is possible to expand the objectives list, as follows:

- Address a literature gap and expand the body of knowledge, which is currently dominated by the Information Technology (IT) field.
- Verify if the barriers found in the literature regarding the implementation of lean and/or agile methodologies, in the field of software development, manufacturing, and Circular Business Models (CBM) are reflected in AI.
- Comprehend the current APM environment of the Portuguese automotive manufacturing companies, and their predisposition to the implementation of AM.
- Categorize barriers and their sources for the implementation of AM.
- Propose possible recommendations and enablers for the identified barriers.

1.3 RESEARCH APPROACH

There are various kinds of classifications for the research approach. This survey is conducted in an exploratory way since it aims to explore the barriers found in the literature, regarding the implementation of AM, and investigate the scenario of the Portuguese automotive manufacturing industry.

Another type of research classification is the research philosophy and, in this study case, realism is considered since there is a part of knowledge that is assumed as correct and not questionable (positivism), and another part that depends on different perceptions of what is happening (interpretivism). For instance, positivism is applied in cases that arguments and/or justifications derive from the literature background, and interpretivism is verified in the characterization of the barriers which depends on each person's perspective. Realism is positioned between these two extremes, and presents itself as the most adequate philosophy for this study.

Another type of classification is the triangle research, which includes three aspects such as data, theory, and analysis. This classification depends on which order the research is conducted, and might be categorized as deduction or induction. Once the first step of this research is to develop a bibliographic research (background theory), the second step is to collect data through a questionnaire, and then analyze the data, these phases are following a deductive path. This research focuses on three categories of the different types of research classifications, being them exploratory, realism, and deduction.

In Fig. 1 is outlined the triangle research, representing a deductive approach.

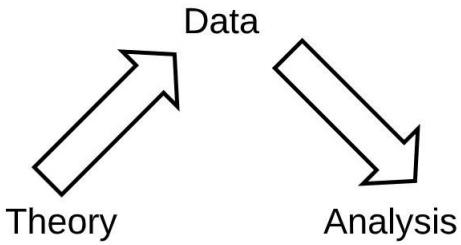

Fig. 1 - Triangle Research - Deduction

1.4 DISSERTATION METHODOLOGY

To accomplish the proposed objectives, it is necessary to define the methods to apply. This study is based on two main methodologies, such as analyze study cases, and develop a questionnaire survey. The first methodology aims to comprehend what was already studied and what conclusions have been achieved, increasing the knowledge in the field, applying that knowledge on the survey, and expecting results. Also, the obtained knowledge might be a basis for arguments and /or provide justifications for conclusions, as well as a contribution to modeling a framework, for instance. Examples of study cases regarding the specific topic of the study, could be found in chapter 2.2.5. The questionnaire survey comprises the practical component of this work, this means that it corresponds to a developed tool, permitting the accomplishment of the defined objectives. The questionnaire survey and its analysis allow the corroboration or not of what was already been studied in other sectors, and also being the cornerstone for reaching new conclusions.

1.5 FRAMEWORK

This dissertation comprises four main chapters as an introduction, background, thesis development, and conclusions. The first chapter intends to introduce the study theme, topics, main aims, and objectives, reveal how the work is organized and in which approach, as well as contextualize the reader. The literature background allows acquiring all the knowledge necessary for the understanding of the study. Also, it presents similar study cases in order to compare the reached conclusions, and comprehend what this research can add to the literature. The third chapter is the thesis development, being divided into two stages such as research planning and execution, and research results. The first stage includes all the steps necessary to obtain the results, and details of how the work was done. After this stage, the accomplished results are presented, as well as a critical analysis of them, leading to the streamlining of possible enablers and recommendations. Lastly, all the reached conclusions of the work are presented, as well as the limitations of the study and outlook for future works.

In Table 1 is depicted the dissertation structure, and the general content of each chapter.

Table 1 - Dissertation framework and chapters description

Dissertation				
		Thesis Development		
Introduction	**Background**	**Research Planning and Execution**	**Research Results**	**Conclusions**
Contextualization Aims and objectives Framework and methodology	Collect information Description of previously obtained results	Detailed description of the developed work, as well as all the applied techniques	Results picture, discussion, and recommendations	Reached conclusions, limitations of the study, and outlook for future works

BACKGROUND

2.1 AUTOMOTIVE INDUSTRY

2.2 PROJECT MANAGEMENT APPROACHES

2.3 SURVEY AND DATA PROCESSING

2 BACKGROUND

2.1 AUTOMOTIVE INDUSTRY

2.1.1 World and Country Overview Regarding Automotive Industry

The AI comprises a wide range of companies and activities involved in the manufacture of motor vehicles, including most components, such as engines and bodies, but excluding tires, batteries, and fuel. The industry's main products are passenger automobiles and light trucks, including pickups, vans, and sport utility vehicles [1]. The AI remains stable despite various economic crises during the past decades, keeping the world number of sales per year in the level of 90 million units during 2015 and 2019, thus proving its resilience [2]. The graphic depicted in Fig. 2 represents the worldwide sales of new vehicles in the last fourteen years.

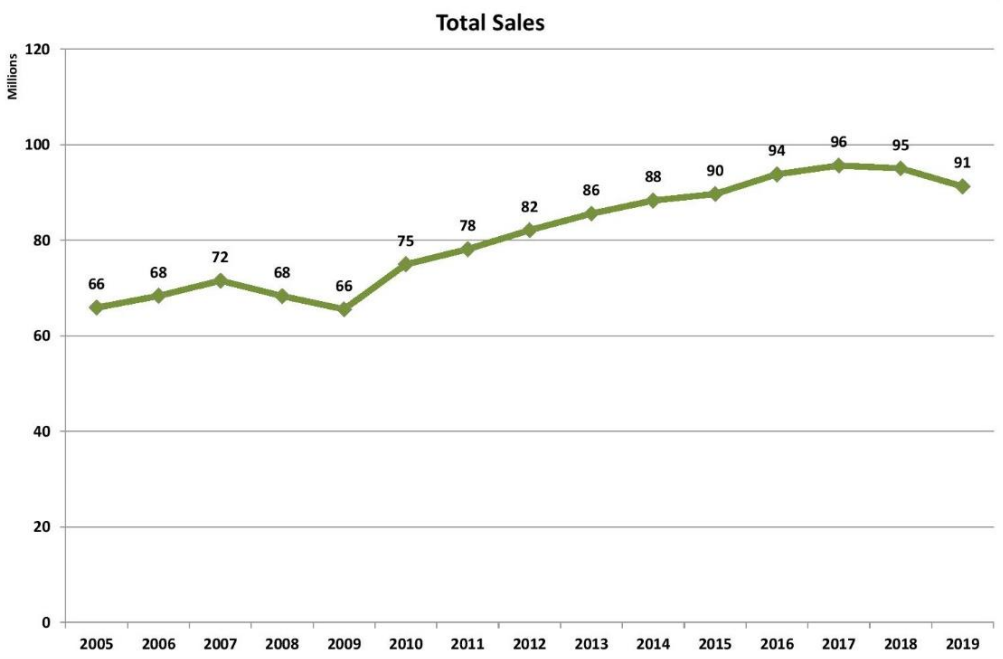

Fig. 2 – Worldwide sales of new vehicles from 2005 to 2019 [2]

This level of demand requires more than 50 million jobs for the activity of automotive manufacturing, demonstrating its essential role for the global economy [3] *apud* [2]. The emergence of new companies, technologies, concepts, and constant evolution creates competitive pressure and further dynamism in the industry [3] *apud* [4]. For that reason, innovative manufacturing strategies have emerged to respond more quickly and accurately to the constantly changing needs, and which will be described later. The level of innovation in AI can also be observed by the investing of almost 85 billion EUR in research, product development, and production, fields that will be specifically explored in this study [5].

The International Organization of Motor Vehicle Manufacturers (OICA) conducted a survey aiming to characterize the AI from the consumers' point of view, and their attachment to the automobile. It was discovered the main factors that contribute to the AI reputation nowadays, as represented in Fig. 3 [6]. The figure highlights the degree of innovation in the sector, the investment in sustainability, the concern about society and consumer needs, as well as the constant search for solutions. These factors empower the industry, giving it the capacity to face and overcome the challenges that may arise.

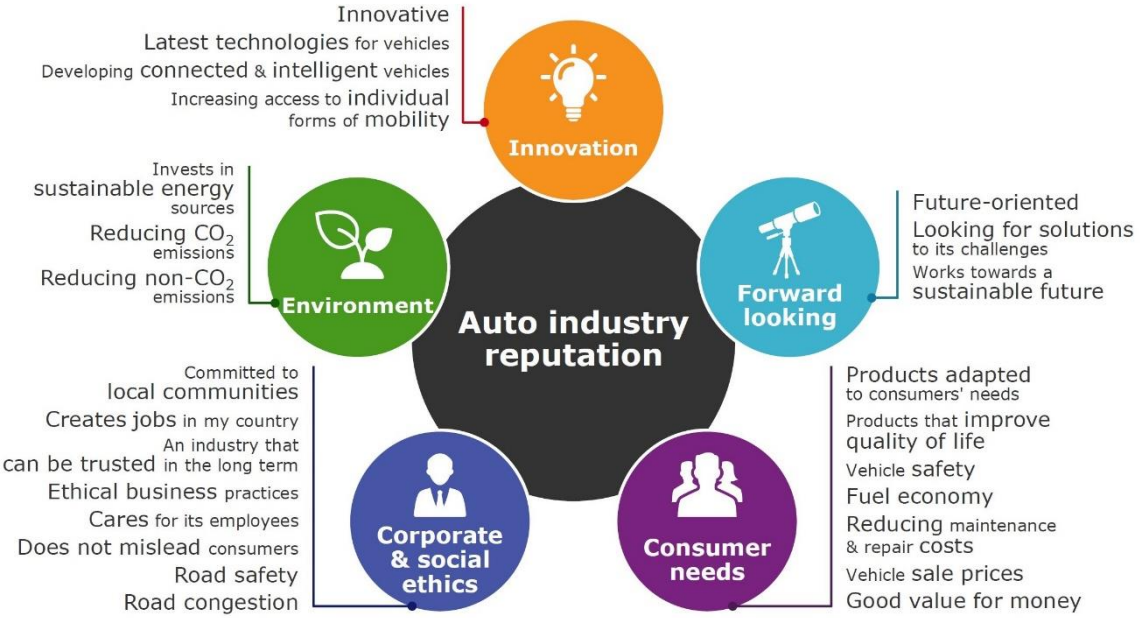

Fig. 3 - Auto industry reputation [6]

According to [7], Portugal was the 28th country that produces more vehicles worldwide in 2019, as shown in Table 2.

Table 2 - World motor vehicle production [7]

Country	Cars	Commercial vehicles	Total
1. China	21360193	4360472	25720665
2. USA	2512780	8367239	10880019
3. Japan	8328756	1355542	9684298
4. Germany	4661328	unidentified	4661328
...			
28. Portugal	282142	63562	345704
29. Argentina	108364	206423	314787
30. Belgium	247020	38777	285797
...			

Portuguese Manufacturers Association for the Automotive Industry (AFIA) evidences that, in the year 2019, there were 240 companies in AI, which represents less than 1% of manufacturing industry companies. These companies employ a total of 59000 persons, involving 8% of the manufacturing industry employment. This industry, in the year 2019, had a turnover of 12 Billion EUR, leading to 6% of gross domestic product. The exportation volume was 9,7 Billion EUR, knowing that 16% of exports correspond to tradeable goods [8]. This information is depicted in Fig. 4.

Fig. 4 – Key Data of Portuguese AI [8]

Additionally, in Fig. 5 it is possible to observe the geographic distribution of the companies, and conclude that Braga, Porto, and Aveiro are the most representative cities in terms of manufacturing sites, concluding that the North Region is the most significant.

Fig. 5 – Location of manufacturing sites [8]

Also, the automotive manufacturing industry includes various fields that companies could particularly be specialized. In Fig. 6 it is possible to have an overview of the turnover by activity.

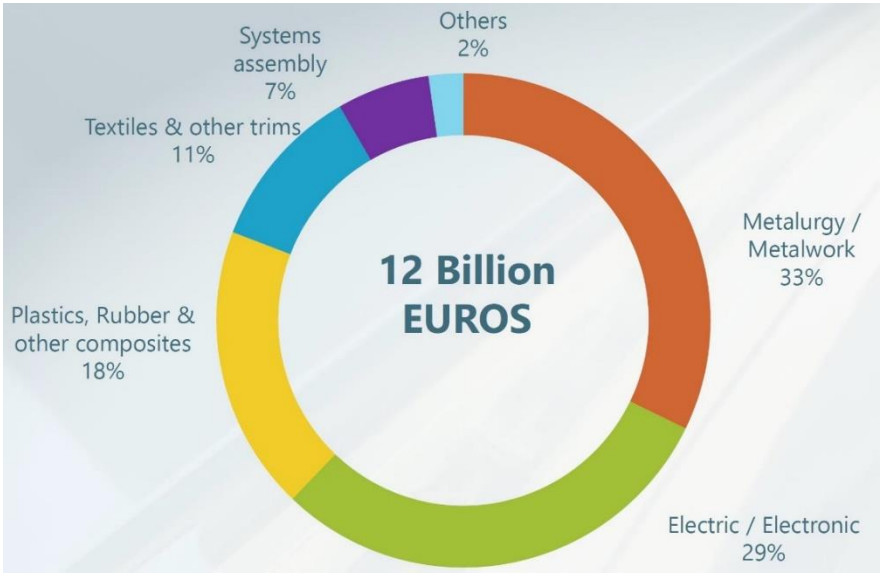

Fig. 6 – Turnover by activity [8]

As demonstrated in the previous data, AI in Portugal has a significant contribution to the economy, a high percentage of exportation, as well employs a very decent percentage of the population.

2.1.2 Manufacturing Processes in Automotive Industry

The automotive manufacturing is characterized by mass production type, which requires a heavy investment in equipment and tooling, and feasible only for large organizations. It is defined as the continuous production of items in a series of steps, such that all steps are performed simultaneously [9]. To justify the investment, the companies follow an economy of scale producing what the market is demanding.

The automotive industry's immense resources in production facilities, as technical and managerial skills, have been devoted predominantly to the building of motor vehicles, but there has been a consistent and strong incentive to extend them into related products, and occasionally, into operations whose relationship to automobiles is remote. This leads us to other production types as batch production, which is a production technique that delivers multiple units in a series of steps, and these units are moved together as a batch. This production type increases flexibility, in comparison with the mass production, once the same equipment can produce more than one product type [10].

Two other production types can be referred, as the continuous process, and unit production. The first one, is a series of processes that can potentially be running at the same time, and each step is running concurrently with every other step. This production type combines productivity, efficiency, and throughput [11]. The other one, is characterized by one-piece manufacture. It allows the non-regulated movement of a product through working stations, and a free working cadence, generally requiring the labor of highly skilled workers, as well as specialized equipment. Any changes occurred in this process cause longer production cycles [12, 13].

The bulk of the world's new cars come from the moving assembly line, introduced by Ford, however, the process is much more refined and elaborated nowadays. Production of a new model also calls for elaborate tooling, and the larger the output, the more highly specialized are the tools in which the manufacturer is willing to invest. For example, it is expensive to install a stamping press exclusively to make a single body panel for a single model, but, if the model run reaches several hundred thousand, the cost is amply justified [1].

2.1.3 Projects in the Automotive Industry

Original Equipment Manufacturers (OEMs) and suppliers, have dramatically increased the pace of new product launches. At the same time, OEMs launch more innovative features more often. As a direct consequence, automotive companies face an emerging challenge: to increase the frequency, reliability, and profitability of the innovations developed in research and advanced engineering and, at the same time, to maintain their ability to develop more vehicles than ever in a context of very tight constraints on quality, cost, and lead time. Such a strategic challenge, called for a deep transition in car manufacturers' product design processes.

This increasing competitive pressure, put emphasis on the ability of industrial firms to improve the quality level, reduce cost, and time-to-market (QCT indicators) of new products, and last but not least, to manage the increasing complexity of products. This shift defined concepts, and organizational frameworks for effective "projectivization" of product development processes, such as heavyweight project management teams, concurrent engineering, and early supplier involvement.

Although projective organizations established core capabilities maximizing QCT indicators, these core capabilities tended to turn into core rigidities that modeled potential products through a stable architecture, and inflexible competencies. These organizations became reluctant to apply innovative features, that were disruptive towards this organizational structure [14]. This leads us, to first introduce the concept of Project Management, and then distinguish two approaches related to it, described in the following chapter.

2.2 PROJECT MANAGEMENT APPROACHES

In times of globalization and expanding markets, more resources, tangible ones as metals and machinery, and less tangible ones like human time and capital, are required to satisfy the specific human needs. This specialization generates a distance among resources and needs, causing various challenges such as information collection, communication, coordination, enforcement, and motivation. Companies have been responding to these challenges, investing in human resources to manage tasks, and creating a more efficient way to organize processes and tasks than traditional business management, that is, Project Management (PM) [15].

PMBOK guide [16] defines PM as the application of skills, knowledge, techniques, and tools to project activities, aiming at the project requirements, and enabling to execute it efficiently and effectively. Projects are a crucial avenue to create value and advantages in organizations, since in today's markets firm leaders need to be managed with less time and resources, stricter budgets, and continuously changing technology. According to the same reference, PM processes are divided into initiating, planning, execution, controlling, and closing processes. These PM process groups are described in the following table (Table 3).

Table 3 - PM process groups [16]

Process groups	Description
Initiating	Define a new project or a new stage of an existing project. Get the approval to start the project or phase.
Planning	Determine the scope of the project, refine goals, and describe the routes and actions to achieve the objectives.
Executing	Execute to complete the job defined in the planning phase.
Controlling	Monitor, track, regulate, and review the development of the project. Identify points in which changes are necessary, and execute the required modifications.
Closing	Formally close the project or phase.

2.2.1 Traditional Project Management

From an operational perspective, most of the management problems are solved using PM tools based on graph concept methods. Some of the most used are the Critical Path Method (CPM), and the Program Evaluation and Review Technique (PERT). These methods both use weighted and direct graphs, and help project managers to track the development of the projects, guarantee they stay on time and within the budget, as well as take action if something does not go as planned. These graph representations can be used to coordinate tasks or activities, and to calculate the number of necessary

resources. A directed graph is a pair (V,E) where V is a set of vertices/nodes (u,v,w,…), and E is a set of ordered pairs of vertices, that are edges (uv,vu,uw,…). On the other hand, in the weighted graph, each edge uv has a real number correlated with it. In the case of a CPM graph, the nodes correspond to the activities that need to be conducted to finish the project, and the existence of an edge means that activity v cannot be started until u is finished. The duration of the activities is represented in the vertices, and the critical path is the longest route (sum of the activities durations) from the beginning to the finishing of the project, being this the duration of the project.

Also, PERT considers the lengths of paths, but the nodes are the targets of the project, meaning that it is an event-oriented method instead of an activity-oriented. Therebefore, this technique is used to manage projects where the activities are uncertain, while CPM is characterized by well-defined activities [15].

In Table 4, are summarized, and added some key differences between both methods.

Table 4 - Key differences between PERT and CPM [17]

PERT	CPM
Planning, scheduling, coordinating, and controlling uncertain activities	Planning, scheduling, coordinating, and controlling of well-defined activities
It evolved as a research and development project	It evolved as a construction project
Is set according to events	Is aligned towards activities
It is a probabilistic model	It is a deterministic model
Three times estimate: optimistic time, most likely time, and pessimistic time	One-time estimate
High precision time estimate	Reasonable time estimate
Non-repetitive job	Repetitive nature
There is no distinction between activities	Demarcation between critical and non-critical activities

From an organizational perspective, risk management and coordination are crucial for organizations to be successful. This activity is conducted throughout the project, establishing communications and contacts between the project manager, and with the entities that identify, analyze, and create mitigation strategies for, in the case of a risk materialize, use these links to minimize the time to start the mitigation strategy. This PM approach prevents the evolution of negative effects, and helps to reduce the unpredicted changes in a project during the planning phase [15].
These operational and organizational PM perspectives and techniques, are methods of the organizations react to the challenges of globalization, as well as create higher values for stakeholders, which allow them to achieve competitive advantage in comparison to their competitors [18].

However, in environments characterized by a high level of turbulence, uncertainty, and complexity, these PM tools, which are based on a predictable and rational model, are ill-suited for these types of conditions [19]. This uncertainty could be generated due to two broad sources, considering the way that the project is structured: internally and externally created. Internally generated uncertainties are related to resources and systems, that can be directly linked with the project, and can be regulated by the organization. The external factors that are not associated with the project, and the company cannot control, are considered externally generated uncertainties [20]. The same authors define more specific subcategories, represented in Fig. 7.

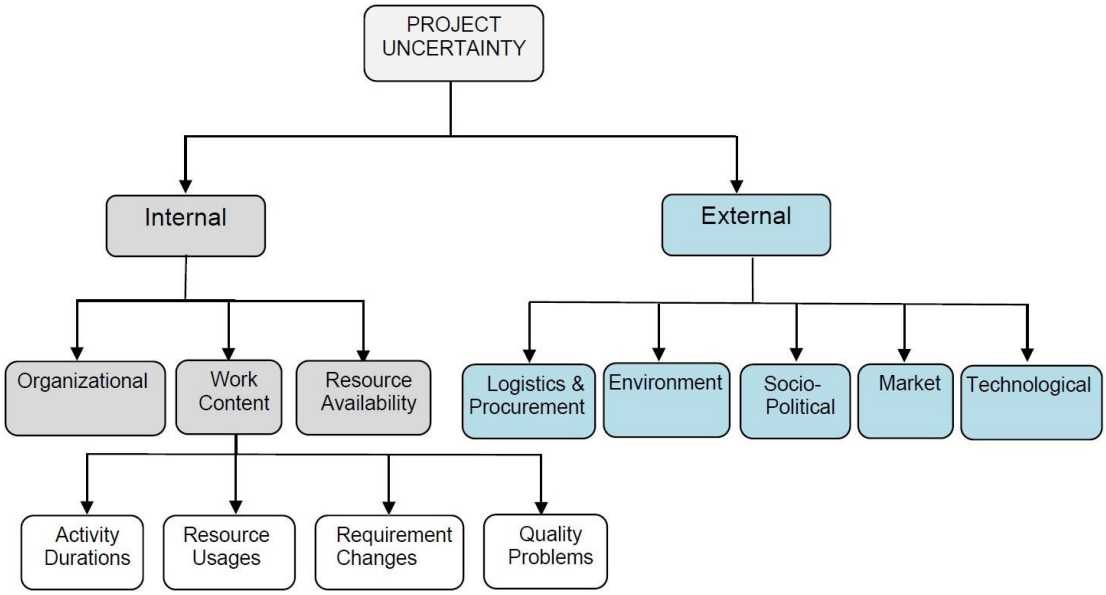

Fig. 7 - Sources of uncertainty [20]

2.2.2 Agile Project Management

Therefore, as projects have grown into more dynamic and complex conditions, consequently the ways of managing them should be reconsidered [21]. This evolution as led to the streamlining of the TPM, to a new agile methodology [22]. Before focusing on APM and agile techniques, it is necessary to understand the various types of PM approaches depending on how specific a project is, and in what environment is considered.

In Agile Practice Guide [23] are mentioned and explained four types of life cycles, such as:

- Predictive life cycle
- Iterative life cycle
- Incremental life cycle
- Agile life cycle

A predictive life cycle is a more traditional approach characterized by high certainty context, including company requirements, fixed team, and low-risk management. This allows teams to organize work into a sequential way of predictable processes, as illustrated in Fig. 8. To achieve this, detailed plans are required that will drive the work, and identify requirements with much detail as possible.

Fig. 8 - Predictive life cycle [23]

In an iterative life cycle is allowed to improve and modify the work, according to the feedback of the unfinished work. This improvement could be accomplished through successive prototypes, where each one income new feedback from stakeholders, and enables the team to rework the activity based on those understandings (Fig. 9). Thus, reworks permit to identify, and reduce uncertainty in the plan. This type of approach is used when complexity is high, and occurs frequent changes in the project.

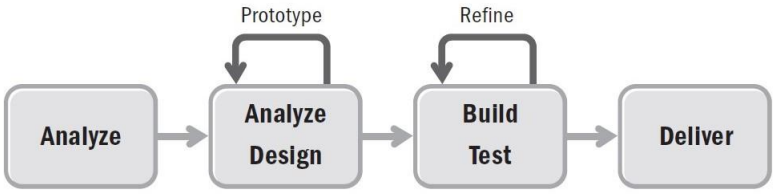

Fig. 9 - Iterative life cycle [23]

An incremental approach has the intention to increase the speed of delivery for products, that the customer may be able to use immediately, even if it is just a subset of the final result.

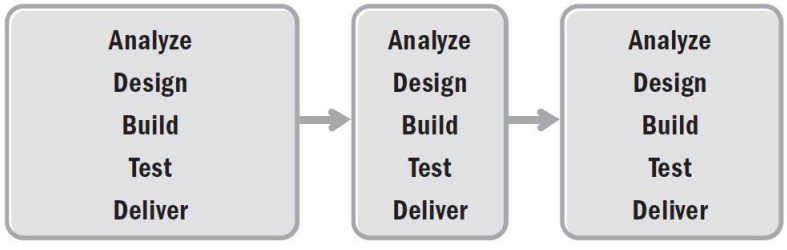

Fig. 10 - Incremental life cycle [23]

At least, an agile approach is both iterative and incremental, that is, before starting any development, the team expects requirements to change, and start the progress (Fig. 11). It is an approach with high customer focus, providing customer visibility, confidence and control of the product, as well as constantly delivering valuable goods [23].

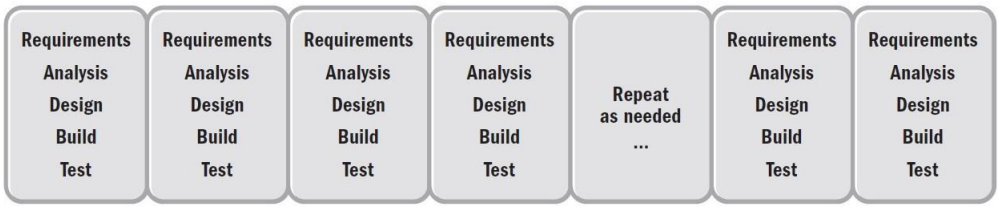

Fig. 11 - Agile life cycle [23]

Agile life cycles fulfill the principles of the Agile Manifesto [24], being them:

- Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
- Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
- Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
- Business people and developers work together daily throughout the project.
- Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.
- The most efficient and effective method of conveying information to, and within a development team is face-to-face conversation.
- Working software is the primary measure of progress.
- Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
- Continuous attention to technical excellence, and good design enhances agility.
- Simplicity is essential - the art of maximizing the amount of work not done.
- The best architectures, requirements, and designs emerge from self-organizing teams.
- At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

In Table 5 are summarized the characteristics of the four life cycles previously mentioned.

Table 5 - Characteristics of the four life cycles [23]

Characteristics				
Approach	**Requirements**	**Activities**	**Delivery**	**Goal**
Predictive	Fixed	Performed once for the entire project	Single delivery	Manage cost
Iterative	Dynamic	Repeated until correct	Single delivery	Correctness of solution
Incremental	Dynamic	Performed once for a given increment	Frequent small deliveries	Speed
Agile	Dynamic	Repeated until correct	Frequent small deliveries	Customer focus through frequent deliveries and feedback

At this time, it is possible to understand which PM approach suits better depending on the characteristics of the environment, and the level of uncertainty, as represented in Fig. 12. Adaptative approaches are related to iterative, incremental, and agile methods, while linear approaches are linked to predictive or traditional methodologies.

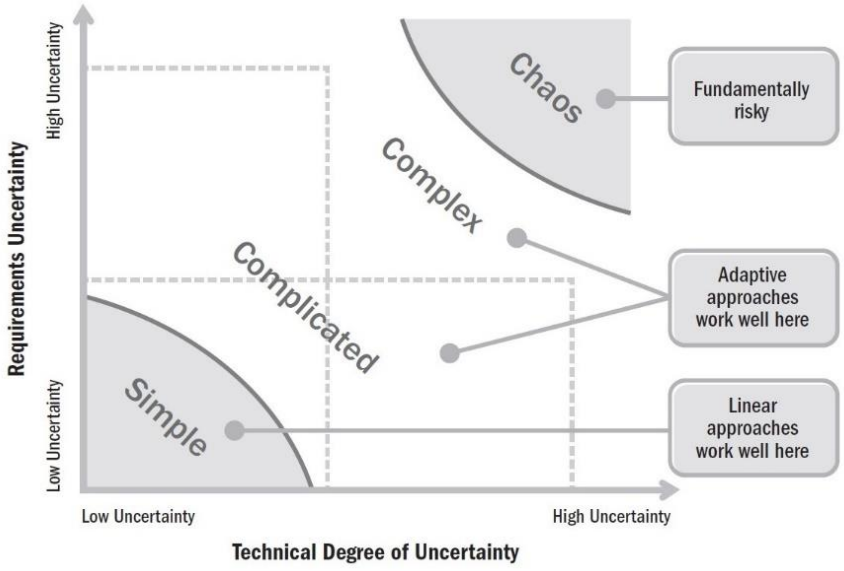

Fig. 12 - Best suited approach for each type of environment [23]

2.2.3 Differences between TPM and APM

As the projects are becoming more complex, with more activities along with complicated interrelations, and with higher levels of uncertainty, it is inevitable the evolution from TPM to APM since the first philosophy is based on linear, sequential and predictive activities relations, and cannot reflect all dynamic and complexity of today's projects. Agility is the word that differentiates the new approach from the traditional, and is defined as constant innovation, product adaption, shortening delivery times, adjustment of processes and people, and reliable results [25] *apud* [26].

In Table 6 are described the differences between TPM and APM considering some project characteristics.

Table 6 - Difference between TPM approach and APM approach [25]

Characteristic	TPM Approach	APM Approach
Requirements	Clear initial requirements Low change rate	Creative, innovative Requirements unclear
Users	Not involved	Close and frequent collaboration
Documentation	Formal documentation required	Tacit knowledge
Project size	Bigger projects	Smaller projects
Organizational support	Use existing processes Bigger organizations	Prepared to embrace an agile approach
Team members	Not accentuated Fluctuation expected Distributed team	Collocated team Smaller team
System criticality	System failure consequences seriously	Less critical systems
Project plan	Linear	Complex Iterative

It is noteworthy that, both traditional and agile approaches have their advantages and disadvantages, so it is not possible to claim that one is better than the other if compared in different project characteristics [25] *apud* [27]. It is crucial for the success of PM, select the approach in accordance with the project characteristics, its life cycle, and the type of environment [28].

In the following table (Table 7), are referenced and summarized some of the most relevant surveys in the literature research, concerning PM approaches.

Table 7 – Literature research regarding PM approaches

Bibliographic Reference	Work Description
[15]	This work intends to explain the necessity that firms had on start using PM. This need happened essentially due to specialization and this one arose because the satisfaction of human needs is being more difficult and complex to achieve. The specialization, industrialization, and globalization have been increasing the distance between resources and needs which force the firms to change their management tasks. The increasing recognition of PM could be explained by the emergence of a new and more economical way to organize management tasks than traditional business management. Then, the authors suggest that a way to structure management tasks is to represent in a graph, connecting a pool of resources with things fulfilling needs. In that way, the paper purposes ways to create preciseness with graph tools to management at operational and organizational levels.
[20]	In this work, the authors create a classification for main sources of uncertainty in projects and surveys in project scheduling considering the uncertainty sources. Then, are investigated approaches and methods to manage uncertainty. PM predominantly address the unpredictability in duration activities whereby, the literature regarding uncertainty caused by other sources is insufficient. The authors focused on this scarce information and highlighted the gaps in modeling project uncertainty.
[21]	Derived from the increased complexity in projects, there has been an intensifying concern about this concept. The authors refer that it is of great importance for project managers to understand how project complexity should be managed, due to the existent differences related to decision-making and goal achievement. Complexity affects project planning and control, it can obstruct the clear identification of objectives, influences on the choice of an appropriate approach, and subsequently affect project outcomes. In the article, are identified various concepts related to project complexity, such as its major factors and characteristics, types of project complexity, and principal project complexity models. This last factor intends to be a great support in assisting PM organizations.
[28]	In the procedure of managing a project, due to the project phase or challenges that occur during it, requirements and approaches are changed. A project has different life cycle phases, where complexity changes over them and uncertainty should be considered as highest at the initial phase. This uncertainty can reduce since information is collected over time. Within the article are explained various PM approaches, their differences, and characteristics to deal with uncertainties as project characteristics and environment.

2.2.4 Agile Techniques

As the TPM has its own characteristics, techniques, and tools (PERT, CPM…), as well APM has various types of specific methods. There are various techniques under the umbrella of the agile methodology (Fig. 13), however all of them have two characteristics in common, being them: they are all iterative, incremental and evolutionary; and the customer involvement through the Software Development Life Cycle (SDLC) is mandatory [29].

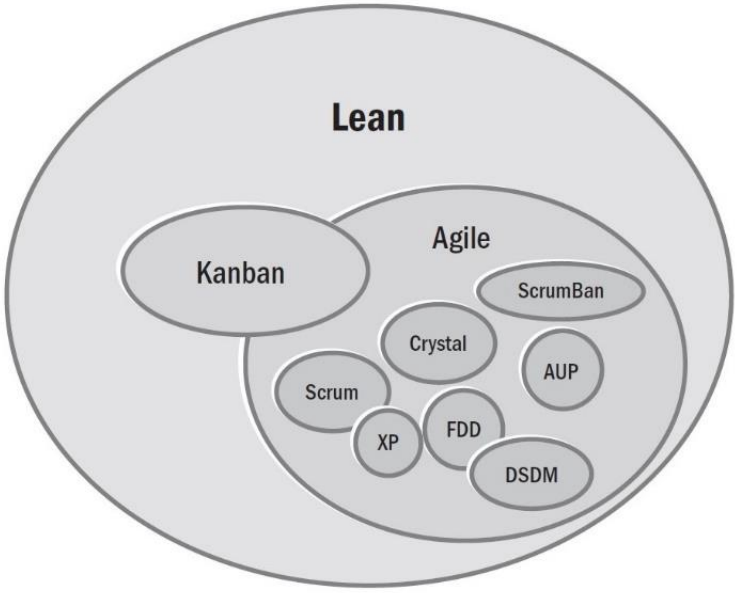

Fig. 13 - Techniques of agile methodology [23]

2.2.4.1 Scrum

Scrum is one of the most common agile techniques, being it a single team iterative process framework used to manage product development, and based on a variety of concepts such as customer feedback, daily scrum meetings, product backlog, sprint backlog, sprints, and delivery-ready after each sprint [29] *apud* [30–32]. These sprints are timeboxes of one month or less with regular durations, where the potentially releasable increment of product is developed. These concepts which are part of the scrum framework, could be divided into events and artifacts as described in Table 8.

The team responsible for this method consists of:

- The Product Owner (PO) – has the objective of maximizing the value of the product.
- The Scrum Team (ST) – is a self-organizing and cross-functional team, consisting of members who have everything they need inside the team to deliver a working product, without depending on others outside of the team.
- The Scrum Master (SM) – Has the job to ensure that the scrum process is sustained and guarantees the scrum team complies with the rules [23, 33].

Table 8 - Scrum events and artifacts [23]

Events	Artifacts
Sprint	
Sprint planning	Product backlog
Daily scrum	Sprint backlog
Sprint review	Increments
Sprint retrospective	

The event “Sprint planning” is a meeting between ST, SM and PO to determine the outputs of the next sprint. “Daily scrum” is a meeting of 15 minutes for each ST element present what did, what will do, and the difficulties encountered. “Sprint review” is a meeting to present the results of one “Sprint”. “Sprint retrospective” is another meeting to evaluate how the “Sprint” was performed, and identify ways to improve the next ones. Regarding the artifacts, the “Product backlog” is a list of items not yet completed that make up the product. “Sprint backlog” is a list of work items identified by the ST to be completed during the “Sprint”. Finally, “Increments” are functional, tested, and/or accepted deliverables that are a subset of the overall project outcome.

The scrum technique allows the reduction of planning overhead due to its flexibility, and easy adaptability to any changes in stakeholders' needs, at any development stage. It focuses on developing customer relationships to increase product quality, and improvement in performance. Each short cycle/sprint permits the release of short prototypes, so that the customer can monitor the development, and provide continuous feedback [29].

2.2.4.2 Kanban

There is a relation between lean, agile, and kanban technique since these last two are descendants of lean thinking, that is, lean philosophy is a superset that shares attributes with agile, and kanban. This relation is represented in Fig. 13. The word kanban could be translated to “card” or “visual sign”, and kanban boards promote the visualization of the system workflow for everyone. This information is structured in columns that represent the states of the work, for example, “to do”, “doing”, and “done”, but could be adapted to any other state needed by the team. The point that the kanban method is not completely under the agile umbrella, could be explained by the fact that, this technique is less prescriptive and less disruptive than other agile

approaches, and consequently is easier to implement. Another fact is that the kanban method does not entail timeboxed iterations. This approach is suitable for organizations that demand the following attributes [23]:

- Flexibility – Teams will work on the highest priority item in the list of work.
- Focus on continuous delivery – Teams are focused on following the workflow of the system, and not starting new work until the pendent is finished.
- Team member focus – Limit the Work In Progress (WIP) permits the team to focus on the present work.
- Increased productivity and quality – These attributes are increased due to the limitation of the WIP.
- Increased efficiency – Verifying which tasks add value, and remove non-value adding activities.
- Reduction of waste – Easier to observe the waste so it can be removed.
- Variability in the workload – Due to the unpredictability of work arriving, the team cannot achieve predictable commitments.

The principles that define the kanban technique, and its main properties are represented in Table 9. This technique is a framework for incremental and evolutionary process transformation for companies, and uses a "pull system" to move the work or tasks through the process. This means that when one task is completed, the team can pull work into that step. It is more important to finish work than start a new one, because there is no value in work that is not completed, as a result the team should work together to complete the WIP.

Table 9 - Kanban Principles and core properties [23]

Defining principles	**Core properties**
	Visualize the workflow
"Start where you are" – start with the current state	Limit work in progress
Accept incremental and evolutionary changes	Manage flow
Comply with process roles and responsibilities	Make process roles explicit
Promote acts of leadership at all levels	Implement feedback loops
	Enhance collaboratively

An example of a kanban board is depicted in Fig. 14.

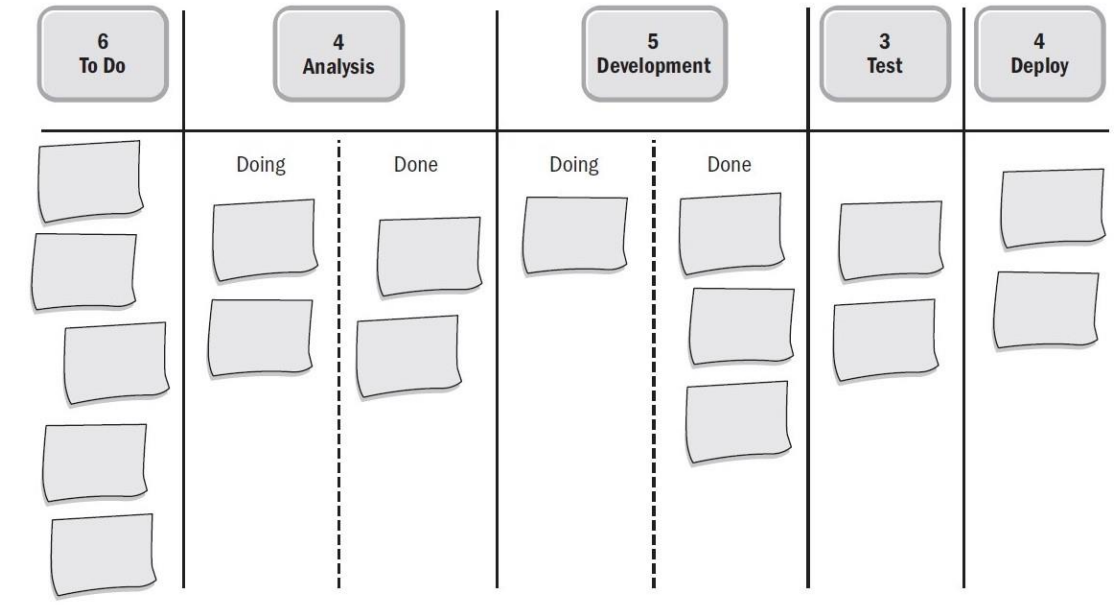

Fig. 14 - Kanban board example [23]

To implement this approach, it is not necessarily high technology, once it is a board where the elements of a team could “touch” and participate, making this method a simple high-touch tech, but with a powerful use. This card provides a clear understanding of the workflow as well as bottlenecks, in overall conditions [23].

Both techniques (scrum and kanban) have the customer focus responding quickly to its requests, and are highly adaptive, collaborative, as well as for self-managing teams. However, has referenced before, scrum is more prescriptive since it gives constraints as the use of timeboxed iterations.

In Table 10 are summarized some differences between scrum and kanban [34] *apud* [35].

Table 10 - Differences between Scrum and Kanban [34]

Scrum	Kanban
Predefined roles of scrum master and team member	Service request manager and service delivery manager (not mandatory)
Timeboxed sprints	Continuous delivery
Work is “pulled” through the system in batches (sprint backlog)	Work is ‘pulled’ through the system (single piece flow)
No changes allowed in mid-sprint	Changes can be made at any time
Uses velocity as default metric for planning and process improvement	Uses lead time as default metric for planning and process improvement
Appropriate in situations where work can be prioritized in batches that can be left alone	Appropriate in operational environments with a high degree of variability in priority
Teams commit to a specific amount of work for this iteration	Commitment is optional
WIP limited indirectly (per sprint)	WIP limited directly (per workflow state)
A scrum board is reset between each sprint	A kanban board is persistent

2.2.4.3 Scrumban

Originally, the transition from the scrum to kanban was designed as scrumban. As new agile techniques emerged, it evolves into a hybrid framework where teams use scrum as a framework, and kanban for process improvement. In scrumban, the work is structured into small sprints, and takes advantage of the kanban boards to visualize and monitor the work. The tasks are placed in the kanban board, and the team manages its work with WIP limits. Daily meetings happen to maintain cooperation between the team, and to remove obstacles. There are no predefined roles in this methodology – the team holds their current roles [23]. It eliminates the planning activities and velocity measurement, and focuses on smooth flow and minimizing WIP [36].

In Table 11 are condensed some surveys found in the literature research, related to agile techniques.

Table 11 – Literature research regarding agile techniques

Bibliographic Reference	Work Description
[29]	To guarantee quality and consistency in product delivery, the industry is moving quickly to agile methodology, since it delivers adaptive approaches taking into account the problem of unpredictability, in alternative to TPM techniques. The authors claim that scrum is the most commonly used agile technique, due to its capacity for fast-changing requirements. Then, the survey complies with the impact of an agile framework applying scrum on the deliverables and comparing it to an iterative model. Various factors were used to compare both methods as SDLC at the moment that defect was identified, number of defects, number of change requests received, and the elements rolled out using both methods. All these factors are crucial to the maintenance of any software. The authors conclude that the use of agile methodologies allows better planning due to customer focus and its involvement, thus more responsiveness to the occurred changes.
[37]	The authors of this paper refer that the maintenance work is more than half of the total effort invested in any software system. The complex challenge of maintaining software and how to use agile techniques to do it, it is a well-discussed theme within the PM community. This issue occurs since SDLC does not have a specific planned method for maintenance. To overcome this problem, it was used a theoretical technique to articulate factors that should be considered during the agile maintenance, for instance, maintenance planning.
[34]	This paper refers that, to improve project visibility, software quality, team motivation, communication and collaboration, software companies are moving to apply kanban after scrum. Nonetheless, it is crucial to verify these effects and companies' real purpose for this transition. It was studied the reasons for teams transitioned to kanban. It was concluded that scrum maintenance teams encountered some challenges, as lack of work visibility, task prioritization, communication and collaboration through the practice of sprints, work synchronization, and changing persons. Then, it was demonstrated how maintenance teams overcome these challenges with kanban.

2.2.5 Barriers and enablers in the Implementation of Agile Methodologies

To define the utilized terms in this section, a barrier means any factor that hinders, affects, or resists to the occurrence of a certain action, resulting in its delay or obstruction. On the contrary, enablers are factors that facilitate, help, accelerate, or encourage the event of that action.

An agile methodology is any practice or method correlated to an APM action, that contributes to the execution of a process, and that may employ one or more techniques and tools [38]. In this way, the term agile technique becomes generalized to an action that fits into the agile philosophy, and may apply its specific tools and techniques. Thus, it is more suitable to discover barriers in the implementation of this approach in unexploited sectors, instead of finding barriers solely in the application of specific techniques.

2.2.5.1 Barriers and enablers found in Agile Software Development

The main focus of the APM application has been the software industry, and there is extensive evidence of its effective use, as well as the barriers found on its implementation. The concept emerged in this sector to meet the rapidly changing requirements imposed by the Internet economy evolution, through iterative development and prototyping. In other words, introduce agile into IT development, enabled the development of software in a better and much more efficient way, thereby reducing the wastage [39].

In Table 12 are referenced some of the barriers found in this sector, regarding the implementation of AM.

Despite there is extensive literature review regarding the application of APM in the software industry, there is a lack of empirical studies in other types of industries, sectors, and projects. The authors of the paper [40] studied the implementation of APM in product development projects due to similarities with the projects from the software industry, such as creativity and development characterized by continuous cycles of prototyping and testing. Also, the authors of the article [41] explored the challenges in implementing agile processes in traditional development organizations, and address the question: “How do you merge agile, lightweight processes with standard industrial processes without either killing agility or undermining the years you have spent defining and redefining your systems?”. These two articles are relatively close to what is intended to explore in this study, since they focus on the shift of the APM for other industries rather than software development, namely on the product development process field, and organizations with traditional roots.

Table 12 – Barriers and enablers found in the literature considering agile software development

Bibliographic Reference	Barriers found	Enablers, possible solutions or recommendations
[42]	Experience with agile methods, organizational culture, resistance to change, lack of staff quality skills, management support, lack of stakeholders' awareness and knowledge, customer collaboration.	Strong management support, friendly-agile organization and team environment, skilled team, strong customer involvement, responsive PM process, training staff.
[43]	Lack of documentation, traceability Issues, regulatory compliance, lack of up-front planning, managing multiple releases.	
[44]	Regulatory limitation to iterative deployment, risk management and quality control, self-organized teams remove decision-making powers, necessary documentation, and traceability	Integrate selected agile practices into the plan-driven SDLC.
[45]	Resistance to change, budget constraint, management support, confidence for the ability to scale, customer collaboration, project complexity, lack of experience.	
[46]	Commitment, staff involvement, training, resources, staff experience, guidance, communication, return on investment.	

Nevertheless, specifically to the AI, there were not found studies that address barriers in the implementation of AM. For that reason, a research was made exploring barriers and enablers in sectors that can be relatively related to the AI, and are presented in the following sections.

2.2.5.2 Barriers and enablers found in Lean and Cleaner Production

Cleaner production and lean manufacturing are similar concepts, though they have different meanings. Cleaner production is an approach that intends to reduce the environmental impacts, while lean is focused on the reduction of costs and time with direct effects on the product and market [47]. In Table 13 are referenced the barriers and enablers found in the implementation of these concepts.

Table 13 - Barriers and enablers found in the literature considering lean and cleaner production

Bibliographic Reference	Barriers found	Enablers, possible solutions or recommendations
[47]	Initial investment costs, complex international supply chain, gaps in company cooperation, lack of consumer eagerness, limited innovation dissemination, lack of awareness and information, absence of means to measure the long-term benefits, limited government support, lack of information, low technical skills.	Potential to increase the number of jobs and the liveliness of companies, ability to improve existing operations, existence of new technologies and willingness to adopt them, collaboration and open communication with stakeholders, creation and management of networks.
[48]	Lack of knowledge and technology, organizational, financial, supply chain, market, and institutional.	Build closer relationships, reduce dependency on third parties, develop knowledge, outsource technical activities.
[49]	Technical and informational, operational and strategic, financial and economic, human barriers.	
[50]	Lack of financial resources, lack of time, lack of knowledge, risk, policies and regulations, existent organizational culture.	Integrated strategy, continuous improvement, stakeholder engagement, streamlining processes.

2.2.5.3 Barriers and enablers found in Agile Manufacturing

As time passes, the manufacturing industry has intended to improve productivity, effectiveness, responsiveness, and quality of the product through the aid of agile manufacturing techniques. From the available literature, it is possible to conclude that the agile techniques are theoretically applicable in most of the industries, and have proven their success in practice, specifically in large organizations [51] *apud* [52].

The concept of agile manufacturing evolved from lean management, and enables the organizations to react and pro-act to the unpredictable and diversified market changes, while minimizing the modifications to the company's main structure by establishing an intimate commercial relationship with the suppliers and the customers [51] *apud* [53].

Once the concept of agile manufacturing is elucidated through literature evidence, a summary of barriers and enablers found in the application of this concept is presented in Table 14.

Table 14 - Barriers and enablers found in the literature considering agile manufacturing

Bibliographic Reference	Barriers found	Enablers, possible solutions, or recommendations
[51]	Lack of management skills, technological limitations, and lack of workforce experience.	Acquire a clear understanding of the agile values and objectives, attain a clear picture of the market and assess the degree of its turbulence, and identification of the company's critical capabilities.
[54]	Improper competency management, improper forecast, improper human resource management, inefficient information management, lack of management involvement, lack of manufacturing flexibility, ineffective production planning, stakeholders' attitude, government policies and support, ineffective customer relationship, ineffective supply chain.	
[55]	Lack of management commitment, fear and resistance to change, financial constraints, lack of training and education, lack of government support, volatile customer demand, technological constraints, market competition, improper communication, lack of planning and strategies, inadequate data collection, poor layout and infrastructure, and lack of mutual trust.	

Bibliographic Reference	Barriers found	Enablers, possible solutions, or recommendations
[56]	Negative attitude towards working collaboratively, lack of professional interactivity, cost and time required for training, and increased design costs.	Relevant research before implementing as standards should be developed by the governmental agencies, develop an appropriate ecosystem for the implementation, and apply lean thinking to improve the management of project time and cost.
[57]	lack of expertise, lack of planning, lack of commitment from top management, lack of strategic perspective, misunderstanding of the lean manufacturing, resistance to change.	Competence and expertise – education and training, commitment from top management, cultural change.
[58]	Company behavior and culture, teams not prepared for the challenge.	A team that deals with APM (AGILE team), composed by a product owner, team leader, and team members, plus a communicational workflow considering 3 momentums (requirements analysis, planning, and design).

The acquired overview regarding these barriers and enablers, identified in similar sectors and study cases, allows the necessary background information and understanding to consequently adapt it to the proposed objectives.

2.2.6 Hybrid Approaches

Due to different project categories, or in a single project, the need of using specific methods and techniques caused by specific requirements, leads to the necessity of applying different approaches in PM. Thus, the PM procedure should consider own and customer organization, and adjust the processes to the specific needs, while customer processes are rigid and complex. Some projects do not have a clear representation of its characteristics, being ill suitable for the exclusive application of one, or another approach. In these cases, it is necessary to find which methodologies of each approach (traditional and agile) are appropriate, and will contribute to the project success [25] *apud* [59]. This allows to apply the best features of each approach, and/or replace the weakness of one method of a certain approach, for another able to overcome that vulnerability [36]. In the Agile Practice Guide [23] hybrid approach is

defined as a combination of predictive (traditional), iterative, incremental, and/or agile approaches.

In Fig. 15 are demonstrated the characteristics of a hybrid approach, and its flexibility. One example of a hybrid approach is when one team uses some approaches like iterations and daily meetings (agile techniques), and others like upfront estimation, work assignment, and progress tracking, defined as predictive approaches. Then, there are another two types of hybrid approaches: predominantly predictive approach with some agile elements, and a largely agile approach with a predictive element. In the first approach, the project is managed using a predictive approach but, in elements characterized by uncertainty, complexity, or opportunity for scope, they are managed in an agile way. In this case, the project majority is routine and predictable. On the other hand, a largely agile approach may be applied when a specific element is non-changeable, which is not executable by an agile approach.

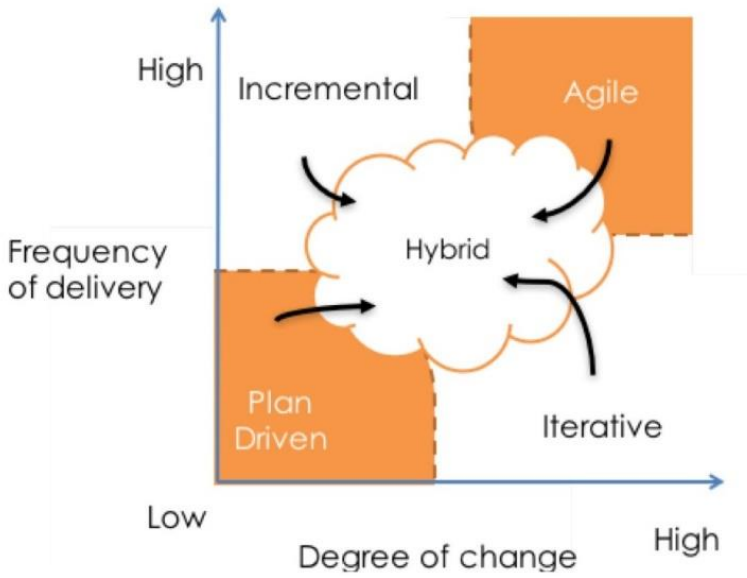

Fig. 15 - Hybrid approach characterization [36]

Hybrid life cycles are a good strategy of transition from TPM to APM since many companies are not able to change ways of working overnight. How larger the organization, and the more ongoing processes, more difficult and longer will be the transition from a predictive environment to a fully agile state. Thus, the initial appliance of both approaches, depending on the specificity of certain elements is a reasonable choice for a gradual transition [23]. A good example of a hybrid approach appliance, could be found in the work referenced in Table 15.

Table 15 – Literature research regarding hybrid approaches

Bibliographic Reference	Work Description
[36]	In this thesis, it was verified that a pure agile methodology does not fit to the addressed project. However, the scrum was the method that indicates better suitability; Thus, it was used as a basic principle. To create a methodology that fully fits the specific project, some elements were tailored with predictive components and other agile. This approach allowed to overcome the weaknesses found in elements that are outside of the agile area. This approach arose intending to transition from predictive approaches to agile, claiming that the appliance of a hybrid approach could be the best bridge to this transition. The whole methodology guarantees that the project is planned more efficiently, resulting in customer satisfaction, reduction of rework, which translates to a reduction of costs.

2.3 SURVEY AND DATA PROCESSING

A questionnaire survey is performed to collect data, and posteriorly analyze it. The statistical analysis allows identifying characteristics of the AI, through the association between variables, and this association could be identified by the means of statistical analysis. The tests used in the statistical analysis, the tool used for the questionnaire evaluation, examples of sample sizes in related surveys, and the software used to achieve all the results, are described in the next sections.

2.3.1 Statistical Tests

Regarding the statistical analysis of the results, some known tests can be applied, such as:

- Mann Whitney;
- Kruskal Wallis;
- Spearman's correlation;
- Chi-square;
- Cohen's kappa.

The first three are non-parametric measures, and these types of tests have no presupposed, once require fewer assumptions about the type of data on which they can be applied. They also reduce the effect of outliers and are frequently used by ordinal data. On the other hand, the non-parametric tests are not, in general, so powerful as its parametric alternatives, when the presupposed are verified [60].

The Mann-Whitney test is intended to compare differences between two independent groups when the dependent variable is either ordinal or continuous.
The Kruskal-Wallis test is a non-parametric test used to compare three or more independent samples. It may be seen as an extension of the Mann-Whitney test when there are more than two groups of an independent variable, on a continuous or ordinal dependent variable.
A Chi-square test for independence is used to analyze the relationship between two categorical variables [60].
The Spearman's rank-order correlation measures the strength and direction of the association between two ranked variables, being utilized for either ordinal variables or continuous data.
Cohen's kappa coefficient is a test that is used to measure inter-rater agreement for categorical scales, when there are two or more evaluators [61].
To decide which statistical test to apply on each investigation hypothesis, it is necessary to consider what are the independent (X) and dependent (Y) variables of it. The Y variables are those that depend on the first ones, that is, the behavior of X variables can influence the behavior of the Y variables. Also, the statistical test to apply varies according to the measure types of the variables, and with the categories (Cat.) number (No.) of the X variables. Therefore, a summary of when to use each statistical test is shown in Table 16.

Table 16 - Summary of when to use the statistical tests

X Variables		**Y Variables**	**Application**	**Statistical Test**
Measure Type	**Cat. No.**	**Measure Type**		
Nominal	-	Nominal	Analyze the relationship between two nominal variables	Chi-square
Ordinal		Ordinal	Measure the strength and direction of the association between two ranked variables	Spearman's rank-order correlation
Nominal	2	Ordinal	Compare differences between two independent groups	Mann-Whitney
Nominal	+2	Ordinal	Compare differences between three or more independent groups	Kruskal-Wallis
Nominal or ordinal	Same number of categories	Nominal or ordinal	Measure the level of agreement between the answers of two or more evaluators	Cohen's kappa coefficient

Then, a summary of how to perform each statistical test was developed, and is represented in Table 17.

Table 17 - Summary of how to use the statistical tests

Statistical Test	Statistical Hypothesis	Test Statistic	p-value	Decision
Mann-Whitney	H_0: $F(X_1) = F(X_2)$ H_1: $F(X_1) \neq F(X_2)$	$W = \min(R_1, R_2)$ R_1 = sum of the order numbers from the first sample observations R_2 = sum of the order numbers from the second sample observations	$=2*P(Z>W_{sample})$	If p-value ≤ α = 0,05 ; Reject H_0
Kruskal-Wallis	H_0: $F(X_1) = F(X_2) = \dots = F(X_k)$ H_1: At least one of the populations tends to yield larger observations	$H = \frac{12}{N(N+1)} \sum_{j=1}^{k} \frac{R_j^2}{n_j} - 3(N+1)$ R_i = sum of the order numbers of the i-th sample	$=P(\chi^2_2>H_{sample})$	If p-value ≤ α = 0,05 ; Reject H_0
Chi-square	H_0: The variables are independents H_1: The variables are not independents	$\chi^2 = \sum_i \sum_j \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \sim \chi^2_{(l-1)(c-1)}$	$=P(\chi_1^2> \chi^2_{sample})$	If p-value ≤ α = 0,05 ; Reject H_0
Spearman's rank-order correlation	H_0: $\rho = 0$ H_1: $\rho \neq 0$	$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$ d = difference between ranks ρ or r_s can take values from -1 (perfect negative association) to +1 (perfect positive association)		If p-value ≤ α = 0,05 ; Reject H_0
Cohen's kappa coefficient		k can range from -1 (no agreement) to +1 (perfect agreement)		If p-value ≤ α = 0,05 ; k coefficient is statistically significantly different from zero

Table 18 describes some examples found in the literature, where a questionnaire survey was developed in order to collect data, and posteriorly analyzed, presenting many similarities with this work. There were found more studies where a questionnaire survey was developed, however, the two referenced ones are those that present greater proximity in the applied techniques.

Table 18 - Examples in the literature where data is collected and analyzed

Bibliographic Reference	Brief Description
[62]	In this article, factors that can influence the adoption of agile methods in software development are investigated. A pilot study using a questionnaire was conducted in two languages, English, and Malay. The investigation hypotheses were analyzed, as well as the correlation between variables and a reliability test.
[63]	In order to access how is the Portuguese packaging industry adapting itself to the increasing demands of the market, while complying with the global environmental requirements, a questionnaire survey was developed aiming to evaluate the implementation of eco-design in the Portuguese packaging industry.

2.3.2 SWOT Analysis

A SWOT analysis is a strategic planning tool that is commonly used in the decision-making process. It provides information that helps identify key internal and external factors, that are important to achieve the proposed objective. The internal factors are strengths and weaknesses, and the external parameters are opportunities and threats [64]. Such an analysis is crucial to identify what could be advantages, disadvantages, prospects, and risks of what it is intended to evaluate. It also permits identifying incongruities doing a cross-check in the SWOT board. In Table 19, are referenced and described two studies whereby SWOT analysis was applied.

Table 19 – Examples in the literature where SWOT analysis was applied

Bibliographic Reference	Brief Description
[65]	The paper presents a method to measure the performance of a company, combining strengths, weaknesses, opportunities, threats, and the balanced scorecard. This combination asses quantitatively a company.
[64]	In this research, factors that influence the decision-making process for the development of a system were analyzed, including strengths, weaknesses, opportunities, and threats. SWOT analysis was used to develop a SWOT matrix for the specific system development.

2.3.3 Sample Size Examples

The sample size is one of the most crucial factors for the success of the survey, and how larger the sample better conclusions can be drawn. Therefore, it is required to identify the sample size of similar study cases, where a questionnaire survey type was developed, intending to posteriorly compare the obtained sample in this study with them. In Table 20 various similar study cases are represented, comprising the same sectors that were addressed in section 2.2.5, and evidencing the considered sample as well as the respective population.

Table 20 - Considered sample in similar study cases

Bibliographic Reference	Considered Sample	Population
[38]	19 medium and large-size companies - 48 respondents	Various Industry sectors considering innovative projects as Mining, Steel and Metallurgical, Automotive, Energy, Telecommunications, among others in Brazil.
[62]	Organizations from the public and private sector - 79 respondents	Software Industry in Malaysia.
[51]	10 small and medium companies	Various Industries as Electronic, food, among others in the UK and Malaysia.
[66]	107 responses	IT field in Argentina, Belgium, Brazil, Chile, China, Colombia, Costa Rica, Dominican Republic, Germany, Spain, Switzerland, United States…
[50]	20 SMEs – 30 respondents	400 Manufacturing sector SMEs including rubber, textile, electronics, marine product, industrial machinery, mulch, and paint manufacturing in Queensland.
[63]	33 companies	641 packaging manufacturers in Portugal.

2.3.4 Software Used to Achieve Results

The development of this work requires the utilization of various software to achieve the proposed objectives. Those objectives entail two main methodologies, such as questionnaire development, and statistical analysis. Table 21 shows the software utilized in this work, as well as some alternatives, for each methodology.

Table 21 - Software used and alternatives in the survey and data processing

Methodology	Software used	Alternatives
Questionnaire development	Google® Forms	SurveyMonkey®
Statistical analysis	SPSS® Microsoft® Excel	Minitab® R®

The first one allows to create and distribute the questionnaire, as collect all the obtained data. It also automatically summarizes, or divide the questions into individual answers, at the same time that allows exporting all the information into different formats. Therefore, the data could be exported to SPSS®, whereby statistical inference and frequencies' calculation, could be done. In order to obtain more personalized graphs for the descriptive analysis, presenting more possibilities in terms of edition, Microsoft® Excel was used.

These software present themselves as the most suitable for the work development, since some prior knowledge about them is acquired, and allow the accomplishment of all the proposed objectives. Nevertheless, some alternatives are also presented.

THESIS DEVELOPMENT

3 THESIS DEVELOPMENT

3.1 RESEARCH PLANNING AND EXECUTION

3.1.1 Specific Research Aims and Questions

This survey aims to identify the main barriers in the implementation of AM in non-IT environments, with a focus on the automotive manufacturing sector. Though, going more deeply there is a wide variety of relevant questions that this survey allows settling, being them:

- Are the benefits of implementing AM visible from the respondent's view?
- The barriers found in the literature, regarding the implementation of AM in software development, can be reflected in other areas as automotive manufacturing?
- These barriers are of technical, institutional, financial, organizational, or market nature?
- Are there barriers found in the companies that are not mentioned in the questionnaire or literature?
- Are internal or external the major source of these barriers?
- How difficult is it to implement an agile approach from the respondent's point of view?
- What is the main enabler for the implementation of AM?
- Do the company characteristics affect the implementation of AM?
- If product requirements come from abroad (OEMs), does it affect the implementation of AM?
- The company production type could be an organizational barrier for AM implementation?
- The need to improve flexibility, PM approach, manufacturing system, and the implementation of AM, have an association with the company's degree of change?
- The APM company culture could be an institutional barrier for the AM application?
- The company's main criteria for projects and products influence AM implementation?
- The minimum qualification for the PM team influences the knowledge about AM and its implementation?
- Is there a lack of top management involvement in the companies?
- Do companies devote the necessary effort to PM?
- The Portuguese companies are predisposed to APM?
- The absence of immediate quantifiable benefits influences AM implementation?

3.1.2 Research Design

To depict the steps followed in the development of this study, a flowchart was developed and is represented in Fig. 16.

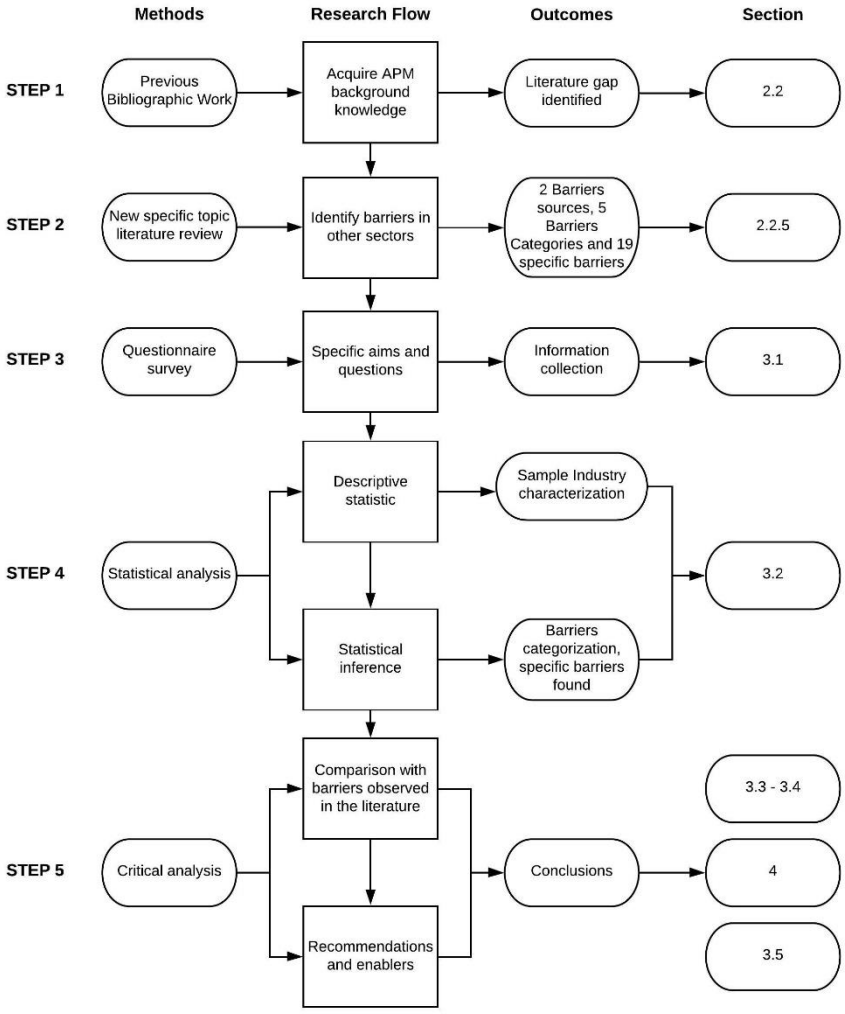

Fig. 16 – Research flowchart

The previous bibliographic work was carried out before this specific research, however, it includes the main topic of the study, such as APM. Then, it was necessary to define the specific theme, topics, and sector that the survey was going to address, being barriers in the implementation of AM in AI. This entailed a new literature review regarding this specific topic. After that, it was possible to create the questionnaire according to the survey purpose. This step includes the questionnaire, its formulation, validation, analysis, and the process of sending and waiting for answers. Once the number of answers received is significant, and the chances of increasing this number are low, it is possible to analyze the received data through statistical analysis. This analysis enabled to characterize the AI, as well as to categorize the barriers found.

Lastly, a critical analysis of results through the comparison of barriers identified in the literature, and also recommending possible enablers, allowed to reach conclusions.

3.1.3 Schedule of Work

For the development of this dissertation a Gantt Chart was built, in order to keep the work organized by phases, provide guidelines in the progress of it, and guarantee that it is completed in time. This graph follows the flowchart previously mentioned from the STEP 2 process, adding the fact of describing the activities duration, and enabling the creation of a work schedule. It was developed on MS Project, and includes a series of activities divided into four main activities: The initial tasks, questionnaire survey, thesis development, and thesis presentation. These activities establish the main event: Complete the master's thesis as observed in the first column. In the second column is defined the duration of the activities, being them assigned through common sense, which means that the dates could not be strictly verified. In the third column is represented the Start Latest Late (SLD) for each activity while the fourth column corresponds to the Finish Latest Date (FLD). In the last column are defined the predecessors for each activity, leading to sequencing them and, consequently, to the construction of the Gantt Chart as shown on the right side of Fig. 17.

Task Name	Duration	Start	Finish	Predecessors
Complete the Mater's Thesis	**102 days**	**Thu 05/03/20**	**Wed 01/07/20**	
Initial Tasks	**10 days**	**Thu 05/03/20**	**Mon 16/03/20**	
Initial Research regarding barriers	2 wks	Thu 05/03/20	Mon 16/03/20	
Define guidelines (research proposal)	2 wks	Thu 05/03/20	Mon 16/03/20	
Define sector	2 wks	Thu 05/03/20	Mon 16/03/20	
Initial considerations regarding the questionnaire	1 day	Mon 16/03/20	Mon 16/03/20	
Questionnaire survey	**54 days**	**Tue 17/03/20**	**Mon 18/05/20**	
Questionnaire development	7 days	Tue 17/03/20	Tue 24/03/20	3;4;5;6
Validate	7 days	Wed 25/03/20	Wed 01/04/20	8
Send	10 days	Thu 02/04/20	Mon 13/04/20	9
Wait for answers	6 wks	Tue 14/04/20	Mon 18/05/20	10
Thesis development	**52 days**	**Sat 25/04/20**	**Wed 24/06/20**	
SWOT Analysis questionnaire	4 days	Thu 14/05/20	Mon 18/05/20	10
Complement the theoretical part	4 wks	Sat 25/04/20	Mon 18/05/20	10
Analyze the data - statistical treatment	4 wks	Tue 19/05/20	Wed 10/06/20	11;14;13
Finalyze the thesis - Conclusions and final adjustments	7 days	Thu 11/06/20	Thu 18/06/20	15
Final thesis delivery	1 wk	Fri 19/06/20	Wed 24/06/20	16
Thesis presentation	**6 days**	**Thu 25/06/20**	**Wed 01/07/20**	
Develop and prepare t	1 wk	Thu 25/06/20	Tue 30/06/20	17
Final Presentation	1 day	Wed 01/07/20	Wed 01/07/20	19

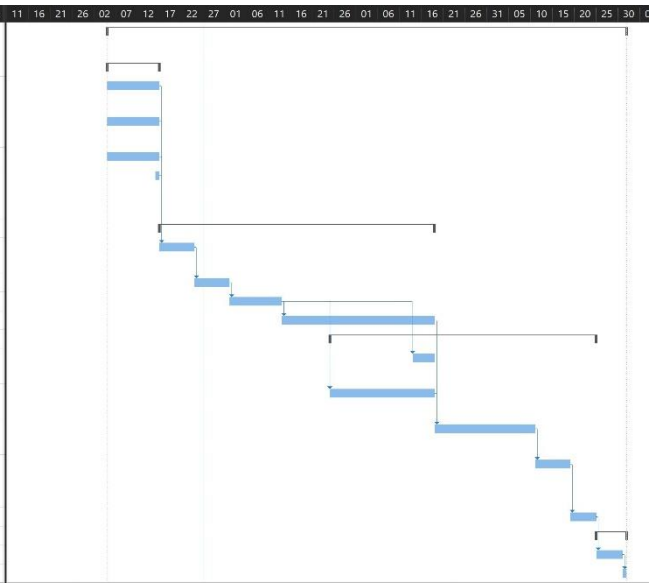

Fig. 17 – Activities, duration, predecessors and subsequent Gantt Chart

The project calendar was defined by an FLD being it 1st July 2020 and which, with the definition of activities duration and predecessors, leads to the LSD of the project being it 5th March 2020. To emphasize that in this chart, due to the unpredictability of the environment, were not considered all the specific steps of the development of this work, considering exclusively the main general and crucial activities to complete the master's thesis.

3.1.4 Questionnaire Framework

For the purposed survey, one of the most crucial components is the questionnaire. It allows to collect data from the Industry, analyze it, and draw conclusions, therefore it must be prepared meticulously considering what is expected to achieve.

Once the main aim of the work is defined: Identifying barriers in the implementation of AM in AI; it is possible to identify groups that must be present in the questionnaire, being them APM and barriers in its methodologies' application. These represent the two last groups of the questionnaire, since they are directly related to the main question. These specific topics could differ according to the company characteristics, systems, processes, etc. thus it is crucial to make the company characterization before questioning the key topics. In that way, it is possible to connect the type of barriers verified in the companies regarding their characteristics. Also, all the answers may depend on the characteristics of the respondent, despite that it should not be a variable of great influence as long as it complies with the main requirement: being familiar with APM. As a result, all the groups, their questions (qn), and variables are identified and sequenced in Table 22.

Table 22 – Questionnaire framework according to its groups, questions, and variables

Groups	qn	Variables
I. Respondent Characterization	1-5	Familiar with APM, Age, Department, and Job Function.
II. Company Characterization	6-11	Region, Employees, Organizational Structure, Exportation Volume, and Product Requirements.
III. Manufacturing Process Characterization	12-19	Production Type, Production Changes and purposes influence, Improve Flexibility, Management Involvement, Machining System, Influence Factors, and Quality Criteria.
IV. Product Development Process and Project Management	20-23	Product Development Process, Project Management Approach, Project and Product Development Criteria, and Project Changes.
V. APM Environment	24-32	APM Transition, APM Culture, AM Application, Departments Applying AM, APM Certification, PM Team, Minimum Qualification, Agile Techniques and Tools, and Agile Techniques and Tools Contribution.
VI. Barriers in the implementation of AM	33-37	Barriers Category, Barriers Source, Specific Barriers, Other impediments, and AM Implementation Difficulty.
VII. Enablers for AM implementation	38	AM Implementation Enablers

Concerning the objectives of each group, the first one intends to guarantee that the questionnaire is answered by persons that already experienced APM, and also understand the respondent position. The second one aims to identify the following company characteristics: region, company size, structure type, culture, customers, and market. The following group seeks to characterize and evaluate the company main priorities regarding the manufacturing process. Group four starts entering in the field of APM describing how the product development process is performed, what are the normally PM approaches applied in the company, and which is the degree of change during this process. All these company characteristics, from group two to group four, could be sources of barriers in the implementation of AM. The fifth group specifies and pretends to analyze, the company's predisposition to AM, as well as the current APM environment, the employer's point of view regarding the benefits of its implementation, and if the company is devoting the necessary efforts to the PM field. The penultimate group permits identifying what specific barriers are found in the automotive sector, and the employers' view regarding its sources. The last group contains one question, which intends to find what factors can be the major enablers for the AM implementation.

3.1.5 Questionnaire Methodology

The questionnaire was developed in the sequence previously mentioned. This sequence allows to first, understand the respondent and company characteristics, and secondly, go through the specific matter. The point is that, with the comprehension of the company environment, it will be possible to justify why some barriers are verified in the implementation of AM. That is, with the questions asked will be possible to connect the answers in group II with those obtained in group VI, to find barriers derived from the characteristics of the organization. For instance, in group VI question 35 of the questionnaire, if the barrier "Improper competency management" has a big influence on the AM implementation, that could be justified from a company characteristic already asked in group III, question 16: "is the management strongly involved with the production department?"; In other words, if the company reveals that the management department is not involved with the production department, it can be deduced that "Improper competency management" is a barrier to the implementation of AM. This methodology was made in several questions in a way that the company characterization group allows to find barriers in an indirect way.

Also, the questions in group V related to the current APM situation in the company, will permit to link with group VI since the barriers found in the implementation of AM, could derive from the current predisposition of the company for its application. For instance, if the answers given in group V reveal that the company does not make the necessary efforts for AM implementation, the barriers described in group VI could be just a justification for the non-implementation.

Furthermore, some questions are similar, however, asked differently (cross-check), such as questions 33 and 34 in group VI. The barrier's categories presented in the first one corresponds to sources mentioned in the second, being possible to observe if both answers match.

To better collect and analyze the data, various type of questions were used, being them:

- Multiple-choice questions;
- Checkboxes questions;
- Dichotomous questions;
- Scaling questions;
- Open questions – for justifying previous answers.

The majority of the questions for statistical treatment were made using a Likert-type scale, which is the most commonly used approach to scaling responses in survey research. When responding to a Likert item, respondents specify their level of agreement or disagreement. The Likert-scale usually includes five levels of agreement/disagreement, however, six levels of measurement were applied instead of standard five. Six levels scale besides allowing more detailed data also avoids that, in case of doubt, the middle option is chosen. Still, the established six levels are not only related to agreement or disagreement, but also with the influence level of some variables from the respondents' perspective.

The questionnaire has an estimated completion time of 10 minutes, and was made with an extremely thought-out methodology, in order to avoid contradictions, and get the most reliable possible data.

3.1.6 SWOT Analysis

To ensure that the questionnaire has the capability to fulfill the purposes, to improve what has room for improvement and, to identify the boundaries, a technical analysis was made. SWOT analysis is a technique that allows assessing four crucial aspects of a product, service, or any other matter that is necessary to be evaluated, being them strengths, weaknesses, opportunities, and threats. The development of this technique, regarding the questionnaire survey, allows identifying what is done well, what has room for improvement, what can be used as an advantage, what is the environmental characteristics, and how they can affect it.

The awareness of all these factors permits understanding the questionnaire capability, as well as adjust the expectation of the results, being represented in Table 23.

Table 23 - Questionnaire SWOT analysis

Strengths	Weaknesses	Opportunities	Threats
Produced with a sequential and well-organized structure			
Allows to collect relevant data for the study purpose	Slightly long questionnaire	Evolving discipline in the manufacturing sector (Agile Project Management)	Current World pandemic situation leads to closing companies, sackings, unavailability of respondents, or there may be no predisposition from the possible respondents
Easily shared by link	Requires to be answered by experts in the field, which reduces the possible sample size	Literature gap – dominated by the IT sector	
Quick answer type questions		Very few bibliographic references found on this specific field (AI)	
Coherence verification questions (Cross-check)			
Validated by experts in the field (technical approval)			

3.1.7 Questionnaire Validation

The questionnaire was made to comply with the following requirements:

- Guarantee that it is easily understandable by the respondents;
- All the questions and answers allow the accomplishment of the established goals;
- All the questions are made to be able to statistically analyze them;
- The content of the questionnaire is technically correct.

To ensure compliance with these requirements, the questionnaire passed through a validation process where various experts in the fields of Mechanical Engineering, Project Management, and Statistical Analysis were contacted, in order to comment and validate the questionnaire. This contact was made through E-mail, toward persons with recognized knowledge and experience in the previously mentioned fields.

In Table 24 are referenced the contacted persons, their professions, abilities, and comments.

Table 24 – Characterization of the responsible persons for validating the questionnaire and its comments

Name	Profession	Abilities	Comments
Luis Torres	Professor in the field of Mechanical Engineering and Automotive Engineering	Special skills in the field of Automotive Engineering	The questionnaire is well prepared, focusing on the most pertinent questions about current management methodologies in the automotive sector
Luísa Hoffbauer	Professor in the field of Statistic	Special skills in Statistic analysis and data treatment (SPSS®)	Made suggestions to specific questions in order to be statistically able to analyze them
Paulo Silva	Responsible for managing car assistance facilities in renowned companies (Peugeot, Renault/Dacia, and Nissan)	Dynamization of daily workflows with a view to maximum flexibility of human and material resources to obtain the best productivity and efficiency	The form is well structured, and will allow to characterize and relate, among other things, the people who respond, the size of the companies, with the perception of each one's reality
Mário Cardoso	Maintenance Manager in the automotive sector	Large experience in Project Management in the production of components for AI	The questionnaire focuses on the most pertinent questions regarding the topic
Carlos Ribeiro	Responsible for after-sales and technical services in the automotive sector	Large experience in the automotive sector as a manager	Interesting survey, also the framework and content; Suggested specifying agile methods as kanban and scrum

The validation documents were received by the same method, and are presented in section 6.2.

3.1.8 Platform Used for the Questionnaire Development

The platform used for the questionnaire development was Google Forms®. It is a very simple tool, that allows creating surveys through forms and questionnaires in a free, and easy way. In a nutshell, the first step is choosing the form title and its description, and then it is possible to add questions. At this point, the tool provides very solid question types that could be from a multiple-choice to a checkboxes grid question.

Also, it is available to change the font format, add images, videos, and sections. Lastly, when the form is done, it can be sent through E-mail, shared link, etc. in order to collect data from the respondents. In Fig. 18 is depicted the appearance, as well as the framework of the platform.

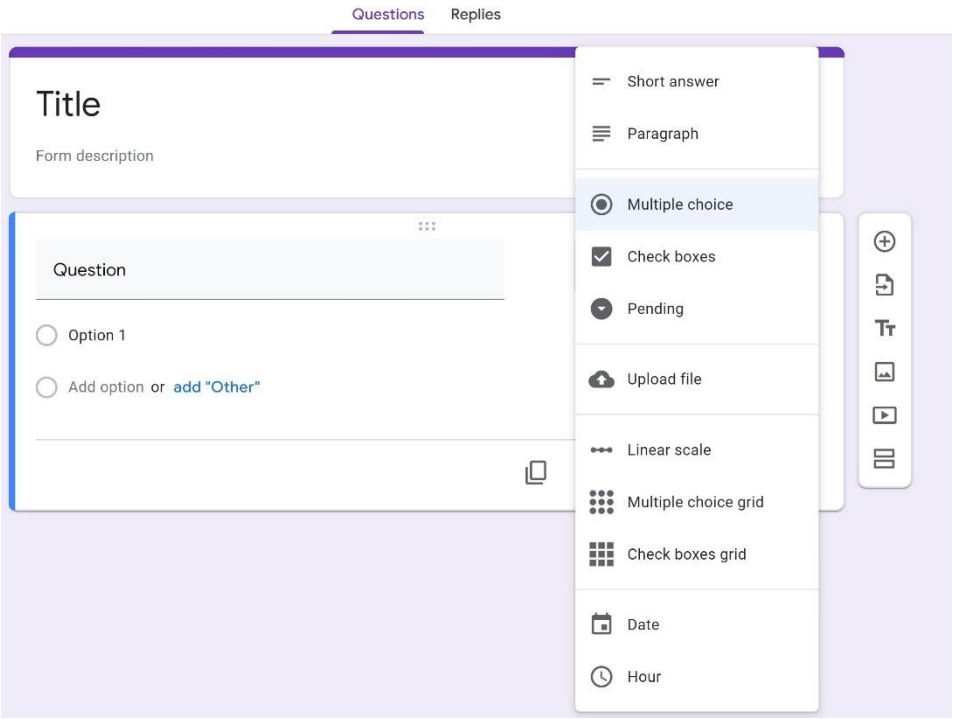

Fig. 18 – Platform appearance and framework

The collected data could be seen by question, individual response, or a summary of responses where the platform automatically organizes the data into pie and bar graphs.

In Fig. 19 and Fig. 20 are demonstrated two examples of how the platform reveals the summary of collected data, through bar and pie graphs, respectively.

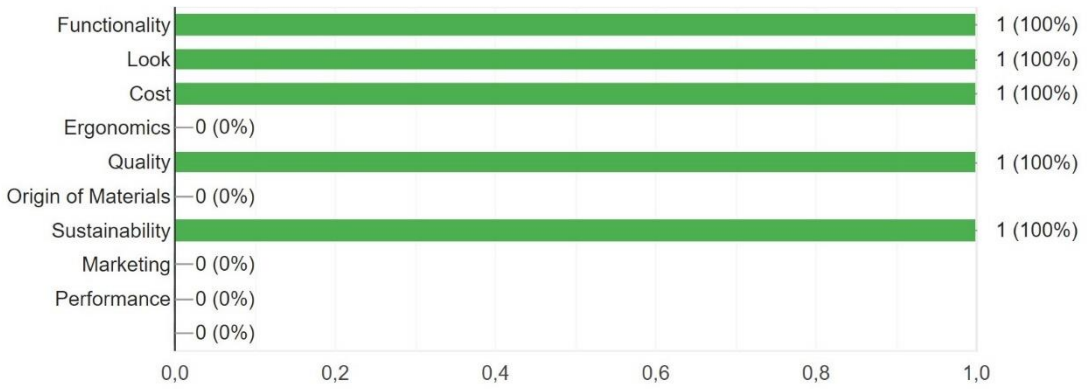

Fig. 19 – Example 1 of how the platform discloses the collected data - Bar chart

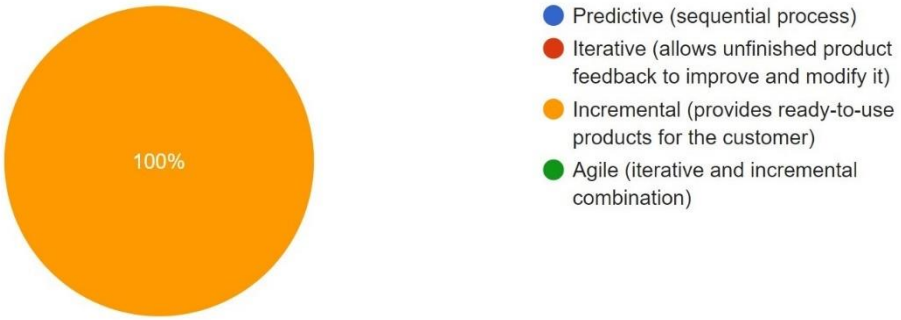

Fig. 20 – Example 2 of how the platform discloses the collected data - Pie chart

In Table 25 are described some of the advantages and disadvantages, observed in the platform used for the questionnaire development.

Table 25 – Google Forms® experienced advantages and disadvantages

Advantages	Disadvantages
Free platform	Necessary to have Google account
Collect information easily and efficiently	
Simple, and easy-to-use	
Availability for various question types, add images, sections, drag items, and organize them	Very limited design customization (just possibility of changing pre-defined colors and fonts), which leads to the easy recognition of the questionnaire source
Record and show the received feedback by individual answer, question, or summary of responses (with the usage of graphs)	
Does not limit the number of questions on the form, and the number of responses received	

3.1.9 Considered Sample

The sample is one of the most crucial factors for the success of the survey, and how larger the sample the better conclusions can be drawn. To accomplish that, the contact was attempted with most of the companies that produce components for the AI. AFIA was contacted, with the purpose of providing the companies list that are part of it. Then, the communication with companies was made by E-mail or by telephone requesting to complete the questionnaire. Also, with the industrial knowledge of the persons that are responsible for the guidance of this work, personal contacts were made to spread the survey inside the AI.

3.1.9.1 Consulted Sample and Effective Sample

According to AFIA, in 2019 there were 240 companies related to the manufacture of components for the AI. About 140 companies were contacted, making the consulted sample. From those 140 companies, 56 (23% of the total population) answers were received representing the effective sample since they have an active role in the dissertation, as they answered successfully to the distributed questionnaire.

A confidence level of 95% was considered for the statistical analysis of the collected data.

3.1.9.2 Comparison with Similar and Relevant Study Cases

Due to the questionnaire specificity, complexity, being directed to middle and top management, and the pandemic environment at the time of spreading the questionnaire, greater difficulty in the possible sample size was entailed. However, in comparison with similar study cases presented in 2.3.3, this survey presents itself with a greater amount of obtained data (larger sample) along with a smaller population, which represents a very reasonable quality sample. In the exemplified study cases, it is possible to observe that just two studies have a larger sample than what was accomplished here. One of them, in Malaysia, with three times of Portugal population, and in the software field, which increases the possible cases of analysis. The other study was made also in the software development field with 107 responses obtained, however with a population that includes an enormously high number of countries. These factors corroborate the good quality of the obtained sample in this survey, allowing the analysis of the data for further discussion of the results.

3.1.10 Statistical Indicators

To analyze the obtained data, and answer to the specific questions referred in 3.1.1, some examination could be done in an almost direct way through charts, and answers percentages evaluation. However, some of the most crucial objectives of this survey

require the application of statistical analysis, and for that reason, investigation hypotheses were defined. The investigation of these hypotheses will allow the comprehension of the relationship between some variables, and their influence in the implementation of AM.

3.1.10.1 Investigation Hypotheses

The investigation hypotheses are described in Table 26, as the related variables, questions, and groups.

Table 26 – Investigation Hypotheses, related variables, questions, and groups

Investigation Hypotheses	Variables	qn	Groups
H_1: The company characteristics affect the implementation of AM	Company size, Structure, Exportation Volume, Product Requirements	8, 9, 10, 11	II
H_2: The company production type influences the implementation of AM	Production Type	12	III
H_3: The manufacturing system used, the need to improve flexibility, AM implementation, and PM approach have an association with the company's degree of change	Manufacturing System, Improve Flexibility, AM Implementation, PM Approach	15, 17,21, 26	III, IV, V
H_4: The APM company culture influences the implementation of AM	APM Culture	25	V
H_5: The company criteria for product and project affects the AM implementation	Improvement of Internal Communication, Follows the Customer Requirements	19, 22	II, III
H_6: The minimum qualification for the PM team influence the knowledge of AM and its implementation	Minimum Qualification	30	V
H_7: The Improper Competency Management affects the AM implementation	Improper Competency Management	35	VI
H_8: The APM Certification has an association with the company's degree of change	APM Certification	28	V
H_9: The change predisposition influences the AM implementation	Change Predisposition	35	VI
H_{10}: The absence of immediate quantifiable benefits influences the AM implementation	Absence of Immediate Quantifiable Benefits	35	VI

3.1.10.2 Analyzed Variables

To define the statistical tests to perform considering the hypotheses that are intended to investigate, it is necessary to classify the variables that are part of this analysis. This classification distinguishes the variables by independent (X) and dependent (Y), as well as define their measure type, and Cat. No. for the hypotheses (Hypos), as represented in Table 27.

Table 27 – Identification of independent and dependent variables, measure type, and their categories

Hypos	X Variables	Measure Type	Cat. No.	Y Variables	Measure Type
H_1	Company Size Structure	Nominal Nominal	4 4	APM Culture	Nominal
	Exportation Volume Product Requirements	Nominal Nominal	4 2	Market and Supply Chain Barrier	Ordinal
H_2	Production Type	Nominal	5	Organizational Barriers	Ordinal
H_3	Manufacturing System Improve Flexibility AM Implementation PM Approach	Nominal Nominal Nominal Nominal	2 2 2 4	Company's Degree of Change	Scale
H_4	APM Culture	Nominal	4	Institutional Barrier	Ordinal
H_5	Improvement of Internal Communication Follows the Customer Requirements	Ordinal Nominal	6 2	Organizational Barrier Market and Supply Chain Barriers	Ordinal Ordinal
H_6	Minimum Qualification	Nominal	5	Knowledge and Technology Barrier Agile Techniques Knowledge	Ordinal Nominal
H_7	Improper Competency Management	Ordinal	6	Organizational Culture Barrier Knowledge and Technology Barrier	Ordinal Ordinal
H_8	APM Certification	Nominal	2	Company's degree of change	Scale
H_9	Change Predisposition	Ordinal	6	No obligation	Ordinal
H_{10}	Absence of Immediate Quantifiable Benefits	ordinal	6	Lack of Financial Support	Ordinal

To reference that, the scale independent variables have to be recoded into new nominal variables in order to enable the statistical analysis. Additionally, the variables production changes and project changes will be converted into one mean variable, intending to characterize the company's degree of change, and simplify the statistical analysis.

3.1.10.3 Statistical Tests

After identifying the dependent and independent variables, and according to the measure type of them (nominal or ordinal), the number of its categories, recode the scale variables, as well as calculate the mean variables of the above-referenced ones, it is possible to define the statistical tests to run as explained in Table 16, section 2.3.1.

In Table 28 are represented the statistical tests applied for each investigation hypothesis.

Table 28 - Statistical tests to run in each Hypothesis

Investigation Hypotheses	Statistical Tests
H_1: The company characteristics affect the implementation of APM	Chi-Square Kruskal-Wallis Mann-Whitney
H_2: The company production type influences the implementation of AM	Kruskal-Wallis
H_3: The machining system used, the need to improve flexibility, AM implementation, and PM approach have an association with the company's degree of change	Mann-Whitney Kruskal-Wallis
H_4: The APM company culture influences the implementation of APM	Kruskal-Wallis
H_5: The company criteria for product and project affects the APM implementation	Spearmen´s Correlation Mann-Whitney
H_6: The minimum qualification for the PM team influence the knowledge of AM and its implementation	Kruskal-Wallis Chi-Square
H_7: The Improper Competency Management affects the APM implementation	Spearmen´s Correlation
H_8: The APM Certification has an association with the company's degree of change	Mann-Whitney
H_9: The change predisposition influences the APM implementation	Spearmen´s Correlation
H_{10}: The absence of immediate quantifiable benefits influences the APM implementation	Spearmen´s Correlation

3.2 STATISTICAL ANALYSIS

This chapter is the most crucial part of this study, since it addresses all the specific formulated questions in 3.1.1. It also provides all the information collected through the questionnaire, the results obtained through statistical treatment, and a critical analysis of the results. It still includes a comparison with similar study cases in other fields, and possible solutions for the identified barriers.

3.2.1 Respondent Characterization

The first group of the questionnaire intends to characterize the respondent, describing his/her age, education level, department, and more importantly, if he/she is familiar with the concept of APM. This question aims to guarantee that the inquiry is directed through and returned by persons that already experienced, or at least, recognize the subject of this study. The results show that almost 85% of the respondents are familiar with the theme in focus, which is a very substantial percentage, and showing that the questionnaire was directed to the intended persons. However, respondents who said they are not familiar with the concept, still answered the questionnaire. This could mean that they are not in an intermediate or top management position, not knowing the specific term, but they are still capable of answer the questionnaire once they work in the field, and are able to describe and characterize the processes, as well as the technical features.

A results' summary for the respondents' characterization is presented in Fig. 21. Approximately 65% of the respondents have between twenty and thirty-nine years, while about 35% have between forty and fifty-nine years. Almost the totality of the respondents (98,2%) have a high education course, which is a very good sign of the knowledge and education present in the companies. Also, about 77% of the respondents belong to departments of interest to this study, being them project management and product development, production, and general management. The remaining percentage corresponds to sectors as process engineering, maintenance, and software.

Respectively to the job position, which is an open-ended question, the most referenced positions were "project manager", "process engineer", "project engineer", "production manager", and "project chief".

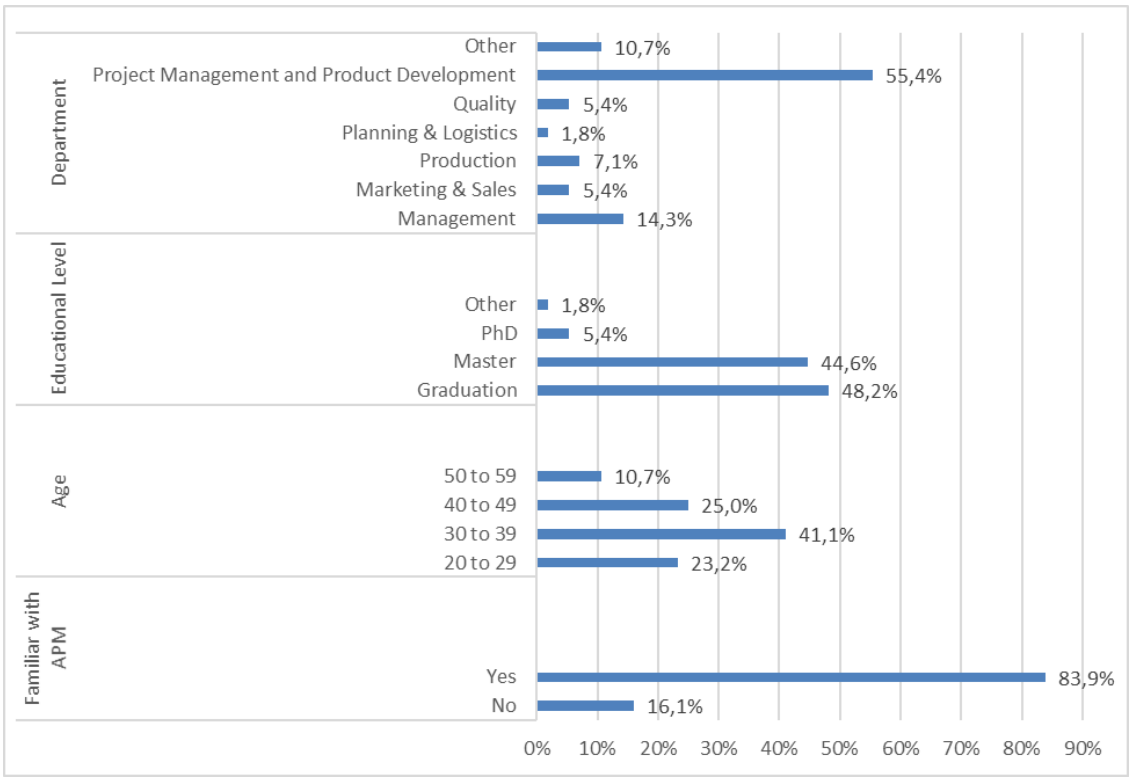

Fig. 21 – Respondents' characterization through a combined bar graph

3.2.2 Company Characterization

In Fig. 22 is represented a summary of results for the variables that are part of the companies' characterization group.

As expected, due to the location of the majority of the automotive manufacturing sites, north and center are the significant regions to analyze. Through the number of employees, it is possible to define the company size in a scope that comprises micro, small, medium, and large companies. More than 90% of the responses define the organizations as medium and large enterprises, indicating that the companies devoted to this sector are significatively relevant.

The percentages relative to the types of organizational structure are distributed in a very similar way, though the functional structure seems to be the more adopted approach by the companies. This structure type is based on specialization and functions distinction, that is, one specialty does not interfere with another, and is normally used in stable environments that do not experience rapid and constant changes, both internally and externally. Also, there is a difficulty of integration, communication, and coordination between sectors, since each team is independent in terms of decision making, and activities performed.

In addition, the company's employees end up losing the global vision of the business, considering that they are very focused and specialized in their work area. This leads to not being able to serve other sectors of the company in an effective way, making it difficult to align with the strategic objectives of the business as a whole. Perhaps, this is not the best approach for those who intend to implement AM.

Near 90% of the companies, which is a huge percentage, exports more than 75% of its production volume, which meets the obtained data through AFIA claiming that from 12 Billion EUR turnover, 9,7 Billion EUR correspond to exportation. This factor can influence the following factor, being it the imposed requirements from OEMs. Since the majority of the companies have a high percentage of exportation, it is understandable that the product requirements also come from abroad. Therefore, the percentage of companies that are subject to product requirements (near 84%) is in accordance with the organizations that have a high level of exportation.

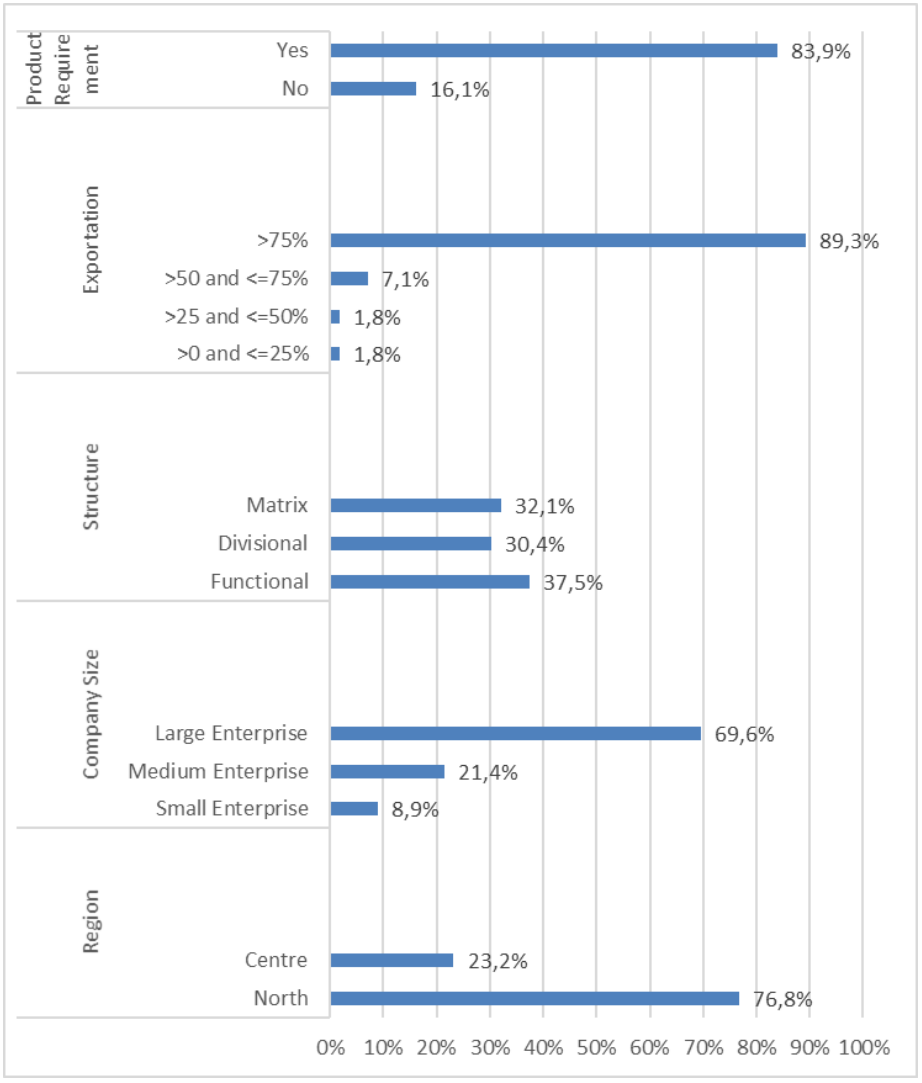

Fig. 22 – Companies' characterization through a combined bar graph

3.2.3 Manufacturing Process Characterization

Regarding the manufacturing process, as expected, the mass production is the production type pointed out with a higher percentage (51,8%), once it is the most common process used by the AI. Batch production also has a significant percentage (23,2%), probably corresponding to the activity of metalworking inside the AI.

More than 62% of the companies experienced changes in the last three years, with a degree of occurrence between three (sometimes) and six (always), on a scale of one to six. The fact that the manufacturing process is constantly changing, means that a predictive approach, since the project and product development phase, will not be effective due to the unpredictable environment and market.

In order to understand the reasons that lead to those changes and their influence on productivity, a stacked bar chart was built, which is depicted in Fig. 23.

It is possible to observe that there are two easy distinguishable factors with clear influence on productivity between moderate and very high. For more than 80% of the respondents, “Increase production” and “Cost reduction” are the main factors. “Imposed changes by OEMs”, “Design”, and “Attempt to implement AM” also have a similar influence for more than 60% of the respondents, while “Environmental issues” plus “Governmental policies” do not significantly represent the purposes of the changes.

Furthermore, the results indicate that almost 93% of the companies, have the intention to improve the manufacturing process to increase flexibility. This flexibility might improve the responsiveness of the company to the occurred changes during the production process.

Considering the degree of involvement among the management and production department, around 85% of the respondents, claim that the management is between highly involved and extremely involved, whereby there seems to be no lack of support from the management team in the sample.

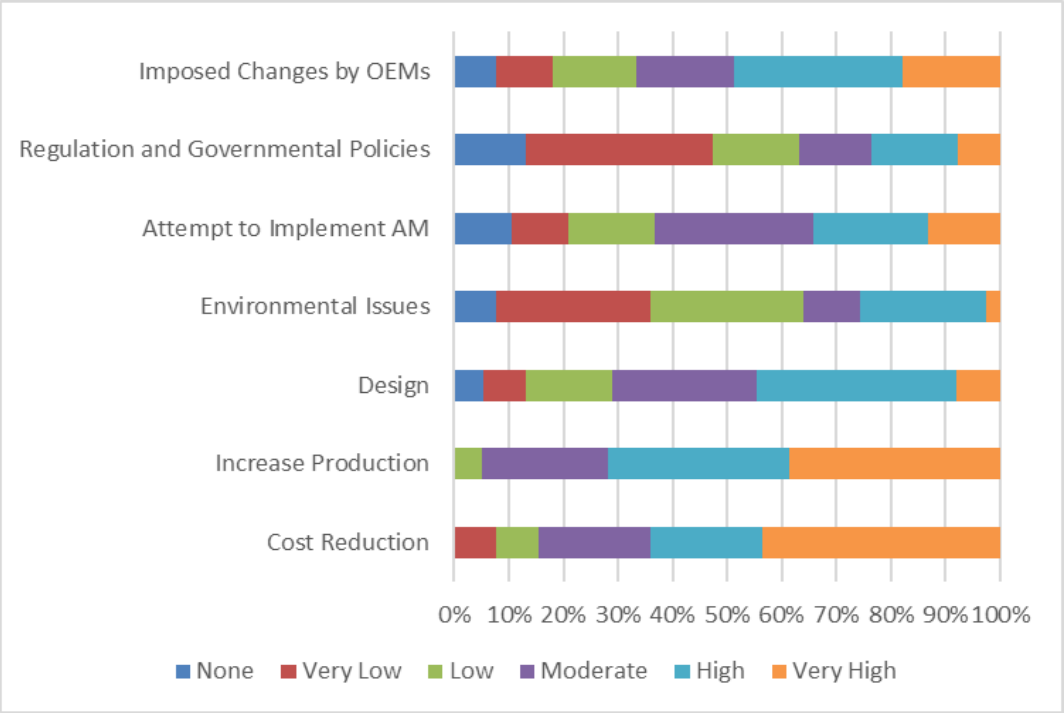

Fig. 23 – Percentages of the change's purposes and influence on productivity

Moreover, as represented in Fig. 24, nearly 81% of the companies feature an agile manufacturing system, meaning that they can produce a planned range of product models in a product class. This type of system is more capable of handle the unplanned changes, once it has the ability to support different processes in a different order, instead of just being prepared for a certain cycle of processes in a certain order.

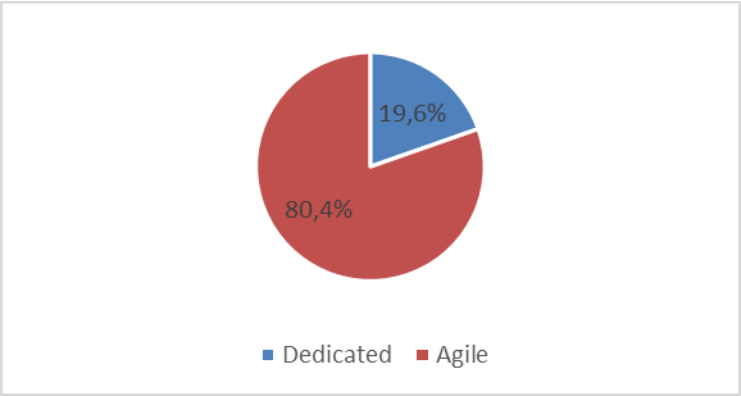

Fig. 24 – Percentage distribution between production systems

In Table 29, factors to compare the manufacturing systems, the way they behave on each system (high or low represented by arrows), and the respondents' perception regarding the influence of each factor in the use of one or another, are represented. For instance, the "Investment cost" is smaller (↓) in a dedicated system than in the agile. Also, the respondents claim that the "Cost to introduce new models" is the factor with the least influence on the choice of one or the other system (32.1%).

Table 29 – Comparison of Dedicated and Agile manufacturing systems, and respondent's perception

Comparison Factors for Machining Systems	Dedicated	Agile	Respondents Percentage
Investment Cost	↓	↑	55,4%
Production Volume Capability	↑	↓	53,6%
Capacity to introduce new (unplanned) models	↓	↑	33,9%
Time to introduce new models	↑	↓	41,1%
Equipment Re-usability for other machining applications	↓	↑	57,1%
Cost to introduce new models	↑	↓	32,1%

From the respondent's perception, "Equipment re-usability" is the factor with higher influence in the use of one or another system, and indeed, it is one of the main advantages of the agile system over the dedicated. However, the further two factors most selected by the respondents, "Investment cost", and "Production volume capability", are factors that provide an advantage to the dedicated system, not coinciding with the system mostly used by companies. In other words, these two factors should not have been the most selected by the respondents, considering the most used manufacturing system in the companies, and showing some incoherence in these two questions.

In Fig. 25 are represented the companies' quality concerns, evaluated on a scale of one (none) to six (very high), aiming to comprehend what are the factors that the companies give more attention to. The responses illustrate that all factors are important, although some differences can be observed. Primarily, the most selected quality concern is "Customer satisfaction", which is a crucial feature in the implementation of an agile methodology. Though, the "Improvement of internal communication" does not seem to be an important aspect from the respondent's point of view. This, aligned with the functional organization type adopted by the companies, demonstrates that the employees are focused exclusively on their work, not mattering the communication and interaction with other sectors, thus ending up losing interest in the overall purposes of the company. This can mean quite the opposite of what an agile philosophy is, giving great importance just to "Productivity", "Financial performance", and "Consistency of product", plus leaving in the background the "Implementation of best practices", and the "Improvement of internal communication".

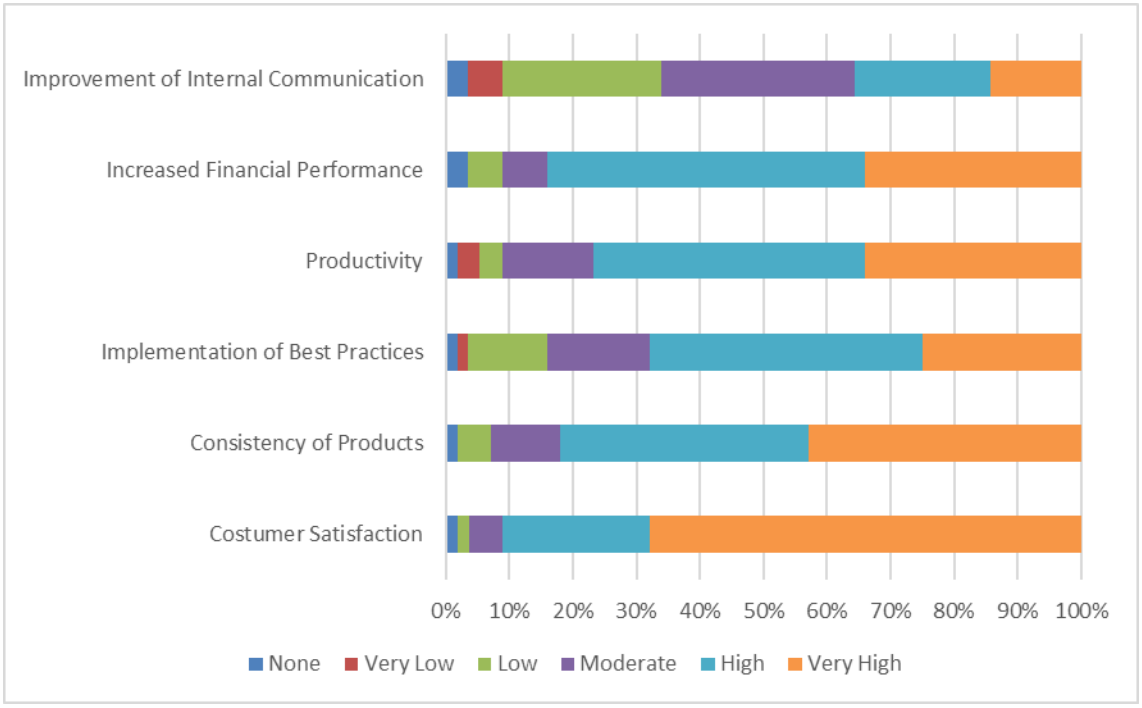

Fig. 25 – Percentages and evaluation of the companies' quality concerns

3.2.4 Product Development Process and Project Management

In order to understand and characterize the product development process, four questions and their variables were defined. Firstly, it is necessary to understand If the companies, whether to develop this process themselves or subcontract abroad. In Fig. 26 it is possible to verify, that more than 91% of the companies develop the majority of the projects within the company.

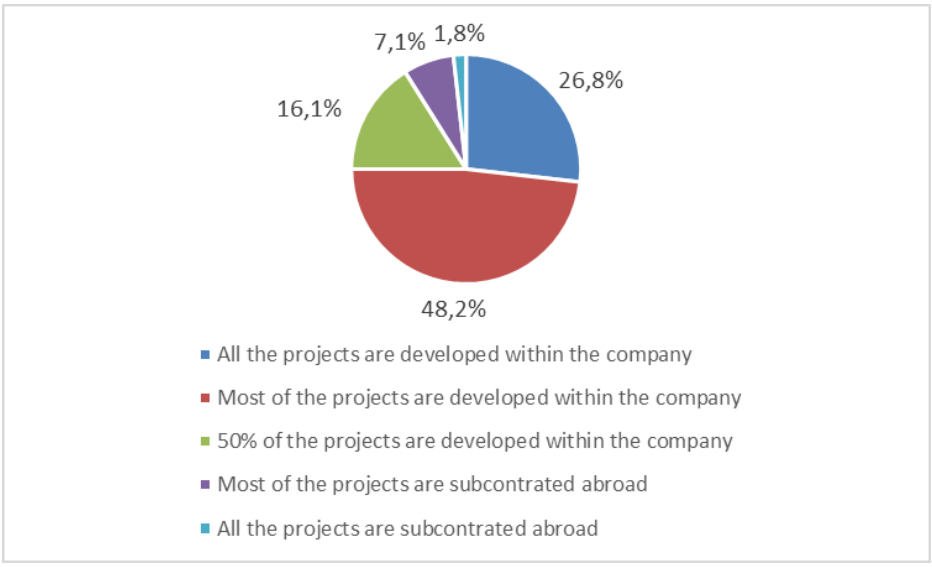

Fig. 26 – Product Development Process characterization

Then, it is needed to know what approach is normally applied in the PM field. Through Fig. 27, it is noticeable that a lot of PM teams are experiencing the agile approach or, at least, iterative or incremental methods. These methods allow feedback from the customer, permitting changes during product development, in order to change and improve it to guarantee customer satisfaction.

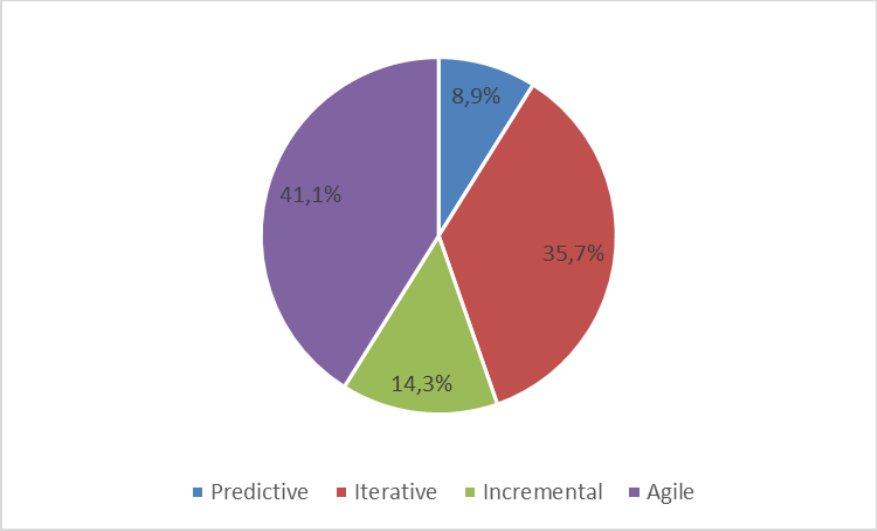

Fig. 27 – Percentage distribution among Project Management Approaches

In Fig. 28 are presented the main criteria during the project and product development process, through a bar chart.

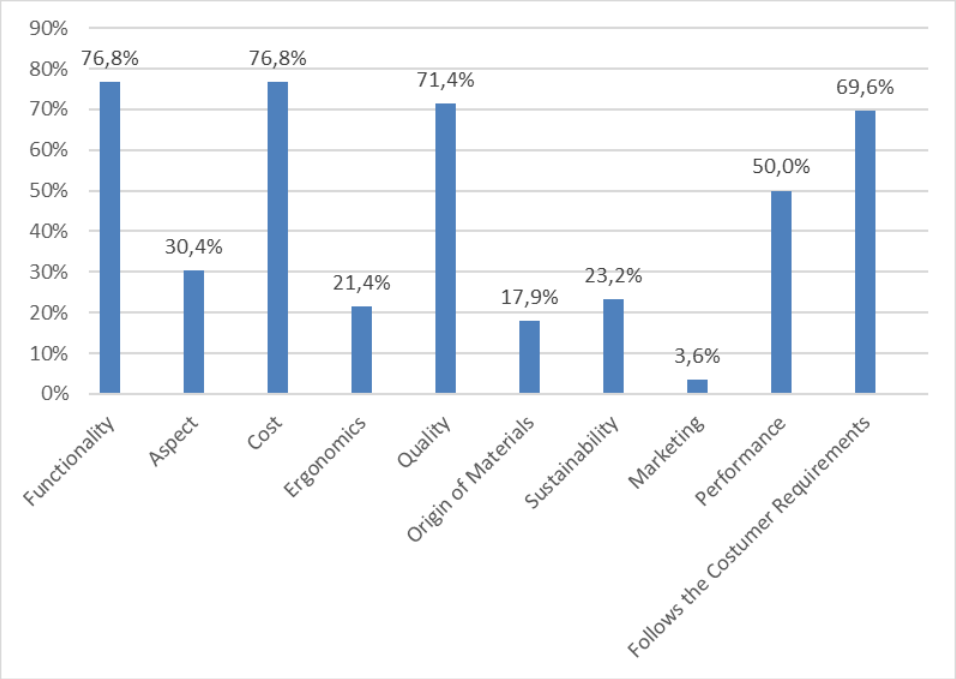

Fig. 28 – Percentages of companies' Project and Product Development Criteria

At a first glance, the most important aspect to analyze is the high percentage of respondents that select “Follows the customer requirements” criteria and that, aligned with the fact that more than 80% of the companies follow the product requirements imposed by the OEMs, proves the high degree of dependence that these companies have in the sector. It is also important to emphasize the low percentage of “Origin of materials”, and “Sustainability” criteria, indicating that the environmental aspect is one of the least important during the project and product development phase.

3.2.5 Agile Project Management Environment

In Fig. 29 is illustrated a combination of bar charts that serves as a results summary, reflecting all the variables that characterize the APM environment group. Regarding the APM culture of the companies, more than 73% of them are studying the implementation or working under AM, which is a very reasonable number. Approximately the same percentage, have departments where agile techniques (kanban, scrum, or scrumban) are applied. Production, planning and logistics, plus project and product development are the departments where this application is more visible.

The last top three variables intend to perceive if the companies are devoting the necessary effort to the transition or implementation of APM. The process of APM certification is still difficult, and not much requested by the companies. Nevertheless, there is a significant percentage of responses (30%), claiming that they have certified collaborators in APM in the company. Also, almost 60% of the companies have more than ten persons dedicated to the PM team. Lastly, the majority of the companies have a minimum qualification as a degree for the project and product development team. However, there is a percentage of minimum qualification as secondary education (19,6%), higher than a master’s degree (14,3%). It does not seem to be the ideal situation, and could lead to a lack of skills and knowledge as a barrier to the AM implementation. Besides that, in a general way, the companies show to be aware of what is APM but, probably, do not devote the necessary effort to adopt a fully agile approach.

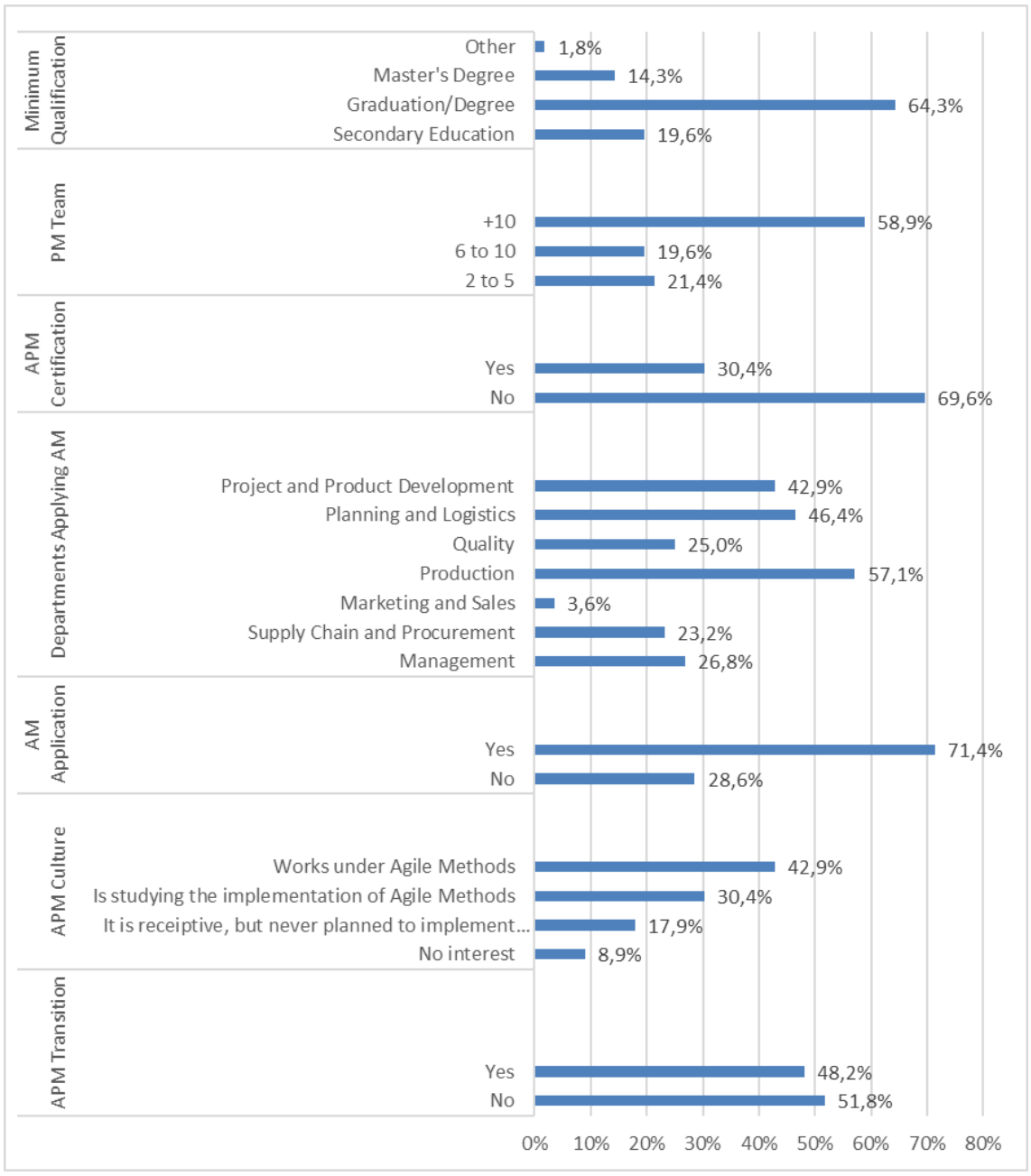

Fig. 29 – Characterization of the companies' Agile Project Management Environment through a combined bar graph

In Fig. 30 is depicted a stacked bar chart where some specific agile techniques are depicted.

The purpose of this question was to observe the knowledge of the respondents regarding this theme and, at the same time, if some of the techniques are applied in the companies. Once again, one of the main detected points was the "Customer integration" feature, reiterating the importance of customer satisfaction and requirements dependency for these companies.

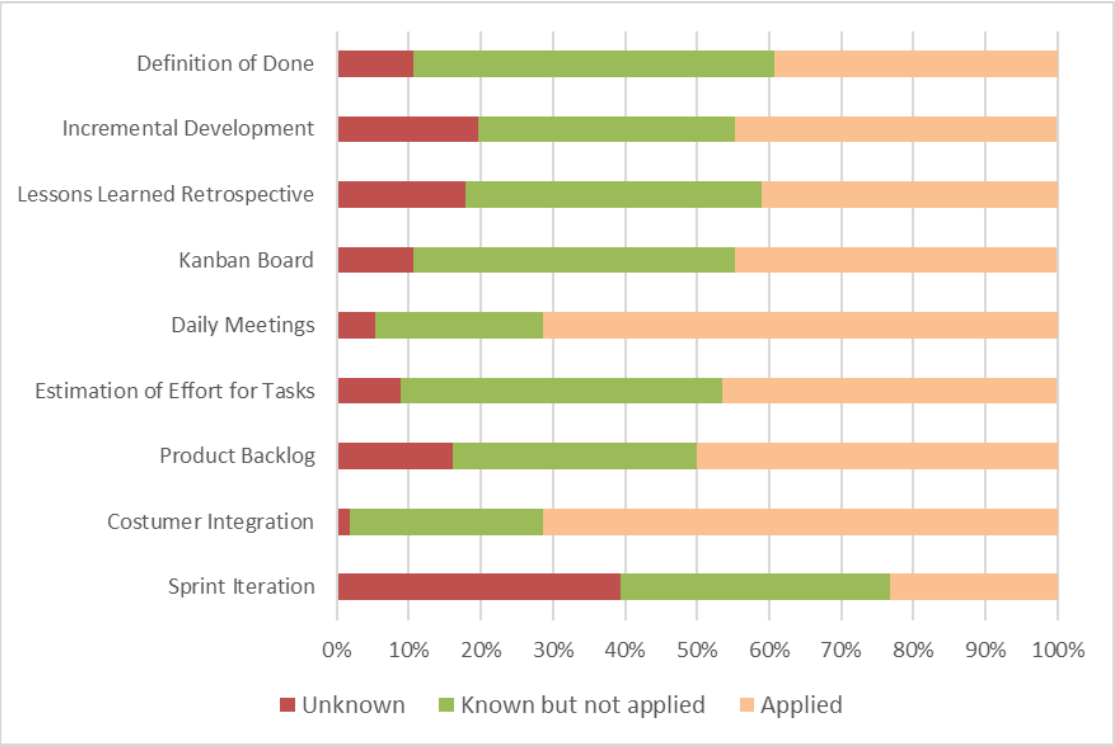

Fig. 30 - Percentages of agile techniques and tools application

Another tool supposedly quite applied is the "Daily meeting", which is part of the scrum technique, though other tools are part of it, as the "Product backlog", "Sprint iteration", and "Incremental development", those were not verified in the same way. This could mean that the companies could apply one or another tool, without fully applying the concept, such as the scrum technique.

Considering the question 32 of the questionnaire, 82,1% of the respondents claim that the contribution of the agile techniques and tools varies between highly and extremely important. It is clear that the respondents notice the importance of these methods in their workplaces, even without applying them in full.

3.2.6 Barriers in the implementation of Agile Methodologies

This topic concerns barriers to the implementation of AM. In Fig. 31 are represented factors that affect the implementation of AM, as well as their influence from the respondents' point of view. These factors are considered as categories for the barriers in this implementation, and the barriers further described will fit these categories.
The most notable categories of barriers, in the stacked bar chart, are "Technical knowledge and capacity", and the "Organizational culture", both with an influence between moderate and very high in more than 60% of the responses. These factors could have an extreme impact on the success of AM implementation. The first one is indispensable, since everyone dedicated to the job needs to be aware of what is supposed to do, and have the necessary knowledge to apply it. The second one is the

factor with the greatest influence, and could be the biggest impediment inside the companies. That is, a company that has been working in one way for several years, or was even built to follow certain procedures, with a fixed organization structure over the years, cannot change these roots rapidly and effectively. Also, it is worth to mention that the "Lack of financial support" does not seem to be a factor with high influence for the non-implementation of AM.

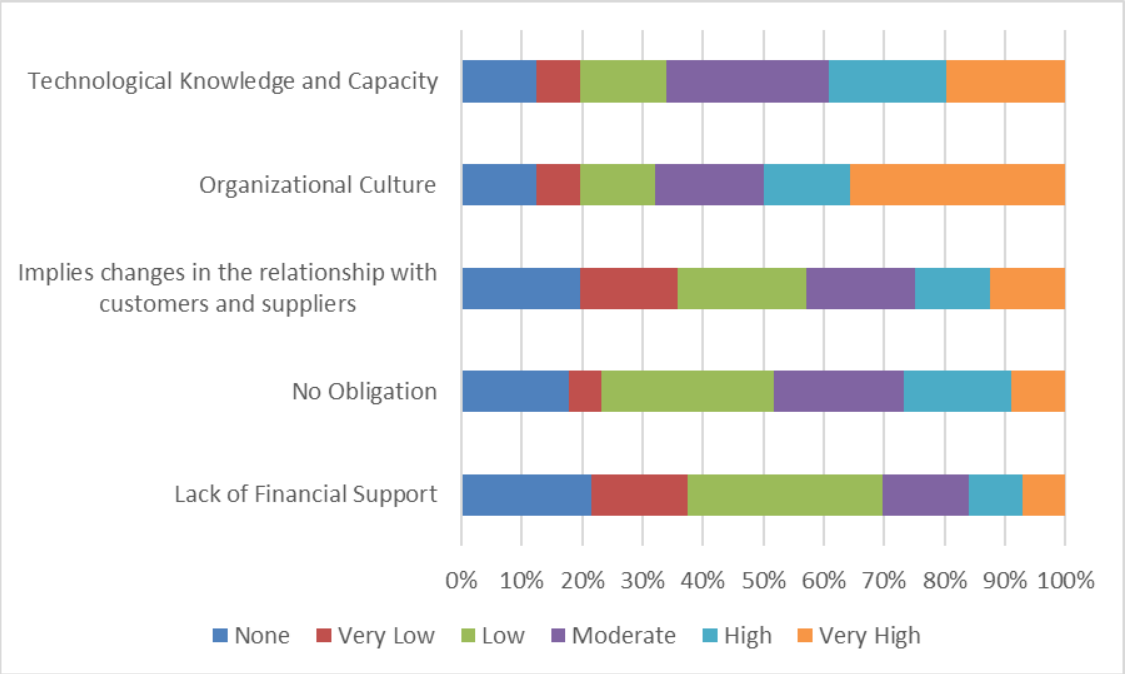

Fig. 31 – Barriers categories and their influence for non-implementation of AM

In Fig. 32 is illustrated a pie chart, to evaluate the major source of barriers from the respondents' point of view. It is clear that the external environment does not have, by itself, influence in the implementation of AM while internal impediments seem to be the most significant. This meets the answers given in question 33 and depicted in Fig. 31, since the two most verified factors ("Technological knowledge and capacity" plus "Organizational culture"), belong to barriers that derive from an internal source.

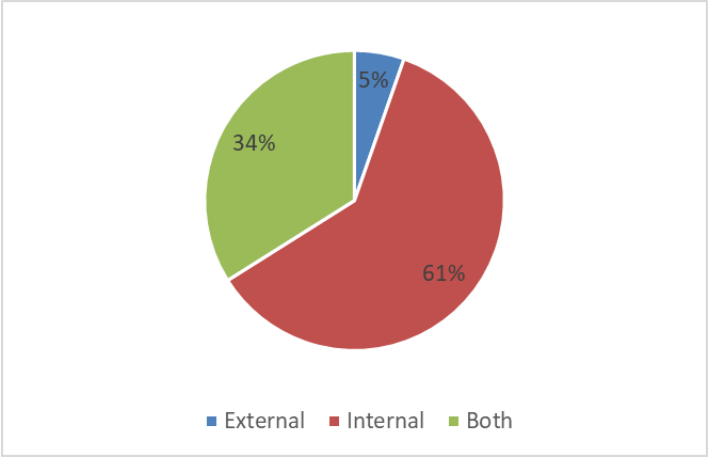

Fig. 32 – Percentage distribution between the Barriers sources

After performing a binomial test, and if p represents the companies' proportion that claims the majority of the barriers' source is solely internal:

H_0: p = 0,5
VS
H_1: p > 0,5

It was obtained an exact Sig. = 0,243 not being feasible to reject H_o, whereby it is not possible to affirm that, the majority of the Portuguese automotive manufacturing companies experiment solely internal barriers, despite 60% of the sample claiming it.

Fig. 33 refers to the responses given in question 35, and represent specific barriers and their influence in the implementation of AM. Each specific barrier fits on a barrier category and barrier source, previously referred. Mentioning the barriers with influence between moderate and very high level, for more than 50% of the respondents, being them the "Lack of knowledge and skills", "Stakeholders attitude", "Time constraints", "Existent organizational culture", "Change predisposition", "Staff not prepared to AM", and "There is no time to think about that". To highlight the low influence of the factors "It is not applicable to our product" and "Organization not able to apply AM" indicating that, indeed, the implementation of AM in the AI is conceivable.

In question 36, an open-ended question was established to verify if there are more observed barriers in the industry, that are not referenced in the questionnaire. Although not many answers were obtained, two factors were mentioned, namely "Certification procedures" and "Lack of collective motivation".

A board was built to group the barriers presented in this survey, according to their source and category, which simplifies their visualization, and is represented in Table 30.

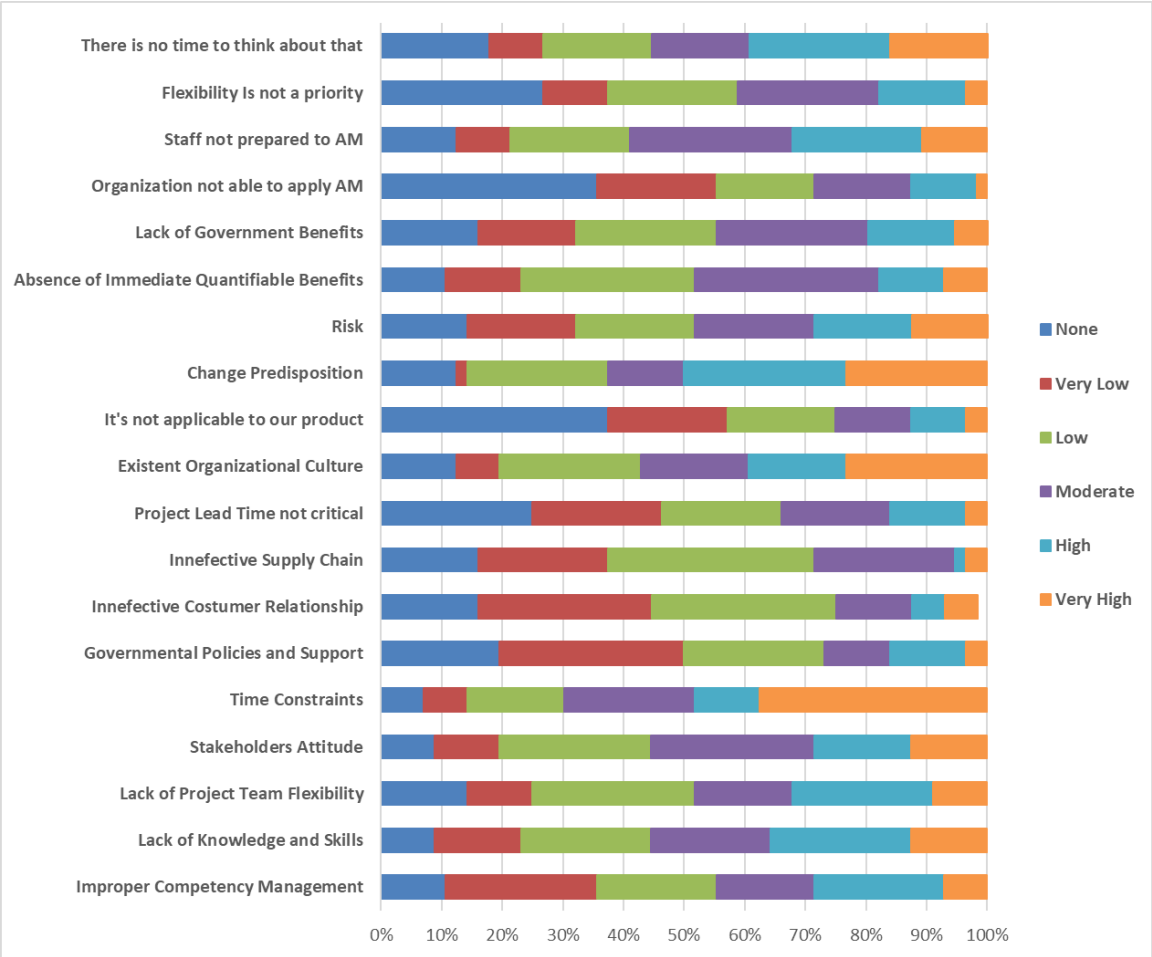

Fig. 33 – Specific Barriers and their influence in the implementation of AM

Table 30 - Summary of barriers, their sources, and categories

Barriers Source	Barriers Category	Barriers
Internal	Financial	Absence of Immediate Quantifiable Benefits.
	Organizational	Lack of Project Team Flexibility, Time Constraints, Project Lead-Time Not Critical, Existent Organizational Culture, It is not applicable to our Product, Risk, Organization not able to apply AM, Flexibility is not a priority, There is no time to think about that.
	Knowledge and Technology	Improper Competency Management, Lack of Knowledge and Skills, Staff not prepared to AM.
External	Supply Chain and Market	Ineffective Supply Chain, Stakeholders Attitude, Ineffective Customer Relationship.
	Institutional	Governmental Policies and Support, Change Predisposition, and Lack of Government Benefits.

In Fig. 34 is portrayed the difficulty, in a general way, of implementing AM in the companies from the respondents' perspective. The results state that almost 90% of the respondents consider a difficulty between moderate and extremely difficult to implement AM. It is visible that it is not an easy approach to adopt, and requires effort and commitment of all those involved.

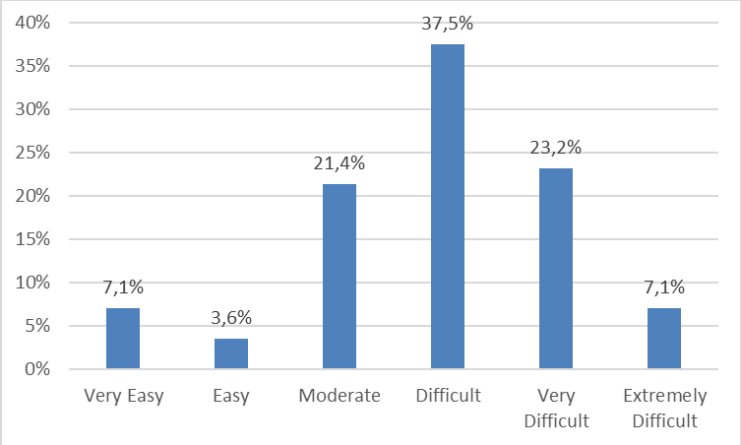

Fig. 34 – AM implementation difficulty from the respondent's perspective

3.2.7 Enablers for the Implementation of Agile Methodologies

The last question of the questionnaire (question 38), represents enablers found in the literature for the implementation of AM, intending to understand which ones have more influence in the automotive sector, and the percentage of the answers are represented in Fig. 35. The two most selected enablers were "Organizational support" and "Investment in training", and these can counter the two most nominated barriers ("Organizational culture", and "Lack of knowledge and capacity"). The first one aims to global and internal organization support, meaning everyone's willingness and effort, while the second claims that the formation and training in the field are essential to have the necessary knowledge for this implementation.

Also, an open-ended option was placed with the intention of checking for other enablers from the respondent's point of view, and in any answer was selected that option, whereby were not found other enablers directly from this questionnaire question.

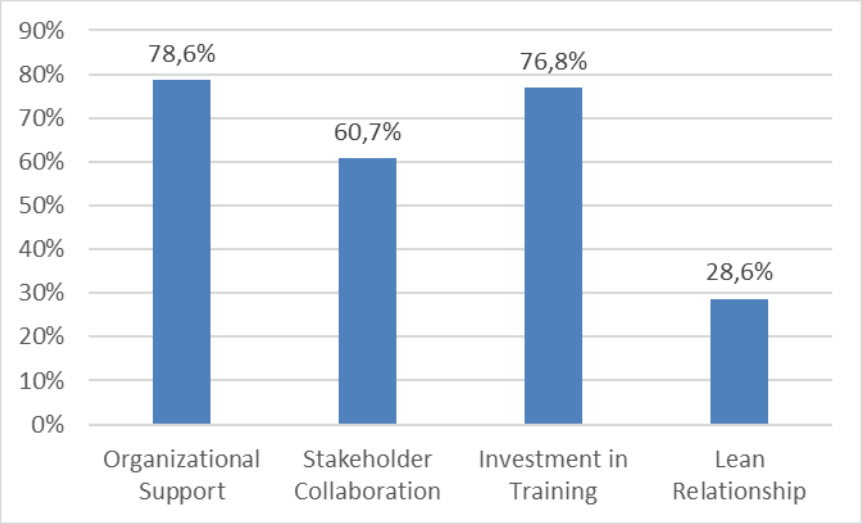

Fig. 35 - Factors to improve the implementation effectiveness of AM

3.2.8 Investigation Hypothesis 1

It is worth mentioning that, for all the hypotheses' investigation, it was solely selected the data that follows the condition: being familiar with APM, reducing the sample to 47 responses, but improving the reliability of the tests.

The first hypothesis attempts to realize if the company characteristics as the "Company size", "Structure", and "Product requirements", may influence the AM implementation:

***H_0*: The company size, structure, exportation volume, and product requirements do not influence the AM implementation in the company.**
Vs
***H_A*: The company size, structure, exportation volume, and product requirements influence the AM implementation in the company.**

Chi-square, Kruskal-Wallis, and Mann-Whitney tests were conducted, and the results are illustrated in Table 31.

It was possible to observe that there is no association between the "Company size", and "APM culture" (χ^2 = 1,651; p = 0,949). The same occurs with the variable "Structure", that does not have any association with "APM culture" (χ^2 = 6,070; p = 0,415), as well as the "Exportation volume" (χ^2_2 = 5,456, p = 0,093). Regarding the "Product requirements", there is no evidence, at the 5% significance level, that allows to state that product requirements influence the AM implementation. Therefore, it is not possible to state that the company characteristics influence the AM implementation.

Table 31 – Test results for Hypothesis 1

Variables	Test Hypotheses	Test Statistic	p-value
Company Size	H_0: The company size and the APM culture are independents H_A: The company size and the APM culture are not independents	$\chi^2 = 1,651$	0,949
Structure	H_0: The structure and the market and supply chain barrier are independents H_A: The structure and the market and supply chain barrier are not independents	$\chi^2 = 6,070$	0,415
Exportation Volume	H_0: $F_{Low} = F_{Moderate} = F_{High} = F_{International}$ H_A: At least one of the populations tends to yield larger observations than at least one of the other populations	$\chi^2_2 = 5,456$	0,093
Product Requirements	H_0: $F_{No} = F_{Yes}$ H_A: $F_{No} \neq F_{Yes}$	W = 163,000	0,214

3.2.9 Investigation Hypothesis 2

This hypothesis intends to evaluate if the "Production type" adopted by the companies could be an "Organizational barrier", that impedes the AM implementation:

***H_0*: The production type does not influence the AM implementation in the company.**
Vs
***H_A*: The production type influences the AM implementation in the company.**

Kruskal-Wallis test was performed and Table 32 shows its results.

Table 32 - Test results for Hypothesis 2

Variables	Test Hypotheses	Test Statistic	p-value
Production Type	H_0: $F_{Unit} = F_{Batch} = F_{Mass} = F_{Continuous\ Process} = F_{Other}$ H_A: At least one of the populations tends to yield larger observations than at least one of the other	$\chi^2_2 = 10,052$	**0,040**

As the p-value is smaller than 5%, the decision is rejecting H_0 leading to conclude that, at a significance level of 5%, there is evidence that there are differences between the groups ($X^2_2 = 10,052$; p = 0,040). It is possible to state that the "Production type" in the companies, could influence the AM implementation through "Organizational barriers".

Performing a multiple comparison test, it was observed that the batch production type represents statically significant differences, at a significance level of 5%, between the mass, continuous process, and other production types

Fig. 36 illustrates a boxplot for the influence of an “Organizational barrier” according to the “Production type”.

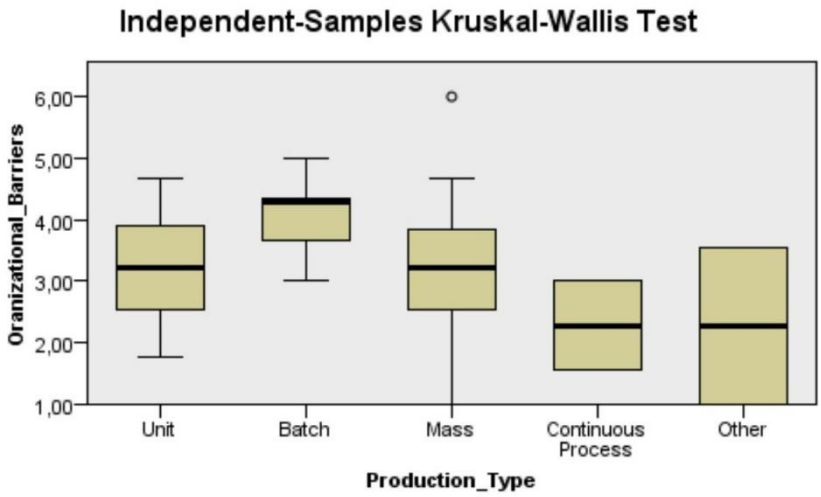

Fig. 36 – Boxplot for the influence of an organizational barrier according to the production type

3.2.10 Investigation Hypothesis 3

Hypothesis 3 aims to investigate if the “Manufacturing system” used, the need for “Improvement on flexibility”, “AM implementation”, and “PM approach” have an association with the “Company’s degree of change”:

***H_0*: The Manufacturing system, the need for improved flexibility, AM implementation, and PM approach do not have an association with the company’s degree of change.**
Vs
***H_A*: The manufacturing system, the need for improved flexibility, AM implementation, and PM approach have an association with the company’s degree of change.**

The Mann-Whitney and Kruskal-Wallis tests were performed, and Table 33 presents their results.

Table 33 - Test results for Hypothesis 3

Variables	Test Hypotheses	Test Statistic	p-value
Manufacturing System	H_0: $F_{Dedicated} = F_{Agile}$ H_A: $F_{Dedicated} \neq F_{Agile}$	W = 203,500	0,386
Improve Flexibility	H_0: $F_{No} = F_{Yes}$ H_A: $F_{No} \neq F_{Yes}$	W = 77,500	0,091
AM Implementation	H_0: $F_{No} = F_{Yes}$ H_A: $F_{No} \neq F_{Yes}$	W = 110,500	**0,048**
PM Approach	H_0: $F_{Predictive} = F_{Iterative} = F_{Incremental} = F_{Agile}$ H_A: At least one of the populations tends to yield larger observations than at least one of the other populations	χ^2_2 = 2,572	0,462

It is not statistically possible to state that the "Manufacturing system" has an association with the "Company's degree of change" (W = 203,500; p = 0,386). Despite the observed differences between the respondents, who state that the company has agile systems (n=38), and those who say that has dedicated systems (n=9), as depicted in Fig. 37.

The same happens with the variable "Improve flexibility" (W = 77,500; p = 0,091), that does not have an association with the "Company's degree of change" (W = 77,500; p = 0,091). Despite the notable differences between the companies that intend to improve flexibility (n=45), in relation to the others (n=2), as represented in Fig. 38.
Also, the "PM approach" does not have an association with the "Company's degree of change" (X^2_2 = 2,572; p = 0,462). Even though some notable differences in the company's degree of change, according to their PM approach, are visible and represented in Fig. 39.
However, there seems to be an association (W = 110,500; p = 0,048) between the "AM implementation", and the "Company's degree of change", as well depicted in Fig. 40.

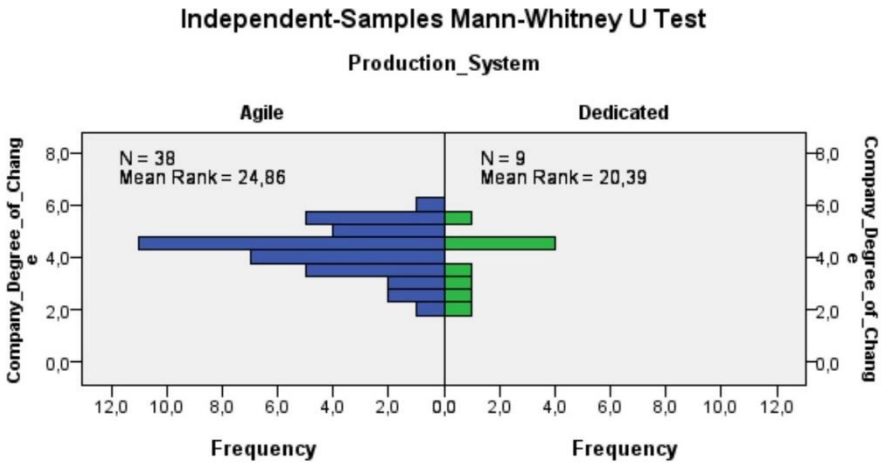

Fig. 37 – Bar chart contemplating the company's degree of change according to the manufacturing system

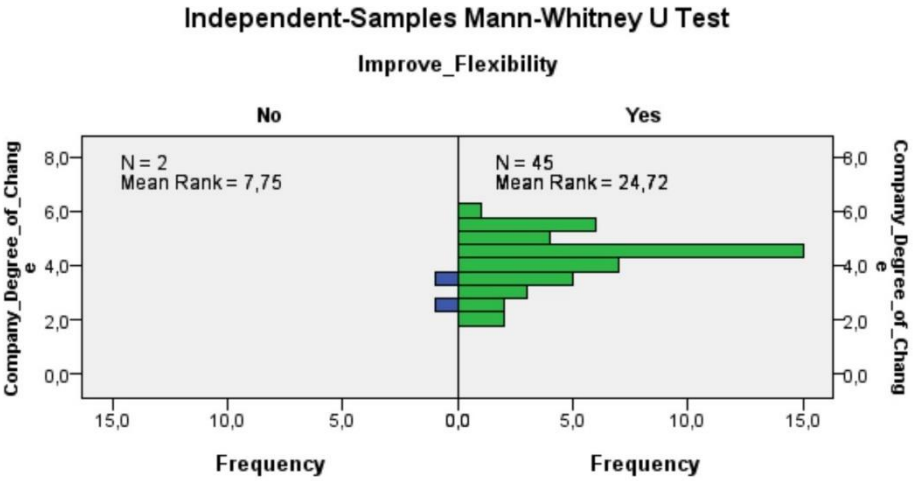

Fig. 38 – Bar chart representing the company's degree of change according to the need of improve flexibility

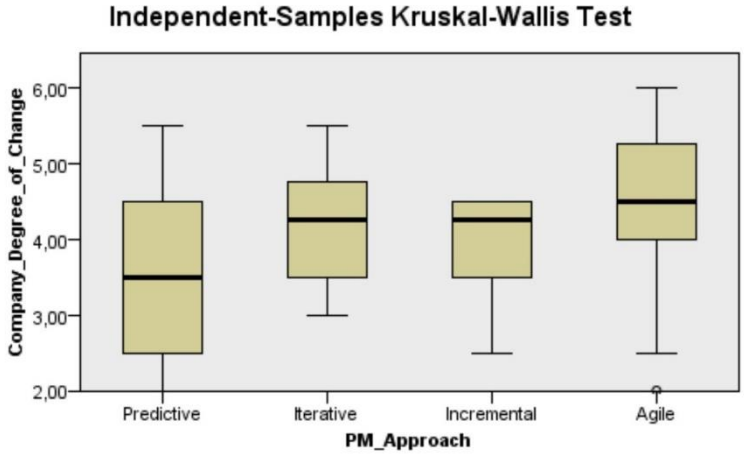

Fig. 39 – Boxplot for company's degree of change according to the PM approach

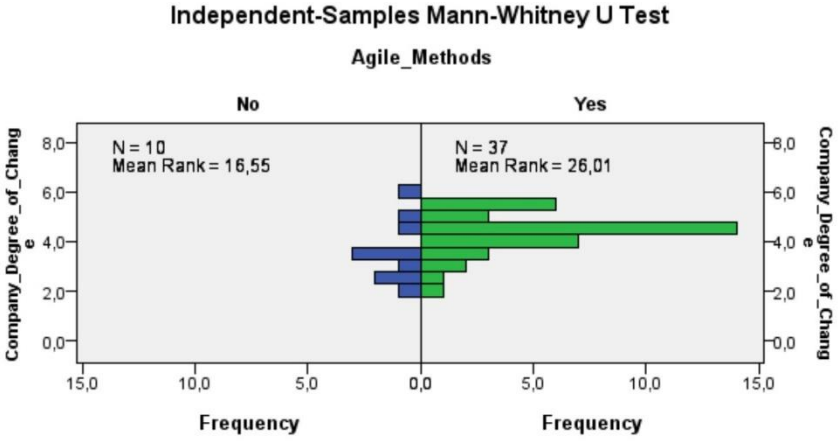

Fig. 40 - Bar chart representing the company's degree of change according to the AM implementation

It is possible to state that the companies that have agile methods implemented, also have a higher degree of change.

3.2.11 Investigation Hypothesis 4

This hypothesis seeks to observe if the "APM culture" influences the implementation of AM through "Institutional barriers":

***H_0*:** APM culture does not influence the AM implementation.
Vs
***H_A*:** APM culture influences the AM implementation.

The Kruskal-Wallis test was performed in order to evaluate the hypothesis, and the results are displayed in Table 34.

Table 34 - Test results for Hypothesis 4

Variables	Test Hypotheses	Test Statistic	p-value
APM Culture	H_0: $F(x_1) = F(x_2) = \ldots = F(x_4)$ H_A: At least one of the populations tends to yield larger observations than at least one of the other populations	$\chi^2_2 = 0{,}438$	0.932

It was verified that, at a significance level of 5%, there is no statistical evidence to state that "APM culture" influences the AM implementation through "Institutional barriers" ($X^2_2 = 0{,}438$; $p = 0{,}932$).

3.2.12 Investigation Hypothesis 5

To comprehend if the companies' criteria for products and projects affect the AM implementation:

***H_0*:** The company criteria for product and project do not affect the AM implementation.
Vs
***H_A*:** The company criteria for product and project affect the AM implementation.

They were selected two criteria to be analyzed as "Improvement of internal communication", and "Follows the customer requirements", as well as their influence on the "Organizational", "Market and supply chain" barriers, respectively. The applied tests were Spearman's correlation, and Mann-Whitney, being the results displayed in Table 35.

With the applied tests, it is not possible to state, at a significance level of 5%, that the companies' criteria for products (r_s = 0,106; p = 0,478) and project (W = 202,000; p = 0,759) affects the AM implementation.

Table 35 - Test results for Hypothesis 5

Variables	Test Hypotheses	Test Statistic	p-value
Improvement of Internal Communication	H_0: $\rho = 0$ H_A: $\rho \neq 0$	r_s = 0,106	0,478
Follows the Customer Requirements	H_0: $F_{No} = F_{Yes}$ H_A: $F_{No} \neq F_{Yes}$	W = 202,000	0,759

3.2.13 Investigation Hypothesis 6

This hypothesis expects to understand if the "Minimum qualification" necessary for the PM team, influences the "knowledge of AM" and its implementation:

***H_0*:** The minimum qualification for the PM team does not influence the knowledge of AM and its implementation.
Vs
***H_A*:** The minimum qualification for the PM team influences the knowledge of AM and its implementation.

The dependent variables to analyze are the "Knowledge and technology" barrier, as well as the "AM knowledge", resulting in the Kruskal-Wallis and Chi-square tests, respectively. For the second hypothesis test, a Chi-square test for each agile technique presented in the questionnaire was carried out, in a total of nine. The results are presented in Table 36.

In none of the performed tests was possible to statistically state that, the "Minimum qualification" influences neither the AM implementation nor the "AM knowledge".

Table 36 - Test results for Hypothesis 6

Variables	Test Hypotheses	Test Statistic	p-value
Minimum Qualification	H_0: $F(x_1) = F(x_2) = \ldots = F(x_5)$ H_A: At least one of the populations tends to yield larger observations than at least one of the other populations	$\chi^2_2 = 1,751$	0,417
	H_0: The minimum qualification, and the knowledge of sprint iteration are independents H_A: The minimum qualification, and the knowledge of sprint iteration are not independents … (the same for each agile technique)	$\chi^2 = 6,012$ $\chi^2 = 5,416$ $\chi^2 = 3,373$ $\chi^2 = 9,431$ $\chi^2 = 3,075$ $\chi^2 = 7,072$ $\chi^2 = 7,996$ $\chi^2 = 3,954$ $\chi^2 = 3,579$	0,198 0,247 0,497 0,051 0,545 0,132 0,092 0,412 0,466

3.2.14 Investigation Hypothesis 7

In order to evaluate if the "Degree of management involvement" affects the implementation of AM, hypothesis 7 was investigated:

***H_0*:** The improper competency management does not affect AM implementation.
Vs
***H_A*:** The improper competency management affects the AM implementation.

The spearmen's correlation was studied for each dependent variable ("Organizational culture" and "Knowledge and technology") to analyze, and the results are represented in Table 37.

Table 37 - Test results for Hypothesis 7

Variables	Test Hypotheses	Test Statistic	p-value
Improper Competency Management	H_0: $\rho = 0$ H_A: $\rho \neq 0$	r_s =0,465	**0,001**
	H_0: $\rho = 0$ H_A: $\rho \neq 0$	r_s = 0,450	**0,002**

It is possible to observe that "Improper competency management" has a positive correlation with the "Organizational culture" barrier (r_s =0,465; p = 0,001), as well as the "Knowledge and technology" barrier (r_s = 0,450; p = 0,002). For that reason, it is possible to state that "Improper competency management" affects the AM

implementation through both "Organizational culture" and "Knowledge and technology" barriers.

3.2.15 Investigation Hypothesis 8

The eight hypothesis aims to investigate if the companies with certified persons in APM, has an association with the "Companies' degree of change":

***H_0*: The APM certification does not have an association with the company's degree of change.**
Vs
***H_A*: The APM certification has an association with the company's degree of change.**

The Mann-Whitney test was applied, displaying the results in Table 38.

Table 38 - Test results for Hypothesis 8

Variables	Test Hypotheses	Test Statistic	p-value
APM Certification	H_0: $F_{No} = F_{Yes}$ H_A: $F_{No} \neq F_{Yes}$	W = 203,000	0,396

There is no statistical evidence able to confirm, that the companies investing in certified agile project managers have an association with the "Companies' degree of change" (W = 203,000; p = 0,396).

3.2.16 Investigation Hypothesis 9

The penultimate hypothesis emerges intending to understand if the "Change predisposition" influences the AM implementation:

***H_0*: The change predisposition does not influence the AM implementation.**
Vs
***H_A*: The change predisposition influences the AM implementation.**

The performed Spearmen's correlation evaluates the correlation between the "Change predisposition", and the "No obligation" barrier, both fitting in the "Institutional" barrier category, and resulting in the values presented in Table 39.

Table 39 - Test results for Hypothesis 9

Variables	Test Hypotheses	Test Statistic	p-value
Change Predisposition	H_0: $\rho = 0$ H_A: $\rho \neq 0$	r_s =0,373	**0,010**

There is statistic evidence (r_s =0,373; p = 0.010) to state that the "Change predisposition" influences the AM implementation, since it is correlated to the "No obligation" barrier. Besides these variables being correlated, they fit into the "Institutional" barrier, thus it is possible to state that the "Institutional" barrier has influence in the AM implementation.

3.2.17 Investigation Hypothesis 10

Intending to verify if the "Absence of immediate quantifiable benefits" influences the AM implementation, hypothesis 10 was investigated:

***H_0*:** The absence of immediate quantifiable benefits does not influence the AM implementation.
Vs
***H_A*:** The absence of immediate quantifiable benefits influences the AM implementation.

It was performed the Spearmen's correlation, trying to understand if there is an association between the "Absence of immediate quantifiable benefits," and the "Lack of financial support" barrier, both fitting in the "Financial" barrier category, resulting in the values represented in Table 40.

Table 40 - Test results for Hypothesis 10

Variables	Test Hypotheses	Test Statistic	p-value
Absence of Immediate Quantifiable Benefits	H_0: $\rho = 0$ H_A: $\rho \neq 0$	r_s =0,380	**0,009**

There is statistic evidence (r_s =0,380; p = 0.009) to state that, the "Absence of immediate quantifiable benefits" influences the AM implementation since it can be correlated to the "Lack of financial support" barrier. Other than these variables be associated, they fit into the "Financial" barrier, thus it is possible to state that the "Financial" barrier has influence in the AM implementation.

3.2.18 Coherence Verification

In order to assess the answers' coherence, some questions were selected to analyze the crosstabulation between variables through Cohen's Kappa. The Kappa value is the proportion of agreement over and above chance agreement, and can range from minus one to one, meaning no agreement and perfect agreement, respectively.

In Table 41, the selected variables are represented, as well as the respective questions, the Kappa value, and the significance value.

Table 41 - Cohen's Kappa Results

Variables	qn	Cross-checked variable	qn	Kappa	p-value
Knowledge and Technology	33	Lack of Knowledge and Skills	35	0,249	0,000
Organizational Culture	33	Existent Organizational Culture	35	0,267	0,000
Lack of Knowledge and Skills	35	Staff Not Prepared to AM	35	0,243	0,000
It is not applicable to our product	35	Organization not able to apply AM	35	0,532	0,000

It was possible to verify that the coherence among the answers varies between fair and moderate agreement, with a kappa value statistically significantly different from zero. The obtained Kappa values are low, demonstrating that, in a general way and as expected, the consistency of the obtained data is relatively reduced. Nonetheless, the Cohen's kappa is usually applied to compare the agreement between two observations, whereby in a sample of this size, 47 observations, a high degree of agreement between answers was not expected.

3.3 CRITICAL ANALYSIS OF RESULTS

After performed the statistical analysis that addresses all the specific questions and objectives, it is possible to analyze and comment the above-referenced results.

It was possible to conclude that the "Production type" influences the implementation of AM. The companies with a continuous process or another production type, seem to experiment fewer impediments, from an organizational perspective, regarding the application of AM. This could mean that if the product manufacturing is divided into processes, simplifies the organizational interactions, and the complexity of the production process. In contrast, the batch type revealed statistical differences between the other groups that, despite allows changes or modifications between batches or during the manufacturing process, requires more planning, scheduling and control over the process, as collecting data, increasing the process complexity. Also, it is performed one step at a time on multiple items, which can be a disadvantage if the product requirements are constantly changing. As a result, the organizations applying

this production type could face “Organizational barriers” in the AM implementation due to its higher complexity.

Additionally, it was verified that the companies that have procedures using agile techniques have an association with the “Companies’ degree of change”. In fact, it was noticed that the “Companies’ degree of change” tends to be higher with the “Implementation of agile methods”. This confirms that organizations with high levels of change have the need to resort to AM.

Moreover, it was observed that the variable “Improper competency management” is related to the variables “Organizational culture”, as well as “Knowledge and technology”, that is, the first one affects the implementation of AM. This influence could derive either from lack of management involvement, from an organizational perspective, or due to lack of expertise and skills from the managers, from the knowledge and technology perspective.

Furthermore, it was corroborated the existence of “Institutional barriers” for the AM implementation in the companies, through the correlation between the “Change predisposition” and “No obligation” variables since they fit in the “Institutional” barrier category. It can be observed that one of the biggest challenges in the application of AM, is the resistance from society and its aversion to change.

Also, it was detected that the “Absence of immediate quantifiable benefits” influences the AM implementation through the “Lack of financial support” barrier. Other than these variables are correlated, they also fit in the “Financial” barrier category, being feasible the presence and influence of financial factors that prevent the AM implementation.

The barriers categories, such as “Organizational”, “Knowledge and technology”, “Institutional”, and “Financial”, were applied in this study once they are able to cover practically all the barriers explored in other sectors. These exact barriers categories were found in the study [48], considering the implementation of CBM. All the other barriers found in agile software development, lean and cleaner production, as well as agile manufacturing can be incorporated into those categories. For instance, in survey [45], the barriers “Management support”, “Lack of experience”, “Resistance to change”, and “Budget constraint” were identified in the IT field, corresponding to the barriers categories above-mentioned, respectively. Also, study [55] analyzes barriers in the implementation of agile manufacturing, such as “Lack of management commitment”, “Lack of training and education”, “Fear and resistance to change”, and “Financial constraints”, which also comprise the applied barriers categories in this work.

Finally, and with the intention of verifying the responses coherence by the respondents, some questions where the answers must match, were examined. It was noticed a coherence between fair and moderate agreement among the answers, demonstrating that, in a general way and as expected, the consistency of the obtained data is relatively reduced. It is worth to mention that, the Cohen's kappa is usually applied to compare the agreement between two observations, whereby in a sample of this size, 47 observations, a high degree of agreement between answers was not expected.

3.4 COMPARISON WITH BARRIERS OBSERVED IN OTHER INDUSTRIES

All of the barriers found in the literature, regarding the implementation of lean and/or agile methodologies, apart from some differences between sectors, meet the categories employed in this study, being them the "Financial", "Organizational", "Knowledge and technology", "Market and supply chain", and "Institutional" barriers. Then, some of the more specific barriers between sectors were applied in this survey, taking into account the most common ones, and those that better fit the AI.

In this survey, all of the barriers' categories defined initially were verified. However, the descriptive analysis of the data is not enough to conclude about the population, in this case, the Portuguese AI. Therefore, through statistical inference, it was possible to conclude about the expected barriers in the AI sector, and still which variables have a direct influence on them.

Across this study, it was possible to identify "Financial", "Organizational", "Knowledge and technology", and "Institutional" barriers in the implementation of AM. However, the "Market and supply chain" barrier was not stated through the performed statistical tests, despite the high level of exportation, and the imposed requirements from OEMs, for more than 80% of the companies, reveal a high external dependence of the companies from the market and supply chain perspective.

The specific variables found, with influence in the implementation of AM in AI were the production type, particularly "Batch production", "Organizational culture", "Companies' degree of change", "Improper competency management", "Change predisposition", "No obligation", "Absence of immediate quantifiable benefits" and "Lack of financial support".

Additionally, the respondents referred two more impediments in the AM implementation, and are represented in Table 42, as well as the comparison of barriers identified in the literature with the new findings.

Table 42 – Comparison of barriers observed in the literature with the new findings

Barriers Category	Found/Not Found	Detected barriers with influence on AM implementation in AI	Barriers referred by the respondents
Financial	✓	• Absence of Immediate Quantifiable Benefits • Lack of Financial Support	
Organizational	✓	• Production Type • Organizational Culture • Companies' Degree of Change	
Knowledge and Technology	✓	• Improper Competency Management	• Certification Procedures
Market and Supply Chain	✗		
Institutional	✓	• Change Predisposition • No Obligation	• Lack of Collective Motivation

3.5 RECOMMENDATIONS TO OVERCOME THE IDENTIFIED BARRIERS

After the analysis and comprehension of the results obtained with this survey, along with the extensive literature review previously performed, some recommendations and enablers could be named to overcome the identified barriers, and improve the effectiveness of AM.

Starting with the "Organizational barrier", influenced by the "Production type" applied in the product manufacturing, and assuming that the type of production is the most suitable to the characteristics of the product, it is not a factor that can be changed once is rooted in the company. However, the differences between the production types could bring different advantages and challenges as well. In the case of batch production, it turns out to be a process with higher complexity that requires more planning, scheduling and control, as collecting data. This complexity along with a constantly changing environment, if it is not overcome with knowledge skills, technological capacity, a strong level of intercommunication and tune by those involved, can create great organizational obstacles.

Regarding the "Companies' degree of change", the best approach to take is APM since it focuses on agility, adaptation, response to unpredictable changes, continuous improvement and innovation, as quality and reliable results. It is necessary that an industry characterized by an intrinsic rigid, predictable, and stable architectures, rapidly adapt to the new requirements of society and constantly changing environments.

Another identified barrier was “Improper competency management”, having influence in both “Organizational”, “Knowledge and technological” aspects. Build closer relationships as strong management support are crucial to prevent the lack of management involvement, from an organizational perspective, and encourage the education and training to guarantee a skilled and competent staff with a clear understanding of the agile objectives, from a knowledge and technology perspective.

Perhaps one of the most difficult barriers to overcome is the “Institutional” aspect, which entails change predisposition, no obligation thinking, resistance from society, and aversion to change. It is vital that the company and all the involved willing to adopt AM, embracing a friendly-agile organization, and team environment philosophy with ambition and motivation. This cultural change is mandatory to increase the liveness of companies.

Considering the “Financial” aspect, there is no formula to comprehend the economic advantages of adopting AM. Nevertheless, the APM intends to reduce the impact of unpredictable changes, improve time-to-market, respond and adapt to complexity, and focus on customer satisfaction. Those should be deemed as values aiming to achieve a competitive advantage. This must overcome the initial investment necessary for staff education and training, as well as all the psychological and organizational changes required.

In Table 43 are described all the recommendations and enablers previously mentioned, with the intention of simplifying the picture of the suggestions for each barrier category.

Table 43 - Enablers and recommendations for AM implementation

Barriers Categories	**Recommendations and Enablers**
Financial	Agile values are the input to achieve competitive advantage: reduce the impact of unpredictable changes, improve time-to-market, respond and adapt to complexity, focus on the customer, etc.
Organizational	Knowledge and technological skills to deal with high complexity organizational challenges, build closer relationships as a strong level of intercommunication and tune by those involved, strong management support
Knowledge and Technology	Education and training to guarantee a skilled and competent staff with a clear understanding of the agile objectives
Institutional	Company and all the involved willing to adopt AM, embracing a friendly-agile organization and team environment philosophy with ambition and motivation. Cultural change is mandatory to increase the liveness of companies

Moreover, in chapter 2.2.5.3 was mentioned the study [58] that addresses the use of APM in manufacturing. The paper proposes a team to deal with APM (AGILE team) and a communicational workflow, in order to improve the agile manufacturing performance. The deployment of a team specifically dedicated to APM could be a massive enabler from an “Organizational”, and “Knowledge and technology” perspective. Firstly, because this team is in charge of complex organizational communications, since the client makes a request until it is successfully approved, drastically improving the organizational dynamism. Then, because the required knowledge for APM implementation is granted through a skilled team with different persons assuming different roles, being uniquely dedicated to this process.

Thus, considering all these recommendations and enablers, it was possible to sequence and represent them in a flowchart, having as an output an effective implementation of AM.

Initially, and to overcome the “Institutional” barrier, it is vital that the company and all the involved have the necessary willingness and predisposition to adopt AM.

Then, agile values should be deemed as the input to achieve competitive advantage, and overcome the “Financial” barrier.

Subsequently, an initial investment is necessary to achieve the next step, the deployment of an agile team with highly skilled collaborators. The agile team should develop frameworks and workflows according to each company's characteristics and environment, in order to drastically improve the “Organizational” and “Knowledge and technology” aspects.

As a result, an effective AM implementation could be achieved, being the respective flowchart represented in Fig. 41.

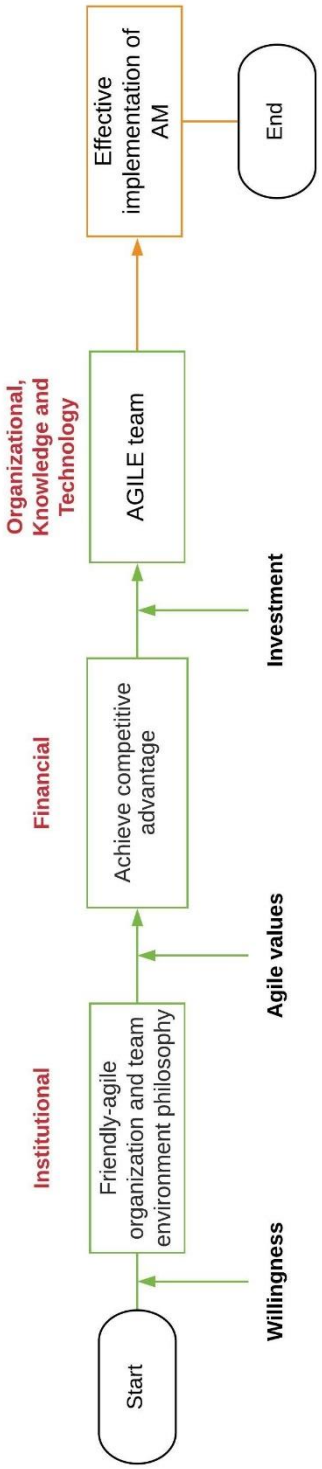

Fig. 41 - Flowchart to improve AM implementation effectiveness

CONCLUSIONS

4 CONCLUSIONS

4.1 DRAWN CONCLUSIONS

This study emerged with the purpose of identifying barriers in the implementation of Agile Methodologies in the Portuguese Automotive Industry.

Initially, an extensive literature review was performed in order to increase the knowledge about the subject, to understand what has been studied in the field, and what can be added to the literature. This acquisition of background knowledge is vital to apply and adapt it to the required objectives, as well as a contribution to all the achieved results and subsequent conclusions. The bibliographic work includes a characterization of AI and its manufacturing processes, the concept of Project Management and its evolving approaches, and finally, the barriers and enablers found in the implementation of Agile Methodologies in different sectors.

In order to accomplish the proposed main objective referenced above, and taking into account the second phase of this work, a questionnaire was developed and distributed to about 140 automotive manufacturing companies, in a population of 240, whereby 56 answers were obtained. Specific questions and hypotheses were formulated, to posteriorly investigate them after obtaining the data. This investigation was performed through statistical analysis, incorporating descriptive statistics and statistical inference. The first one allowed an easy perception of the companies' and respondent's characteristics, the APM environment, and predisposition to AM implementation, while the second permitted to analyze the relationship between variables, and extrapolate the results to the population.

It was verified that almost 85% of the respondents are familiar with APM and near 80% belong to departments of interest for this study. The companies are located in the north and center region, 70% of them are large companies, and have high levels of external dependence since they claim high levels of exportation (>75%), as well as imposed requirements from abroad, 89% and 83% respectively. The majority of the companies manufacture under a mass production type, however, almost 25% present a batch production type which leads to a significant influence in the AM implementation, identifying the “Production type” as an “Organizational” barrier. 62% of the companies claim to experiment changes in the production process mainly intending to “Increase production” and “Reduce costs”, and 93% feel the necessity to “Improve flexibility” despite 80% have agile manufacturing systems. Considering the companies’ quality concerns, the most selected is “Customer satisfaction”, which is a crucial feature in the implementation of an agile methodology. Though, the “Improvement of internal communication” does not seem to be an important aspect from the respondent’s point of view. Regarding the project and product development

process, only 8% of the companies are still employing predictive approaches, and the main criteria are “Functionality”, “Cost”, “Quality” and “Follows the customer requirements”. Taking into account the production and project changes, it was computed the “Companies’ degree of change”, and verified that this variable has a relation with the AM implementation in the sense that the organizations with high levels of change have the need to resort AM. Concerning the APM environment in the companies, only 9% have no interest in implementing APM, and 70% are already applying agile methods. Although companies seem to be predisposed to AM, maybe they are not taking the necessary effort since 65% of them have a degree as a minimum qualification, 20% have secondary education, and 70% of them do not have certified agile project managers. These qualifications may be enough to apply one or other agile tool, but insufficient to apply a fully agile approach, since high skilled collaborators with special knowledge in the field are required. The barriers with the main influence in the AM implementation from the respondents’ point of view are “Organizational culture” and “Knowledge and technology”, and 61% of them say that the main barriers’ source is solely internal.

They were found “Organizational”, and “Knowledge and technology” barriers in AI, through the factor “Improper competency management”. Despite around 85% of the respondents claim that the management involvement is between highly and extremely involved, it was verified that the “Improper competency management” affects the AM implementation in an organizational way, possibly due to the “Lack of management involvement” percentage. The same factor is related to the “Knowledge and technology” barrier, demonstrating that the lack of expertise and skills from the managers could be present. Although companies seem predisposed to AM it was corroborated the existence of “Institutional” barriers for the AM implementation in the AI, through the aspect “Change predisposition”, and its correlation with the “No obligation” barrier. The resistance from society and aversion to change, although not visible at first sight, was recognized through statistical inference. The same happened with the “Lack of financial support” that was not significantly selected by the respondents as a barrier category, however, it was found a relation between the aspect “Absence of immediate quantifiable benefits” with the “Lack of financial support” barrier. These variables fit in the “Financial” barrier category, being feasible the presence and influence of financial factors that prevent the AM implementation. The respondents evaluated the difficulty in implementing AM, and 90% of them consider a difficulty between moderate and extremely difficult, referring two barriers not presented in the questionnaire, being them “Certification procedures” and “Lack of collective motivation”. They also consider that the main enablers for AM implementation are “Organizational support” and “Investment in training”, being in accordance with the two main barriers selected, “Organizational culture” and “Knowledge and technology”.

Recommendations to overcome the identified barriers were presented, and a framework that sequence these recommendations was developed, in order to achieve an effective AM implementation. It starts with the willingness of the company and all the involved people to adopt AM, looking for the agile values as an input to achieve competitive advantage, followed by an initial investment. The initial investment intends to attain the deployment of an agile team, which is composed by highly skilled collaborators with a clear understanding of the agile objectives. This team should work and develop frameworks and workflows, according to each company's characteristics and environment.

In this way, all the objectives initially defined (chapter 1.2) have been met, as well as all the specific questions formulated (chapter 3.1.1) were addressed.

4.2 STUDY LIMITATIONS

One of the main limitations of this study was the obtained sample size, despite being significantly relevant, taking into account the size of the population, and in comparison with other relevant studies, hindered the statistical inference and, consequently, the extrapolation of the results to the Portuguese AI.

4.3 OUTLOOK FOR FUTURE WORKS

Regarding future works, it would be interesting to increase the sample size, collecting more data from the automotive manufactures, and perhaps, obtain different results for the hypotheses tested, and also find correlations that were not possible in this study. It would be of greater interest, investigate the relation of the automotive companies with OEMs, as well as its influence on the companies' procedures, thus comprehending the impact of "Market and supply chain" factor in the implementation of AM.

It is also important to increase the literature background regarding the APM in AI, once it is one of the biggest contributions for the global economy, and requires the rapid adaptation and change mindset in order to be aligned with the World's needs.

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ANNEXES

6.1 QUESTIONNAIRE

6.2 QUESTIONNAIRE VALIDATIONS

6 ANNEXES

6.1 Questionnaire

6.2 Questionnaire Validations

6.1 QUESTIONNAIRE

Agile Methodologies in Portuguese Automotive Industry

This questionnaire is part of the development of a Master's thesis and aims to identify barriers in the implementation of Agile Methodologies in the Automotive Industry.

The data obtained through this questionnaire is of great importance for the success of this study and will be used exclusively for this purpose.

Estimated completion time: 10 minutes

Thank you in advance for your response.
*Required

1. Are you familiar with the concept of Agile Project Management? If yes, please answer to the following questions. *

   Mark only one oval.

   - ◯ No
   - ◯ Yes

2. Respondent age? *

   Mark only one oval.

   - ◯ 20 to 29
   - ◯ 30 to 39
   - ◯ 40 to 49
   - ◯ 50 to 59
   - ◯ 60 to 69
   - ◯ 70 or more

3. Education Level? *

Mark only one oval.

- ◯ Basic Education (Less or equal to 9th grade)
- ◯ Secondary Education (12th grade)
- ◯ Higher Education - Graduation
- ◯ Higher Education - Master
- ◯ Higher Education - PhD
- ◯ Other: _____

4. Position in the Company? *

Mark only one oval.

- ◯ General Management
- ◯ Supply chain & Procurement
- ◯ Marketing & Sales
- ◯ Production
- ◯ Planning & Logistics
- ◯ Quality
- ◯ Project Management and Product Development
- ◯ Other: _____

5. Job Function?

_____

6. Company Name? (Not mandatory)

_____

7. Country Region? *

Mark only one oval.

- North
- Center
- South

8. Number of Employees? *

Mark only one oval.

- < 10 employees
- >= 10 and < 50 employees
- >= 50 and < 250 employees
- >= 250 employees

9. Internal Organizational Structure? *

Mark only one oval.

- Functional (specialization by function or process)
- Divisional (division by products / customers)
- Matrix (functional and divisional combination)
- Other: _____

10. Volume of exportation?

Mark only one oval.

- > 0 and <= 25%
- > 25 and <= 50%
- > 50 and <= 75%
- > 75%

11. Are the product requirements imposed by OEMs? *

Mark only one oval.

- ◯ No
- ◯ Yes

12. Type of Production? *

Mark only one oval.

- ◯ Unit
- ◯ Batch
- ◯ Mass
- ◯ Continuous process
- ◯ Other: _____

13. Classify, on a scale of 1 to 6, the occurrence of changes in the last 3 years on production process? [1-Never; 2-Very rarely; 3-Few times; 4-Sometimes; 5-Many times; 6-Always] *

Mark only one oval.

	1	2	3	4	5	6	
Never	◯	◯	◯	◯	◯	◯	Always

14. If you answered between 3 and 6 in the previous question, answer this group of questions: What are the purposes of these changes and their influence on productivity? [1-None; 2-Very Low; 3-Low; 4-Moderate; 5-High; 6-Very High]

Tick all that apply.

	1	2	3	4	5	6
Cost reduction	☐	☐	☐	☐	☐	☐
Increase production	☐	☐	☐	☐	☐	☐
Design	☐	☐	☐	☐	☐	☐
Environmental issues	☐	☐	☐	☐	☐	☐
Attempt to implement Agile Methods	☐	☐	☐	☐	☐	☐
Regulation and Governamental policies	☐	☐	☐	☐	☐	☐
Imposed changes by OEMs	☐	☐	☐	☐	☐	☐

15. Is there any concern to improve the Manufacturing processes in order to increase the flexibility?

Mark only one oval.

- ◯ No
- ◯ Yes

16. Is the Management department strongly involved with the Production department? *

Mark only one oval.

	1	2	3	4	5	6	
Nothing involved	◯	◯	◯	◯	◯	◯	Extremely involved

17. Predominant Manufacturing system? *

Mark only one oval.

- ◯ Dedicated (produce a single model of a product class)
- ◯ Agile (can produce a planned range of product models in a product class)

18. What factor(s) influence(s) in the use of one or other system? *

Tick all that apply.

- ☐ Investment Cost
- ☐ Cost to introduce new models
- ☐ Time to introduce new models
- ☐ Production Volume Capability
- ☐ Equipment reusability for other machining applications
- ☐ Capacity to introduce new (unplanned) models

Other: ☐ _____

19. When it comes to quality, what are the company's main concerns? [1-None; 2-Very Low; 3-Low; 4-Moderate; 5-High; 6-Very High] *

Mark only one oval per row.

	1	2	3	4	5	6
Customer Satisfaction	◯	◯	◯	◯	◯	◯
Consistency of products	◯	◯	◯	◯	◯	◯
Implementation of best practices	◯	◯	◯	◯	◯	◯
Productivity	◯	◯	◯	◯	◯	◯
Increased Financial Performance	◯	◯	◯	◯	◯	◯
Improvement of Internal Communication	◯	◯	◯	◯	◯	◯

20. Regarding product development... *

Mark only one oval.

- ◯ All the projects are developed within the company
- ◯ Most of the projects are developed within the company
- ◯ 50% of the projects are developed within the company
- ◯ Most of the projects are subcontracted abroad
- ◯ All projects are subcontracted abroad

21. Which approach is normally applied in Project Management? *

Mark only one oval.

- ◯ Predictive/Waterfall (sequential process)
- ◯ Iterative (allows unfinished product feedback to improve and modify it)
- ◯ Incremental (provides ready-to-use products for the customer)
- ◯ Agile (iterative and incremental combination)

22. In the Project and Product Development, what are the main criteria for products?

Tick all that apply.

- ☐ Functionality
- ☐ Look
- ☐ Cost
- ☐ Ergonomics
- ☐ Quality
- ☐ Origin of Materials
- ☐ Sustainability
- ☐ Marketing
- ☐ Performance
- ☐ Follows the customer requirements

23. How often is it necessary to make changes during the Product Development? *

Mark only one oval.

	1	2	3	4	5	6	
Never	◯	◯	◯	◯	◯	◯	Always

24. The company, is or has been in a transition from Traditional Project Management to Agile Project Management? *

Mark only one oval.

- ◯ No
- ◯ Yes

25. Describe the company's culture regarding Agile Project Management. *

Mark only one oval.

- ◯ No interest
- ◯ It is receptive, but never planned to implement Agile Methodologies
- ◯ Is studying the implementation of Agile Methodologies
- ◯ Works under Agile Methodologies

26. Is there any internal procedure that use Agile techniques (Scrum, Kanban, Scrumban...)? *

Mark only one oval.

- ◯ No
- ◯ Yes

27. If yes, In which department?

Tick all that apply.

- [ ] General Management
- [ ] Supply Chain & Procurement
- [ ] Marketing & Sales
- [ ] Production
- [ ] Quality
- [ ] Planning & Logistics
- [ ] Project and Product development

Other: [ ] _____

28. Is there anyone in your company certified in Agile Project Management? *

Mark only one oval.

- ◯ No
- ◯ Yes

29. How many people belong to the Project Management team? *

Mark only one oval.

- ◯ 1
- ◯ 2 to 5
- ◯ 6 to 10
- ◯ + 10

30. Minimum qualification for this function (Project and product development team)? *

Mark only one oval.

- ◯ Secondary Education
- ◯ Degree
- ◯ Master's Degree
- ◯ Phd
- ◯ Other: _____

31. Are there various tools and techniques to support the Project and product development process. Which ones do you know, and which ones are used? [1-Unknown; 2-Known but not applied; 3-Applied] *

Mark only one oval per row.

	1	2	3
Sprint (Iteration)	◯	◯	◯
Costumer Integration	◯	◯	◯
Product Backlog	◯	◯	◯
Estimation of effort for tasks	◯	◯	◯
Daily Meetings	◯	◯	◯
Kanban Board	◯	◯	◯
Lessons learned (Retrospective)	◯	◯	◯
Incremental Development	◯	◯	◯
Definition of Done	◯	◯	◯

32. Contribution of those tools and techniques to the company? *

Mark only one oval.

	1	2	3	4	5	6	
None	◯	◯	◯	◯	◯	◯	Extremely Important

33. Classify, on a scale of 1 to 6, the influence of the following factors for NOT applying Agile Methodologies. [1-None; 2-Very Low; 3-Low; 4-Moderate; 5-High; 6-Very High] *

Mark only one oval per row.

	1	2	3	4	5	6
Lack of financial support	◯	◯	◯	◯	◯	◯
No obligation	◯	◯	◯	◯	◯	◯
Implies a change in the relationship with customers and suppliers	◯	◯	◯	◯	◯	◯
Organizational culture	◯	◯	◯	◯	◯	◯
Knowledge and technology	◯	◯	◯	◯	◯	◯

34. What kind of barriers do you think have more influence in the implementation of Agile Methodologies?

Mark only one oval.

- ◯ External
- ◯ Internal
- ◯ Both

35. On a scale of 1 to 6, evaluate the influence of the following factors for NOT applying Agile Methodologies. [1-None; 2-Very Low; 3-Low; 4-Moderate; 5-High; 6-Very High] *

Mark only one oval per row.

	1	2	3	4	5	6
Improper Competency Management						
Lack of Knowledge and Skills						
Lack of Project Team Flexibility						
Stakeholders Attitude						
Time constraints						
Governmental Policies and Support						
Ineffective Costumer Relationship						
Ineffective Supply chain						
Project Lead Time is not critical						
Existing Organizational Culture						
It is not applicable to our product						
Change Predisposition						
Risk						
Absence of Immediate Quantifiable Benefits						
Lack of Governmental Benefits						
Organization not able to apply Agile Methodologies						

Staff not prepared to Agile Methods						
Flexibility is not a priority						
There is no time to think about that						

36. Have you noticed any other impediment to the implementation of Agile Methodologies? If yes, which one?

_____

37. On a scale of 1 to 6, how difficult is to implement an Agile Methodology in your company? *

Mark only one oval.

	1	2	3	4	5	6	
Relatively easy							Extremely hard

38. What factor(s) can improve the effectiveness of implementing Agile Methodologies? *

Tick all that apply.

- [ ] Organizational Support
- [ ] Stakeholder Collaboration
- [ ] Investment in training
- [ ] Lean relationship

Other: [ ] _____

6.2 VALIDATIONS

De: Francisco J. G. Silva
Enviado: 31 de março de 2020 06:36
Para: Daniel Soares (1130482)
Assunto: FW: Pedido de ajuda para validação de inquérito (dissertação de mestrado) (2ª VIA).

Olá Daniel,

Mais uma para juntar ao lote já existente.
Abraço,
Francisco Silva

De: Luis Miranda Torres <lmt@isep.ipp.pt>
Enviado: 30 de março de 2020 19:04
Para: Francisco J. G. Silva <fgs@isep.ipp.pt>
Cc: Luis Miranda Torres <lmt@isep.ipp.pt>
Assunto: RE: Pedido de ajuda para validação de inquérito (dissertação de mestrado) (2ª VIA).

Olá Francisco,

Analisei o inquérito sobre "**Barreiras à aplicação de metodologias ágeis na Gestão de Projectos no sector automóve**l" e considero que o mesmo se encontra bem elaborado, focando as questões mais pertinentes sobre as atuais metodologias de gestão no sector automóvel.

Junto, para os devido efeitos uma nota biográfica.

Um abraço,

Luis Miranda Torres
Professor Adjunto / Diretor do Laboratório Automóvel
Departamento de Engenharia Mecânica
Instituto Superior de Engenharia do Porto
Rua Dr. António Bernardino de Almeida, 431 - 4200-072 Porto
Telf.: +351 22 8340500
E-mail: lmt@isep.ipp.pt

De: Francisco J. G. Silva
Enviado: 23 de março de 2020 23:13
Cc: Daniel Soares (1130482) <1130482@isep.ipp.pt>
Assunto: Pedido de ajuda para validação de inquérito (dissertação de mestrado).

Caros Colegas,

Tenho um estudante a fazer uma dissertação de mestrado sobre "Barreiras à aplicação de metodologias ágeis na Gestão de Projectos no sector automóvel".

De: Luísa Hoffbauer
Enviado: 31 de março de 2020 15:12
Para: Francisco J. G. Silva
Cc: Daniel Soares (1130482)
Assunto: RE: Pedido urgente de validação de um inquérito (em termos de tratamento de dados e análise estatística).

Questões colocadas:

1. Na questão "Volume de Exportação?", <=25% inclui o 0, pelo que sugiro a segunda opção ser ">0% e <=25%"
2. As questões "Qual ou quais os propósitos destas mudanças?" e "Qual a influência destas mudanças na produtividade?" só podem ser respondidas por quem não respondeu "1" na questão "Avalie, numa escala de 1 a 6, a ocorrência de mudanças na Empresa nos últimos 3 anos, relativamente ao processo produtivo", pelo que estas questões deveriam ser reformuladas.
3. Na questão "No que diz respeito ao desenvolvimento do produto...", a introdução da opção "A Empresa produz de acordo com os requisitos do cliente" faz com que as opções não sejam mutuamente exclusivas.
4. Tenho dúvidas na formulação de que as opções "Está a implementar Metodologias Ágeis" e "Coloca a Filosofia Ágil como prioridade" sejam mutuamente exclusivas e traduzam a gradação pretendida. Quer ordenar-se a prioridade atribuída ou o grau de implementação?
5. Na questão "Quantas pessoas pertencem à equipa de Projeto e desenvolvimento de produto?", qual o significado da opção "Outra"?

Nota biográfica:

Licenciatura em Matemática Aplicada pela FCUP. Mestrado em Matemática Aplicada com dissertação na área de Probabilidades e Estatística pela FCUP. Doutoramento em Matemática Aplicada pela FCUP.
Leciona, desde 1991, disciplinas na área da Estatística no ISEP, onde é Professora Adjunta. Lecionou, através da Associação para o Desenvolvimento e Inovação Tecnológica (ADITEC), o módulo de Estatística e Fiabilidade em dez cursos de Pós-graduação em Higiene e Segurança no Trabalho. Ministrou sete edições do Curso de Especialização em Análise Quantitativa de Dados em SPSS entre 2012 e 2019.
Membro fundador – com Sandra Ramos - do Grupo de Consultoria em Estatística, em 2014. A finalidade deste grupo é prestar apoio estatístico na análise de dados em projetos de I&D.
Membro da Comissão Organizadora do XXIV congresso da Sociedade Portuguesa de Estatística.
Tem trabalhos publicados na área de Mecânica Probabilística.

De: Paulo Jorge Lourenço Ferreira Da Silva
Enviado: 26 de março de 2020 23:04
Para: Francisco J. G. Silva
Cc: Daniel Soares (1130482)
Assunto: RE: Pedido de ajuda para validação de inquérito (dissertação de mestrado).

Viva Francisco,

Conforme pedido analisei a formulário criado para a avaliação pretendida.

Uma das coisas que me chamou a atenção é a solicitação do nome da empresa.
Tendo como base o tipo de inquérito e respostas pretendidas eu não colocaria esta questão a não ser que a mesma seja absolutamente fundamental para alguma análise específica.

Na minha opinião o formulário está bem estruturado e permitirá caracterizar e relacionar, entre outras coisas, as pessoas que respondem, e dimensão das empresas, com a perceção da realidade de cada um.

O segredo estará na obtenção do maior número de respostas possível e depois ter a capacidade de conseguir relacionar e concluir sobre os dados obtidos.

Se possível gostaria, como cultura geral e pessoal, ter acesso ao número de respostas e às conclusões finais.

Por último e de forma resumida indicar que faço a gestão de 5 instalações de assistência automóvel na Direção Norte do Grupo Entreposto Auto representando as marcas: Peugeot, Renault/Dácia e Nissan.
Sou responsável pela otimização e dinamização dos fluxos de trabalho diário com vista à máxima flexibilização dos recursos humanos e materiais na obtenção da melhor produtividade e eficiência em cada momento.
Estou neste momento a preparar a implementação das metodologias Kaizen na assistência após-venda nas 2 instalações principais do grupo no norte do país.
Este projeto terá o acompanhamento do Kaizen Institute Portugal em parceria com a Renault Portuguesa.

Cumprimentos,

Paulo Jorge Silva

De: mario.cardoso@ficosa.com
Enviado: 27 de março de 2020 11:39
Para: fgs@isep.ipp.pt
Cc: Daniel Soares (1130482)
Assunto: Re: Pedido de ajuda para validação de inquérito (dissertação de mestrado) (2ª VIA).

Bom dia Francisco
Analisei o inquérito sobre "Barreiras à aplicação de metodologias ágeis na Gestão de Projectos no sector automóvel" e considero que o mesmo foca as questões mais pertinentes referentes a essa temática.
Na Ficosa existe uma ferramenta especifica para a gestão de projectos chamada FDS - Ficosa Development System que contém 7 fases que vai desde a fase de ornamentação até fase 7 que é a validação da linha de montagem com aprovação de todos os departamentos.
A gestão de projectos no sector automóvel é obrigatória para o sucesso dos projectos.

Cumprimentos / Best Regards,

Mário Silva Cardoso
Maintenance Manager
FICOSA
FICOCABLES PORTUGAL
Address: Rua do Cavaco, Nº 115, 4470-263 Maia, Portugal
Mobile: +351 912 540 470 (Ext. 9975)
mario.cardoso@ficosa.com
www.ficosa.com/
Follow us:

From: fgs@isep.ipp.pt
To:
Cc: 1130482@isep.ipp.pt
Date: 26/03/2020 15:43
Subject: Pedido de ajuda para validação de inquérito (dissertação de mestrado) (2ª VIA).

Caros Colegas,

Só para relembrar o pedido realizado abaixo.
Basta que me enviem um texto conforme indico abaixo:

"Analisei o inquérito sobre "Barreiras à aplicação de metodologias ágeis na Gestão de Projectos no sector automóvel" e considero que o mesmo foca as questões mais pertinentes referentes a essa temática."

De: Francisco J. G. Silva
Enviado: 27 de março de 2020 10:01
Para: Carlos Ribeiro; Luis Miranda Torres
Cc: Daniel Soares (1130482)
Assunto: RE: Pedido de ajuda para validação de inquérito (dissertação de mestrado).

Caro Carlos Ribeiro,

Muito obrigado pela preciosa ajuda.
Certamente o Daniel terá em conta os detalhes apontados e, em breve, teremos o inquérito em circulação.
Mais uma vez, muito obrigado pela excelente colaboração.

Ao Luís Miranda Torres, igualmente o meu muito obrigado pela recomendação do Carlos Ribeiro.

Melhores cumprimentos,
Francisco Silva

De: Carlos Ribeiro <carlos.alex.ribeiro@gmail.com>
Enviado: 27 de março de 2020 09:56
Para: Luis Miranda Torres <lmt@isep.ipp.pt>
Cc: Francisco J. G. Silva <fgs@isep.ipp.pt>
Assunto: Re: Pedido de ajuda para validação de inquérito (dissertação de mestrado).

Olá Luis,

Desculpa a minha resposta tardia, mas apesar de estar em casa parece que o trabalho não abranda.
Relativamente ao inquerito o conteúdo e a apresentação está correcto e apresentado de forma clara.

Como reparo apenas acrescentava os Métodos Ágeis (Lean, Kanban, Scrum, Sprint,...) como os métodos ágeis; sou forte apoiante da lingua Portuguesa, mas neste dominio os anglicanismos são prefereciais para a rapida compreensão do tema.

Acrescento que em toda as estruturas existem barreiras e inércias à mudança, mas as Industrias Aeronauticas e Automóveis, por motivos diferentes, aodptam metodologias com alguma rapidez desde que sejam visiveis vantagens, e as vantagens têm que ser traduzidas em beneficios económicos.
Por outro lado, as barreiras são de várias naturezas e de diferentes sectores da empresa.

Mas não me alongando mais, o inquerito está interessante, a forma e conteudo também, apenas usava nomenclaturas e jargões que se são o dia-a-dia da Industria.

Sem mais de momento, despeço-me com os melhores cumprimentos,

Carlos Ribeiro

Luis Miranda Torres <lmt@isep.ipp.pt> escreveu no dia terça, 24/03/2020 à(s) 00:24:

> Olá Carlos,
>
> Podes dar a tua opinião (como especialista) sobre o e-mail abaixo.
>
> Obrigado.
> Um abraço,
>
> Luis Miranda Torres
>
> Início da mensagem reencaminhada:
>
> > **De:** "Francisco J. G. Silva" <fgs@isep.ipp.pt>
> > **Data:** 23 de março de 2020, 23:13:25 WET
> > **Cc:** "Daniel Soares (1130482)" <1130482@isep.ipp.pt>
> > **Assunto: Pedido de ajuda para validação de inquérito (dissertação de mestrado).**
> >
> > Caros Colegas,
> >
> > Tenho um estudante a fazer uma dissertação de mestrado sobre "Barreiras à aplicação de metodologias ágeis na Gestão de Projectos no sector automóvel".
> >
> > Podem encontrar o inquérito aqui: https://forms.gle/jeZ3opM5BL96akfm6
> >
> > Antes que o mesmo seja distribuído, gostaria que o mesmo fosse validado por EXPERTS no sector.
> >
> > Assim, gostaria de pedir a vossa ajuda para que lessem o inquérito (são 7 minutos) e me enviassem uma mensagem no sentido de o validar ou não. Essa mensagem servirá para o Daniel Soares incluir nos anexos da sua tese, como prova da validação por EXPERTS. Para tal, na mensagem, agradecia que incluíssem um breve resumo da vossa actividade profissional ligada à indústria/comércio automóvel, ou em Gestão de Projectos, para atestar da validade da vossa opinião.