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Identifying Barriers in the Implementation of Agile Methodologies in Automotive Industry

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Abstract: Projects have grown into more dynamic and complex endeavors, and agile project management should be considered as a way to deal with them. This is a novel study in this field, because the implementation of agile project management in the automotive industry was not explored so far, thus, this work intended to fill this gap, by identifying barriers in the implementation of agile methodologies in project management regarding the automotive industry. This was conducted through a questionnaire survey, which was developed and distributed to 148 manufacturing companies of components for the automotive industry, out of a total number of companies of 240, and 56 complete answers were obtained (23.33%). Statistical analyses were performed using a Kruskal–Wallis test, a Mann–Whitney test, and Spearmen's correlation. A real picture of the implementation of agile project management in the Portuguese automotive industry is depicted through this work. 'Organizational', 'Knowledge and Technology', 'Institutional', and 'Financial' barriers are found to be the most important. However, in overcoming these barriers, companies can be more sustainable in economic, environmental, and social terms. Recommendations on how to overcome these barriers were presented, and a framework sequencing these recommendations was presented, leading to an effective implementation of agile methodologies. It starts with the willingness of the company, and all collaborators, to adopt the agile methodologies, looking for the agile values as an input in order to achieve a competitive advantage. It is followed by an initial investment, which intends to attain the deployment of an agile team, composed of highly skilled collaborators with a clear understanding of the agile objectives, who disseminate knowledge about agile methodologies to the other collaborators, increasing their ability to implement agile methodologies in project management. This team should work and develop frameworks and workflows, according to each company's characteristics and environment. The studied aspects can be replicated in other countries, and allow a comparison of the situation between countries, trying to correlate the culture of each country with the ability to implement agile methodologies, among other aspects, such as economical level of the companies, type of production, and the commitment of the collaborators to improve processes and create competitive advantages with which to face competitors.

Keywords: agile project management; agile methodologies; barriers; enablers; automotive industry; sustainability in industry

1. Introduction

The automotive sector is a vital sector in the worldwide economy. It contributes to the growth of other related activities, such as metallurgy, plastic/rubber processing, electronics, textiles, etc., and consecutively empowers global industrialization [1]. The

outstanding contribution of the automotive industry (AI) to technological advancement was the establishment of full-scale mass production. The increasing competitive pressure of the market emphasized the ability of industrial firms to improve the indicators of quality, cost, and time-to-market of new products. The management of the increasingly complex products became more and more important. This brought attention to investment in human resources to manage tasks following previously defined concepts and organizational frameworks, through project management (PM) activities, even under rigid, stable, and inflexible capabilities [2,3]. The globalization and expanded markets increased the dynamism and complexity of projects, leading to the shift from traditional PM to agile project management (APM) [4,5]. The implementation of agile methodologies (AM) faced various barriers, and there is extensive literature regarding this matter in the information technology (IT) field, where APM emerged [6]. However, the literature background is much less extensive regarding the manufacturing sectors, and almost nothing exists regarding the automotive industry (AI) [7].

Despite an intense search, no works were found that focused directly on identifying barriers in the implementation of APM in the automotive industry, or exploring eventual gains in sustainability for the companies. There are several works focused on agile software development [8,9]. Thus, this was the main motivation and novelty of this work. This research focused on this literature gap, by seeking to define and characterize the AI regarding the implementation of AM through a questionnaire survey. In particular, the aim was to answer the following research questions:

- Do the AI companies need to implement AM?
- Are the AI companies predisposed to AM?
- What are the main barriers for implementing AM in the AI?
- What are the main enablers for implementing AM in the AI?

Thus, it was intended to identify the main barriers impeding component-producing companies from implementing AI, and establish new strategies to overcome the difficulties of these companies in adopting agile project management methodologies. Thus, it is possible to ensure a more sustainable future for their organization, and corresponding relationship with stakeholders.

2. Literature Review

2.1. Agile Project Management

The AI dramatically increased the pace of launching new products. As a direct consequence, automotive companies face an emerging challenge: to increase the frequency, reliability, and profitability of the innovations resulting from research. At the same time, they need to keep their ability to develop more vehicles than ever, and maintain tight constraints on quality, cost, and lead time. Fritzsche [10] argues that such a strategic challenge called for a deep transition in car manufacturers' product design processes. However, Beaume et al. [2] state that these organizations became reluctant to apply disruptive concepts regarding organizational structure. Taking this into attention, San Cristóbal et al. [4] claim that as projects have grown in complexity, the ways of managing them should be reconsidered. This evolution is studied by Sanchez et al. [5], and these authors refer to some projects that streamlined the traditional PM, and transitioned to a new agile approach, namely agile project management (APM). This is studied by Špundak et al. [11] and Highsmith et al. [12], who point out that agility is the word that differentiates APM from traditional PM. In fact, agility deals with constant innovation, product adaption, shortening delivery times, adjustment of processes and people, quality, and reliable results. Hence, Beck et al. [13] show that APM evolved since the creation of an agile manifesto for software development, in 2001. Furthermore, APM proposes a series of agile methods, practices, and tools used today, as pointed out by Conforto et al. [6].

Agile project management is also studied in terms of sustainability in several other industrial and service sectors, but not in the automotive industry. Silva et al. [14] develop frameworks creating the corresponding linkages between the tools and artifacts of the

APM, and the three pillars of sustainability. They conclude that implementing APM practices leads to increased sustainability of the companies in the economic, environmental, and social aspects. Obradović et al. [15] also study the relationship between APM practices and sustainability, concluding that the first has direct repercussions on the second. Žužek et al. [16], taking into account the SMEs Slovenian panorama, also study the implications of APM practices on sustainability, but outside of the software sector. They conclude that, even in small companies and out of the software area of work, the effect is clearly felt. Thus, it is assumed that implementation of APM practices also induces clear gains in the sustainability of companies. In the work by Sharma et al. [17], who study the effect of agility in the industry, several definitions of agility linked to production systems are found, as well as some barriers to the implementation of these agile systems in manufacturing.

2.2. Agile Methodologies

As traditional PM has its own characteristics, methods, and tools (program evaluation and review technique (PERT), critical path method (CPM), etc.), APM also presents some specific methods. There are various techniques under the AM umbrella, with some characteristics in common: they are all iterative, incremental, and evolutionary; and customer involvement is mandatory [18]. Scrum is one of the most common agile techniques, being a single team iterative process framework used to manage product development. Scrum is based on a variety of concepts such as customer feedback, daily scrum meetings, product backlog, sprint backlog, sprints, and being delivery-ready after each sprint [19]. As defined by PMI and Agile Alliance [20], these sprints are timeboxes of one month or less, with regular durations, where the potentially releasable increment of a product is developed. The team responsible for this method consists of the product owner, who tries to maximize the value of the product; the scrum team, which is a self-organized and cross-functional team, who have everything they need inside the team to deliver a working product; and the scrum master, who ensures that the scrum process is sustained and guarantees the scrum team complies with the rules. The scrum method allows for a reduction in planning overhead, due to its flexibility and easy adaptablity to any changes in stakeholders' needs, at any stage in product development. It focuses on developing customer relationships to increase product quality, and improvement in performance. Each short cycle/sprint enables the release of short prototypes, so that the customer can monitor the development and provide continuous feedback [14,21].

There is a relation between lean, agile, and kanban methods, since these last two are descendants of lean thinking. Freitas et al. [22] give a good description of this methodology, stating that the word kanban is translated to 'card' or 'visual sign', because 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'. However, it can adapted to any other state needed by the team. The cards used in the kanban method provide a clear understanding of the workflow, as well as bottlenecks, in overall conditions. Both scrum and kanban have the customer as a focus when responding quickly to requests, are highly adaptive, and collaborative, fitting self-managing teams very well. Originally, the transition from the scrum to kanban was designed as scrumban. As new agile methods emerged, it evolved into a hybrid framework where teams used scrum as a framework, and kanban for process improvement. In scrumban, the work was structured into small sprints, and took advantage of the kanban boards to visualize and monitor the work. The tasks were placed on the kanban board, and the team managed its work within the work in progress limits. Daily meetings happened to maintain cooperation between the team, removing impediments. There were no predefined roles in this methodology—the team maintained their current roles. It eliminated the planning activities and velocity measurement, and focused on smooth flow, minimizing work in progress.

2.3. Barriers and Enablers in the Implementation of Agile Methodologies

A barrier means any factor that hinders, affects, or resists the implementation of a certain action, resulting in its delay or obstruction. Conversely, enablers are factors that facilitate, help, accelerate, or encourage the completion 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 methods and tools [22]. Despite the extensive literature regarding the application of APM in the software industry, there is a lack of empirical studies on other types of industries, sectors, and projects [23]. Bohem and Turner [24] explore management challenges in implementing agile processes in traditional development organizations and frame 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?'. In order to expand the research from the IT field to the AI, it is necessary to investigate similarities between these sectors. Moreover, it is also necessary to explore eventual barriers that are observed in the AI, and previously identified in the IT sector. Two fields are considered as common regarding IT and the AI: cleaner production and lean manufacturing. As defined by Silva and Gouveia [25], cleaner production is an approach that intends to reduce environmental impacts, while lean manufacturing focuses on the reduction of costs and time. Both aspects have a direct influence on the product and market. These tools tend to help manufacturing processes become more sustainable.

From the available literature, it is possible to conclude that agile methods are theoretically applicable in most industries, and prove their success in practice, specifically in large organizations [7,26]. The concept of agile manufacturing evolved from lean management, and enabled the organizations to react and proact to the unpredictable and diversified market changes [27]. The barriers found in the literature regarding the above-mentioned sectors are presented in Table 1. The enablers, possible solutions, or recommendations found in the literature are presented in Table 2.

Table 1. Barriers found in the literature and employed in the questionnaire.

Literature Reference	Barrier(s)
Vermunt et al. [28]	Internal; external; financial; organizational; knowledge and technology; supply chain and market; institutional.
Potdar et al. [29]	Improper competency management.
Silva and Gouveia [25]; Potdar et al. [29]; Sindhwani et al. [30]	Governmental policies and support.
Ghani and Bello [31]; Salinas et al. [32]; Potdar et al. [29]; Sindhwani et al. [30]	Ineffective customer relationship.
Vermunt et al. [28]; Caldera et al. [33]; Ghani and Bello [31]	Lack of knowledge and skills.
Silva and Gouveia [25]; Vermunt et al. [28]; Potdar et al. [29]	Ineffective supply chain.
Ghani and Bello [31]; Caldera et al. [33]	Existent organizational culture.
Caldera et al. [33]; Tan et al. [34]	Time constraints.
Caldera et al. [33]; Kostić [35]	Risk.
Ghani and Bello [31]; Potdar et al. [29]	Stakeholders' attitude.
Added through the authors' personal experience and industrial knowledge	Absence of immediate quantifiable benefits; lack of project team flexibility; project lead time not critical; not applicable to our product; organization not able to apply AM; flexibility is not a priority; there is no time to think about that; staff not prepared to AM; lack of government benefits; change predisposition.

Table 2. Enablers, possible solutions or recommendations, employed in the questionnaire.

Literature Reference	Enablers, Possible Solutions or Recommendations
Ghani and Bello [31]; Vermunt et al. [28]	Organizational support
Ghani and Bello [31]; Silva and Gouveia [25]	Stakeholder collaboration
Ghani and Bello [31]	Investment in training; lean relationship

2.4. Hypotheses Formulation

In the production of components for the automotive industry, a relatively high degree of automation is normally used [36], which must be adapted to the quantity produced per batch, and the variety of products carried out on each production line [37]. Thus, given the series produced and the diversity of products manufactured, each company must adopt the most appropriate manufacturing system [38]. This has direct implications for project management, as a mass-manufactured product may have a line dedicated only to that product, with fixed automation. On the other hand, a family of products requires a flexible production system [39]. Agile project management is much more useful in the latter case, and this gives rise to the first hypothesis considered in this work: "The company production type influences AM implementation". The lifetime of each product in production is also an extremely important factor in defining the manufacturing process and, consequently, in the project [40]. Avery short life cycles implies the need for greater agility, while longer cycles are managed through a conventional management system. This depends on the relationship with stakeholders, and the time-to-market required by customers [41]. Moreover, this defines the second hypothesis considered in this work: "The AM implementation has an association with the company's degree of change?". Decision making for agile project management implies that top management have a deep understanding of the tools normally used, and know how to manage them with dexterity [29]. Thus, a third hypothesis is formulated: "Improper competence management affects AM implementation". However, there has to be an entire team (or teams) that conveniently operationalizes the implementation of agile management. To this end, the teams should be initially sensitized, and presented with the advantages and methodologies to be adopted, so that there is a predisposition to change from a traditional philosophy to an agile methodology [16]. Thus, a fourth hypothesis is formulated: "The change predisposition influences AM implementation". However, the results of adopting an agile methodology do not always appear immediately, and are not always perfectly quantifiable. The doubt regarding the level of benefit that results for the company and its employees could be a factor that negatively affects the teams. In fact, it is theoretically impossible to predict what level of benefits everyone will see, and when, through the implementation of agile methodologies [22]. Thus, a new hypothesis emerges: "The absence of immediate quantifiable benefits influences AM implementation". In sum, the following hypotheses were considered in this study:

H1. The company production type influences AM implementation.

H2. The AM implementation has an association with the company's degree of change.

H3. The improper competency management affects AM implementation.

H4. The change predisposition influences AM implementation.

H5. The absence of immediate quantifiable benefits influences AM implementation.

3. Methodology

This study focused on the automotive industry, because this sector was responsible for the sharp growth in Portuguese exports. In addition, the automotive industry is highly dynamic, in terms of launching new products, which implies continuous management of new products and projects. The sector still presents high standards of demand, thus benefitting more intensely from the advantages brought by agile project management. The automotive industry is subject to strict quality standards and high supplier accountability, which is also in line with some of the benefits brought by agile project management. Furthermore, it is a sector extremely concerned with sustainability, which is why it fits perfectly into the principles that guide agile project management. The study focused on this sector, as there was no study in this area for this sector. Furthermore, as it is an industry that forms the basis of several highly industrialized countries, it allows similar studies to be developed for the same sector in other countries, thus, sustaining its scalability.

The adopted research methodology utilized a well-established pattern used in similar studies [7,32,42]. Figure 1 shows the methods used, the research flow, and the expected outcomes. In sum, after careful investigation work, the gap that gave rise to the work was determined. Barriers to AM implementation in other sectors were identified, namely in software development. Based on these barriers, a questionnaire was developed. A compilation of the results, and corresponding statistical treatment, was carried out. Based on these results, a flowchart was designed for an easier implementation of AM and the recommendations and enablers are pointed out.
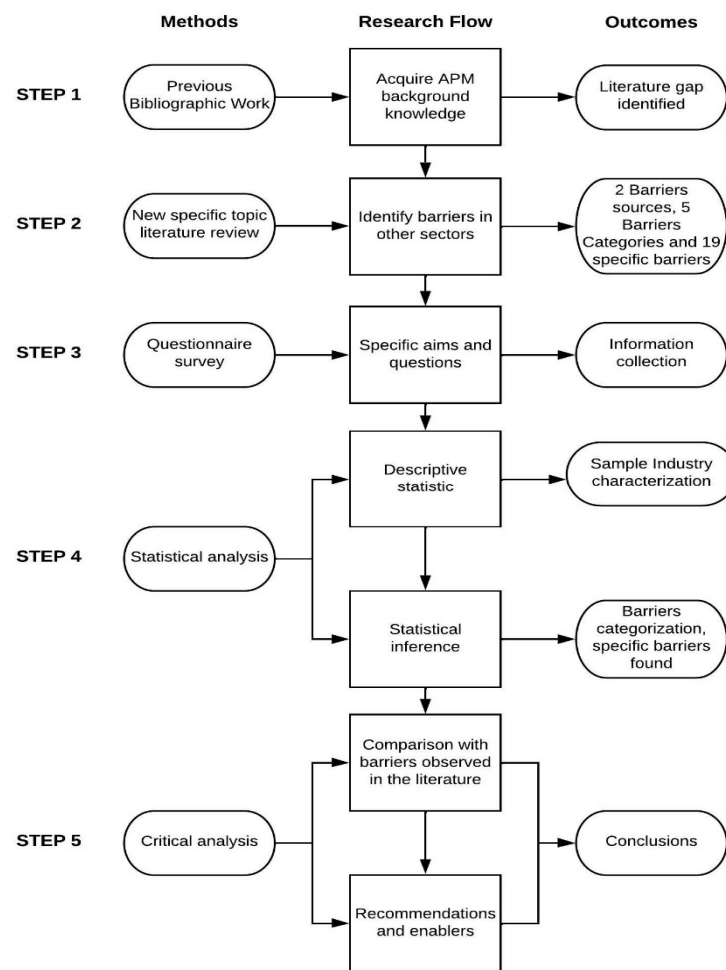

Figure 1. Flowchart with the methodology used, research flow, and expected outcomes.

3.1. Research Instrument

The questionnaire included 38 questions of multiple-choice, checkboxes, scale, and open type questions. The scale questions were drawn using a Likert-type scale. The questionnaire also presented some cross-check questions in order to verify the coherence of the answers. Table 3 shows details about the questions and variables in the questionnaire.

Table 3. Questionnaire framework.

Groups	Questions	Variables
Respondent characterization	1–5	Familiar with APM; age; department; job function.
Company characterization	6–11	Region; employees (company size), organizational structure; exportation volume; product requirements.
Manufacturing process characterization	12–19	Production type; production changes and purposes influence; improve flexibility; management involvement; manufacturing system; influence factors; quality criteria.
Product development process and PM	20–23	Product development process; PM approach; project and product development criteria; project changes.
APM environment	24–32	APM transition; APM culture; AM application; departments applying AM; APM certification; PM team; minimum qualification; agile techniques and tools; agile techniques; tools contribution.
Barriers in the implementation of AM	33–37	Barriers category; barriers source; specific barriers; other impediments; AM implementation difficulty.
Enablers for the implementation of AM	38	AM implementation enablers.

To ensure its compliance, the questionnaire was evaluated by a panel of five experts in the fields of mechanical engineering, PM, and statistical analysis.

3.2. Survey Sample

The sample size used in the study was determined using the equation [43]:

$$
n \geq \frac{\frac{z^2 \cdot p \cdot (1-p)}{e^2}}{\frac{N-1}{N} + \left(\frac{z^2 \cdot p \cdot (1-p)}{N \cdot e^2} \right)} \tag{1}
$$

where n is the sample size, N is the population size, p represents the population proportion of companies that implement agile methodologies, e is the sampling error, and z is the $(1 - \alpha/2) \times 100\%$ percentile of a standard normal distribution, with $(1 - \alpha) \times 100\%$, representing the confidence level. The sample size obtained with the previous equation ensures that the estimate of the proportion of the population of companies implementing agile methodologies are within e of the true population proportion.

According to the Portuguese Manufacturers Association for the AI sector, in 2019, there were 240 companies operating in Portugal related to the manufacture of components for the AI [44], who represent the theoretical study population (sample). As no pilot study was conducted, nor was there prior information on the percentage of companies implementing AM, in the calculation of the sample size it was considered $p = 0.5$. This value leads to the largest sample size and, consequently, the highest probability of hitting the target.

The formula presented above, with $N = 240$, $p = 0.5$, $z = 1.96$ (for 95% confidence level), and a maximum sampling error of 5%, leads to $n \geq 148$. Of the 148 questionnaires sent out, 56 were completed and returned to the authors. All responses were valid for further analysis. Unfortunately, the high non-response rate reduced sample size for 56 affected the sampling error, which became 11.5%.

3.3. Data Analysis

Data collected was analyzed using two different approaches: descriptive analysis and inferential analysis. In descriptive analysis, bar graphs with percentages were used. The inferential analysis was used to generalize the sample. This analysis included comparisons among groups, and a correlation analysis. Group comparisons according to the findings related to the barriers in the implementation of AM in the AI were performed using the Mann–Whitney U test, when comparing two groups based on ordinal variables. Otherwise, the Kruskal–Wallis test (with multiple comparisons if the test results in a significant result) was used when the number of groups to be compared was at least three. Spearman's correlation analysis was performed to assess the association between two ordinal variables.

Statistical analyses were performed using R/RStudio software version 1.0.153. Hypothesis tests with a *p* value of 0.05 or lower were considered as statistically significant results.

4. Results

4.1. Respondents' Characterization

In this survey, almost 85% of the respondents are familiar with APM, which is a very substantial percentage. Almost all respondents (98.2%) have a higher education degree, and about 80% of respondents belong to project management and product development (PM & PD), management, and production departments. These departments are directly linked to this study. The summary of the results regarding the respondents' characterization is presented in Figure 2.
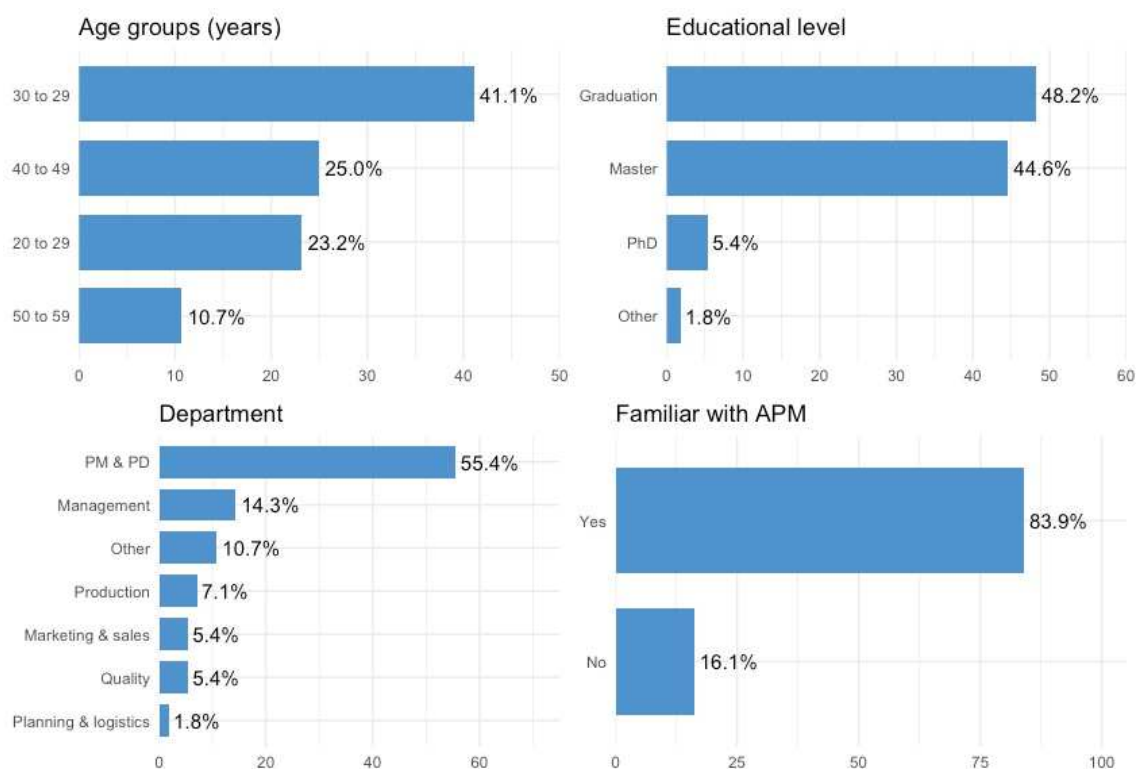

Figure 2. Respondents' characterization.

4.2. Companies' Characterization

Figure 3 depicts a summary of the results for variables directly linked to the company' characterization. About 70% of the inquired companies are large and relevant companies in this sector, with almost 90% claiming high levels of exportation (>75%). Moreover, about 84% are subjected to imposed requirements from original equipment manufacturers (OEMs). This reveals that these companies present both international relevance and dependency. Regarding the organizational model, the functional structure is the most commonly adopted approach by Portuguese companies within the automotive sector. In this organizational model, specialties do not interfere each other, usually being used in stable environments that do not experience quick and constant changes, either internally and externally. This structure causes difficulties 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 do not retain a global vision of the business, believing that they are uniquely focused and specialized in their work area. This circumstance avoids better alignment of them with the company strategic objectives, and is not the best departure point for AM implementation.
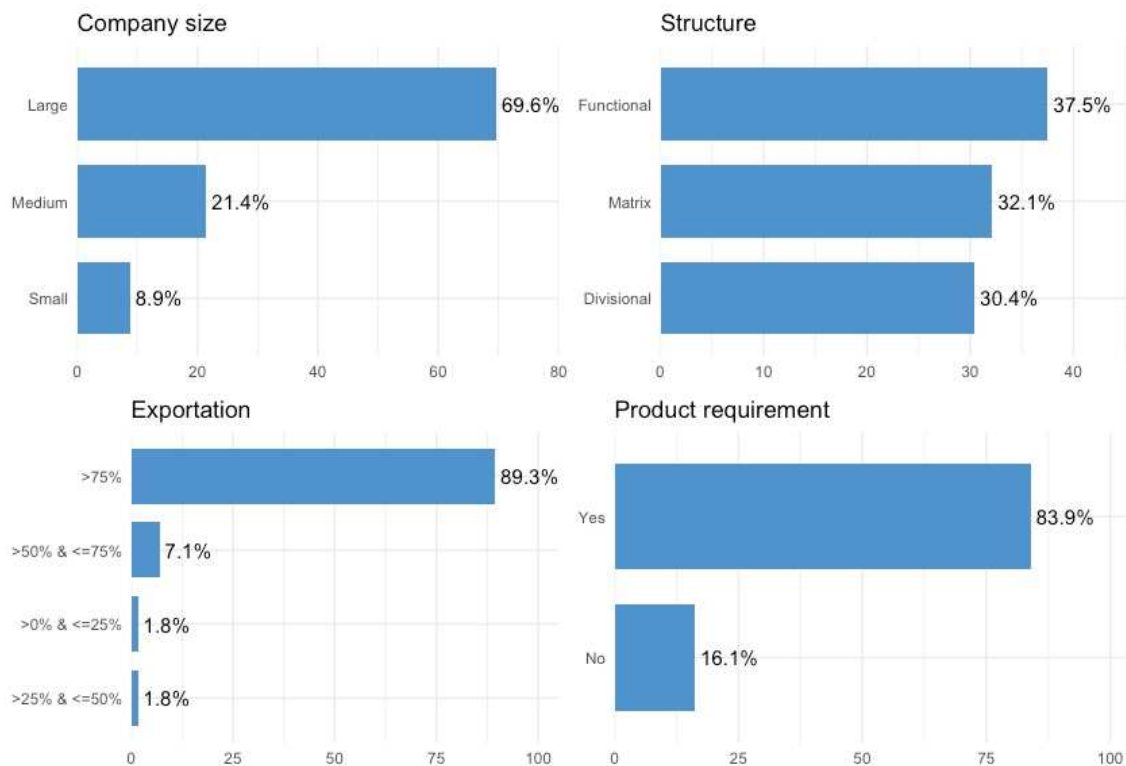
Figure 3. Companies' characterization.

4.3. Manufacturing Processes' Characterization

Regarding the production type, mass production is the main manufacturing system mentioned (51.8%), as it is the most common process used in the AI. Batch production also represents a significant percentage (23.2%), corresponding partially to the activity of metalworking sector in the AI. More than 62% of the companies experience manufacturing changes in the last three years. For more than 80% of the respondents, 'Increase production' and 'Cost reduction' are the main factors that dictate these changes. 'Imposed changes by OEMs', 'Design' and 'Attempt to implement AM' are highlighted as the main reasons of the need for these changes by more than 60% of the respondents. However, "Environmental issues" and "Governmental policies" do not significantly account for the above-referred changes. Furthermore, the results suggest that almost 93% of the companies intend to improve manufacturing processes, in order to increase flexibility. This flexibility might improve companies' responsiveness, because of the changes occurring in the production process. Considering the degree of involvement between top management and production departments, around 85% of the respondents claim that the top management is highly or extremely involved. This shows that there is no lack of support from the top management team regarding AM implementation. About 81% of the companies declare that they possess an agile manufacturing system, meaning they can produce a planned range of product models within a certain family of products. This type of system is more capable of dealing with unplanned changes. Indeed, this system possesses enough ability to support different processes in a different sequence, instead of just being prepared for one certain cycle of processes in one certain sequence.

The companies' quality concerns were evaluated, on a scale of one (none) to six (very high), aiming to identify factors companies give more attention to. The responses illustrate that all factors are important, although some differences are observed. Primarily, the main quality concern is 'Customer satisfaction', which is a crucial feature in AM implementation. On the other hand, 'Improvement of internal communication' did not attract the respondents' attention. This matches with the functional organization type adopted by the companies, demonstrating that they are focused exclusively on their work, and

that communication and interaction with other sectors does not matter. Thus, employees end up losing interest in the overall goals of the company. This idea is completely opposite to the principles of agile management. Indeed, employees are just focused on 'Productivity', 'Financial performance', and 'Consistency of product', leaving aspects such as 'Implementation of best practices', and 'Improvement of internal communication' in the background.

4.4. Product Development Processes and Project Management

In order to understand and characterize the product development process, four questions were defined. Firstly, it was sought to understand if the companies develop this process by themselves, or through subcontracting external services. It was possible to verify that more than 91% of the companies develop their projects mostly in house. It was then necessary to find out what kind of approach is usually applied in the PM field. It was noticeable that a lot of PM teams experience the agile approach or, at least, iterative, or incremental methods. These methods allow for customer feedback, enabling changes during the product development phase to adjust and improve it. Thus, they guarantee customer satisfaction using this process. The main criterium taken into account during the project and product development process is 'Follows the customer requirements. This confirms the high degree of dependence that these companies are subjected to. This is also corroborated by another fact: more than 80% of the companies follow the product requirements imposed by the OEMs. It is also important to emphasize the low percentage of the 'Origin of materials' (17.9%), and 'Sustainability' (23.2%) criteria, indicating that the environmental aspect is one of the least important during the project and product development phases. This depicts how the AM implementation is useful regarding the desired and needed increase in sustainability, and also shows a lack of knowledge in how AM empowers all sustainability pillars.

4.5. Agile Project Management Environment

Figure 4 shows how familiar the companies are with AM practices. Regarding the APM culture of the companies, more than 73% of them are studying the implementation of, or are working under, AM, which is a very reasonable indicator. Approximately the same percentage have departments where agile techniques (kanban, scrum, or scrumban) are applied. The APM certification process is still difficult and less requested by companies. Nevertheless, a significant percentage of responses (30%) claim they have certified collaborators in APM inside the company. Also, almost 60% of the companies have more than ten workers devoted to the PM team. Lastly, most of the companies have a minimum qualification of a bachelor's degree for the project and product development teams. People with secondary education or master's degree represent 19.6% and 14.3% of respondents, respectively. The situation is not the best, and represents a lack of skills and knowledge regarding the implementation of AM, which constitutes a serious barrier. Besides that, in a general way, the companies demonstrate they are aware of what APM is. However, it is likely they do not devote the necessary efforts to adopt a fully agile approach.

Figure 5 depicts a stacked bar chart where some specific agile techniques are illustrated. The purpose of this question was to understand the level of knowledge of the respondents regarding these techniques and, at the same time, if some of the techniques are applied inside the companies. Once again, one of the most referred topics is 'Customer integration', confirming the importance of customer satisfaction for these companies. Another concept often referred to as being usually applied is the 'Daily meeting', which is part of the scrum technique. Nonetheless, other tools are part of the 'Daily meeting' technique, such as 'Product backlog', 'Sprint iteration', and 'Incremental development'. However, those tools are not used in the same way. This could mean that companies could apply one or another tool, without fully applying the concept, such as the scrum technique.
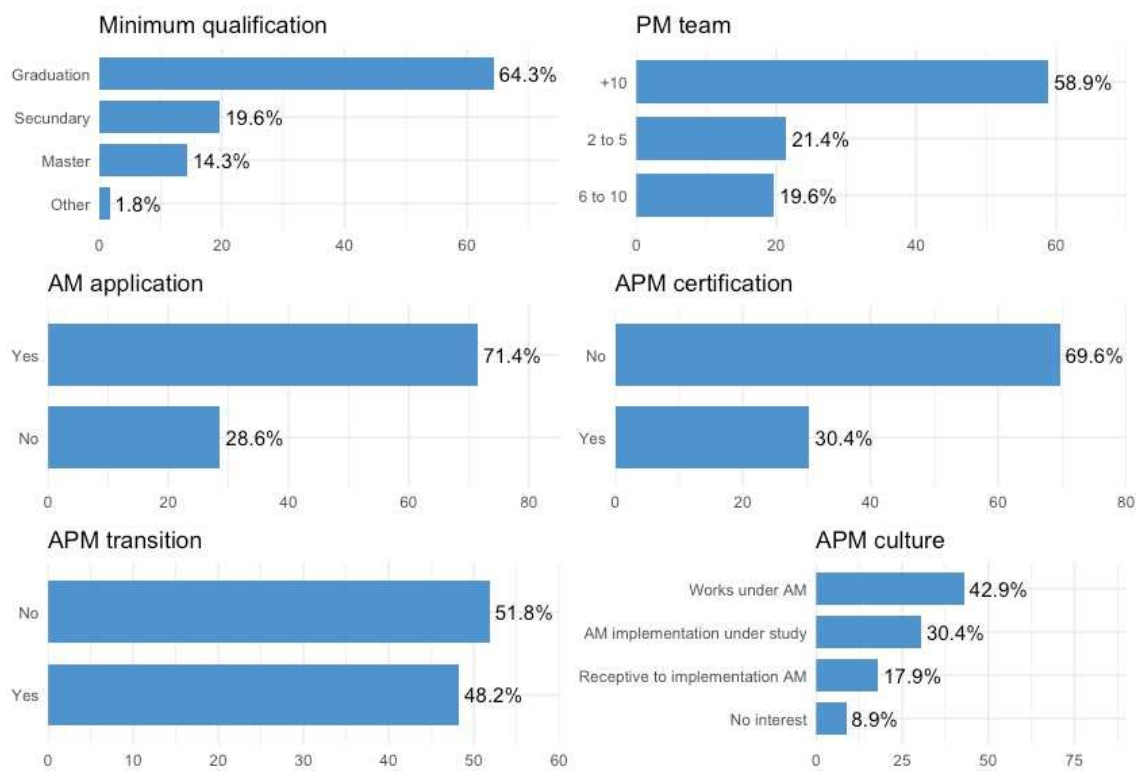
Figure 4. Characterization of the APM environment into the companies.
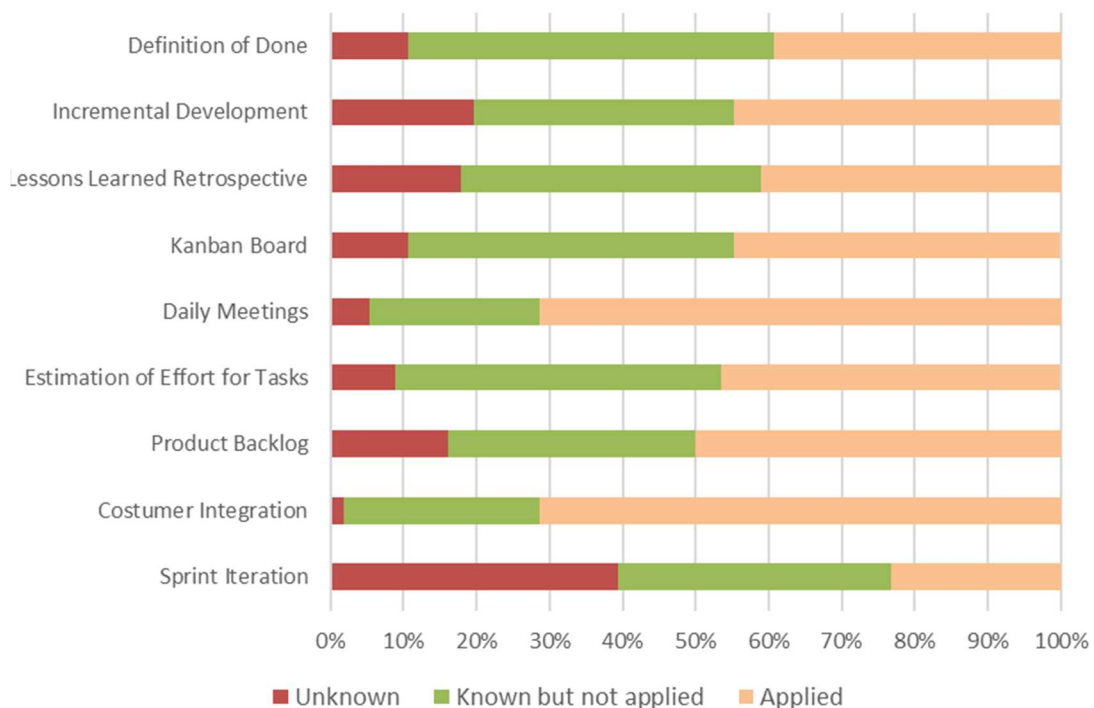

Figure 5. Percentages of agile methods and application of tools.

Moreover, 82.1% of the respondents claim that the contribution of agile techniques and tools to the companies vary between highly and extremely important. Respondents clearly point out the importance of these methods in their workplaces, even without applying them in full. It should be noted that the methods described in this study do not represent

most of the practices, tools, and techniques comprising APM theory, but only a small and selected sample.

4.6. Barriers in the Implementation of Agile Methodologies

Figure 6 presents factors that affect AM implementation, as well as their influence from the respondents' point of view. These factors are considered as categories for the barriers in the implementation of AM, and barriers further described fit these categories. The most notable categories of barriers in the stacked bar chart are 'Technical knowledge and capacity' and 'Organizational culture', both with an influence of 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 is imperative, since everyone dedicated to the job needs to be aware of what they are supposed to do. Moreover, all workers need to possess the knowledge to develop their own tasks. The second is the factor with the greatest influence, which could be the biggest hurdle for AM implementation in the companies. This means that a company established for several years is less flexible in changing the way it is organized, being less able to change these roots rapidly and effectively. Also, it is worth mentioning that the 'Lack of financial support' does not seem to be an impediment to the implementation of AM.
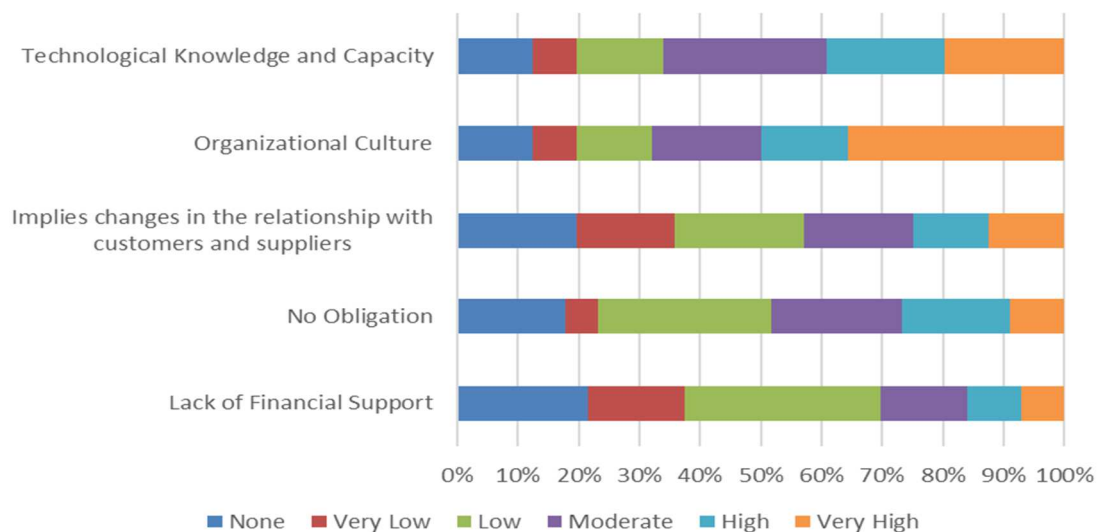

Figure 6. Barriers' categories and their influence for non-implementation of AM.

The main sources of barriers from the respondents' point of view are internal (61%), external (5%), or both (34%). Thus, external environment presents a low influence on the AM implementation, while internal impediments are the most significant. This correlates with the answers given in the previous question and depicted in Figure 6, since the two most observed factors belong to barriers arising from an internal source.

Figure 7 represents specific barriers and their influence on the implementation of AM. Each specific barrier fits into a barrier category and barrier source, previously referenced. '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', are barriers with an influence between a moderate and very high level for more than 50% of the respondents. It is worth highlighting the low influence of factors such as '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.
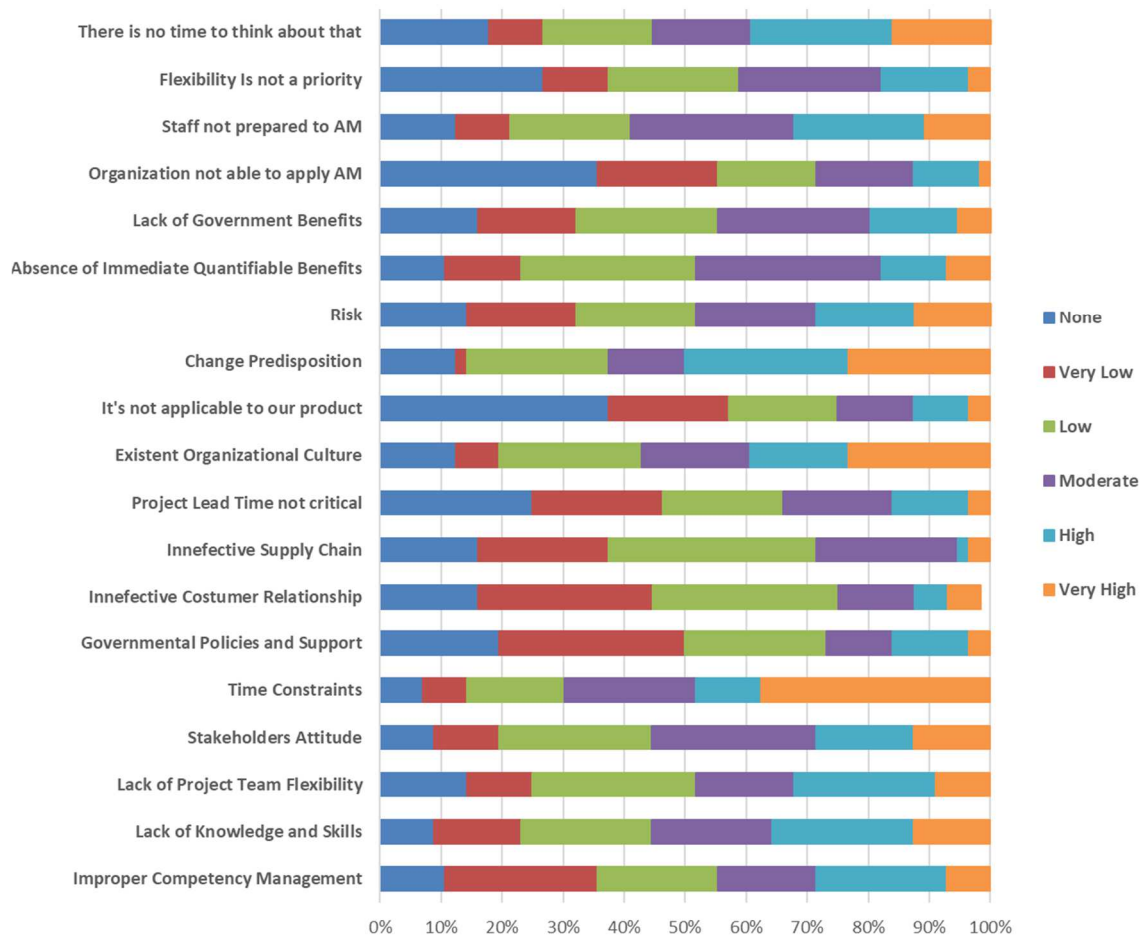
Figure 7. Specific Barriers and their influence on AM implementation.

Barriers with a lower impact are those such as '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'. Otherwise, barriers such as 'It is not applicable to our product' and 'Organization not able to apply AM' are almost disregarded by respondents. Regarding the open-ended question, two factors are highlighted: 'Certification procedures' and 'Lack of collective motivation'.

4.7. Enablers for the Implementation of Agile Methodologies

The last question of the questionnaire, representing enablers found in the literature for the implementation of AM, intended to understand which factors have more influence on the automotive sector. The obtained results are as follows: 'Organizational support' (78.6%), 'Stakeholders collaboration' (60.7%), 'Investment in training' (76.8%), and 'Lean relationship' (28.6%). 'Organizational support' and 'Investment in training' are the most referenced enablers. The first aims to acquire the adequate support from the top management, while the second claims that formation and training in the field are essential to implement AM. No extra enablers are pointed out by respondents in the open-ended question.

4.8. Statistical Analysis—Hypotheses' Investigation

Data analysis was performed through charts and the evaluation of results so far. However, the extrapolation of results to the population studied requires the application of statistical inference. Thus, the following five investigation hypotheses were defined for this purpose:

H1. The company production type influences AM implementation.

H2. The AM implementation has an association with the company's degree of change.

H3. The improper competency management affects AM implementation.

H4. The change predisposition influences AM implementation.

H5. The absence of immediate quantifiable benefits influences AM implementation.

It is worth mentioning that, for all tests of hypotheses, only data corresponding to responses in which the respondent claimed to be familiar with AM are considered. Also, only the results related to tests statistically significant are presented.

Hypothesis 1 (H1) intends to evaluate if the 'Production type' adopted in each company is an 'Organizational' barrier that inhibits the AM implementation. Thus, the null hypothesis (H0) is: the production type does not influence the AM implementation in the company. Based on the Kruskal–Wallis test, there is evidence that there are differences between the groups (χ^2 (2) = 10.052; p value = 0.040), which supports the statement that the 'Production type' in each company influences the AM implementation through 'Organizational' barriers. According to multiple pairwise comparison, it is observed that the batch production type represents statistically significant differences between the mass (median = 3.5; min. = 1; max. = 6), continuous process (median = 2.5; min. = 2; max. = 3), and other production types (median = 2.5; min. = 1; max. = 4). It is possible to conclude that the companies producing through a continuous process, or another production type, seem to encounter fewer impediments in AM implementation from an organizational point of view. This means that if product manufacturing is divided into processes, the organizational interactions, and the complexity of the production process, is simplified. In contrast, companies under batch production type reveal statistical differences among the other groups. These companies, despite allowing for changes or modifications between batches, require more intense and accurate planning, scheduling, and control over the process, i.e., a higher complexity. Also, just one step is performed at a time on multiple items, which is a disadvantage if the product requirements are constantly changing. As a result, the organizations applying this production type could face 'Organizational barriers' in implementing AM, due to a higher management complexity.

Hypothesis 2 (H2) aims to investigate if the 'AM implementation' has a relationship with the 'Company's degree of change'. Thus, H0 is as follows: AM implementation does not have a relationship with the company's degree of change. According to the Mann–Whitney test, there is a relationship between the 'AM implementation' and the 'Company's degree of change' (W = 110.500; p value = 0.048; median = 2.5; min. = 2; max. = 6 for no AM implementation; median = 4.5; min. = 2; max. = 6 for AM implementation). This confirms that the organizations with high levels of change need to adopt AM.

In order to evaluate if the 'Degree of management involvement' affects the implementation of AM, hypothesis 3 (H3) is investigated. Thus, H0 is as follows: the improper competency management does not affect AM implementation. The Spearmen's correlation is studied for each dependent variable ('Organizational culture' and 'Knowledge and technology'). It is possible to observe that 'Improper competency management' has a positive correlation with the 'Organizational culture' barrier (rs = 0.465; p value = 0.001), as well as the 'Knowledge and technology' barrier (rs = 0.450; p value = 0.002). For that reason, it is possible to state that 'Improper competency management' affects the AM implementation through both the 'Organizational culture' and 'Knowledge and technology' barriers. This influence could arise either from a lack of management involvement, or due to a lack of expertise and skills of the managers. This depends on if the problem is being analyzed from the organizational point of view or from the knowledge and technological point of view, respectively.

Hypothesis 4 (H4) emerged intending to understand if the 'Change predisposition' influences the AM implementation. Accordingly, H0 is drawn as: the change predisposition does not influence the AM implementation. The Spearmen's correlation evaluates the cor-

relation between the 'Change predisposition' and the 'No obligation' barriers, both fitting in the 'Institutional' barrier category. There is statistical evidence (rs = 0.373; *p* = 0.010) to state that the 'Change predisposition' influences the AM implementation, because it is correlated to 'No obligation' barrier. Moreover, these variables are framed in the 'Institutional' barrier. Thus, it is possible to state that the 'Institutional' barrier has influence on the AM implementation. It is confirmed that one of the biggest challenges in the application of AM is the resistance from society, and its aversion to change.

Lastly, the study intended to verify if the 'Absence of immediate quantifiable benefits' influences the AM implementation. Thus, hypothesis 5 (H5) is investigated, with H0 being defined as follows: the absence of immediate quantifiable benefits does not influence the AM implementation. Spearmen's correlation is performed, trying to understand if there is an association between the 'Absence of immediate quantifiable benefits', and the 'Lack of financial support' barriers. Both barriers fit into the 'Financial' barrier category. There is statistical evidence (rs = 0.380; *p* value = 0.009) to state that the 'Absence of immediate quantifiable benefits' influences AM implementation, since it is correlated to the 'Lack of financial support' barrier. These variables are associated, as they also fit into the 'Financial' barrier category; thus, it is possible to state that the 'Financial' barrier has direct influence on AM implementation.

5. Discussion

The 56 questionnaires with valid responses allow this survey to provide a group of interesting results concerning the implementation of AM in the AI in Portugal. Through statistical inference, it was possible to draw conclusions about the identified barriers in the AI sector, as well as the variables that have a direct influence on them.

5.1. Analysis about the Barriers Found

Across this study, 'Financial', 'Organizational', 'Knowledge and technology', and 'Institutional' were identified as the main categories of barriers in AM implementation. These results are in line with what is mentioned in [31] and [33]. However, the 'Market and supply chain' barrier is identified through the performed statistical tests, despite the high level of exportation, and the imposed requirements from OEMs regarding more than 80% of the companies. This corresponds to a high external dependence of the companies on the market and supply chain. The specific variables found to have influence on the implementation of AM in the AI are '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'. These barriers are also identified in other sectors, namely, in the software development industry [32]. Indeed, Vermunt et al. [28], Ghani and Bello [31], and Caldera et al. [33] reference 'Lack of knowledge and skills' as one of the main barriers on the integrated development of the companies in different fronts: lean practices implementation, circular economy, and IT use. On the other hand, 'Organizational' barriers are mainly related to lack of time to implement new methodologies and improper management, which is corroborated by Potdar et al. [29], Caldera et al. [33], and Tan et al. [35], through observations made on the software development industry. Problems related to supply chain are referenced previously by Silva and Gouveia [25], Vermunt et al. [28], and Potdar et al. [29]. Thus, it is observed that some barriers cross different sectors of activity, from software development to the production of components for the automotive industry. However, when detailing the difficulties that each sector refers to as significant, there is a clear difference: while the software development sector needs a strong connection with its stakeholders, understanding their needs and reacting in an agile way, the producers of components for the automotive industry are essentially dependent on their main customer, an original equipment manufacturer (OEM). These OEMs set quality standards, timeframes, and maximum costs, imposing a much more demanding level of restrictions on the producers of components for the automotive industry. This fact limits

the creativity of automotive components manufacturers, and imposes development paces difficult to manage using traditional management technics. Thus, the adoption of agile methodologies would be of great interest for this sector. The difference regarding the relationship between the automotive sector and the software development sector is observed in the work by Ciriello et al. [45], which essentially addresses the relationship between the software industry and its stakeholders. However, beyond the traditional barriers to the agile methodologies already identified in other sectors, the AI needs to overcome other important identified barriers, such as: (a) the difficulty in quantifying the real benefits of the agile implementation; (b) the non-obligation of adoption of these methodologies by the current standards and rules; (c) the rooted culture of conducting the projects in a traditional way; and (d) the type of production. However, because automotive models are changing quickly, agile adoption would help this industry present increased responsiveness in answering the OEM requests. This can be accomplished as shown by what is already conducted by the aircraft repair sector, as described by Freitas et al. [22]. Cultural barriers are something equally common to several sectors, but it is particularly observed in the automotive industry, due to the specificity of standards and technologies involved. In a recent work, Smite et al. [46] mention that the cultural barrier is also felt in offshore projects. In fact, the cultural aspects are very different between these sectors, and there is another crucial difference: software can be distributed digitally, and manufacturing projects usually need complex hardware. This implies an adequate supply chain, as referred by Shashi et al. [47], and the present study also confirms it as a barrier to adopting agile methodologies. However, as argued by Brandl et al. [48], and confirmed in this work, manufacturing includes other barriers not considered in the software industry. In order to standardize the taxonomy used in the designation of barriers identified around agile methodologies, Shameem et al. [49] created five categories. These categories integrate 22 different barriers identified around the software industry, but that same taxonomy left out some barriers from other sectors, namely those discussed in this work.

5.2. Analyzing Possible Enablers

After the analysis of the obtained results, along with the extensive literature review previously performed, some recommendations and enablers were pointed out to overcome the identified barriers and improve the AM effectiveness, in line with the enablers pointed out in [33]. 'Organizational barrier' is influenced by the 'Production type' followed in the manufacturing and, usually, it is not an easy factor to change once it is rooted in the company [50]. However, the differences between the production types bring different advantages, as well as challenges. In the case of batch production, it is a process of higher complexity that requires intense planning, scheduling, and control [51,52]. This complexity, and the constantly changing environment, can create great organizational obstacles. This is particularly true if there is no knowledge, skills, technological capacity, strong level of intercommunication, or tune among the team involved. Hariyani and Mishra [53] study the main organizational barriers and enablers to some manufacturing companies becoming more sustainable. Indeed, some of them fit the results obtained through the survey very well, namely, competence, flexibility, and quickness. Moreover, Ahmed et al. [54] argue that managers must focus on the human capital to allow their organization more flexible and ready to change.

Regarding the 'Companies' degree of change', the best approach to take is adopting APM, since it focuses on agility, adaptation, response to unpredictable changes, continuous improvement, and innovation [11,12]. A recent study by Bottani [55] concludes that the introduction of agile management in companies has a very small number of enablers, and that they vary markedly between different types of industries. Given the results obtained in this work, some enablers are identified. However, the number of barriers encountered is substantially higher, and more difficult to overcome. It is necessary for industries usually characterized by intrinsic rigid, predictable, and stable architectures to rapidly adapt to the new requirements of society and constantly changing environments.

Another identified barrier is 'Improper competency management', having influence on both the 'Organizational' and 'Knowledge and technological' aspects. This is in line with the conclusions obtained by Potdar et al. [29]. Building closer relationships, such as strong management support, is crucial to prevent a lack of management involvement, and encourage education and training. This guarantees a skilled and competent staff, with a clear understanding of the agile objectives from a knowledge and technological perspective, as pointed out in [33]. Additionally, Sarangee et al. [55] reference organizational issues and technological knowledge as barriers in the development of new products in universities. This means that both in services and industry, these barriers are identified as some of the main factors affecting the implementation of agile methodologies. In the study performed by Loiro et al. [56], addressing the APM use in manufacturing, the deployment of a team to deal with APM (AGILE team) and a communicational workflow is proposed, 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' points of view. Firstly, because this team oversees complex organizational communications, such as a customer making a request until it is successfully approved, this drastically improving the organizational dynamism. Then, the required knowledge for APM implementation resides in a skilled team with different persons assuming different roles, being uniquely dedicated to this process.

Perhaps one of the most difficult barriers to overcome is the 'Institutional' aspect. In fact, it entails a predisposition to change, no obligation thinking, resistance from society, and aversion to change. This factor is also pointed out in the work developed by Vermunt et al. [28], and by Gonçalves et al. [57]. It is vital that companies, and all people involved, show willingness to adopt AM, embracing a friendly, agile organization, and a team environment philosophy with ambition and motivation. This cultural change is mandatory to increase the liveliness of companies.

Regarding the 'Financial' aspect, there is no formula to realize the economic advantages of adopting AM. Beyond this work, this barrier is pointed out by Vermunt et al. [28]. The authors believe that this barrier is more prone to upsurges in the automotive industry and countries where the productivity is lower, because the business yield is usually reduced. These facts constraint the use of a company's own financial resources to support agile transition, even when agile methodologies bring back the investment needed in a reduced period. Indeed, the APM intends to reduce the impact of unpredictable changes, improve time-to-market, respond and adapt to complexity, and focus on customer satisfaction. These factors help to bring back the initial investment necessary for staff education and training, as well as all the psychological and organizational changes required.

5.3. Flowchart

Thus, considering all these recommendations and enablers, it was possible to sequence and represent them in a flowchart, having an effective AM implementation as the outcome. Initially, and to overcome the 'Institutional' barrier, it is vital that the company and all people 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 is achieved, as represented in Figure 8.
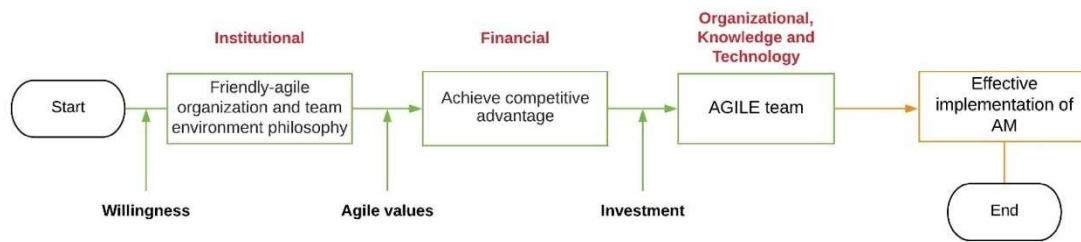
Figure 8. Flowchart to improve AM implementation effectiveness.

6. Conclusions

This study intended to identify barriers in AM implementation in the AI, after this gap was identified in the literature. The approach follows the proposal described by Sandberg and Alvesson [58].

First, intense bibliographic research was carried out in order to identify possible barriers previously identified in the implementation of agile methodologies in other sectors, such as software development. Based on these initial data, a survey was prepared, which was validated by experts in this field. The survey was distributed to 148 companies, with 56 valid responses. The results were compiled and treated statistically, incorporating descriptive statistics and statistical inference. The generic data obtained from the responses collected allowed us to understand that:

- 'Companies' degree of change' has a direct relation to AM implementation;
- 'High levels of change in the products' induce the need to adopt AM;
- Just 9% of the companies have no interest in implementing APM, and 70% are already applying agile methods;
- Most of respondents do not have skills in APM; their qualifications may be enough to apply agile tools, but insufficient to apply a fully agile approach;
- The main identified barriers are 'Organizational culture' and 'Knowledge and technology', and 61% of respondents state that the main barriers' source is solely internal;
- 'Organizational', and 'Knowledge and technology' barriers in the AI were identified due to the 'Improper competency management' factor;
- 'Lack of management involvement' seems to be a problem. The same factor is related to the 'Knowledge and technology' barrier, showing a lack in managers' skills;
- 'Change predisposition', and its correlation with the 'No obligation' barrier act as 'Institutional' barriers for the AM implementation;
- 'Lack of financial support' does not seem to be a barrier, however, a relation between the 'Absence of immediate quantifiable benefits' and 'Lack of financial support' barriers is established;
- A total of 90% of the respondents pointed out two barriers not included in the questionnaire: 'Certification procedures' and 'Lack of collective motivation';
- They also consider that the main enablers for AM implementation are 'Organizational support' and 'Investment in training'.

Based on these data and regarding the research questions pointed out, it was possible to draw the following conclusions:

- Do the AI companies need to implement AM? It became clear that the type of production followed by the AI requires agile methodologies to respond in due time to market requests. There is a constant modification and updating of products, requiring greater flexibility and reaction speed on the part of automotive component manufacturers. Thus, AM could significantly contribute to reducing the time needed to introduce products into the market and improve the dialogue between stakeholders. With these improvements, the efficiency of the processes improves, reducing costs and avoiding waste in terms of time and consumption of natural resources. This increases the sustainability of the processes.

- Are the AI companies predisposed to AM? Yes, companies are willing to adopt AM, but there is still some lack of preparation in both top and middle management, in order to facilitate an effective implementation of AM. However, the preparation in terms of skills still seems to be insufficient, and it is still possible to perceive that companies wait for governmental financial support (targeted support programs). This minimizes the investment necessary for the adoption of AM practices.
- What are the main barriers for implementing AM in the AI? 'Organizational culture' and 'Knowledge and technology' are identified as the main barriers. To understand this result, it is necessary to know that most Portuguese companies in the sector are of family origin, and that there is a considerable deficit of training in engineering and management in many companies. Due to international competitiveness and the need to impose themselves on the market, most companies significantly improved this aspect, but it appears that there are still some gaps.
- What are the main enablers for implementing AM in the AI? Based on the previous topic, it is not surprising that the main enablers focus on 'Organizational support' and 'Investment in training'. The organizational structure of the companies still shows a lack of training in the area of management and, despite the mandatory training of employees in a certain percentage of their annual working time, this training is still not strategically programmed or directed to some aspects, such as the adoption of AM. Indeed, the implementation of AM is not yet a priority for companies.

The framework developed will certainly facilitate the adoption of AM practices in companies in this sector, and the same can be adopted in other sectors presenting similar characteristics.

The realization of this work, and the conclusions drawn, show a real picture of the current situation in a European country about the implementation of AM in the field of the automotive components manufacturing. Project management in the automotive industry is a constant, but the introduction of agile methodologies is still scarce. Although there are numerous studies on sustainability in the automotive area, none, so far, have addressed how sustainability can be improved in this sector through the adoption of agile methodologies. This is the main novelty of this work, leaving open future topics for research, and allowing the extension of the scope of this work to other countries, taking into account the specificity of the automotive industry. As lines for further investigation, the following topics can be considered:

- What are the barriers and enablers related to other important Portuguese industries, such as the cork industry and the textile industry?
- Are there similarities between the barriers and enablers found within the Portuguese AI compared to other European countries? What about other industrialized countries on other continents?
- Can the developed framework be applied in other types of Portuguese, European, or world industries?
- How will this situation evolve over time?

It is hoped that this study is read and understood by political and industrial decision-makers, and they realize that the sustainability they are looking for, in economic, social, and environmental terms, can be achieved more quickly and effectively if the key barriers are quickly overcome, and priority is given to identified enablers. Since there is no study in this area and in this country, it is a pioneering study, which can now be replicated in other European countries, or in other regions of the world, allowing a comparison between different realities and approaches.

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