NOVA SCHOOL OF SCIENCE & TECHNOLOGY

DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING

EVANDER FERRAMENTA AFONSO

Undergraduate in Engineering Sciences and Industrial Management

EXPLORATORY STUDY ON AGILE (IN) MANUFACTURING, OPERATIONS AND CONTINUOUS IMPROVEMENT MANAGEMENT

INTEGRATED MASTER IN INDUSTRIAL ENGINEERING AND MANAGEMENT

NOVA University Lisbon

March, 2024

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ABSTRACT

Organisations nowadays are intensively adopting new technologies, due to the competition keeping up with digitalization and industry 4.0, values as sustainability and agility are becoming determinant factors in a organization success leading to new project and operations management approaches. This is essential to navigate the dynamic market conditions driven by a sustained demand for customized and high-quality products. To meet these challenges, there is a growing need for production systems to demonstrate flexibility, agility, and rapid responsiveness, qualities that align well with the potential benefits offered by agile practices.

This dissertation reviews agile approaches that might be incorporated in productive systems, in their operations and continuous improvement, the advantages and challenges associated as well as how it is being applied by conducting a scoping review supported by PRISMA model for reporting systematic literature review. From the results obtained, approaches such as DevOps, SAFe and Scrum, integrated with other methodologies like Lean (VSM, Kanban, and Kaizen), Digital Twins and Cyber-Physical Systems were identified as the most interesting to be used in productive systems to facilitate continuous improvement efforts, enhancing communication, delivery predictability and flexibility, while the main challenges were strict organizations and low standardization.

Following previous surveys and in order to execute a comparison analysis a new survey was developed to assess and confirm the current utilization and application of Agile methodologies in productive systems and continuous improvement initiatives, finding that hybrid approaches and digital technologies are being implemented within Information Systems and Business & Organization Change Projects while across industries there's a need for tailored agile approaches to meet evolving operations and project management needs and trends.

Keywords: Agile, Agile Manufacturing, Continuous improvement, Project Management, Surveys

RESUMO

Atualmente, as organizações estão a adotar novas tecnologias relacionadas com a digitalização e a indústria 4.0, devido a competição, valores como a sustentabilidade e agilidade tornaram-se fatores determinantes para sucesso de uma organização impulsionando novas abordagens de gestão de projetos e operações. Superar estes desafios requer que os sistemas produtivos demonstrem flexibilidade, capacidade de resposta rápida e agilidade, potenciais benefícios de práticas agile.

Esta dissertação analisa as abordagens agile que poderiam ser incorporadas em sistemas produtivos, nas suas operações e na melhoria contínua, as vantagens e desafios associados, bem como a forma como estão a ser aplicadas, recorrendo a uma revisão sistemática da literatura. A partir dos resultados obtidos, abordagens como DevOps, SAFe e Scrum, integradas com outras metodologias como Lean, Digital Twins e Sistemas Ciber-Físicos foram identificadas como as mais interessantes a serem utilizadas em sistemas produtivos para facilitar esforços de melhoria contínua, melhorando a comunicação, a previsibilidade de entrega e a flexibilidade, enquanto os principais desafios foram rigidez de organizações e a pouca normalização.

Dando continuidade a questionários anteriores e de forma a realizar uma análise comparativa, foi desenvolvido um novo questionário para avaliar e averiguar a atual utilização e aplicação de metodologias Agile em sistemas produtivos e iniciativas de melhoria contínua, constatando a utilização de abordagens híbridas e tecnologias digitais, nomeadamente em Sistemas de Informação e Projetos de Mudança de Negócio e Organização, enquanto nas restantes indústrias há uma necessidade de abordagens agile adaptadas para atender a evolução das operações e tendências de gestão de projetos.

Palavras chave: Agile, Agile Manufacturing, Melhoria contínua, Gestão de projetos, Questionários

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ACRONYMS

AM	Agile Manufacturing
ASD	Adaptive Software Development
CPPS	Cyber-Physical Production Systems
CPS	Cyber-physical systems
DSDM	Dynamic Systems Development Method
FDD	Feature-Driven Development
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
LeSS	Large-scale Scrum
LM	Lean manufacturing
PMBOK	Project Management Body of Knowledge
PMO	Project Management Office
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SAFe	Scaled Agile Framework
VSM	Value Stream Mapping
WOS	Web of Science
XP	Extreme Programming

1

INTRODUCTION

In this chapter an Introductory note will be given on the research context, the background and motivations under the theme of the dissertation, as well as the scope, objectives, methodology, and finally the structure of the dissertation Is to be explained.

1.1 Background and motivation

The actual market climate pressure is applied to all supply chain in manufacturing Industries such as the demand from customers, vendors and states (Logeshwaran & Nachiappan, 2022) that is becoming more and more instable Is forcing the manufacturing sector to adopt more flexible, personalised and reconfigurable systems that can adapt to different requests during the life cycle of the product in order to respond successfully to this and others challenges (e.g product complexity) (Ugarte Querejeta et al., 2020). So, most Stakeholders feel the need to update and improve the manufacturing Industries status to meet their expectation in terms of sustainability and quality (Paranitharan K.P et al., 2017). This need opens the door to new technologies and approaches like Digitalisation and Industry 4.0, which transforms the manufacturing process using automation into an intelligent and digital system and also helps improve efficiency and effectiveness, as well decreasing the development time and costs (Ugarte Querejeta et al., 2020). Industry 4.0, often referred as the 4th Revolution in Industry, is a paradigm that adopts innovative and disruptive technologies, including autonomous vehicles and the Internet of Things (IoT), using the IoT, a physical space such as a factory or warehouse can be transformed into a cyber-physical system that integrates people, processes, and technologies, the success of this integration requires managers to motivate and engage their employees to embrace the new operational models (Vlachos et al., 2023).

The pursuit of Industry 4.0 technological advances is nowadays is considered a key factor in the survival in today's manufacturing environment as they offer brand new chances to increase competitiveness via optimization of cost, service levels, quality, and flexibility (Fatorachian & Kazemi, 2018). Using industry 4.0 technology and cost reduction might not be enough for a manufacturing company reach its full potential, to stay competitive during

the entire product lifecycle, a company needs to be both flexible and cost-efficient (Pozzi et al., 2023). Focusing more on the flexibility and the ability that a manufacturing company has to respond to abrupt changes in the supply chain, economy and customer demand are two main goals in agile manufacturing from mass production to Engineering To Order manufacturing organizations.

So manufacturers in today's market need desperately to update their operations and manufacturing practices to support product development and management continuous improvement efforts to deal with the current market dynamics and level of competition on increasing constant demand aligned with highly customized and high-quality products demanding for higher levels of productions systems flexibility, agility and a quick response from the manufacturer side, which agile practices on manufacturing systems has the potential to support and fulfil.

1.2 Scope and Objectives

This study is of exploratory research nature on organizations regarding their agile perspectives and approaches for manufacturing systems in operations and continuous improvement management projects considering two main types of projects (product development and continuous improvement actions and operations) which are frequent in manufacturing environments. Current available data from one published first survey results were also used to discuss current and future detected insights and trends. Qualitative and quantitative techniques were used for bibliometric and survey results analysis.

The dissertation objectives can be retrieved considering the following research questions: RQ1: How Agile approaches are being adopted in productive systems related to continuous improvement? RQ2: Which Agile approaches are being adopted in productive systems associated with continuous improvement? RQ3: What are the impacts of adopting Agile approaches?

1.3 Research Methodology

To start the study a brief topic search was made mostly on dissertations from the Department of Mechanical and Industrial Engineering of NOVA SST find key orders and in in order to contextualize the use of agile in non-IT environments, more specifically in manufacturing, then with the relevant terms identified. A Scoping Review was executed following PRISMA approach (Page et al., 2021). With the information gathered from the results of the scoping review and the knowledge retrieved from a previous dissertation from DEMI a Survey to update which Agile approaches are being adopted in manufacturing environments in Portugal was used and published on drive platform for organisations to respond. Finally, after collecting the survey results the data was analysed and discussed with the purpose of extracting valuable insights. In the **Erro! A origem da referência não foi encontrada.** is pre-

sented the diagram with the methodology for the project describing the five steps executed during the study.

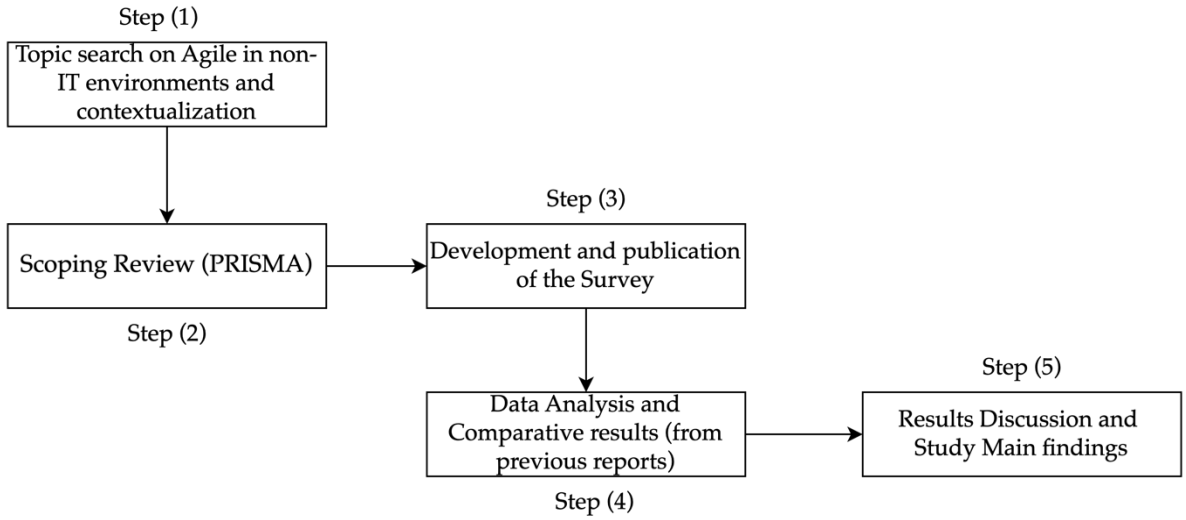

Figure 1.1 - Dissertation Methodology

In the first phase was developed within a Scoping Review approach in order to identify current knowledge and reported uses of agile in manufacturing systems as well as to identify current main agile paradigms associated with manufacturing operations, continuous improvement projects and management approach that can be associated with current agile tools and frameworks. The second phase consists of designing a survey to address what agile practices are being implemented to support productive systems manufacturing efforts, brought benefits and current gaps and challenges.

The first step (1) consisted in doing a quick search on Nova University Repository (RUN) and Production Planning & Control Journal to contextualize the study background and gather insight on previous works done related to Agile at the Department of Mechanical and Industrial Engineering of NOVA SST, the dissertation *An Essay On Agile Project Management Practices* by Gouveia, (2015). was selected because it assessed the possibility of implementation of agile approaches in non-IT environments. The theme is highly relevant for this study so questions from Gouveia survey were also used in step (3), on the survey of this study to also compare the results and evaluate the tendencies.

After this first contextualization of the subject and also definition of the research questions, in step (2) a Scoping Review On Agile In Manufacturing was conducted.

The third step (3) a questionnaire for manufacturing companies was designed, primarily to address what agile practices are being implemented the benefits and current challenges, using and adapting previous surveys questions and creating new ones based on the takes from the literature review.

In step (4) a qualitative and quantitative techniques were used for bibliometric and survey result analysis.

Finally, the fifth step (5), the analysis and discussion of questionnaire results were carried out in comparison to previous questionnaires and whether they are in line with current knowledge and practices identified in the scoping review.

1.4 Dissertation Report Structure

The present dissertation is organised in 5 sections. First, the Introduction where presentes part of the actual tendencies in manufacturing and defined the objectives of the dissertation , why there's a need for the exploratory study and how it will be executed.

The second chapter, the Scoping Review, aimed to understand the agile methods and approaches more suitable for productive systems (manufacturing and operations) and their continuous improvement management. It starts with a general view of Agile, followed by the meaning of the agile Manufacturing term over the years and finishing with advantages, challenges and normatives that are being associated with agile.

The third chapter described the development of the survey to access organizations on their current application of agile approaches or whether they would consider implementing agile. This survey is composed by 6 sections: Organization, Project and Improvement Actions Management, Organisation Practices, Implementation Of Agile Practices, Organisation Agile Practices and the final section Participant. The pre-test and the proposed analysis method is also exposed.

On the fourth chapter the results of two previous surveys were presented and discussed with the findings of the scoping review.

Finally the last chapter, the main conclusions of the study were summarized mentioning the agile practices related to productive systems and their impacts and the identification of the limitations of the research and finally suggestion for future work.

2

SCOPING REVIEW ON AGILE IN MANUFACTURING

A scoping review was conducted using the Preferred Reporting Items for Scoping Reviews and Meta-Analyses (PRISMA) guidelines aiming to respond RQ1. The search engines (Scopus and Web of Science) were consulted to find papers, books and journals relative to RQ1. The search was made during April and May of 2023, the publications considered were recent (from the past 10 years 2013-2023) and had the abstract, title or keywords related to Agile Manufacturing. The keywords applied in the searches were:

- "Agile Manufacturing", "Agile manufacturing" AND ("continuous improvement" OR kaizen) ",
- "agile" AND "adaptive project management",
- "Agile" AND "Project Management" AND "impacts" AND "ISO Standards"

The records' title, keywords, abstract, authors' names and publication year were transferred into a Excel file. As the only reviewer the abstracts and titles of the records and papers that were screened and the ones that were not related to agile in manufacturing environments related to continuous improvement, some lean related papers were also considered relevant as this approach has a relation to agile and obviously continuous improvement. All the information collected was analysed and filtered, so that the crucial was mentioned in the scoping review. The PRISMA diagram for the agile manufacturing search string can be found in the Figure 2.1.

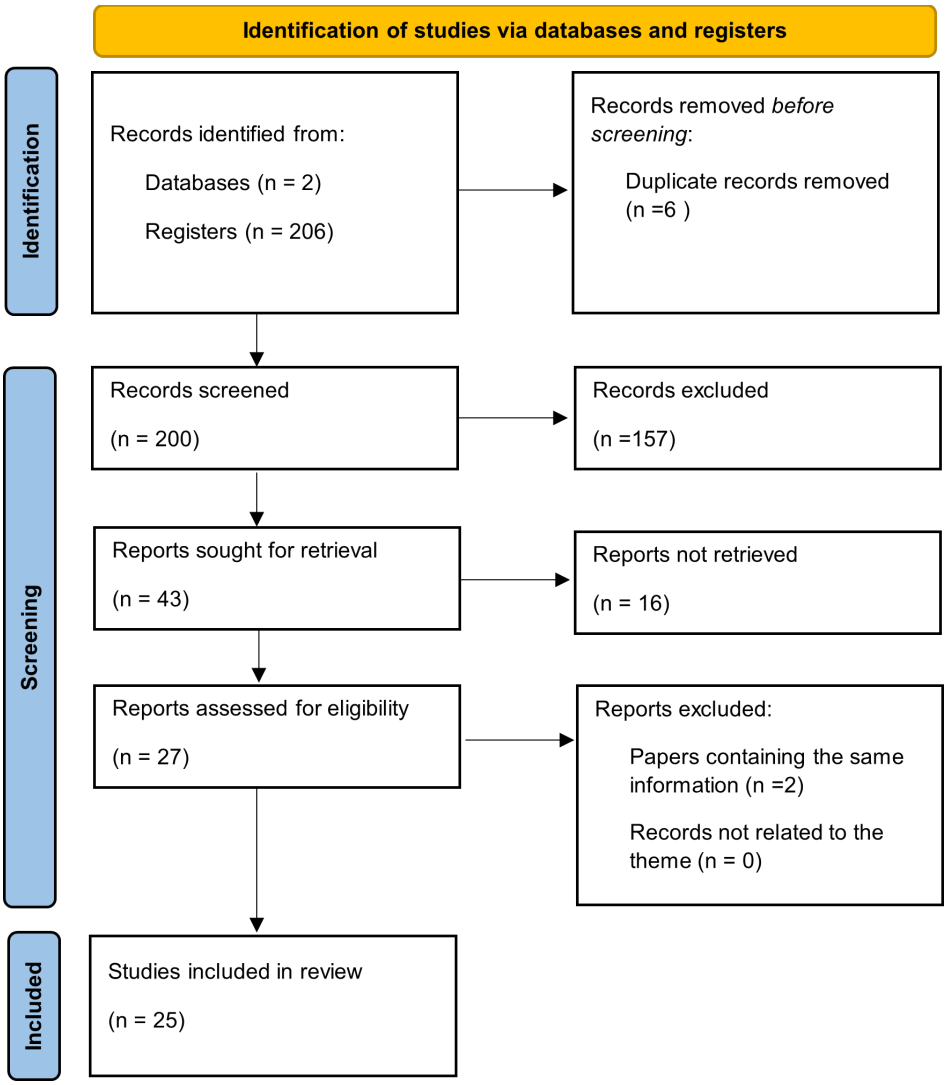

Figure 2.1 - PRISMA flow diagram (adapted from Page et al., 2021,)

VOSviewer was used to perform a keyword analysis. All keywords from the 200 articles were identiffied and VOSviewer generated 1551 keywords. The minimum occurrence of each keyword was set to 10, leaving 37 keywords. Figure 2.2 shows the keyword co-occurrence graph with 4 clusters agile manufacturing systems, lean production, continuous improvements, agile manufacturing and manufacture.

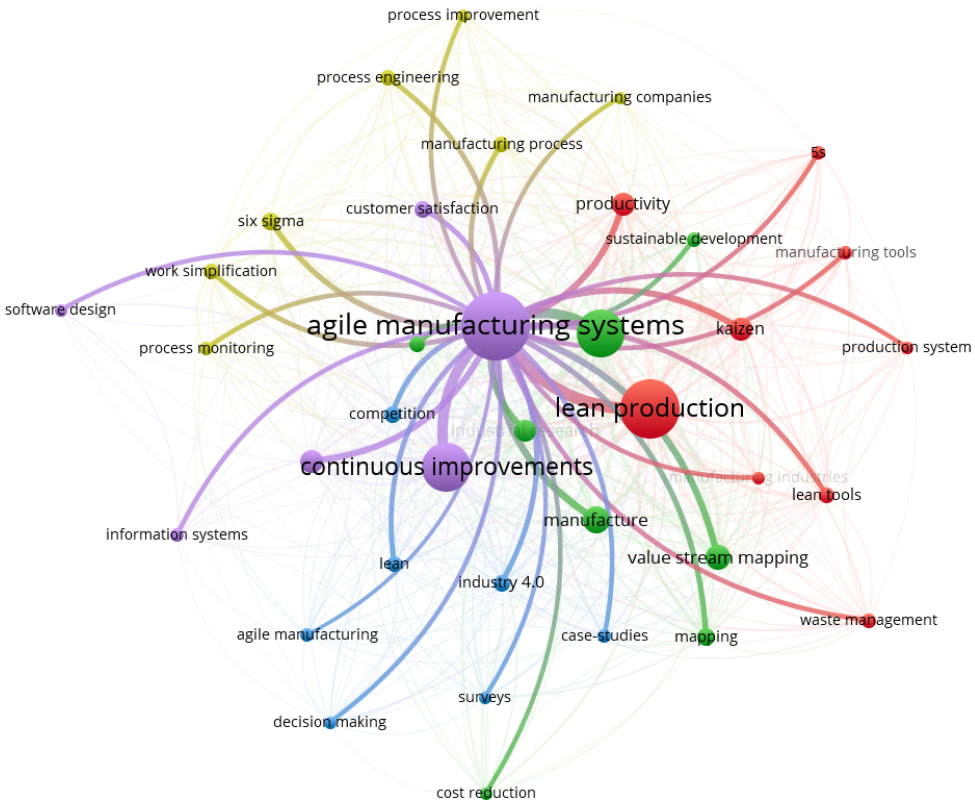

Figure 2.2 - Keyword co-occurrence graph

The process of manufacturing is a crucial strategic activity for any organisation, which encompasses both goods and services aimed at serving the general public. By adding value to raw materials and services, it serves as the foundation of an organisation's economy. As a creative and essential process, manufacturing is driven by a specific objective (Logeshwaran & Nachiappan, 2022).

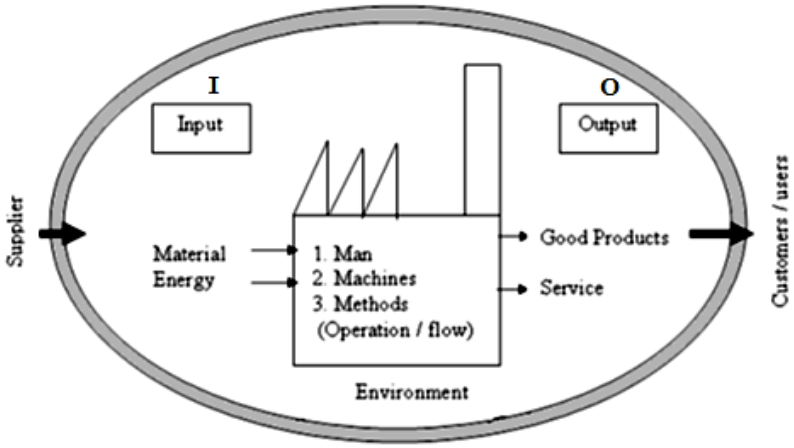

Figure 2.3 - Modules of fundamental manufacturing system (Logeshwaran & Nachiappan, 2022, pp. 26)

In a very simple and resumed Illustration as Figure 2.3. shows, raw materials normally acquired from a supplier and with energy involved presents the Inputs(I) of the process that after the transformation using the components man, machine and methods (all being a part of the operating environment) an output(O) Is generated and It can be a product or service normally for a customer (Logeshwaran & Nachiappan, 2022). The manufacturing segment has been acquiring modern and advanced technologies with the intent to respond to the actual demanding and very volatile market (Mundra et al., 2021), for example, Cyber-physical systems (CPS) that fuse technology and digital elements, enabling interaction between users and systems, opening new avenues for technology management(Robayo et al., 2023). This fusion integrates traditional physical layers with new CPS aspects. In manufacturing, Cyber-Physical Production Systems (CPPS) interconnect various CPS to operate autonomously and collaboratively. CPPS, as outlined by Ugarte Querejeta et al., (2020), must meet specific objectives: timely responses to system and environmental changes, intelligent behavior of CPPS components, and seamless connectivity among different elements, sub-systems, services, and other systems.

In 2001, the term Agile was linked to a set of techniques called "Agile methods". These methods are characterized by a strong partnership between the customer and the development team, regular delivery of the business value, and self-managed teams (Zaouali & Ghannouchi, 2016). On the other hand, Agile Manufacturing (AM) was already referenced in 1999 (Gunasekaran, 1999) and concentrates on creating a production system that can swiftly adjust between different models of products or lines based on real-time feedback from the

customer regarding product type and volume. The concept introduced, addressing the contemporary approach to enhance organizational performance and meet the demands of 21st-century manufacturing competitiveness. This pioneering work identified and outlined the key tactics and technologies compatible with the principles of agile manufacturing (Patel & Brahmbhatt, 2021).

Information and communication technologies play a vital role in modelling Agile Manufacturing, as they enable Industry 4.0 (Ding et al., 2021). The main goal of this scoping review is to evaluate and gather information on Agile methods being used in manufacturing contexts more specifically in continuous improvement-related processes and operations. Also compare the terminology Agile methods from the agile manifesto (2001) and the term Agile manufacturing, if they are related and how.

2.1 Introduction of Agile

Agile is a software development methodology that emphasises continuous improvement in product or service development using short development cycles (Salehi, 2019). Agile organises the process of development, emphasising constant and straightforward communication, frequent engagement with the customer during the development cycle, short iterations, constant deliveries of software increments and a capable response to change rather than avoid it (Myklebust et al., 2020). Nowadays, Agile is widely used by organisations as it presents itself as a adaptive and strong substitute for the former rigid software development methodologies as Waterfall approach (Zorzetti et al., 2021).

Agile, which is a value-driven methodology, is widely known for its frameworks like Scrum and Kanban, primarily in software development but increasingly being applied to other areas in a modified manner. Unlike the plan-oriented approach, Agile emphasizes people-oriented teamwork, where hierarchies play a less important role, and cooperation is carried out on an equal footing to achieve common success (Looks, 2022). Scrum and XP are agile team approaches, whereas Kanban is applicable to both team and large organizations. For synchronization of multiple teams in large organisations, Large-scale Scrum (LeSS), Scaled Agile Framework (SAFe), Nexus and Scrum@Scale approaches are used, and there are many other variants like Disciplined Agile Delivery (DAD) or Agile Modeling (Poth et al., 2019) . The primary objective of transitioning to Agile is to increase the delivery speed, team autonomy, and flexibility to respond customer demands and survive dynamic markets (Poth et al., 2019).

According to Poth et al. (2019), the transition process comprises four distinct steps as:

- Preparation: This initial step involves evaluating the team and product setting. It encompasses activities such as conducting a kick off workshop, seeking consultation from project leads and the development team, and establishing an agile workflow.
- Implementation of Methods and Tooling: In this phase, the coaches take on the role of training the team members and various roles like Scrum Master and Product Owner, ensuring that they are equipped to carry out their respective tasks effectively. The

guide also facilitates crucial meetings, including reviews, daily stand-ups, retrospectives, planning sessions, and refinements.

- Stabilization: Coaches remain consistently available to offer support and assistance. In specific instances, they might also take on the role of moderators. This step involves motivating the team, inspecting ongoing progress, adapting strategies as needed, and reinforcing the changes to ensure their lasting impact.
- Consulting: If the client requires assistance, the coaches are ready to provide guidance and answers related to events, roles, and workflow. Additionally, the guides play a pivotal role in aiding change management, managing conflicts, and facilitating the adoption of innovative practices.

2.1.1 Agile main frameworks

The key approaches or frameworks identified in the scoping review that are more associated with manufacturing, product development and cyber-physical systems are Scrum, DevOps and SafeScrum. Design Thinking is also a method used by some agile practitioners that is also widely mentioned in the papers analysed.

- **SCRUM**

Besides Scrum original indication for software development projects, the framework is simple and works well for other innovative or complex areas (Zaouali & Ghannouchi, 2016). Overall, Scrum is an agile framework for work management which supports project management improvement and practices for complex products development and preservation. It is formulated for teams of three to nine developers who divide their tasks into manageable iterations known as sprints. Progress is monitored and adjustments are made through concise 15-minute stand-up meetings called daily scrums. In larger organizations, various approaches are employed to coordinate multiple scrum teams, including LeSS, SAFe, scrum of scrums, and Scrum@Scale (Salehi, 2019) .

Scrum relies on a self-managing, multidisciplinary team. Within Scrum, there is no single team leader who assigns tasks or dictates problem-solving approaches. Instead, these matters are collectively decided by all the team. Three vital roles exist in Scrum: the product owner, the Scrum master and the Scrum team members. The creation and prioritization of a product backlog is under the responsibility of the product owner. Teams chose items from the product backlog and select the most suitable approach to complete the tasks. The work is to be finalized in a designated sprint. The Scrum master holds brief daily meetings with the teams to receive progress updates. Sprint reviews are carried out at the sprint ending. The procedure, presented in Figure 2.4, then restarts until all work or backlog items are successfully accomplished (Salehi, 2019).

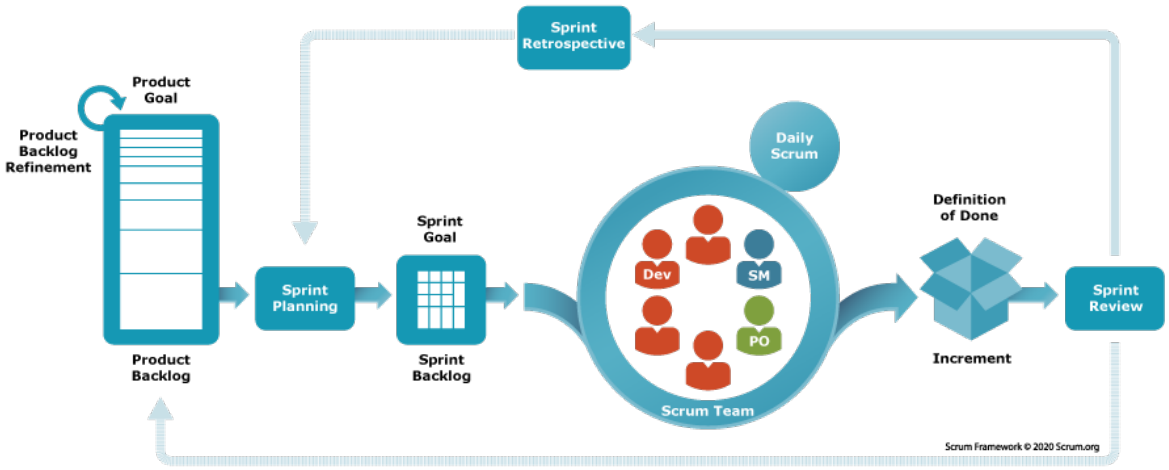

Figure 2.4 - Scrum process (Scrum.org)

Zaouali & Ghannouchi, (2016) describes Scrum as structured by three main aspects, team, artefacts and the meetings:

a) Scrum Team

A Scrum team contains three fundamental roles:

- The Product Owner

  Carries all the responsibility of the Product Backlog by himself, only him can define the User Stories, rank them and describe them to the team. He is the representative of the expected users for the team.

- The Scrum Master

  Pivot point of the framework as he to guarantee the commitment of the team towards Scrum's rules and practices and also facilitate and protect the team and goal from external setbacks that might put the progress in risk.

- The development team

  The primary purpose of this team is to facilitate the progress of User Stories listed in the Sprint Backlog throughout a Sprint. Comprising individuals with essential skills such as analysts, designers, programmers, and more, its size typically ranges from 5 to 6 members. The distinguishing feature of this team lies in its self-organizing nature (the autonomy to make decisions regarding "what to do?" and "how to do it?").

b) Scrum Artefacts

Scrum has three main artefacts:

1) The Product Backlog:

Contains all the information and requirements in User Stories defined by the Product Owner. Due to the changes of requirements during the project, this artefact is dynamic, and rectifications and improvements are applied. User Stories are ranked and estimated correspondingly to the value it adds for the user, its Business Value.

2) The Sprint Backlog:

It comprises a compilation of User Stories extracted from the Product Backlog to be addressed during the Sprint, with each User Story further broken down into a set of tasks. In practical terms, this information is visualized through a table affixed to the wall, featuring four columns. Post-it notes are used to document the 'User Story' column, which contains the list of User Stories, the 'To Do' column, corresponding to the tasks for each User Story, the 'In Progress' column, indicating tasks currently being worked on, and finally, the 'Done' column, listing tasks that have been completed.

3) The Burn Down Chart:

This chart main function is to control the work left to do during a Sprint to prevent as early as possible potential problems.

c) Scrum Meetings

Scrum has the following meetings:

1) Sprint Planning Meeting: Normally takes 4 hours for a 2 week sprint, 8 hours for a one month sprint and it requires the presence of the entire Scrum team. The Product Owner presents and explains the User Stories to the team and then those stories are estimated in effort points using planning techniques like "planning Poker" by the development team members. User Stories previously estimated are added to the Sprint Backlog of the following Sprint. Finally, the User Stories are decomposed in tasks which will be placed in the "To Do" column of the Sprint Backlog.
2) Daily Scrum: During the Sprint, this meeting takes place every day, and the main point is update the Sprint Backlog by the development team moving the tasks to the relevant column and each member updates the rest of the team about what they have done on since the previous meeting, what are they going to do that day and if run into obstacles. At the end of this meeting the Burn Down Chart is updated.
3) The Sprint Review: All the Scrum team, at the ending of a Sprint, meet to adapt the Product Backlog, adding or removing User Stories and evaluate the acquired increment.
4) The Retrospective Sprint: Following the Sprint Review, all the team reunite again to inspect themselves, more related to how the process was developed and plan the next iteration.

- **DEVOPS**

DevOps main goal is to conciliate the software Development (Dev) and Operations (Ops), using the best approaches from each area and fostering teams collaboration. DevOps has three vital principles as described by Ugarte Querejeta et al., (2020) are presented bellow and in Figure 2.5.

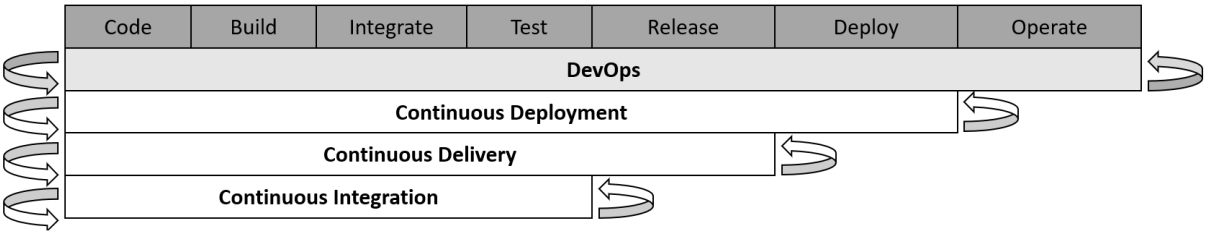

Figure 2.5 - DevOps and software life cycle (Ugarte Querejeta et al., 2020, pp.3)

- Continuous Integration: is a fundamental principle that places significant importance on the ongoing software integration process and the implementation of automated testing. Its primary objective is to identify potential issues swiftly and at an early stage. By doing so, this principle sets the foundation for achieving continuous delivery of software products.
- Continuous delivery: is a strategic approach that seeks to expedite the delivery of new software features, enhancing both speed and frequency of releases. The key focus is to maintain the software in a perpetually releasable state, encouraging the release process to be automatic and to ensure a seamless and continuous flow of updates.
- Continuous Deployment: is often mistaken for Continuous Delivery, but it takes the concept a step further. In Continuous Deployment, every successful change that is committed in the initial phases of the development is automatically deployed to the production environment without manual intervention

DevOps leverages these principles to achieve several advantages, including lowering development costs, reducing time to market and enhancing productivity while ensuring a higher level of quality. It also covers all the software development and operational life cycle, fostering collaboration between development and operations teams (Ugarte Querejeta et al., 2020).

With a focus on rapid IT service delivery, DevOps adopts agile and lean practices within a system-oriented approach. The key emphasis lies in people and culture, as DevOps seeks to enhance collaboration and communication between traditionally separate operations and development teams. In essence, DevOps aligns with the needs and goals of developers, providing an environment that supports their work and facilitates seamless delivery of software solutions. DevOps extends the development team by integrating site operations into the development process. This approach ensures that the system is continually evolving,

benefiting from real-world experience and system monitoring, which in turn contributes to its ongoing improvement (Myklebust et al., 2020).

Transitioning to DevOps necessitates a cultural and mindset shift. At its core, DevOps aims to break down the barriers that traditionally exist between operations and development teams. In certain organisations, there might not exist distinct operations and development teams, as engineers handle the two responsibilities. In a DevOps environment, these teams collaborate closely to ensure the reliability of operations and enhance the productivity of developers. The ultimate goal is to create a seamless and efficient workflow that fosters continuous improvement and delivers high-quality software products (Salehi, 2019).

- **SAFESCRUM**

SafeScrum builds upon the Scrum process framework known for its incremental and iterative development approach, widely adopted as the standard model for numerous industrial software engineering projects. To align with safety standards, especially the generic IEC 61508:2010, SafeScrum introduces supplementary activities and roles, including a QA-role responsible for ensuring adherence to relevant safety standards in all process steps and documentation using a reliability, availability, maintainability, and safety (RAMS) validation and an assessor facilitating dialogue. These additional elements are designed to ensure compliance with safety requirements and address the specific needs of safety-critical software development projects. By incorporating these modifications, SafeScrum aims to provide a framework that not only maintains the benefits of Scrum but also meets the necessary safety standards and guidelines (Myklebust et al., 2020).

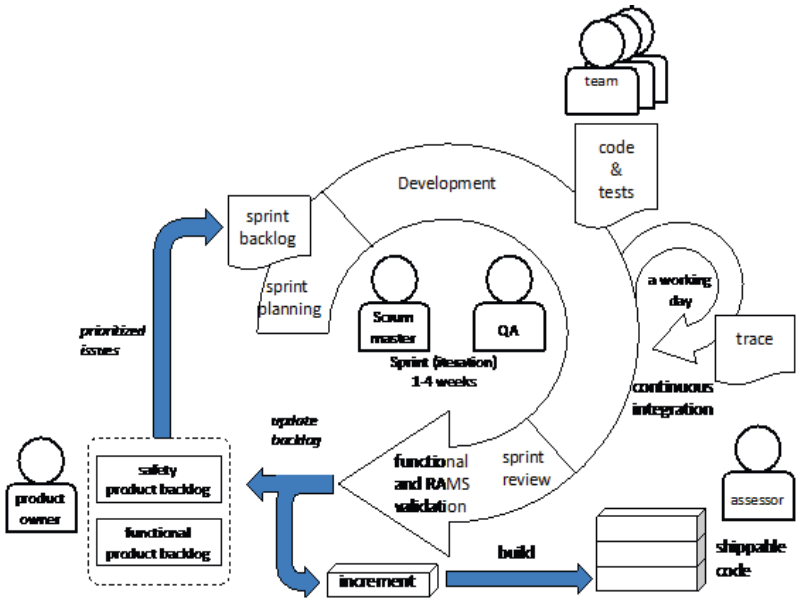

Figure 2.6 - SafeScrum process (Myklebust et al., 2020, pp.273)

2.1.2 Agile vs Lean

Numerous software organizations employ Agile methodologies in their software development processes, recognizing the advantages they bring for process improvement. Additionally, Lean software development is also a popular approach used to improve the development processes, primarily focusing on waste reduction to enhance the efficiency of all activities and eliminate inefficiencies (Kišš & Rossi, 2018). Lean management could potentially be a precursor to Agile Manufacturing (AM). AM is characterized as a combination of lean production and flexible manufacturing (Mohaghegh et al., 2021). In the literature, the positive influence of both soft and hard lean management practices on AM is very established.

Lean management can be defined as an integrated socio-technical method primarily focused on eliminating both internal, related to production, and external, related to customer and supplier wastes. Focusing solely on "hard" and practices related to production, such as set-up time reduction, statistical process control and planned maintenance, might prove insufficient for achieving long-term success (Mohaghegh et al., 2021). The primary objective of the lean concept is to optimize the workflow of the production process by eliminating waste. Waste refers to any unnecessary activity that does not add value to the final product. Management teams concentrate on identifying and removing waste from the production system to streamline operations and improve efficiency. In the context of Industry 4.0, technologies play a crucial role in enhancing the effectiveness of lean-based approaches. The implementation of corrective action-based systems with the help of Industry 4.0 technologies further supports waste reduction and continuous improvement efforts (Tripathi et al., 2021). Lean management also highlights the importance of both retrograde coordination with suppliers through partnerships and progressive coordination with customers via their active involvement (Mohaghegh et al., 2021).

An effective manufacturing approach for lean management is the Kanban method, which facilitates minimal inventory levels and reduced overall costs, including operational costs, waste reduction, scrap reduction, and minimizing overproduction stocks. These practices encompass formal continuous improvement initiatives, process capability management and quality management programs. Total Productive Maintenance (TPM) serves as a comprehensive maintenance system, addressing waste linked to failures and low equipment availability and using Kanban with flexible workstations to maintain better control over manufacturing processes (Saravanan et al., 2018).

As stated in Mohaghegh et al., (2021), studies present empirical evidence indicating that adopting a Just-in-Time (JIT) purchasing strategy enhances a firm's manufacturing agility and the positive impact of Total Quality Management (TQM) and AM. Just-in-Time (JIT) practices aim to continually eradicate production-related waste, including scrap and excess inventory, by implementing process reengineering, cycle time reduction, lot size reduction, quick changeover and bottleneck removal. Total Quality Management (TQM) emphasizes

practices necessary to enhance and sustain product and process quality, meeting and surpassing customer expectations. Value Stream Mapping (VSM) stands as a prominent process optimization approach in today's scenario, proving to be highly effective in enhancing operational performance. By eliminating Non-Value-Adding Activities present in shop floor management, VSM contributes to productivity improvements. Several parameters are employed to analyse production conditions within VSM, including total cycle time, total uptime, working time, available time, downtime, number of workers, production per day, number of shifts, total changeover time, total idle time, and Non-Value-Adding Time. Through careful examination of these parameters, organizations can identify inefficiencies and implement targeted improvements to streamline their processes and achieve better operational outcomes.

In the context of achieving sustainable outcomes, three higher-order capabilities are recognized and conceptualized as "lean-related Dynamic Capabilities" (DCs):

- Agile manufacturing (AM)
- Systematic problem-solving (SPS)
- Continuous improvement (CI)

These capabilities are viewed as regular progressions of lean management practices, designed to bring about changes in existing routines. Dynamic Capabilities (DCs) are defined as a stable and learned patterns of collective activity within an organization. Through these DCs, the organization systematically creates and adjust its operational routines, all with the aim of improving overall effectiveness. Demonstrations reveal that lean management and AM complement each other as mutually supportive paradigms, with leanness serving as a precursor to agility. In fact, various lean practices can be essential elements for enhancing a firm's change proficiency, thereby recognizing them as critical enablers of agile manufacturing (Mohaghegh et al., 2021).

Lean Manufacturing is widely recognized as a management philosophy that enhances customer value by eliminating waste in production systems, leading to superior quality and efficiency. Despite its benefits, some companies struggle to successfully implement lean principles, often due to factors like a lack of leadership commitment or an unsupportive business. The Internet of Things (IoT) has the potential to revolutionize manufacturing in three main ways: automation, digitization, and connectivity. Through IoT, items in a manufacturing space can be connected to create an integrated, cyber-physical environment, fostering seamless operations and enhanced efficiency. In line with lean thinking, complexity is viewed as a form of waste that requires elimination. This can be achieved through carefully designed action plans that simplify processes and interactions among technology, people, and operations (Vlachos et al., 2023). Lean manufacturing (LM) embodies a continuous improvement philosophy, often associated with Kaizen or the Toyota Production System. The core idea behind lean philosophies is to maximize customer value while minimizing waste, thereby increasing the overall value of products (Saravanan et al., 2018).

According to Kišš & Rossi, (2018) the benefits and challenges observed following the implementation of lean principles within an ongoing agile development process are displayed in Table 2.1 and Table 2.2, respectively.

Table 2.1 - Benefits Agile-to-lean based on Kišš & Rossi, (2018)

Benefits	Description
Reduced lead time	Lead time is defined as the total duration from receiving a customer request to the final delivery of the completed work. By minimizing lead times, activities are organized in a continuous and streamlined manner, facilitating smooth and timely deliveries to customers.
Improved flow	The key to enhancing flow is controlling the number of Work-in-Progress (WiP) items. By reducing simultaneous tasks and achieving a lean flow state with constant throughput, the overall flow of work is optimized. Lowering the number of WiP items accelerates the entire process, allowing for the swift implementation and delivery of more features.
Continuous improvement	Enabling each team to self-organize and set their own WiP size fosters a culture of continuous improvement. Daily efforts towards improvement have demonstrated a significant increase in software delivery predictability.
Improved defect fix rate	Lean practices prioritize early detection and resolution of defects, ensuring better quality control from the outset. Continuous integration tools play a vital role in the lean software development paradigm, facilitating effective defect identification and resolution.

Table 2.2 - Challenges Agile-to-lean based on Kišš & Rossi, (2018)

Challenges	Description
Embracing the Lean Mindset	When adopting new ways of working, encountering resistance to change is a common obstacle. An essential principle to uphold in the lean mindset is the reduction of waste. However, identifying what constitutes "true waste" within the organization can be challenging, and eliminating such waste may be even more difficult. While establishing teams and promoting self-organization have been relatively achievable, challenges arise in scaling flexibility and involving business management tasks within the lean approach.
Challenges Related to Iterations	Studies have faced difficulties with coaching, estimates, and pair programming during the development iterations. Team coaches encountered obstacles in ensuring timely and quality delivery of tasks.
Scaling Flexibility	Scaling flexibility, defined as the ease of making changes during the software development process, emerged as a key challenge. In the "agile-to-lean" transition, flexibility needs to permeate the entire value stream, adding complexity compared to pure agile contexts.

The integration of both lean and agile approaches enables companies to achieve a harmonious and effective manufacturing process, aligning with customer demands and achieving quality, cost, and delivery objectives. The adoption of a combination of lean and agile principles can lead to similar outcomes in workforce practices across different organizations, regardless of their size (Paranitharan K.P et al., 2017).

Implementing a centralized agile governance can facilitate the scaling of agile transitions within large enterprises, especially in product and service teams. The effectiveness of this governance structure is contingent upon its alignment with the lean and agile mindset, as it rapidly develops when embraced by the governing body. The primary role of this governance is to support and serve the agile teams, ensuring their compliance with both external and internal requirements. However, finding the right equilibrium between standardized integrated tools and granting sufficient freedom to the agile teams presents a significant challenge. In Agile and Lean environments, each enterprise requires a governance structure to ensure that fundamental tasks are carried out in a reliable manner. Agile and Lean teams need to establish and maintain the state-of-the-art practices for their products and services, ensuring that additional factors, such as market advantages, are considered based on product-specific aspects. External team coaches often deliver this guidance during the coaching phase aligned with the transition kit (Poth et al., 2019).

2.1.3 Agile vs Agility

While agile is a specific methodology that can be implemented within an organization, agility is a more fundamental characteristic of an organization's culture and mindset. An agile organization is one that is able to adapt and pivot quickly in response to changing circumstances, and that values experimentation and learning (Sarangee et al., 2022).
On the other hand, agility is a broader concept that relates to an organization's ability to quickly and efficiently respond to change, uncertainty, and unpredictability in its environment. Agility encompasses not only software development but also other aspects of an organization's operations, such as marketing, finance, and customer service (Walter, 2021)

Agility is more than just a set of predefined practices; it is a mindset that needs to be adapted and integrated into the specific context of each user, making it highly dependent on individual situations. The transition to an agile way of working occurs during the process of agile transformation, wherein agile values are embraced and put into practice. A vital aspect of the Agile mindset is the commitment to continuous improvement, driven by feedback and learning from experiences (Looks et al., 2021). To comprehensively understand agility, six dimensions based on a comparison of agile values with traditional values were identified in Looks, (2022):

- Communicative - Emphasizing direct communication within the development team and with the customer.
- Change-Affine - Acknowledging that in the plan-based approach, changes in requirements may deviate from the initial plan.

- Iterative - Promoting iterative development with periodic re-evaluation of open requirements.
- Self-organized - Encouraging the team to work in a self-organized manner and make decisions independently without a central authority.
- Product-Driven - Prioritizing a strong focus on the product, with consideration for the customer's benefit.
- Improvement-Oriented - Regular retrospectives are conducted to continuously improve the project approach and deliver a product with high customer benefit(Looks et al., 2021).

Each of these dimensions reflects the essence of agility and its impact on various aspects of work and organizational behaviour. By embracing these dimensions, organizations can foster a more agile and adaptive approach to meet the challenges of an ever-changing environment.

2.2 Agile Manufacturing and Enablers

Agile Manufacturing (AM) represents a firm's capacity to swiftly and effectively align its processes, resources and capabilities with the dynamic demands of the marketplace, such as , flexibility, timely delivery, speed and responsiveness. The Catalyst for agility is the recognition that change is a constant factor in business. Consequently, the literature refers AM as "change proficiency." AM emphasizes the importance of sensing, seizing, and reconfiguring capabilities, making it closely related to the concept of Dynamic Capabilities (DC). It involves frequent monitoring of the production setting and external entities within the supply chain, including suppliers, customers and competitors. This monitoring aspect is linked to the sensing ability, which pertains to the organisation's capability to discern future changes, dynamic needs, and recognize promising opportunities worthy of investment (Mohaghegh et al., 2021).

AM positively impacts operational performance, resulting in improved marketing and financial outcomes. A notable aspect of an agile system is its consideration for human conditions, fostering participation and empowering employees to work collaboratively, even without direct supervision from management. This approach builds trust between workers management, cultivates team spirit and thereby can enhance social performance. Furthermore, agile supply chains stimulate collaboration among partners. This collaborative environment allows supply chain partners to execute efficient actions with fewer resources, thereby contributing to a good environmental performance (Mohaghegh et al., 2021). Agile Manufacturing not only benefits operational, marketing, and financial aspects but also embraces human-centred values and facilitates environmental sustainability through effective supply chain collaboration. AM ability to reconfigure and adapt for operation in volatile environments (Mundra et al., 2021).

The main characteristics addressed by De Jesus Pacheco et al., (2020) related to AM refer to the rapid introduction of new and modified products on the market, the dynamic re-

configuration of production processes, quality and highly customised products, among others. It is a production management paradigm that aims to ensure flexibility, speed, quality and efficiency through the integration of technology, skilled human resources and organisation. Agile practices help in achieving quick and efficient response to the introduction of a new product model, as well as in providing capacity to meet unexpected demands (De Jesus Pacheco et al., 2020).

While agile methods initially originated in the realm of software development, the discussion surrounding their applicability to other types of development projects has been gaining momentum in recent years. In particular, there is an increasing focus on integrating agile principles in the development of mechatronic products. However, it's essential to recognize that the boundary conditions differ significantly between software development and mechatronic product development, for instance, concerning the use of virtual versus physical prototypes (Salehi, 2019). In the current business landscape, clients have a growing preference for revolutionary products and models produced in specific volumes. To meet these demands, conventional manufacturing companies are required to adopt AM principles. AM empowers companies to swiftly manufacture customized, exceptional products in varying lot sizes, catering to the unique needs and desires of the modern-day client (Patel & Brahmbhatt, 2021).

To succeed in Agile development, teams have to possess the necessary skills to develop and validate the product. Several approaches, like Design Thinking and Human-Centered Design, involve working closely with users to understand their needs and create systems that are useful, usable, and desirable to humans, focusing on higher levels of human needs. Another important method is Agile Systems Design , a comprehensive and organized methodology for development of mechatronic, validation and production systems using agile, including product strategy consisting of methods, principles and processes of Product Generation Engineering (Salehi, 2019).

Based on the literature review, various enablers that promote AM, displayed in Table 2.3, have been identified.

Table 2.3 - Agile Manufacturing Enablers

Enabler	Description	References
Human Resource Management	Training, development, empowerment, compensation, recognition, Multifunctional Teamwork and focus on roles in an organizational culture	(De Jesus Pacheco et al., 2020), (Kumar Potdar & Routroy, 2018), (Paranitharan K.P et al., 2017)
Adaptability	Ability to respond to predictable and unpredictable conditions.	(Kumar Potdar & Routroy, 2018)
Technology management	Hardware, Information technology, Planning and control systems	(De Jesus Pacheco et al., 2020), (Kumar Potdar & Routroy, 2018), (Paranitharan K.P et al., 2017)
Product and Process Automation	Design, produce parts and develop processes. Implementation of computer-aided-technologies	(Kumar Potdar & Routroy, 2018)
Supply Chain Integration	Integrating the logistics and management through the supply chain	(De Jesus Pacheco et al., 2020), (Kumar Potdar & Routroy, 2018)
Manufacturing Management	Manufacturing planning and control, production methodologies, waste management and concurrent engineering	(De Jesus Pacheco et al., 2020), (Kumar Potdar & Routroy, 2018), (Paranitharan K.P et al., 2017)
Continuous improvement	New methods for ongoing improvements. It helps in reducing the process variability by continuously improving its output	(De Jesus Pacheco et al., 2020), (Paranitharan K.P et al., 2017)
Information system	Better management of internal communication and the rest of partners	(De Jesus Pacheco et al., 2020), (Paranitharan K.P et al., 2017)
Customer Relationship Management	Maintain a growing and sustainable relationship with the customer by satisfying their ever increasing requirements by maintaining appropriate level of responsiveness	(Kumar Potdar & Routroy, 2018)

Within these categories other specific factors play essential roles in facilitating AM, such as Management Responsibility, Collaboration Management, Logistic, Competence, Team Building, Quality, Knowledge-Based System, Cross-Functional Team and Systems Standardization (Paranitharan K.P et al., 2017). These enablers and factors contribute to creating a conducive environment for implementing Agile Manufacturing principles and practices, ensuring improved efficiency and responsiveness in the manufacturing process.

2.3 Impacts on Agile

An agile development process offers several advantages for the development of safety-critical software: Frequent testable results (increments) facilitate continuous testing and validation. Tests and code are developed simultaneously, enabling faster and more efficient progress. Traceability is ensured for both development and quality assurance aspects. For example, the agile safety case is developed in parallel with the software ensuring a more integrated and efficient approach and a learning process that allows ongoing improvement of functional requirements (Myklebust et al., 2020). Transparency enhances communication and collaboration, which can be advantageous during assessment processes, such as in the agile safety case approach and sprint review.

Research indicates that adopting the Agile method improves teamwork among employees. The implementation of Agile as a project management approach in the IT industry has resulted in increased productivity, however, like any project management approach, the success of Agile relies on proper study, application, and suitability to the project's nature, otherwise, it can lead to failure (Issa et al., 2019).

Putta et al. (2021) , conducted an empirical survey assessing the benefits and challenges of adopting an agile methodology. Gathering 100 eligible responses, Figure 2.7 highlights some of the benefits identified.

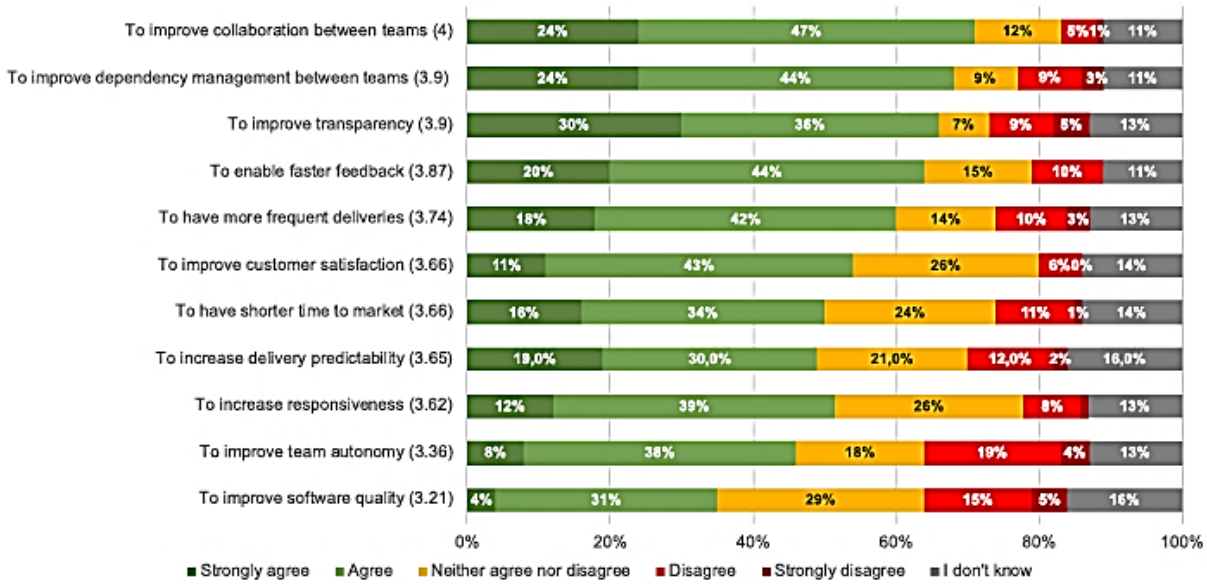

Figure 2.7 - Agreement of the Benefits sorted according to the Mean Values (Putta et al., 2021, pp.181)

From the benefits, five had a percentage of agreement over 60%:

- Improved collaboration between teams: Cross-team collaboration, enhancing communication and cooperation among different groups within the organization.
- Improved dependency management between teams: Mechanisms for managing dependencies between teams, ensuring smoother coordination and integration of work.

- Transparency: Transparency in the development process, making it easier to track progress, identify issues, and make informed decisions.
- Faster feedback: Agile enables faster and more frequent feedback loops, allowing teams to receive input and adapt their approach accordingly.
- More frequent deliveries: With Agile, organizations can achieve more frequent and regular product deliveries, leading to quicker value realization for customers.

It's essential to acknowledge that adopting and implementing agile may also present some challenges that need to be addressed to ensure its successful integration within the organization. The same survey also questioned about whether the respondents agreed with some challenges as presented in Figure 2.8.

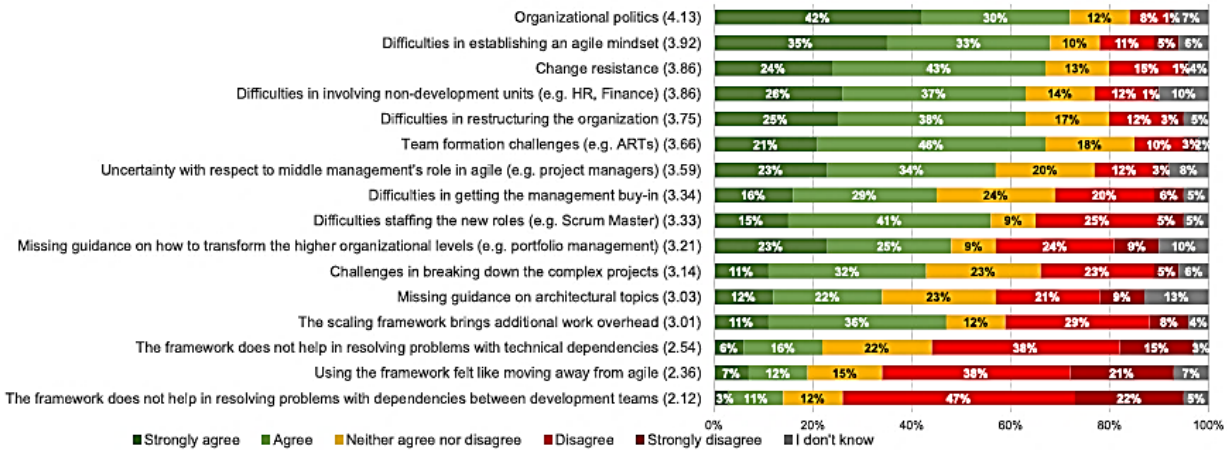

Figure 2.8 - Agreement of the Challenges sorted according to the Mean Values (Putta et al., 2021, pp.183)

The main challenges identified in the survey, with over 60% of agreement by the respondents, were:

- Organizational politics: The existing power dynamics and politics within an organization can hinder the smooth implementation of Agile.
- Difficulties in establishing an agile mindset: Shifting from traditional to agile thinking may be challenging for some individuals and teams.
- Change resistance: Resistance to change from employees and stakeholders can slow down the adoption of Agile.
- Difficulties in including non-development units: Integrating non-development units into the agile process can be complex and requires careful planning.
- Restructuring the organization: Adopting Agile may necessitate organizational restructuring to align with the new agile practices.
- Team formation challenges: Forming and aligning teams to work effectively in the Agile framework can be a demanding process.

Addressing these challenges through proper planning, communication, and training should help organizations successfully navigate the transition to Agile.

3

CHECKING PROJECT MANAGEMENT AND AGILE TRENDS AND IMPACTS

According to the research methodology, in this section the main results of previous surveys on Agile implementation (Gouveia, 2015) and Study on project management in Portugal within the scope of the Portuguese Project Management Observatory will be presented and analysed with the purpose of achieving a better comprehension on the differences and evolution of the utilization of Agile approaches and their impacts.

3.1 Agile Normatives and Project Management Standardization

The implementation of Agile methodologies extends across multinational corporations as well as in Very Small Entities (ISO/IEC29110) . This indicates that future endeavours in this domain should encompass diverse organizations spanning various sectors, cultures, and economic as well as scientific domains. The European standard (CoEPM² 2021) along with its corresponding PM² Agile Guide (CoEPM² 2021a) collectively establish and explicitly acknowledge agile methodologies: " Agile is an approach to managing projects based on a specific set of principles and practices, which promote adaptive planning, evolutionary development, early incremental delivery and continuous improvement. It encourages rapid and flexible responses to change … Agile takes into account the inherent uncertainty of the project environment and creates an organisation that is highly adaptive."

PRINCE2 is grounded in seven principles that must be consistently adhered to, accompanied by seven corresponding themes (Business case, Organisation, Quality, Plans, Risk, Change, Progress), that align with ISO 21502's 'Management practices for projects.' The method positions itself as neutral towards various delivery approaches. Given the prevalence of "agile approaches," it provides dedicated tailoring guidance within the manual for each process and theme. Furthermore, a comprehensive manual version is dedicated to prevalent agile techniques and their compatibility with the PRINCE2 methodology.

Hence, the quality principles outlined in ISO 9001, which certified companies learn and internalize in their daily practices, can be aligned with agile values. However, challenges arise in highly regulated development projects when attempting to integrate different quality standards and improvement frameworks, such as ISO 9001, ITIL, COBIT, and CMMI, with agile practices. Some authors highlight difficulties related to documentation requirements when combining ISO 9001 with agile approaches. To assess quality in teams, indicators can be categorized into three domains: people (e.g., customer satisfaction, team satisfaction, internal improvement suggestions), process (e.g., automated tests, open incidents, % of incidents expired due date, schedule efficacy), and outcome (e.g., implemented features, failed features, critical defects reported by customers, % of improvement features) (Coyle & Barata, 2016). To improve the quality in teams effectively, a small set of indicators should be utilized, but adaptable to changing project requirements in line with adaptive project management.

The newly introduced ISO/IEC/IEEE 26515:2018 standard includes dedicated clauses specifically tailored for agile development. Within Clause 5 (Information development process), it acknowledges the inherent volatility of software requirements and thus discourages the creation of exhaustive engineering support documentation and intricate technical specifications (Mathrani et al., 2022).

The ISO/IEC 29110 standard was designed for organisations with very small cores, 1 to 25 individuals, its inherent structure, regardless of its slight nature it can't be categorized as truly agile. Therefore, small-scale software development entities employing agile methodologies such as Scrum or XP, and aiming to adhere to regulatory standards, grapple with the "agility-rigor reconciliation problem." This refers to the challenge of reconciling the inherent differences between two distinct software process approaches (Galvan-Cruz et al., 2021).

The literature shows that there is a constant will to try and stablish several frameworks that could be used in a large scale regarding the application of Agile in industries however it has not been an easy task because of the variety of methods, tools and ways of using the principles. The manufacturing sector could potentially benefit from adopting the DevOps approach but one of the significant challenges faced is the absence of standardized digital representation (Ugarte Querejeta et al., 2020).

Numerous publications on scientific platforms such as Scopus and Web of Science reveal that agile methodologies are being examined in conjunction with various ISO standards. These standards encompass a broad range of topics including systems and software engineering, product quality, information and documentation, quality management, ergonomics, and manual handling. Some notable standards in this context are ISO 15288 for system life cycle processes, ISO/IEC/IEEE 26515 for developing information in an agile environment, ISO/IEC 25000 for systems and software engineering, and ISO/IEC 9126 for software engineering product quality. Additionally, the exploration includes standards like ISO/IEC 24744 for software engineering, ISO 16439 for information and documentation, ISO/IEC/IEEE 12207 for software life cycle processes, ISO/IEC TR 29110-5-1-2 and ISO/IEC 29110 for systems and software engineering, ISO/IEC 25022, ISO 9001 for quality manage-

ment systems, ISO 11228 for ergonomics in manual handling, and ISO 11226 for evaluating static working postures. This trend signifies a considerable integration of agile practices with well-established international standards, underscoring their increasing significance in various domains of systems and software engineering.

Although agile is extensively being aligned with standards and the work on the standardization of the application is growing it is still a lack on the methodology as various authors empathise this state as one of the main challenges and setbacks in implementing agile in a more concise and assertive way. It is important to understand and state the needs of organisations in terms of practices guidelines and documentation as well in order to spread the benefits of a good agile transition throughout the world.

3.2 Trends and Impacts

Miranda et al., (2023) in Study on project management in Portugal within the scope of the Portuguese Project Management Observatory, along with the Portuguese Association of Project Management developed a Study on project management in Portugal. The research aimed to study the tools and techniques used by organizations, the implementation of agile methodologies, the maturity of various PM areas, and the KPIs used to measure project success. An online questionnaire was used for data collection, leveraging Lime Survey. The study involved 133 professionals working in project management, who were reached through social media and email dissemination.

The research questions focused on identifying the most and least used PM tools and techniques, exploring the influence of demographic factors (age, gender, experience, position, education) on tool selection, examining sector-specific tool preferences, understanding the adoption of agile methodologies, assessing the impact of agile practices on project outcomes, evaluating the maturity levels of PM practices, analysing sector-specific maturity variations, and identifying the most valued KPIs.

Descriptive statistical analyses were performed using SPSS software. Tools and techniques were categorized according to the project life cycle stages: Initiation, Planning, Execution, Monitoring and Control, and Closure. The most used tools included Kick-off Meeting, Progress Meetings, Project Work Breakdown, Gantt Chart, and Activity List, while the least used included Monte Carlo Analysis, Decision Tree, PM Software for Simulation, and Critical Chain Method, as presented in Figure 3.1. The Kruskal-Wallis test revealed that tool usage varied significantly across factors such as age, experience, position, and education.

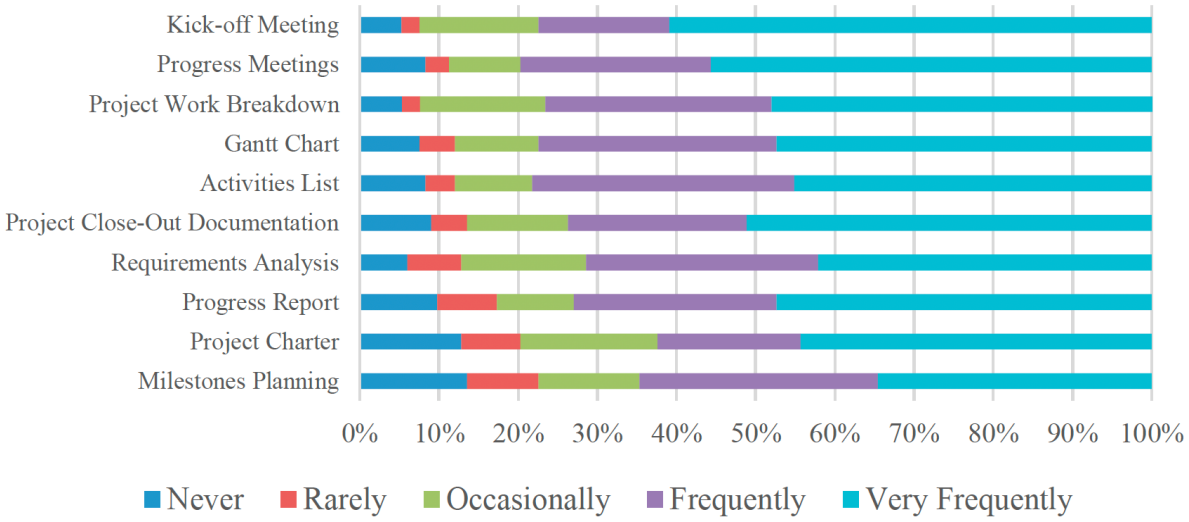

Figure 3.1 - Most used Project Management Tools and Techniques (Miranda et al., 2023)

Agile methodologies were inquired in order to identify if organizations use agile methodologies in their operations and which one do they use the most; If the use of agile methodologies influence projects finishing within scope, time and cost. found to be widely adopted, with Scrum being the most popular, followed by Kanban. However, no significant correlation was found between the use of agile methodologies and project completion within scope, time, and cost constraints.

The study also assessed PM maturity across ten knowledge areas of the PMBOK: Project Integration Management, Project Scope Management, Project Schedule Management, Project Cost Management, Project Quality Management, Project Resource Management, Project Communication Management, Project Risk Management, Project Procurement Management, and Project Stakeholder Management. Each area was evaluated for maturity, with processes like "Monitoring and Control of Project Work" and "Definition of Scope" showing the highest maturity levels. However, no significant differences in maturity levels were found across different activity sectors.

Regarding KPIs, the most valued by organizations were Customer Satisfaction, Time, and Cost. The least valued included Employee Satisfaction Index, Level of Employee Involvement, Capacity Utilization Rate, and Waste Reduction Rate.

Additionally, about the impacts The 15th State of Agile survey Report (Digital.ai, 2021) reveals congruent findings, pointing to the two primary motives for adopting agile methodologies: the ability to effectively manage rapidly changing priorities and expedite software delivery. The study emphasizes additional advantages, including increased team productivity and advancements in business and IT alignment, along with enhanced software quality, improved delivery predictability, heightened project visibility, and reduced project risk. Beyond these core factors, the survey identifies supplementary benefits such as a more responsive approach to volatile market conditions. Additionally, the TC 258 mention agile impacts like increased people values arise from active involvement and motivation, complemented

by efforts to foster an understanding of team culture. Change value is intricately linked to the ISO/IEC 29110 standard, reinforcing project management processes, and bolstering software implementation procedures. Effectively engaging people, encouraging necessary innovations, and cultivating dynamic capabilities become pivotal strategies to navigate the Volatile, Uncertain, Complex, and Ambiguous (VUCA) world, thereby supporting continuous adaptation to ever-changing environments where agile is very useful.

Issa et al., (2019) stated that adopting agile practices such self-organizing and cross-functional teams, daily meetings and product backlog in addition to the overall flexibility that agile brings to an organization, can help on employee retention by bringing new ideas, happy and friendly environment which will able the employees to achieve more and impact positively the organization culture. Kišš & Rossi, (2018) analysed the benefits of using agile and lean simultaneously finding that it can reduce the lead time, improve the process flow, enhance the continuous improvement impacting the delivery prediction and improve the fixing of defects. Myklebust et al., (2020) analysed the application of agile in industrial automation and control systems(IACS) and safety instrumented systems (SIS) and found that it strengthens communication in all phases of a project and regarding agile safety cases, facilitates navigating the status of the safety case decreasing the time used on the development. Ugarte Querejeta et al., (2020), suggesting the use of DevOps alongside Digital Twins it places the organization closer to a continuous production system avoiding interoperability issues.

The main setbacks to applying agile identified were strict, vertical hierarchical structures, Iteration-related challenges, scaling, organizational politics, change resistance and team formation challenges. The low level of documentation that agile has also is viewed by authors as a major setback and the lack of standards for scaling and adopting the methodologies.

3.3 Agile Adoptions discussions

Agile is a continuously growing approach mostly in the IT sector but is quickly spreading across various business sectors and in more than software development activities.

Various authors emphasise the level of difficulty associated to implementing agile, they also refer to the process as more than just adopting agile practices and approaches mentioned in the methodologies. They defend that this transition is highly related to a change of mindset and behaviour from the company structure all the way to their employees, as the use of agile outside the IT sector is a main focus in this study, in productive, manufacturing and cyber-physical systems as well in implementation of continuous improvement actions and there is no standard methodology defined for these areas the transition process can have even more challenges than usual. Some of the examples presented in the various papers selected previously in the SLR can help preparing institutions for this transition.

Gouveia, (2015) in the "Survey on a Potential Implementation of Agile Methods" (p. 55) gattered 60 valid responses from individuals where 1/3 of the respondents were from the IT sector, 13% from Educational Services and around 8 % belonged to manufacturing industries as shown in Figure 3.2. Most of the respondents worked with teams of 4 to 10 members where the criticality of the project was mostly evaluated as having Significant Impact(Significant Costs) if the project fails. About the team skillset and behaviours (Q8-12) less than 15% negative responses were obtained and most of the respondents agreed on their company team members overall qualities. On the company's bureaucracy more respondents disagreed with their company being highly bureaucratic and their project's scope being vague by nature. Regarding the innovative of the product and market most people agreed.

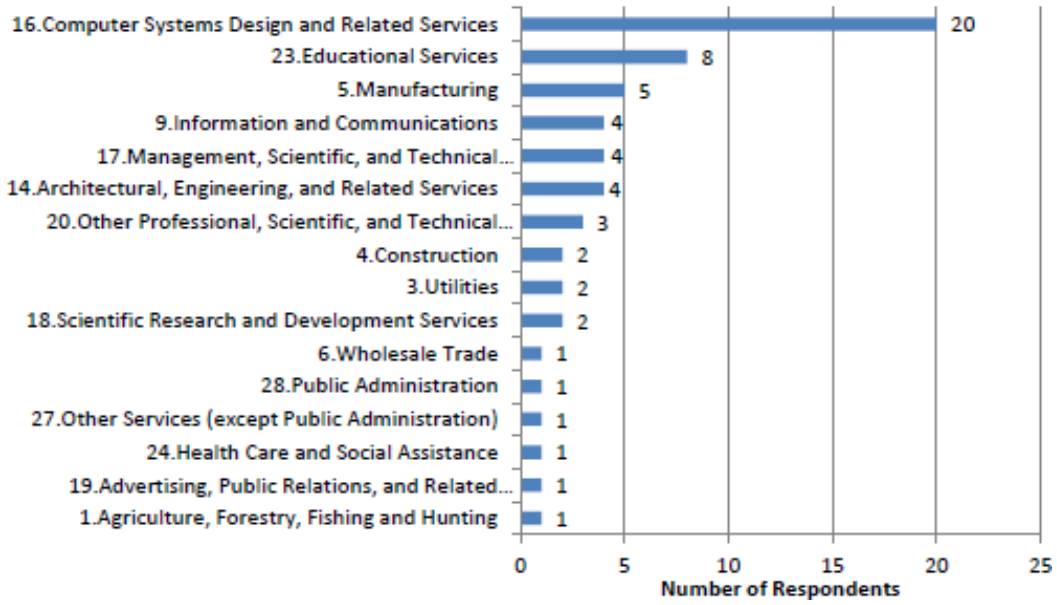

Figure 3.2 - Nº Respondents by sector (Gouveia, 2015 pp.60)

About the "potential of applying an agile approach" section of questions in Gouveia, (2015) Survey (18 to 34, Linkert scale) using artefacts and tools such as: Requirement's Backlog, Cross-functional Teams, Kanban, small teams, self-managed teams, Burndown chart, Metaphor, Review Meetings, Available Client, Collective Ownership, Test-driven development, Retrospective Meetings, Daily Meetings, 40h week, constant testing and Co-located teams. The average of the answers to the questions was approximately 4 which suggested that implementing agile was seen with a positive impact by the project managers. The Manufacturing, Information and Communications sectors presented promising results when it comes to adopting Agile Methods, because Project Managers in these sectors strongly agreed with the idea that employing an iterative method can have a good impact on projects. Concerning the implementation in non-IT fields, over 75% respondents indicated that the utilization of Requirement Backlog, Available Client, Cross-functional teams, Kanban and Burndown Chart could yield useful impacts on their projects. The IT sector exhibits a greater pro-

pensity for embracing agile practices, as expected and presented in the Figure 3.3, even beyond traditional software development projects, but also for product development and research endeavours. New Product Development projects exhibited a greater potential for the implementation of agile approaches not just in the IT sector, but overall and this type of project is probably the number one prospect in the transition of agile practices from the software development to other areas and productive systems.

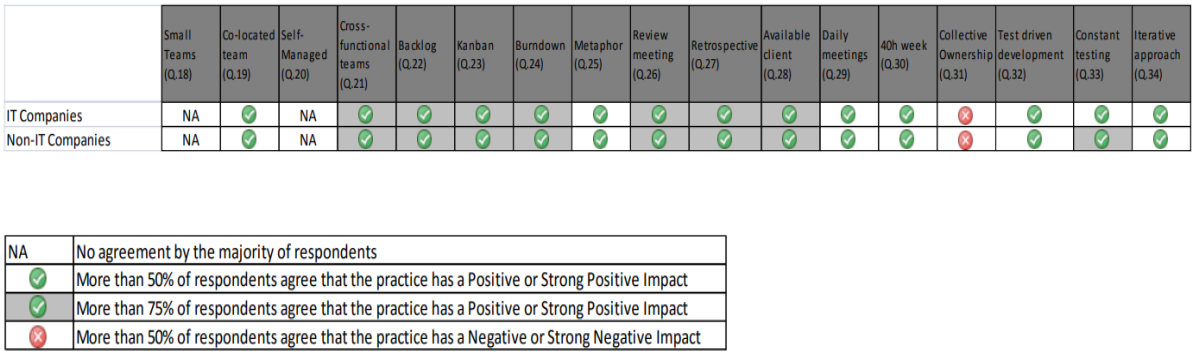

Figure 3.3 - IT vs Non-IT in agile approaches (Gouveia, 2015, pp.88)

Collective Ownership, on the other hand, may have a potential negative effect, and that might be due to the traditional structures that organizations have where there is a clear chain of commands and passing away accountability and responsibility of certain project tasks to project team members can be difficult and challenging, as this was one of the major challenges identified in the Scoping Review, the change resistance to the agile mindset and the middle management role.

The Manufacturing, Information and Communication sectors have been singled out as having a big potential for embracing an iterative approach, making them solid candidates for the adoption of agile methodologies. It's important to note, however, that the sample size of the survey is insufficient to make comprehensive conclusions regarding the adoption of agile methods across various sectors. Three distinct characteristics were considered very important when contemplating the implementation of an agile approach in the results of the survey: the competitiveness of the market in which the company operates, the experience and autonomy of project members and the innovation level of the project's final products.

Several studies (Digital.ai, 2021; McAvoy & Sammon, 2005; Zielske et al., 2022) are reporting that the most frequently used agile methodologies were the presented in Table 3.1, but more recently the most common agile methods are Scrum, Kanban, and Scrumban.

Table 3.1 - Agile Methodologies and Characteristics

Approach	**Main characteristics**
Scrum	Many changes in requirements and definition of sprints as having a maximum of 30 days
Crystal Methodologies	A humanistic focus on the people who make up the group
Dynamic Systems Development Method (DSDM)	Defines an incremental and iterative process and proposes five stages
Adaptive Software Development (ASD)	Focuses particularly on the software components and is tolerant of changes
Feature-Driven Development (FDD)	Defines an iterative process as having at most two weeks.
Extreme Programming (XP)	Defines an iterative process as having continuous unit tests and frequent product deliveries.

Also reports on agile showed that institutions prioritise the use of the approaches that they feel useful for they purpose besides of just applying strictly one methodology by it's full, organizations and project managers tend to apply tools from various approaches in a hybrid version (Schwartz, 2021).

Agile is being widely adopted all around the world and the interest of companies and organizations keep growing (Bastiaansen & Wilderom, 2021). Introducing agile practices throughout various organizational levels and utilizing tools to establish the framework within which projects are carried out can carry challenges from which some Barriers can be identified(Bastiaansen & Wilderom, 2021; Digital.ai, 2021; Schwartz, 2021):

- Inconsistencies in processes and practices
- Cultural clashes
- General organizational resistance to change as well as Lack of skills/experience with agile methods
- lack of leadership participation
- Inadequate management support and sponsorship; Insufficient training and education as well as the pervasiveness of traditional development methods
- difficulty estimating, understanding the scale in large projects and the inability to split the user stories adequately and many found point estimation difficult when faced with opaque technology

- Difficult with sprint planning in large meeting, too much time spent of scrum events: sprint planning, daily meetings, retrospective meetings
- Divide focus when meetings focus attention on specialized teams made other participants feeling estranged and detached and ineffectual to problem solving
- The lack of technical skills of a product owners or customers

As mentioned in the SLR Agile Manufacturing, been associated with a method to achieving agility in production industries by some authors but as also been mentioned more recently as an application of agile approaches in productive systems. As demonstrated by Kumar Potdar & Routroy, (2018), their proposed framework using Agile Manufacturing Enablers to analyse and track the agility of a large scale manufacturer and supplier. It started by forming a cross functional team of key members of the organization and discussed the enablers and concluded that adaptability, devolution of authority, supply chain integration and Information visibility and transparency were the most relevant for the adoption of agile manufacturing.

From continuous improvement of industrial control and safety systems processes, mechatronic systems, product strategy, validation and production systems, Safescrum, DevOps, Design Thinking and Agile Systems Design were some of the methodologies and tools that the papers more establish a relation with applying agile in productive systems from various areas. It centers on the seamless incorporation of Product Generation Engineering into the development process, establishing a balance tailored to the specific situation between structured and agile components (Salehi, 2019).

Ugarte Querejeta et al., (2020) stated that the utilization of a digital twin serves as the primary facilitator for implementing a DevOps in CPPS. Acting as a link between the physical and virtual realms, the digital twin advances the integration with DevOps through its agile framework for continuous production systems. By merging real-time operational production data and artificial data from the virtual design, the digital twin establishes a dynamic production development procedure. This process gathers insights on ongoing operations and identifies new requirements, enabling real-time adjustments and fostering a proactive and continuous optimization process.

4

SURVEY ON AGILE PRACTICES IN PRODUCTIVE SYSTEMS CONTINUOUS IMPROVEMENT

To evaluate the current use and application of Agile approaches a in productive systems, continuous improvement actions and the effects a survey was conducted. In order to gather information about the practices that are being used and how the industry views this emergent innovative approach. Aligned with the previous work of Gouveia, (2015) where he assessed a possible implementation of agile practices in different business contexts, this study also will help understand what practices have more potential of implementation and the type of companies and projects that can be “agile-prone”.

Aligned with the RQ1 and RQ2 the two main goals of this survey is to understand how agile approaches are being used in continuous improvement on productive systems and the impacts RQ3. The business area that the companies are agile prone and which sectors not, hypothesis test if they're the same between two variables.

4.1 Survey Design and Development

The study has as its instrument of analysis a questionnaire directed to manufacturing industries to assess their agile practices, sent under the title "Agile practices in Productive Systems Improvement" and which is presented in the annex to this dissertation. It was developed, adapted from Gouveia, (2015) and using as main references Putta et al., (2021) which included several specific questions for characterisation of organisations, agile approaches, practices, tools, benefits and challenges.

The final survey has 58 items separated in 6 parts. The first two parts (1) and (2) gather information about the organisation's sector of activity, approaches and the type of projects; The part (3) will be used to assess the factors identified in Gouveia, (2015) framework for an Agile Implementation Decision Model evaluating a project that has recently been completed or is currently in progress; The part (4) will evaluate the viability and potential success of various approaches based on the respondent's viewpoint; The part (5) is crucial because it's

the section where the organisations that use agile approaches are questioned about what practices they use, how and the benefits and challenges they came across. The part (6) is a respondent characterization.

To a better understanding and gather more viable conclusions the target population was defined based on the main objectives of the survey, that is studying agile practices in manufacturing environments.

For the survey, we aimed to target the population of organisations in Portugal, from the manufacturing sector that use agile practices in their activity. In the first phase, we targeted only Portuguese organisations and besides the questions contain numerous economic sectors, IT is one that we planned to exclude from the analysis as we know agile has already a strong presence in that sector. Non-Random sampling strategies were used such as purposive in the first publication of the survey aiming manufacturing industries and snowball for the following publications to spread the survey through referrals from previous respondents.

4.1.1 Questionnaire Structure

This section will display and explain the questions within the first 5 parts mentioned earlier. The questionnaire is annexed in Annex I - Survey.

- **ORGANIZATION (1) and PROJECT AND IMPROVEMENT ACTIONS MANAGEMENT (2)**

Table 4.1 - Organization, Project and Improvement Management (Survey Questions)

Questionnaire Section	Question	Designation	Variable	Classification
ORGANIZATION (1)	1	Country	countr	Nominal
	2	Commercial presence	presenc	Nominal
	3	Organisation size	orgsize	Ordinal
	4	Main economic activity	activi	Nominal
	5	Implementation of improvement through projects	proj	Ordinal
	6	Project criticality	critic	Ordinal
	7	Organisation bureaucracy	bureau	Ordinal
	8	Highly innovative market	innov	Ordinal
	9	Importance of Agility	agility	Ordinal
PROJECT AND IMPROVEMENT ACTIONS MANAGEMENT (2)	10	Typology of the project/actions	typroj	Nominal
	11	Project/actions team size	teamsiz	Ordinal
	12	Organisaton Methodologies	orgmeth	Nominal
	13	Use of Agile Practices	agile	Dichotomous

The characterisation of the Organisations (1) and respondents under analysis, systematised in Table 4.1 , was developed with the objective of defining the organisational characteristics of the companies, their environment and how they manage project and improvement actions (2), that can be fundamental to a better comprehension of the results verified in the analysis to be carried out. Questions 6 and 11 involves evaluating the criticality of the project and the impact of the size of the team on the implementation of agile approaches respectively.

The Variable agile carried out by the item number 13. Does your organisation use Agile practices?' also works as trigger to separate the organisations that use agile from those who don't. Depending on the answer to this question the respondent will be sent to different sections of the questionnaire, if the response is 'Yes' then the next section is the part (5)- Organisation Agile practices; 'No' or 'I don't know' as a response leads to part (3) and then (4) (Organisation Practices and Implementation of Agile practices).

- **ORGANISATION PRACTICES (3) and IMPLEMENTATION OF AGILE PRACTICES (4)**

Table 4.2 - Organisation Practices (Survey Questions)

Questionnaire Section	Question	Designation	Variable	Classification	Likert Scale
ORGANISATION PRACTICES (3)	OP1	Team skills	skills	Ordinal	1-4
	OP2	Team experience and autonomy	experien	Ordinal	1-4
	OP3	Team motivation	motiv	Ordinal	1-4
	OP4	Face-to-face communication	faceto	Ordinal	1-4
	OP5	Trust environment	trust	Ordinal	1-4
	OP7	Product innovativeness	prodinn	Ordinal	1-4
	OP9	Scope vagueness	scopevag	Ordinal	1-4
	OP10	Highly innovative market	markinn	Ordinal	1-4
	OP11	Market competitiveness	mark-comp	Ordinal	1-4

The characterisation of organisation practice (3), presented in Table 4.2, intended to assess both the company and the project in accordance with the framework providing a Decision Model for an Agile Implementation (Gouveia,2015). The questions have a 4 scale answers to evade neutral responses – 1."Strongly Agree", 2."Disagree", 3."Agree" and 4."Strongly Disagree".

Table 4.3 - Agile Implementation Practices (Survey Questions)

Questionnaire Section	Question	Designation	Variable	Classification	Linkert Scale
IMPLEMENTATION OF AGILE PRACTICES (4)	IA1	Small teams	smlteam	Ordinal	1-5
	IA2	Work in same space	workspace	Ordinal	1-5
	IA3	Self-managed teams	selfmanag	Ordinal	1-5
	IA4	Cross-functional teams	crossfunc	Ordinal	1-5
	IA5	Requirement's Backlog	backlog	Ordinal	1-5
	IA6	Kanban	kanban	Ordinal	1-5
	IA7	Burndown Chart	burndown	Ordinal	1-5
	IA8	Methapor	methapor	Ordinal	1-5
	IA9.	Review Meeting	meetrev	Ordinal	1-5
	IA10.	Retrospective meetings	meetret	Ordinal	1-5
	IA11.	Stakeholders presence	stakehol	Ordinal	1-5
	IA12.	Daily meetings	meetdai	Ordinal	1-5
	IA13.	40h week	40week	Ordinal	1-5
	IA14.	Collective Ownership	owner	Ordinal	1-5
	IA15.	Test-driven development	testdriven	Ordinal	1-5
	IA16.	Constant testing	conststst	Ordinal	1-5
	IA17.	Agile familiarization	agilefamil	Ordinal	-

The Implementation of agile practices section of the questionnaire, Table 4.3, aims to evaluate the applicability of certain agile characteristics on the non-agile environments. Each identified characteristic will be presented to the respondents, who will then indicate how its implementation would affect the progress of the project. A 5 point Likert Scale, will be utilized for the respondents to choose from the following options: 'Significantly negative impact'; 'Negative impact'; 'No impact Positive impact'; 'Significantly positive impact'. With the purpose of comparing the results in different time frames was decided to use the same scale.

For the item IA17, (IA17. Are you familiar with Agile terms and management practices?), those who respond 1. or 2. (Yes) responses, will also be questioned additionally about the advantages and challenges of agile they felt or think would be relevant (NA9.1 and NA10.1).

- **ORGANISATION AGILE PRACTICES (5)**

Table 4.4 - Organisation Agile Practices (Survey Questions)

Questionnaire Section	Question	Designation	Variable	Classification
ORGANISATION AGILE PRACTICES (5)	A1	Frameworks	agfram	Nominal
	A2	Behaviours	agbehav	Nominal
	A3	Methods	agmetho	Nominal
	A4	Tools	agtool	Nominal
	A5	Meetings	ameet	Nominal
	A6	Pure or combined Agile	agcomb	Dichotomous
	A7	Standards in agile practices	agstand	Nominal
	A8	Rapid prototyping	agrapid	Dichotomous
	A9	Agile advantages(11)	agadvan	Ordinal
	A10	Agile challenges(16)	agchalle	Ordinal
	A11	Agile influence	aginflue	Ordinal
	A12	Agility dimensions(6)	agdim	Ordinal
ADVANTAGES AND CHALLENGES OF AGILE (Non Agile)	NA9.1	Agile advantages(11)	nagadvan	Ordinal
	NA10.1	Agile challenges(16)	nachall	Ordinal

The Organisation agile practices (5) characterisation, which is summarised in Table 4.4, concerns variables that were introduced specifically to verify the application of agile approaches, tools, methods and artefacts among the organisations under analysis, in order to characterise the motivation of the companies towards it, the benefits they extract, the challenges they faced, the importance of the use of agile in their environment and the agility of the organisation through the 6 dimensions (Looks et al., 2021), presented in Table 4.5. A9 and A10 were extracted from (Putta et al., 2021), initially designed for a SAFe survey but used in this study for any agile framework.

Table 4.5 - Agility Dimensions (Survey Questions)

Dimension	Previous Questionnaire (Gouveia, 2015)	This Dissertation [Non-Agile]	This Dissertation [Agile]
Communicative	"11. Face-to-face communication is preferred over formal communication" (pp. 80).	PO4.	A12. How do you classify the following agility dimensions in your organisation? [Communicative]
	"29. Daily Meetings take place where every team member answers the following questions: What have you contributed to the project since last meeting?, What will you deliver between now and the next meeting?, and Is there anything that is preventing you to work as efficiently as possible? (No prolonged discussions are allowed at these meetings)" (pp. 83).	IA12.	
Openness to Change	"31. Every piece of work can be edited by any project member." (p. 84)	IA14.	A12. How do you classify the following agility dimensions in your organisation? [Openness to Change]
	"28. An end user or a representative is always close and available to act as a consultant whenever the project team needs" (pp. 83).	IA11.	
Iterative and incremental	"16. The project's initial scope is vague by nature" (pp. 81).	PO7.	A12. How do you classify the following agility dimensions in your organisation? [Iterative and incremental development]
	"23. Use of a chart which complements the list of requirements identifying tasks as Ready, Ongoing, and Complete" (pp. 82).	IA6.	
Self-Organized	"20. Project teams are self-managed" (p. 82).	IA3.	A12. How do you classify the following agility dimensions in your organisation? [Self-organized]
	"31. Every piece of work can be edited by any project member" (pp. 84).		
Product-driven	"21. Teams should be cross-functional in two basic dimensions: people who can identify business value and people with technical knowledge" (pp. 82)..	IA4.	A12. How do you classify the following agility dimensions in your organisation? [Product-Driven]
	"25. A final product scenario must be read by every team member and is always available for consultation" (pp. 83).	IA8.	
Improvement-oriented	"27. The use of Project Retrospective Meetings attended by the project team to discuss the current processes and to propose new approaches in order to improve communication, teamwork, etc" (pp. 83).	IA10.	A12. How do you classify the following agility dimensions in your organisation? [Improvement Oriented]
	"33. Tests are carried out constantly, and if possible, applied to small parts of the final product" (pp. 84).	IA16.	

The next section of the survey, PARTICIPANT (6), aims to characterise and profile the respondents through questions on age, gender, years of experience and main professional activity. Finally, the last part is the submission part where the respondent is invited to submit suggestions and comments. On the other hand, the characterisation of the respond-

ents will make it possible to control biases (given the subjectivity of some of the answers) that may arise in the answers given and also to determine at which organisational level the responsibility for the information requested lies.

4.2 Survey Analysis Methodology

For the information analysis procedure, the main focus will be the questions from parts (1) ,(2) and (5) - ORGANIZATION, PROJECT AND IMPROVEMENT ACTIONS MANAGEMENT and ORGANISATION AGILE PRACTICES, as they will represent the primarily survey target audience , companies that are using agile approaches in their productive systems or continuous improvement actions. There are three questions that can be found highly subjective due to its direct personal evaluation method.:

- A9. Agile advantages(11)
- A10. Agile challenges(16)
- A12. Agility dimensions(6)

Due to the exploratory and descriptive nature of the study and open questions format they will be categorized using key words mentioned which will then regrouped into similar thematic categories and coded as nominal variables.

4.2.1 Pre-test, Results and Analysis

A pre-test was conducted,Table 4.6, where the questionnaire was sent to a few companies and researchers from IST, UMinho, NOVA IMS and NOVA SST to receive feedback about the overall opinion on the questionnaire and get some inputs on certain agile terminology, their meaning and translation for the Portuguese version of the questionnaire (Annex II - portuguese). Thanks to their contribution some corrections were applied to agile related questions in order to use more updated and concise expressions.

Table 4.6 - Survey distribution and respondents numbers

Date	Stage	People sent to	People that responded
22/06/2023	Pre-T	15	3
25/09/2023	1st publication	40	5
01/03/2024	2nd publication	30	10

Given the large number of questions to be analysed and the type of variables used, as well as the analysis instruments to be used (the SPSS computer application in closed questions and MAXQDA in open questions), descriptive statistical analysis and non-parametric tests are expected because of the majority of variables are categorical.

From the 18 responses gattered, the respondents had an average years of experience in project or operations management of approximately 13 years, 89 % being men older than 25 years and with professional activity related to consultancy and Project management as show in Figure 4.1, Figure 4.2 and Figure 4.3.

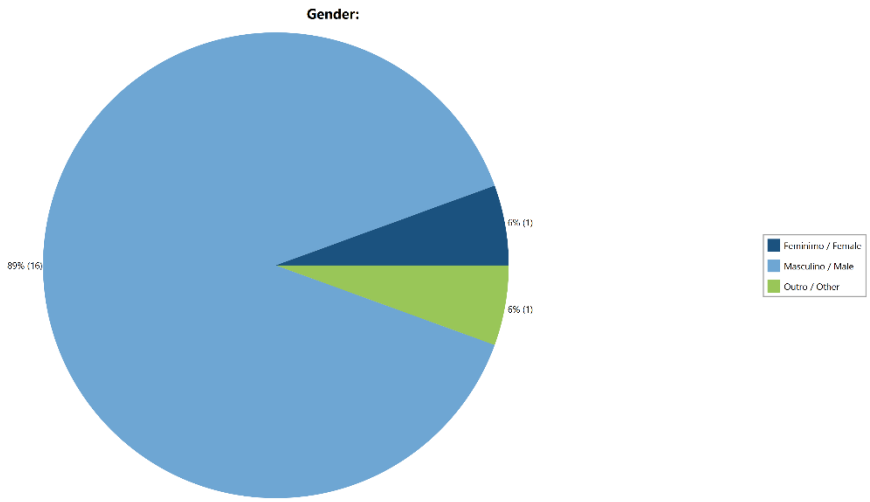

Figure 4.1 - Respondents gender profile

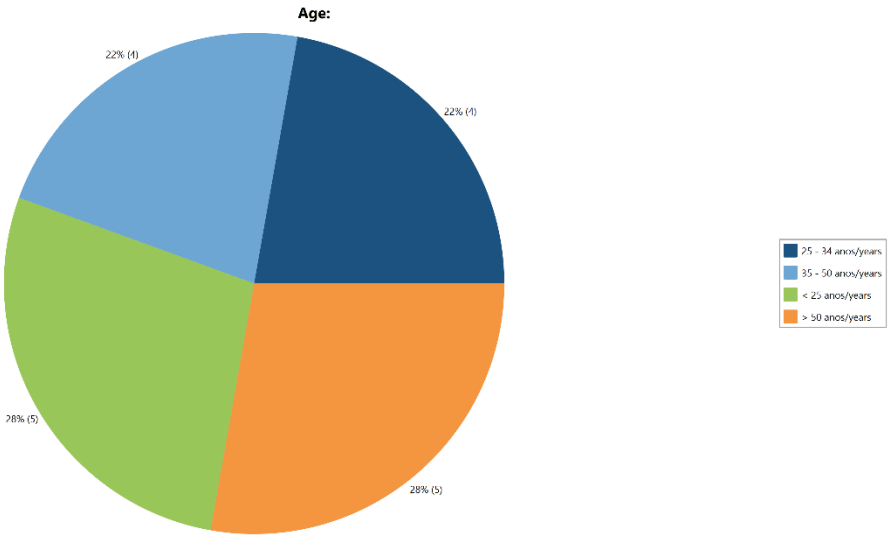

Figure 4.2 - Respondents age profile

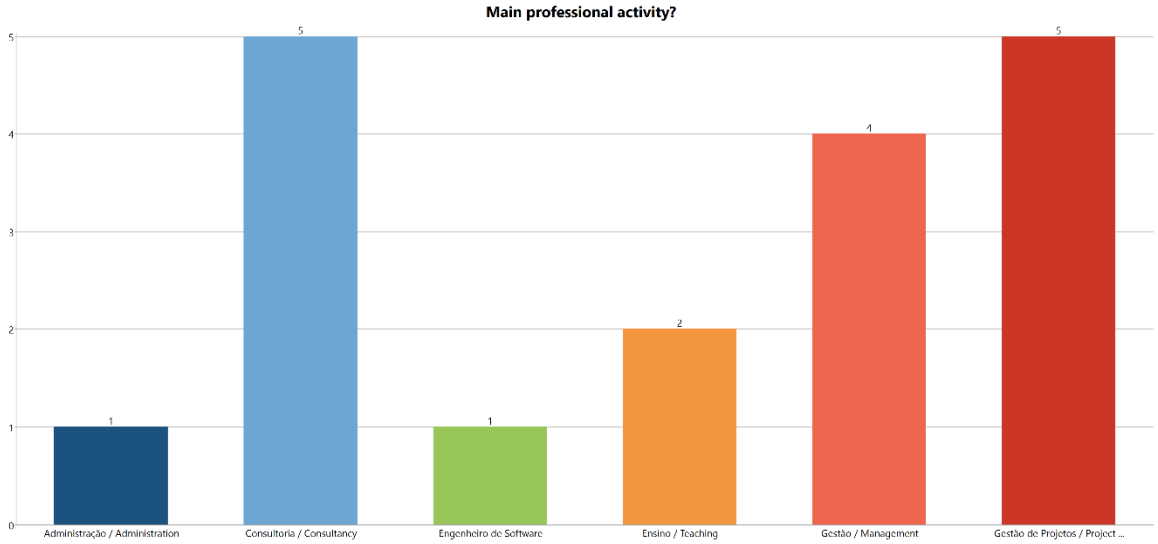

Figure 4.3 - Respondents professional activity

The main sectors identified were Manufacturing Industries, Consulting and Information activities, as presented in Figure 4.4.

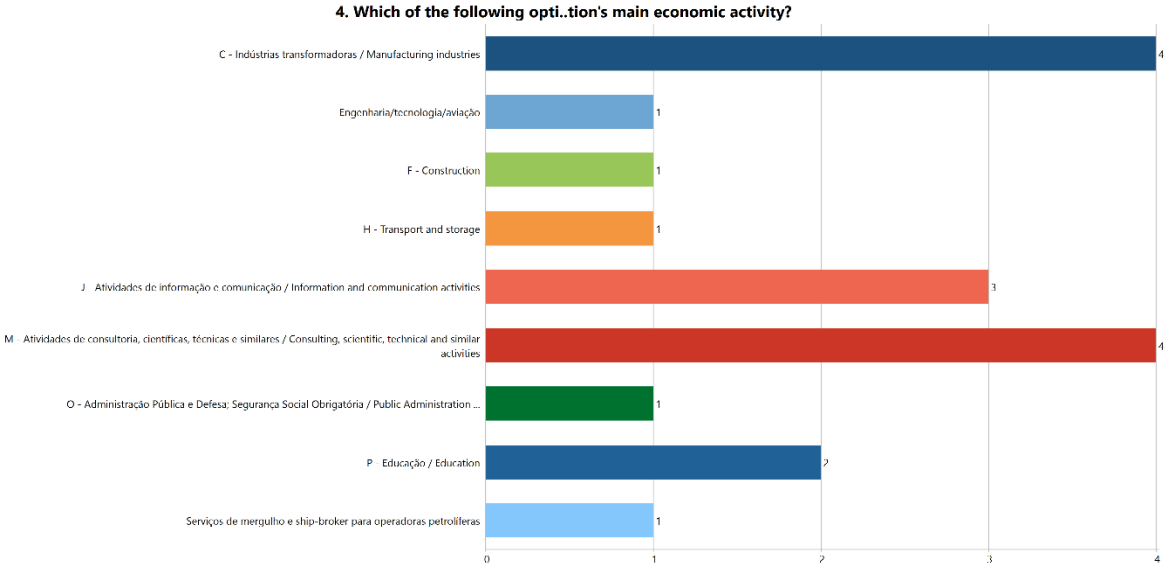

Figure 4.4 - Respondents by activity sector

The number of respondents that stated that use agile, 72 %, are also showed in Figure 4.5, as well as their distribution by project type in Figure 4.6 and finally the main frameworks mentioned, with scrum being having a highest frequency,Figure 4.7.

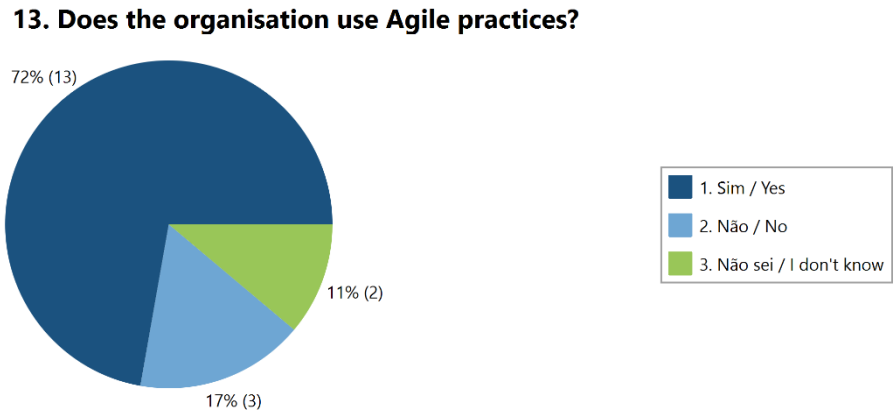

Figure 4.5 - Respondents that use Agile

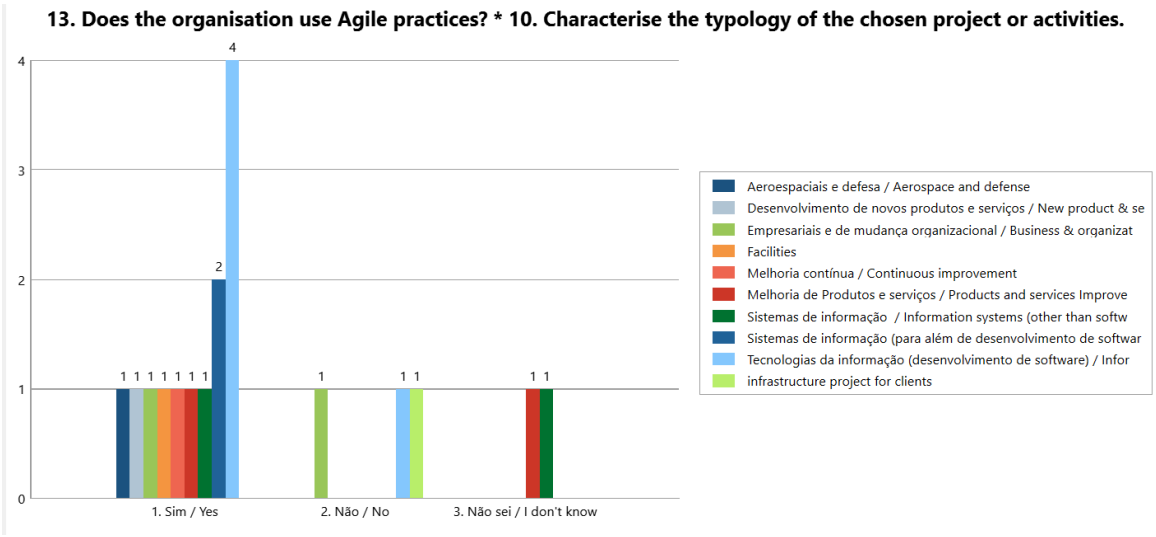

Figure 4.6 - Agile practitioners by Project type

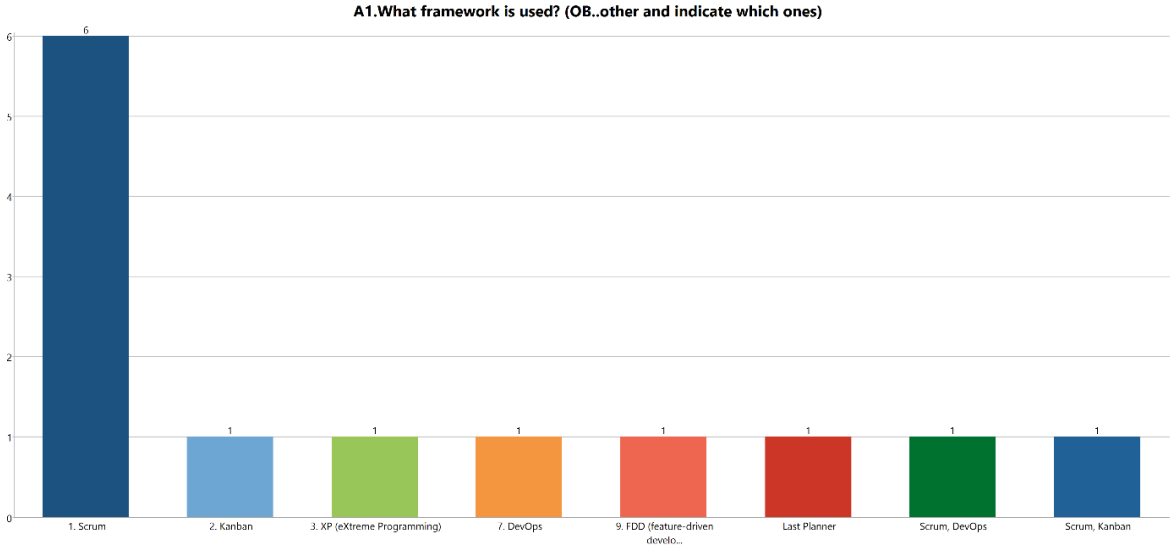

Figure 4.7 - Used Agile Frameworks

The main challenges indicated are represented in Table 4.7 with the highest concordance scores and the advantages in Table 4.8 were similar to the identified in the systematic literature review.

Table 4.7 - Agreement of the top Challenges Mean Values

Challenges	Mean value
Difficulties in restructuring the organisation	3,78
Organizational politics	3,77
Change resistance	3,75
Team formation challenges	3,64

Table 4.8 - Agreement of the top Advantages Mean Values

Advantages	Mean value
More frequent deliveries	4,15
Improved team autonomy	4,08
More Transparency	4
Faster feedback	4

While Miranda et al. (2023) did not find a significant correlation between agile practices and project success metrics (scope, time, cost), our study does not directly address this correlation. However, their results suggest that agile methodologies alone may not guarantee improved project outcomes. This could imply that factors other than agile adoption influence project success, such as organizational culture or external conditions.

Gouveia (2015) study's positive perception of agile's impact, especially in non-IT sectors, resonates with our findings about the potential benefits of agile methodologies in various industries. However, Gouveia's findings also suggest challenges related to organizational resistance and traditional structures, which mirror the setbacks identified in Miranda et al. (2023)

The survey supports the predominance of Scrum among Portugal, consistent with Miranda et al. (2023) and other literature. However, discrepancies in findings regarding the impact of agile practices on project success suggest that further investigation is needed in how agile practices interact with various contextual factors to provide a more nuanced understanding of their effectiveness.

5

STUDY CONCLUSIONS

In this final section of the dissertation a recap of the research conducted is provided, pointing specific conclusions and its potential contributions. Furthermore, the limitations of the study will be addressed as well recommendations for future research.

5.1 Main Results and Findings

In the past years the world faced extremely challenging times, a pandemic, wars, economic and environmental crises and the industries, organizations and businesses in general were strongly affected by these new paradigms. Adaptability, change responsiveness, high level of technology processes and approaches were already crucial characteristics and tools for any organization in this so-called 4th revolution of industries and their relevance is constantly increasing across various areas. Agile has been growing across the world mostly as a mindset with a set of tools, behaviours and approaches, linked to the Agile Manifesto published in 2003, that can help a organization respond to these challenging times, from a rising in academic documents to organizations not directly related to Information Systems applying various practices from different agile approaches.

Organizations that operate in a productive system philosophy are chasing digital transformations and are using Agile on their improving projects of their operations using methods of the likes of DevOps, SaFeScrum and Scrum incorporated with other methodologies practices like lean, specifically VSM, Kanban (who is also identified as an agile method) and Kaizen. Digital Twins are being used in order to easily test and simulate real environments in a informatic way combined with DevOps approach can help identify problems and improvement points in a structured manner helping the continuity of the production by establishing a better communication across different sectors, the Cyber Physical systems also represent a method used combined with agile to test and develop automated and integrated production flows, in order to achieve continuous improvement.

The agile practice that has been more related to the continuous improvement of an organization has been kanban and DevOps. kanban as already mentioned is also a approach

widely used by lean practitioners and its relation to Kaizen is obviously extremely relevant, it's also important to mention that in early years before the Agile Manifesto, the term agile was associated with agility, meaning the ability of a organization adapt and respond quickly to changes and new environments, and some authors suggest, mostly using the Agile Manufacturing term as transforming the company or industry processes and operations more flexible and ready to execute their tasks in challenging situations. The continuous approach of DevOps in the integration, delivery and deployment is strongly gaining space in organizations as clear way to keep improving their informatic part of their processes as well in the Cyber Physical systems.

Agile still being a firstly software development methodology approach and more directed to the IT sector, most of the impacts found in the study were directly or indirectly related to these areas and when agile were actually applied in different industry sectors were combined with other methods so we can't really have a direct relation between the approaches used and impacts. Moreover, the main impacts identified were a more constant and predictable deliveries, improve employee retention in a organization because of the flexibility related to the team members and it has a significant contribution to an organization continuous improvement as the iterations and constant testing are a big part of most of agile approaches.

The study also suggests a survey to access the application of Agile approaches in productive systems, continuous improvement actions and the effects, developed using a big part of questions from previous surveys on the theme while adding a new set of more specific and direct questions about agile methods, tools and behaviours. Designed to gather the actual status of agile in organizations and also evaluate a potential implementation of Agile practices, which adds as a contribution to the academic studies as a tool to in future works implement.

The results of two questionnaires were analysed in order to fill the gap of the lack of responses gathered by the developed survey, findings about areas where agile has a bigger potential to be applied and what tendencies organizations have in project management, one of the researches highlighted the prevalent tools and techniques in Portuguese PM, the influence of demographic and sectoral factors, the adoption of agile methodologies , being scrum and Kanban the most mentioned, and the maturity levels of PM practices. The study identified key areas for improvement and emphasized the importance of regular assessments to track the evolution of PM practices in Portugal. The developed survey involved 18 respondents with significant experience in project or operations management, averaging 13 years, predominantly male (89%), and primarily engaged in consultancy and project management. The main sectors represented were Manufacturing Industries, Consulting, and Information activities. A notable 72% of respondents reported using agile methodologies, with Scrum being the most frequently mentioned framework.

5.2 Limitations and Future Work

The big limitation faced during this study was the lack of agile terminology specifically directed to productive systems, manufacturing and more agile tools that could actually be directly related with other areas than software, IT and development projects. From the 5 people in total who responded, this low engagement been one of the main limitations and reasons for using other surveys, it was commented that the survey was software focused, this aspect can also be improved in future applications of the survey by others.

Apply the survey to organizations in the future and test with a significant sample size the survey effectiveness in this particular theme that is Agile in productive systems as well as the use of case studies to have a better insight and understanding about the methodologies and approaches to enhance the questions objectivity and practical range and reach.

The findings of the study still highly related directly or indirectly with software development as the digital twins and cyber-physical systems mesh the two words, the digital and the practical, so it would be interesting for a study of agile more directed to the operations directly.

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A

APPENDIX

A.1 Annex I - Survey

ORGANIZATION
PROFILE
In the following questions please consider your current or last organisation where you worked on

1. In which country is your organisation based? *

2. What kind of commercial presence does your organisation have? *

1. Local
2. National
3. International
4. Global

3. What is your (current or last) organization size?*

Microenterprise (1-9 employees)
Small enterprise (10 to 49 employees)
Medium-sized enterprise (50 to 249 employees)
Large enterprise (250+ employees)

4. Which of the following options best describes your (current or last) organisation's main economic activity? *

A - Agriculture, animal production, hunting, forestry, and fishing
B - Extractive industries
C - Manufacturing industries

D - Electricity, gas, steam, hot and cold water and cold air
E - Water collection, treatment and distribution; sanitation, waste management
F - Construction
G - Wholesale and retail trade; repair of motor vehicles and motorcycles
H - Transport and storage
I - Accommodation, catering and similar
J - Information and communication activities
K - Financial and insurance activities
L - Real estate activities
M - Consulting, scientific, technical and similar activities
N - Administrative and support service activities
O - Public Administration and Defense; Compulsory Social Security
P - Education
Q - Human health and social support activities
R - Artistic, show, sports and recreational activities
Other:

5. The organisational improvement concerns and activities are implemented through projects? *

1. Yes, very often
2. Yes, with some frequency
3. Sometimes, but not frequently
4. No, they're implemented just through punctual actions

6. What is the most typical impact of a project failure in your organization?*

1. No Significant Impact
2. Low Impact (Small Costs)
3. Significant Impact (Significant Costs)
4. High Impact (a life)
5. Catastrophic Impact (many lives)

7. How would you rate the following statement "The organisational culture ishighly bureaucratic."*

1. Strongly Disagree
2. Disagree
3. Agree
4. Strongly Agree

8. How would you rate the following statement: "The market in which your organisation operates is highly innovative."*

1. Strongly Disagree
2. Disagree
3. Agree
4. Strongly Agree

9. According to your knowledge and the following definition provided:

Agility - "an organization's ability to quickly and effectively respond to change, uncertainty, and unpredictability in its environment"

How would you rate the importance of the Agility for the organisation's competitiveness in your business context? *

(scale from 1 to 5 between)

Not important

Totally Important

PROJECT AND IMPROVEMENT MANAGEMENT

In the following questions please consider a representative project or improvement activities in which you were involved where you consider the best practices were applied

10. Characterise the typology of the chosen project or activities.*

Business & organization change
Facilities
Information technologies (software development)
Aerospace and defense
Communication systems
Events organization
Information systems (other than software development)
Continuous Improvement
International development
Media & entertainment
New Product & service development
Products and services Improvement
Research & development
Other:

11. How big is the team?*

Up to 3 members
4 to 10 members
11 to 30 members

31 to 100 members
More than 100 members

12. Which of the following management approaches are/were used inyour organisation? *
Lean
Theory of Constraints (TOC)
Six Sigma
Total Quality Management
Other:

13. Does the organisation use Agile practices?*
1. Yes
(Move to question A1)
2. No
3. I don't know

13.1 If yes, please indicate at what level
1. Operations and activities
2. Projects
3. Program
4. Portfolio

13.2 If no, please indicate why not
(open question)

ORGANISATION PRACTICES
For the following sentences, please state your position, considering the chosen project or improvement activities (Scale 1-4 with the options : Strongly Disagree, Disagree, Agree, Strongly Agree)

OP1. Team members have good interpersonal skills.*

OP2. Team members are experienced and autonomous.*

OP3. Team members are motivated individuals.*

OP4. In a team Face-to-face communication is preferred over formal communication.*

OP5. The team organisation has a trust environment between individuals.*

OP6. Final products or results are highly innovative.*

OP7. Initial scope is in general vague by nature.*

OP8. Projects or improvement activities usually have fixed budget and present a significant level of change in processes and requirements.*

OP9. The market in which your organisation operates is highly competitive.*

IMPLEMENTATION OF AGILE PRACTICES

Please state your opinion on the plausible impact arising from the implementation of the following practices in the chosen project or improvement activities:
(Scale 1-5 with the options : 1.Strong negative impact to 5.Strong positive impact)

IA1. Teams must be kept as small as possible.*

IA2. Teams must work in the same space.*

IA3. Teams are self-managed.*

IA4. Teams should be cross-functional in two basic dimensions: people who can identify business value and people with technical knowledge.*

IA5. A list of requirements split into tasks (which are estimated and prioritized)is made available and is visibly displayed for the team at all times.*

IA6. Use of a chart which complements the list of requirements identifying tasks as "Ready", "Ongoing", and "Complete". *

IA7. Using tracking graphs which plot workload over the elapsed time, allowing also an estimation of completion by drawing a trend line (only complete tasks are used to update the graph).*

IA8. A final product scenario must be read by every team member and is always available for consultation.*

IA9. Use of Review Meetings generally supported by the use of presentations to show the main accomplishments to previously selected key stakeholders.*

IA10. The use of Retrospective Meetings attended by the team to discuss the current processes and to propose new approaches in order to improve communication, teamwork, etc.*

IA11. An end user or a client representative is always close and available to act as a consultant whenever the project team needs.*

IA12. Daily Meetings take place where every team member answers the following questions: "What have you contributed to the project since last meeting?", "What will you deliver between now and the next meeting?", and "Is there anything that is preventing you to work as efficiently as possible?" (No prolonged discussions are allowed at these meetings)*

IA13. A week's work cannot be longer than 40 hours except for meeting tight schedules. (If extra-work is recurrent it must be addressed as a problem)*

IA14. Every piece of work can be edited by any team member.*

IA15. Functional tests are written up before any development takes place. These tests are then used as requirements.*

IA16. Tests are carried out systematically, and if possible, applied to small parts of the final product.*

IA17. Are you familiar with Agile terms and management practices?*

1. Yes, I've used them
(Move to question NA9)
2. Yes but I haven't used them
(Move to question NA9)
3. I recognize the concept
(Move to Participant section)
4. Not familiar with
(Move to Participant section)

ORGANISATION AGILE PRACTICES

In the following questions please consider the project or improvement activities in which you were involved where you consider that agile practices were well applied.

A1.What framework is used? (OBS: In case of more than one is applied,please select the "option" other and indicate which ones)*

1. Scrum
2. Kanban
3. XP (eXtreme Programming)
4. SAFe (Scaled Agile Framework)
5. ASD (Adaptive Software Development)
6. DAD (Disciplined Agile Delivery)
7. DevOps
8. DSDM (Dynamic Systems Development Method)
9. FDD (Feature-Driven Development)
10. SafeScrum
11. AgilePM

Other:

A2. What are the behaviours adopted?*

1. Collaborative
2. Self-organizing
3. Customer-focused
4. Empower
5. Trusting and not blaming

Other:

A3. What methods or ways are used?*

1. Prioritizing what is delivered
2. Working iteratively and incrementally
3. Phased deliveries
4. Time-focused
5. Inspect and adapt
6. Kaizen
7. Limiting work in progress (WIP)

Other:

A4. What tools or techniques are used?*

1. Burn charts
2. User stories
3. Timeboxing

4. Measuring flow
5. Backlog
6. Sprints
7. Releases
Other:

A5. What meetings are used?*
1. Retrospective meetings
2. Daily Stand-up meeting
3. Iteration Planning meetings
4. Iteration Review meetings
Other:

A6. Do you use agile practices individually or combined with otherapproaches? In case of other, please indicate which ones.*
1. Yes, pure agile
Other:

A7. Within projects and improvement activities what guides or standards areused within agile practices?*
1. PMBOK®
2. Prince2®
3. PM²
4. ISO 21500 (Project, programme and portfolio management)
5. ISO/IEC/IEEE 26515 (Systems and software engineering)
6. ISO/IEC DTR 29110 (Systems and software engineering)
7. ISO 9001 (Quality Management)
8. ISO 14001 (Environmental management)
9. ISO 45001 (Occupational health and safety management)
10. ISO/IEC 27001 (Information security management)
11. ISO 22000 (Food Safety)
12. ISO 13485 (Medical Devices)
13. TL9000 (Telecommunications)
14. AS 9100 (Aerospace)
15. ISO 17025 (Testing/FDA)
16. ISO 29001 (Oil and Gas)
Other:

A8. Does your organisation use Rapid Prototyping techniques? If yes, please indicate which ones.*
1. No
Other:

A9. Advantages of using Agile approaches*

	1.Strongly Disagree	2.Disagree	3.Neither agree nor disagree	4.Agree	5.Strongly Agree	6. I don't Know
Improve collaboration between teams						
Improved dependency management between teams						
More Transparency						
Faster feedback						
More frequent deliver-ies						
Improved customer satisfaction						
Shorter time to market						
Increase delivery pre-dictability						
Increase responsive-ness						
Improved team auton-omy						
Improved software quality						

A10. Challenges of using Agile approaches *

	1.Strongly Disagree	2.Disagree	3.Neither agree nor disagree	4.Agree	5.Strongly Agree	6. I don't Know
Organisational politics						
Difficulties in establishing an agile mindset						
Change resistance						
Difficulties in involving non-development units (e.g. HR, finance)						
Difficulties in restructuring the organization						
Team formation challenges						
Uncertainty with respect to middle management's role in agile(e.g. project managers)						
Difficulties in getting the management buy-in						
Difficulties in staffing new roles (e.g. ScrumMaster)						
Missing guidance on how to transform the higher organizational levels (e.g. portfolio management)						
Challenges in breaking down the complex projects						
Missing guidance on architectural topics						
The scaling framework brings additional work overhead						
The framework does not help in resolving problems with technical dependencies						
Using agile frameworks felt like moving away from agile						

A10. How do you classify the impact of the agile practices in your organisation success?*
(scale from 1 to 5 between)

Not significant

Highly significant

A12. How do you classify the following agility dimensions in your organisation?*

	1. Not significant	**2. Minor Significance**	**3.Neutral**	**4.Significant**	**5.Highly significant**
Communicative					
Openness to Change					
Iterative and incremental development					
Self-organized					
Product-Driven					
Improvement Oriented					

A13. If there are other relevant agility dimensions on your organisation, please indicate and classify them using the previous scale.
(open question)

PARTICIPANT PROFILE

How long (in years) have you been responsible for projects orimprovement activities?*

Gender:*

Female

Male

Other

Age:*

< 25 years

25 - 34 years

35 - 50 years

> 50 years

Main professional activity?*

Administration

Management

Project Management

Consultancy

Teaching
Training
Other:

Please identify your organisation for segmentation process support (not mandatory)

Submission
If you have any problems or need assistance with your submission please contact by ef.afonso@campus.fct.unl.pt

Concluding, please, share with us the survey response time and further comments or suggestions.

If you wish to receive the results of this study, please provide your contact information.

Name:

Email:

THANK YOU FOR YOUR VALUABLE COLLABORATION AND RESEARCH SUPPORT!

A.2 Annex II - Annex II - Proposed adaptation of Agile terms to portuguese

English	Portuguese
Burn charts	Gráficos de consumo
User stories	Histórias do utilizador
Timeboxing	Janelas temporais
Measuring flow	Medição de fluxo
Backlog	Itens por endreçar
Sprints	Iterações
Releases	Passagens a produção
Retrospective meetings	Reuniões de retrospetiva
Daily Stand-up meeting	Reuniões diárias
Iteration Planning meetings	Reuniões de planeamento de iteração
Iteration Review meetings	Reuniões de revisão de iteração (demonstrações)
Empowerd	Capacitado
Time-focused	Orientado ao tempo