INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO

MESTRADO EM ENGENHARIA MECÂNICA

# Aplicação de SAFe® a um Projecto de Manutenção de Aviões

DIOGO DA GAMA OSÓRIO ALMEIDA E SILVA

dezembro de 2020

POLITÉCNICO
DO PORTO

# APPLICATION OF SAFE® TO AN AIRCRAFT MAINTENANCE PROJECT

Diogo da Gama Osório Almeida e Silva

**2020**
ISEP – School of Engineering, Polytechnic of Porto
Department of Mechanical Engineering

POLITÉCNICO
DO PORTO

POLITÉCNICO
DO PORTO

Instituto Superior de Engenharia do Porto

# APPLICATION OF SAFE® TO AN AIRCRAFT MAINTENANCE PROJECT

Diogo da Gama Osório Almeida e Silva
1130389

Dissertation presented to ISEP – School of Engineering, Polytechnic of Porto to fulfill the requirements necessary to obtain a master's degree in Mechanical Engineering, carried out under the guidance of Professor Francisco José Gomes da Silva from the Department of Mechanical Engineering.

**2020**
ISEP – School of Engineering, Polytechnic of Porto
Department of Mechanical Engineering

POLITÉCNICO
DO PORTO

POLITÉCNICO
DO PORTO

# JURY

**President**
Luís Carlos Ramos Nunes Pinto Ferreira, PhD
Adjunct Professor, School of Engineering, Polytechnic of Porto - Portugal
**Supervisor**
Francisco José Gomes da Silva, PhD
Adjunct Professor, School of Engineering, Polytechnic of Porto - Portugal
**Examiner**
Ana Maria Pinto de Moura, PhD
Adjunct Professor, University of Aveiro - Portugal

# ACKNOWLEDGEMENTS

The completion of this master's dissertation is the culmination of an arduous path roamed, built with effort and plenty of knowledge. To those who supported me throughout this course here is my gratitude.

Firstly, I would like to acknowledge Mr. Karl Thomas Schwolle, for selecting me to do an internship in the project and allowing me to perform the master's dissertation in cooperation with the company, despite all the constraints lived during the current times. For being always present and willing to clarify all questions regarding the project. For believing in my capabilities to develop a complex and innovative methodology. To Professor Francisco Silva for the guidance on the development of the dissertation and all the knowledge transmitted. For the meticulous analysis and wise advice to overcome any problem that occurred. For the constantly availability on explaining any doubts, despite the troubled moments. To Professor Margarida Freitas for the spent time on helping me in the English review. To Sensei Ramos for the physical and mental hardening.

Lastly, to my family that are always present and concerned in providing me the best opportunities. To my parents and sister for being by my side, giving me support during this journey and believing in my competencies. To my uncle Alberto and aunt Isabel for the critical thinking, always encouraging me to follow different directions and leaving my comfort zone. To my university colleague and friend Daniel Soares, as well as to my girlfriend Catarina Agostinho for the hours spent together studying, for the suggestions given and for being with me throughout this journey. I would like to finish this section with a quote from the Chinese philosopher Lao Tsé, that ironically was born in Wuhan, and could define the state of mind going through the tumultuous events that society has experienced:

*"Life is a series of natural and spontaneous changes. Do not resist them - that only creates sorrow. Let reality be reality. Let things flow naturally forward in whatever way they like."*

**KEYWORDS**

Project Management, Agile Approach, Hybrid Approach, SAFe®, Aircraft Maintenance Sector

# ABSTRACT

Maintenance, repair and overhaul (MRO) operations have a great impact on the life cycle of an aircraft (A/C). MROs organizations address various challenges on planning activities to ensure the maximum reliability of an A/C, given the amount of unscheduled maintenance. Subcontracting MRO activities by airline companies, has been continuously increasing as an alternative of performing the heavy maintenance themselves, adding a constraint on this type of industries which is to manage the customer demands.

Considering the main issues, it is required to select the most suitable approach to plan and manage A/C maintenance projects. Agile Project Management (PM) could be a solution to overcome the main difficulties in this sector, managing the uncertainty throughout the project, providing customer visibility and control over the service.

This work arises in a real-life case of a subcontracted MRO program in a multinational A/C manufacture enterprise, which also suffers from significant challenges of planning and managing maintenance activities throughout the project life cycle. The program has experimented agile methodologies that revealed a positive impact. In order to the whole program embrace agility and overcome the identified main problems, it was proposed the usage of an elaborate and well-defined agile framework. Scaled Agile Framework for enterprises (SAFe®) is an online knowledge base that implements diverse agile techniques to support businesses, develop and deliver solutions, achieving business agility.

As SAFe® was mainly developed for software industries, due to the characteristics of the project and the type of industry where it is inserted, the application of this framework needed to be customized. Accordingly to the particularities of the project, the most suitable PM approach is a hybrid approach, where initially the scope of the project is delineated, with a contingency plan, supported by SAFe® to manage the issues that arise throughout the project. The agile methodologies allow customer centred attention, more communication channels, and by iterating over the product, planning the unscheduled work focusing on high priority tasks. Lastly, a framework in the core of the appearance of the issues was developed, to define the interconnection between the whole SAFe® concepts and to provide an extended view of how the project will progress with the new approach.

***PALAVRAS CHAVE***

*Gestão de Projetos, Abordagem Ágil, Abordagem Híbrida, SAFe®, Sector de Manutenção de Aviões*

# RESUMO

*As operações de manutenção, reparação e revisão produzem grande impacto no ciclo de vida de uma aeronave. As organizações que operam neste setor enfrentam vários desafios no planeamento das atividades que garantem a máxima confiabilidade de uma aeronave, dada a quantidade de manutenção não programada. A subcontratação deste tipo de atividades, por parte das companhias aéreas, tem crescido continuamente como uma alternativa à realização da própria manutenção pesada, adicionando um constrangimento para este tipo de indústrias: gerir as exigências dos clientes.*

*Considerando os principais problemas, é necessário selecionar a abordagem mais adequada para planear e gerir projetos de manutenção de aviões. A gestão ágil de projetos poderá ser uma solução para superar as principais dificuldades deste setor, gerindo as incertezas ao longo do projeto, proporcionando visibilidade ao cliente e controlo sobre o serviço.*

*Este trabalho surge num caso real de um programa subcontratado numa empresa multinacional de fabrico de aviões, que também sofre de desafios significativos no planeamento e gestão de atividades de manutenção ao longo do ciclo de vida do projeto. O programa experienciou metodologias ágeis que revelaram um impacto positivo. Para que todo o programa adote a agilidade e supere os principais problemas identificados, foi proposto o uso de uma elaborada e bem definida estrutura ágil. O* Scaled Agile Framework *para empresas é uma base de conhecimento online que implementa diversas técnicas ágeis para apoiar as empresas no desenvolvimento e entrega de soluções, alcançando a agilidade nos negócios.*

*O SAFe® foi desenvolvido principalmente para indústrias de software, devido às características do projeto e ao tipo de indústria em que está inserido, a aplicação desta estrutura necessitou de ser personalizada. De acordo com as particularidades do projeto, a abordagem de gestão de projetos mais adequada é uma abordagem híbrida, onde inicialmente o projeto é delineado, com um plano de contingência, apoiado pelo SAFe® para gerenciar os problemas que surgem ao longo do projeto. As metodologias ágeis permitem centrar a atenção no cliente, mais canais de comunicação e, ao iterar sobre o produto, planear o trabalho não programado com foco em tarefas de alta prioridade. Por fim, foi desenvolvido um* framework *no cerne do surgimento dos problemas, de forma a definir as interligações entre todos os conceitos do SAFe® e fornecer uma visão ampliada de como o projeto irá progredir com a nova abordagem.*

# LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

| | |
|---|---|
| A/C | Aircraft |
| AOG | Aircraft on Ground |
| ART | Agile Release Trains |
| AUP | Agile Unified Process |
| DSDM | Dynamic Systems Development Method |
| DSU | Daily Stand Up |
| DY | Calendar Day |
| FAA | Federal Aviation Administration |
| FC | Flight Cycles |
| FDD | Feature Driven Development |
| FH | Flight Hours |
| I&A | Inspect and Adapt |
| IP | Innovation and Planning |
| MRO | Maintenance, Repair and Overhaul |
| NC | Non-Conformance |
| NFR | Non-Functional Requirement |
| PI | Program Increment |
| PjI | Project Increment |
| PM | Project Management |
| PO | Product Owner |
| RFP | Request for Proposal |
| RTE | Release Train Engineer |
| SAFe® | Scaled Agile Framework for enterprises |
| SoS | Scrum of Scrums |
| ST | Solution Train |
| STE | Solution Train Engineer |
| TO | Technical Order |
| US | United States |
| WIP | Work in Progress |
| WSJF | Weighted Shortest Job First |
| XP | Extreme Programming |

List of symbols

| | |
|---|---|
| % | Percentage |

# GLOSSARY OF TERMS

| | |
|---|---|
| Approach | Ideas or actions intended to deal with a problem or situation. |
| Gemba | Japanese term that means "the real place". When applied in manufacturing, it refers the place where value is created. For instance, in a factory setting, it would be where the actual work is done, the shop floor. |
| Kanban | Japanese word literally translated to "visual sign". It is a method that utilizes a physical board providing clear perceptiveness of workflow through columns that represent the state of work. |
| Methodology | A set or system of practice, techniques, and principles for regulating a given discipline. |
| PDCA cycle | The Plan-Do-Check-Act cycle is an iterative four-step model used as a project planning tool for control and continuous improvement of processes and products. The plan step establishes objectives, the do performs the objectives, the check step is the study of the results, and finally the act serves as an improvement of the processes. |
| Scrum | A single-team framework used to manage the project life cycle. Scrum properly tests product increments within short iterations. The short iterations are called Sprints, where a potentially releasable increment of product is produced. Scrum defines five types of meetings: sprint planning meeting, daily scrum meeting, sprint review meeting, sprint retrospective meeting, backlog refinement meeting. |
| Scrumban | Methodology that uses Scrum as a framework, and Kanban for process improvement. |

# FIGURES INDEX

# TABLES INDEX

# INDEX

# INTRODUCTION

1.1 CONTEXTUALIZATION

1.2 MAIN GOALS

1.3 METHODOLOGY

1.4 DISSERTATION FRAMEWORK

# 1 INTRODUCTION

## 1.1 Contextualization

MRO´s organizations, especially in the A/C maintenance sector, address various challenges on planning activities, once they are inside in an unpredictable and ambiguous scope.

As consequences of these difficulties, it is necessary to obtain an optimal approach and methodologies to plan an A/C maintenance and, consequently manage that project during its life cycle. Deciding which approach is the most suitable for the project circumstances is a challenge, in certain situations, agile approaches in PM are the best way to handle this problem, but frequently the association with predictive approaches proves to be another path to follow.

Concerning the main problems contextualised above, this work arises in the context of a real-life case study of a maintenance and upgrade program in an A/C manufacturing enterprise. The enterprise, besides the development of A/Cs, provides extensive maintenance services, *i.e*. the A/C is fully disassembled, all parts are inspected in detail, including electrical and avionic devices, some are repaired, and others must be replaced. Furthermore, to keep up with technological advances, update modifications occur, not only in software level but also in hardware.

At this point, a hybrid approach for the planning phase and a traditional approach for the execution phase are utilized in the program, where planning and execution phases are ongoing in parallel. In the production, some agile methodologies without a background and a know-how about this type of methodology are experienced. All other areas of the project have only predictive approaches. The modification projects are totally applying predictive approaches with clear separation, planning and execution phases. Hardly ever, does the program follow as planned. Once throughout its life cycle frequently unplanned work occurs, that is findings that erstwhile were not predicted or were not included in the initial proposal, and only with the first ground inspections can be detected.

The first experiences with agile methodologies proved positive results. Therefore, implementing in the program a stabilized and well elaborate agile framework was proposed, in order to plan the turnaround time and accomplish it timely, due to the investment associated. Another reason was to manage and support teams interconnecting all departments in such a complex project, attempting to control the unstable environment with the planning and execution phase ongoing in parallel, and complying with all variables and requirements evolving airworthiness directives.

## 1.2 Main Goals

Due to the main challenges of the organization, and taking into account the transition of predictive to agile approaches in the PM, the main objective is to apply the SAFe® methodology in the program, considering that some parts are not using agile techniques, and defining what these elements must fulfil. Thus, the following specific objectives have been defined:

- Identify the major issues on planning and managing activities in A/C maintenance projects;
- Relate the identified issues in the A/C maintenance sector with the ones that occur in the program;
- Characterise the main problem on planning and managing maintenance activities in the program;
- Apply and tailored SAFe® concepts within the program to overcome the blocking points.

## 1.3 Methodology

To achieve the proposed objectives, it was necessary to follow certain steps that could lead to a proper characterisation and a feasible application of SAFe® within the program.

Understanding the projects with complex inspection/repair tasks in the A/C sector and their particularities is essential to detect the major blocking points on this type of projects. Therefore, a literature research regarding this topic was conducted, in order to evaluate frequent issues on similar projects in this type of sector. The experience acquired on the program, as well as the feedback provided by the organization, were also factors that support the characterisation of the problems in the sector and, more precisely, on the program.

Previously to the application of SAFe® in the program to overcome the barriers formerly identified, it is necessary to obtain an extensive knowledge concerning this framework. Thus, the initial step was to distinguish the main differences among the four configurations to determine the appropriate configuration to be applied in the program. As the main difference relies on the value streams and Agile Release Trains (ARTs), it was required to identify some elements within the program. Identifying the operational value streams, the systems that support them and the people who develop and maintain those systems, is crucial to define the development value stream that contains the system and the people. Furthermore, to add the people necessary to build the full business solution and identify the ARTs that realise the development value stream, provided a general spectrum of the program and the people working on it, supporting the decision of the most suitable configuration to be applied in the program to suppress the barriers found. Once selected, the appropriate configuration is indispensable to grasp the set-up in detail, and to recognize the concepts that are useful to accomplish the main objective.

Subsequently to the assessment of the whole concepts of the configuration and their interconnections, follows the application of SAFe® concepts in the program, by adapting the concepts to this genre of projects, saving resources without losing agility, and avoiding over allocation.

For an easy application of SAFe® after identification of the ARTs, it was selected the one where the main study issues in this work occur. After all the concepts have been tailored and applied in the program, it is necessary to specify how all the items interconnect and correlate through the development of the project. Nevertheless, it is important to mention how these elements coordinate in time. For that, a schedule with the meetings in an attempt to avoid loss of work and to provide a general view of the events' disposition was developed.

For a clear comprehension of the aforementioned methodology, the following points describe, in short, the several steps utilized to accomplish the proposed objectives:

1. Research in literature and understanding projects with complex inspection/repair tasks and their particularities;
2. Detect the biggest issues on this type of project;
3. Research and understand SAFe®;
   3.1. Distinguish the main differences among the four configurations;
   3.2. Identify the operational value streams;
   3.3. Identify the systems that support the operational value stream;
   3.4. Identify the people who develop and maintain those systems;
   3.5. Define the development value streams that contain the systems and people;
   3.6. Add the people needed to build the full business solution;
   3.7. Identify the ARTs that realize the development value streams;
   3.8. Determine the appropriate configuration and comprehend the set-up in detail;
4. Overcome the barriers implementing SAFe® concepts;
   4.1. Select the critical ART;
   4.2. Adapt the concepts to this kind of project and save resources without losing agility;
5. Specify concepts' correlations through ART's life-cycle;
6. Schedule the meetings to avoid loss of work.

## 1.4 Dissertation Framework

This dissertation contains four main chapters: Chapter 1 – Introduction, Chapter 2 - Bibliographic work, Chapter 3 – Development and Chapter 4 – Conclusions. The first chapter contextualises the environment where the work is inserted and introduces the topic of the work, specifies the main objectives of the study and the utilized methodology to reach the goals. The bibliographic work chapter is the theoretical work that supports the development of the dissertation, the main topics were researched, describing the main studies regarding those themes. The core of the dissertation is in the development chapter, where the main issues are characterized, the adaptable application of SAFe® in the program gives a general framework of the project with the interconnection of the new implemented concepts, it also clarifies how the events are distributed over time. At the end, the limitations of the work are presented in a critical review. In the final chapter the conclusions of the dissertation are presented, as well as some suggestions are given for future works regarding this theme and how SAFe® could be implemented in the program.

# BIBLIOGRAPHIC WORK

# 2 BIBLIOGRAPHIC WORK

## 2.1 Aircraft Maintenance

Maintenance is not only a group of techniques and actions to restore a failure or deteriorated system, but it should be actions to prevent breakdowns or degradations experienced by the operations, by improving its conditions and prolonging the life cycle of that system [1 – 3]. A system has a hierarchical structure: a system can include various sub-systems, with each sub-system involving other sub-systems, and so on. A system is entitled a single or multi-unit system based on the decisions of maintenance and the viewpoint of the agents. For instance, at an advanced military supply depot, an engine may be considered a single-unit system to be replaced in case of failure or a multi-units system when the components require a repair [4].

On maintenance actions two types are distinguished, preventive and corrective. Preventive actions are planned based on time, age, usage, or condition information and performed before the failure of a unit, with the objective to decrease the probability of failure and provide a solid long-time range operational equipment. Corrective actions occur after the failure, in an attempt to minimise the severity of the equipment malfunctions [4, 5].

The aviation industry has grown due to the development of global economy and consequently, increased the demand for commercial air transportation. As a result, this type of industry must overcome many challenges on planning activities to ensure the maximum reliability of A/C [6] *apud* [7 – 9]. Maintenance and inspection operations of A/C structures have a great impact on the life cycle cost of an A/C. Many airline companies are re-evaluating their maintenance practices to ensure that MRO operations on their fleet, continue to be conforming to the regulations of aviation authorities [6, 10]. The cost of MRO is the third highest cost behind fuel and labour cost, being around 9% of the annual operating cost for airlines. Outsourcing of A/C MRO activities has been continuously increasing in airline companies, as an alternative to conducting the heavy maintenance requiring significant inputs in terms of the hiring of licensed engineers, holding maintenance materials and operating a maintenance hangar within the airline company [6].

The objective of airlines is to maintain the reliability of A/C at a minimum cost, while the objective of MRO facilities is to receive a component unit, identify required MRO tasks, complete a repair, and return the unit to the customer at the lowest time possible, and by this, increasing revenue and reducing costs [11, 12]. It is illustrated in Fig. 1, the relationship between the level of MRO support that is needed in contrast to the involvement from airline companies, relating to different maintenance contract types [13].

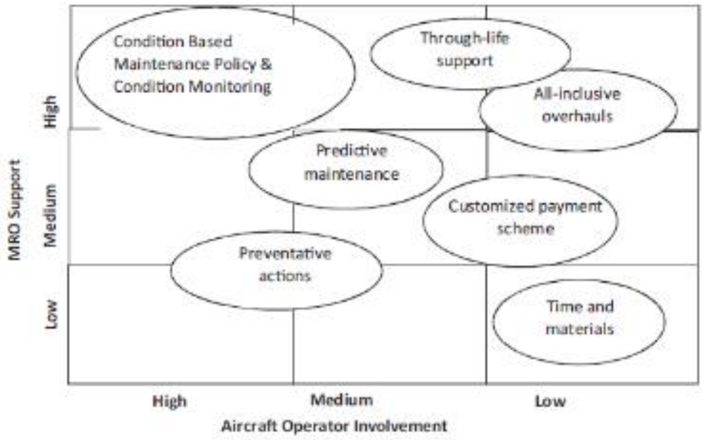

Fig. 1 - MRO Support vs Aircraft Operator [13]

The budget of maintenance is calculated not only using the cost that is related to the maintenance process, such as cost of labour, inventory, material and equipment, but also including the downtime cost, avoiding a lengthy Aircraft On Ground (AOG) when an A/C is subjected to maintenance operations, which will increase this cost [12, 14].

Scheduling the maintenance is mentioned as preventive maintenance in aviation. Formally defined by the relevant authorities, e.g. the Federal Aviation Administration (FAA) in the US, are all the individual maintenance tasks to be performed according to the maintenance time limitations. This type of maintenance has become progressively difficult due to the prominence of efficiency and absence of a precise and appropriate maintenance scheduling tool [11, 15].

In the aviation industry, A/C are aged by daily utilization with respect to three different usage parameters, calendar day (DY), flight hours (FH) and flight cycles (FC). One DY is a full-24-hour period; FH refers to the elapsed time between wheel lift-off and touch down; and a FC is defined by a complete take-off and landing sequence [15]. These factors lead to the schedule maintenance packages that are represented by an alphabetic designation, the so-called checks.

The three commonly used letter checks consist of: A-Check, C-Check, and D-Check. The A-Check generally consists of a general inspection of the interior/exterior of the airplane with selected areas opened. The A-check is typically performed biweekly to monthly. Examples of A-check tasks are checking and servicing oil, filter replacement, lubrication, operational checks, and inspections. The C-Check is typically scheduled every 12-20 months depending on the operator, airplane type and utilization. Examples of C-check tasks include functional and operational systems checks, cleaning and servicing, attendance to minor structural inspections and, Service Bulletin requirements. The D-Check, Heavy or Maintenance Visit, occurs every 6-12 years, depending on the airplane type and utilization. Usually, the A/C is taken out of service for several weeks and many of the A/C’s internal components are functionally checked, repaired/overhauled, or exchanged [16].

During a normal operation routine, an A/C will require unscheduled maintenance that may result from scheduled maintenance tasks and is mainly identified at the end of the A/C inspections. A significant part of the maintenance work is stochastic, given the amount of unscheduled maintenance, being able to reach as high as 198% of the scheduled workload [11, 16].

Summing up, planning the maintenance is a problem for this type of industry, which deals with various uncertainties and is based on three aspects, the capacity planning, spare parts management, and tasks scheduling. The traditional planning process of MRO enterprises is represented in Fig. 2. Maintenance capacity planning determines the amount of necessary resources, but the critical aspect focuses on defining the exact number of resources to face future work as well as planning the required space in the hangar due to ambiguity of work demand [6, 11]. Spare parts are kept in stock according to the inventory, often having variable or unknown supply lead times and present highly random demand. Task scheduling is related to when and where each A/C should submit to different maintenance interventions, according to specific parameters [11].

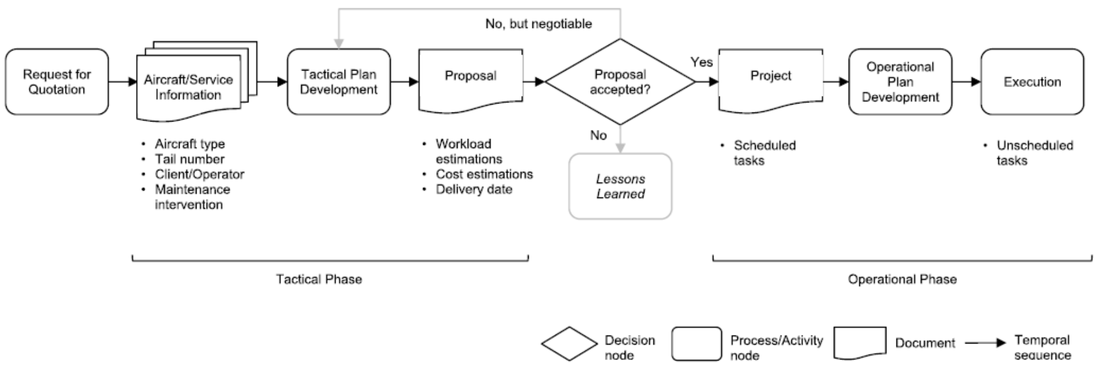


Fig. 2 - MRO Planning Process [11]

Intelligent MRO have become gradually more important in aviation industry. A/Cs are now entirely equipped with sensors that continually collect information about their status, diagnosis, and possible faults. The use of this information and communication technologies, as well as artificial intelligence techniques, can help to make these operations more cost effective and facilitate effective maintenance management [10, 17].

Some studies were performed with the purpose of decreasing and finding the main reasons that affect this type of actions in this singular industry. From the research on this theme, the most complete studies that present a solution for this problem were selected, as depicted in Table 1.

Table 1 - Research regarding Aircraft Maintenance

| Bibliographic References | Work Description |
| --- | --- |
| D. Dinis, A. Barbosa-Póvoa, and Â. P. Teixeira, "A supporting framework for maintenance capacity planning and scheduling: Development and application in the aircraft MRO industry", 2019 [11]. | Due to the uncertainty of the maintenance work, given the amount of unscheduled maintenance, this paper suggests a new framework, different from the traditional planning process of the A/C maintenance enterprises, which allows MRO organizations in managing this stochastic work throughout the maintenance planning process, and comprises for that end a set of requirements for data treatment and a method for data analysis. This developed method is based on some indicators calculated from historical data to comprehensively understand the expected maintenance work, trying to minimise the unscheduled work and facilitate the maintenance planning. Additionally, future data recordings need to be defined in order to overcome important shortcomings, as identified in the collected data. |
| Y. Qin, Z. X. Wang, F. T. S. Chan, S. H. Chung, and T. Qu, "A mathematical model and algorithms for the aircraft hangar maintenance scheduling problem", 2019 [6]. | Frequently, hangar space is a bottleneck in planning the maintenance schedule for the maintenance company, as the movement of A/C causing blocking and geometric factor for A/C parking are unique features in hangar maintenance scheduling. This work, integrates the scheduling and parking layout planning problems in a mathematical model, in order to give an effective and feasible solution for large size instances covering a long planning period. |

## 2.2 Project Management

A project is a temporary endeavour assumed to create a unique product, service, or result. An objective is defined, and projects are undertaken to accomplish those objectives. The temporary nature of projects indicates that a project has a definite beginning and end. Temporary does not necessarily mean a project has a short duration. The end of the project is reached when the objectives are accomplished or cannot be met. Some factors determine the initiation context of a project, which are capable of changing an organization and enabling business value creation [18].

To achieve a specific objective, projects are divided into five groups which correspond to independent project phases. They are the initiating process group, planning process group, executing process group, monitoring and controlling process group, and closing process group. In addition to process groups, processes are also categorised by knowledge areas that are interrelated. A knowledge area is a recognized area of PM, characterized by its knowledge requirements and described in terms of its component processes, practices, inputs, outputs, tools, and techniques. The ten knowledge areas are project integration management, project scope management, project schedule management, project cost management, project quality management, project resource management, project communications management, project risk management, project procurement management and project stakeholder management [18].

Projects exist in environments that can have an influence on them. These factors may improve or constrain the progress of the project and may have a positive or negative influence on the outcome. Two major categories are enterprise environmental factors and organizational process assets. Enterprise environmental factors refer to conditions, not under the control of the project team, that influence, constrain, or direct the project. These conditions can be internal, such as organizational culture, structure, and governance, geographic distribution of facilities and resources, infrastructure, information technology software, resource availability, employee capability; and/or external to the organization, in this case they can be marketplace conditions, social, cultural influences and issues, legal restrictions, commercial databases, academic research, government or industry standards, financial considerations and physical environmental elements. Organizational process assets are the plans, processes, policies, procedures, and knowledge bases specific to and used by the performing organization. The project team members may be able to update and add to the organizational process assets as necessary throughout the project. They may be grouped into two categories: processes, policies, and procedures; and organizational knowledge bases [18].

PM is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. PM is accomplished through the appropriate application and integration of the PM processes identified for the project. PM enables organizations to execute projects effectively and efficiently. Using PM processes, tools, and techniques, puts in place a sound foundation for organizations to achieve their goals and objectives [18].

Although PM did not appear as a subject until the early 20$^{th}$ century, it has performed a fundamental role through history, otherwise such great architecture icons as the Pyramids of Giza, the Great Wall of China or the Coliseum in Rome would not have been built. Henry Gantt (1919) conceived tools to better design and track large projects by dividing them into discrete tasks. In the 1960's and 1970's, experience with large projects led to methods designed to focus on task interdependencies and establish attention on the most critical tasks (Project Evaluation Review Techniques, Critical Path Method, *etc*.). In the 1980's and 1990's, following the increased use of computers, several software programs emerged to help organizations achieve their goals while managing risks. Since then, professionalization has been promoted by the International Project Management Association and the Project Management Institute, with decidedly mixed results [19] *apud* [20, 21].

Several schools of thought are recognized in PM. In the optimization school, the project is seen as a machine and is based on a mathematical optimization. The modelling school attempts to optimize the project from the perspective of one or two objectives (for example, time and cost) and the interactions between its components. The governance school consider the project as a legal entity and focuses on the governance of this entity and the relationships between project participants. The behaviour school acknowledge the project as a social system. The success school recognize the project as a business objective, focuses on success and failure of projects. The decision school sees the project as a computer, focusing on data and information collection, processing it, in order to examine the impact these have on the project. The process school describes the PM as a structured process, comparing it to an algorithm. The contingency school considers that every project is different, and the management approach needs to be adjusted to the details of the project. The marketing school introduces the perspective of marketing of the project, linking it to needs of stakeholders and their management [22] *apud* [23, 24].

Recently, projects and their management are recognised as “a way to sustainability”. Thus, identifying the sustainability as a school of thought, considering projects in a societal perspective, having a management for stakeholders approach and taking into account the balance between three criteria, economic, social and environmental sustainability, the so called triple bottom line concept, applied for business case and project success [22].

In Fig. 3 the dimension of the sustainable PM, considering the globalization and the duration of the project is illustrated.

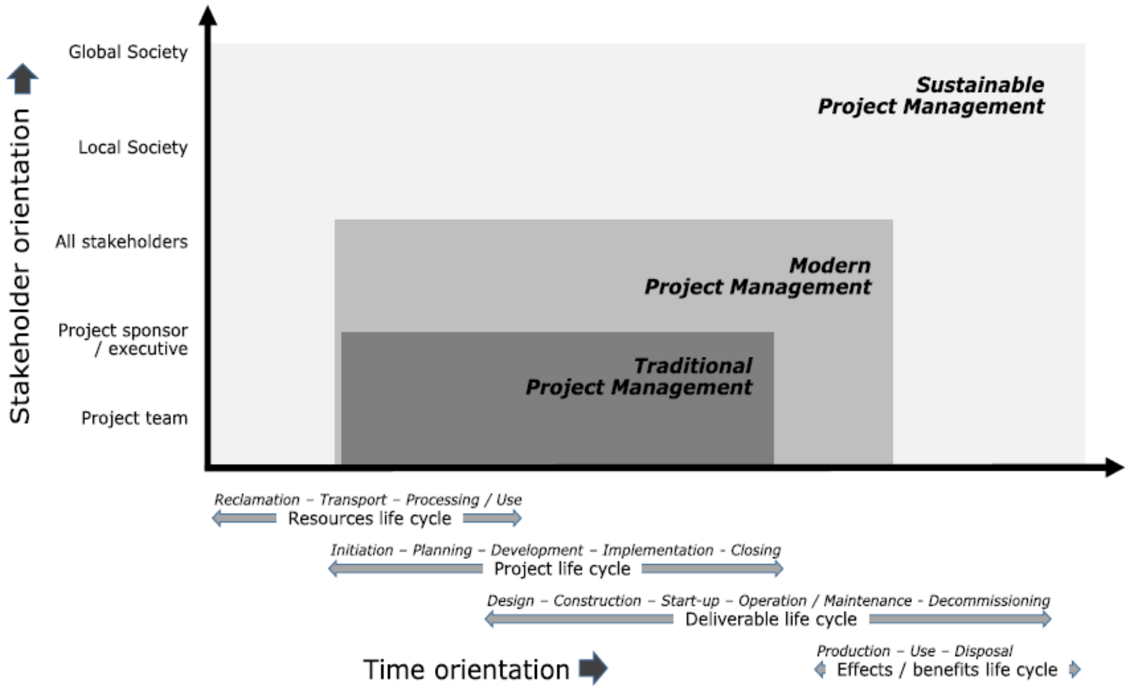


Fig. 3 - Dimension of Sustainable Project Management [22]

The new operating environment for projects is increasingly unstable, turbulent, and shaped by diverse and vocal interests. Thus, the development economics literature and the rich lessons of development projects implemented in volatile, complex and crisis ridden contexts, are now highly relevant to developed countries. Adaptable PM processes, systems thinking, as well as experimental approaches to the project cycle should be adopted, as appropriate [19].

There are a variety of ways to organize a project, based on the environment that it is surrounded, with high degree of change or not, *i.e.*, whether it is involved in high uncertainty or predictable and common situations; and the frequency that occurs the delivery of the project, *i.e.,* whether it is a long and common project or if it is delivered in small systems needing adjustments during the project, or even if it has high delivering rates changing the conditions through the diverse projects. It is up to the project teams to choose the best approach that can satisfy those characteristics. Four types of approaches are recognised: predictive, iterative, incremental, and agile. Fig. 4 illustrates the context where these approaches are applied [25].

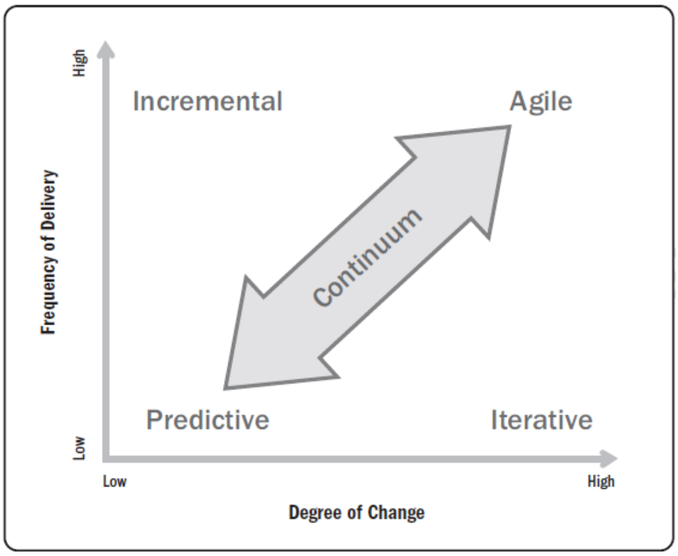


Fig. 4 - Approaches' Context [25]

**Predictive**

A more traditional approach is involved in high certainty and predictable environments, taking advantage of things that are known and proven. It is executed in a sequential process, as shown in Fig. 5, reducing uncertainty and complexity and does not typically deliver business value until the end of the project [25].

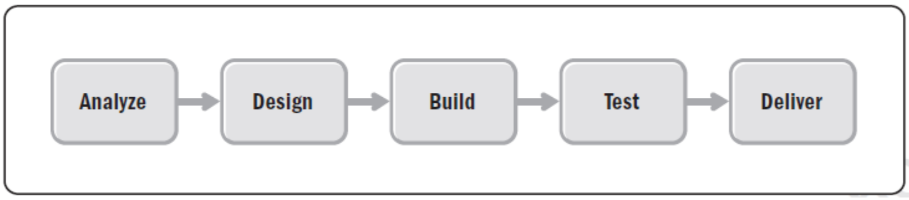


Fig. 5 - Predictive Life Cycle [25]

**Iterative**

An approach that allows feedback on partially completed or unfinished work to improve and modify that work. Results of successive prototypes or proofs of concept, which provide a feedback to the stakeholders. Based on this acquired knowledge, there is a rework for improvement of the project, which is shown in Fig. 6. Iterations help to identify and reduce uncertainty. Projects benefit from this type of approach when complexity is higher or the project suffers frequent changes, but the frequency of delivery is low [25].

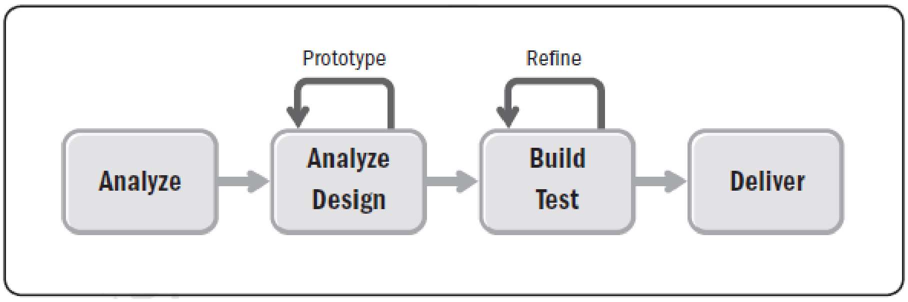


Fig. 6 - Iterative Life Cycle [25]

### Incremental

An approach that provides finished deliverables that the customer may be able to use immediately. It optimizes projects for speed of delivery, delivering value more often. The degree of change is less important than ensuring the customer gets value sooner than at the end of the project. This frequent delivery or smaller deliverables are exemplified in Fig. 7. This reduces potential rework and/or customer dissatisfaction [25].

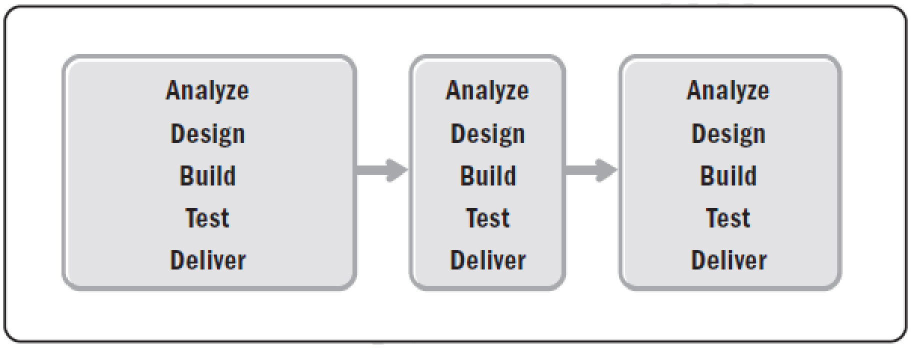


Fig. 7 - Incremental Life Cycle [25]

### Agile

An approach that leverages both the aspects of iterative and incremental characteristics to refine work items, and deliver them frequently in order to adapt to high degrees of change, and deliver project value more often. When teams use agile approaches, they iterate over the product to create finished deliverables. The team gains early feedback and provides customer visibility, confidence, and control of the product. The project may provide an earlier return on investment, because the team delivers the highest value work first [25].

Table 2 summarises the characteristics of the four approaches above-mentioned.

Table 2 - Characteristics of the Approaches [25]

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

### 2.2.1 Agile Approach

Agility is stated and defined by many authors, leading to different interpretations. One such interpretation is, in terms of ability, being able to overcome and respond to change in order to revenue in high uncertainty environments; others include the knowledge and experience to adapt to new environments and ambiguous situations; or is viewed as persistent behaviour or ability of a complex entity that is able to surpass expected or unexpected changes rapidly; or even the transition of traditional methodologies, in order to be prepared for turbulent environments and accelerate project deadlines [26] *apud* [27 – 29].

Thus, the best description of agility is viewed more as an ability of the project team, assumed that it is not a characteristic or an attribute of method or practice. Agility as a team performance, provides a more comprehensive view of the agile methods, practices, and tools. Three essential factors that characterize the environment where agile approach is involved are the rapid project planning and change, as well as active customer involvement [26].

Summarizing, agile PM results in three main implications:

1. Agility should be considered a project team's performance and not merely an adjective of a certain practice or method, e.g., “agile methods”.
2. The agility performance might be affected by a combination of ability to change the project plan and active customer involvement.
3. Agility as a team's performance indicator has different levels and it would be relevant to investigate how different levels of agility are influenced by internal and external factors, and how these levels might impact project results in different degrees and circumstances [26].

There are a wide variety of different agile methodologies. Some of the most popular and often analysed are: Scrum, extreme programming (XP), Kanban, lean software development, feature driven development (FDD), agile unified process (AUP), dynamic systems development method (DSDM), and others. The agile methodologies try to define the following disciplines: PM, project life cycle, team management, engineering, and delivery. But not all methods cover all the disciplines.

Fig. 8 exhibits a sample of these methodologies based on their depth of guidance needed and breadth of project’s cover. Some techniques are designed for a single project and some provide a larger number of resources than others, or even, some of these frameworks are well formalized, but are not commonly used in projects or organizations, as a result of a design of specific frameworks for single contexts or a particular type of organizations [25, 30].

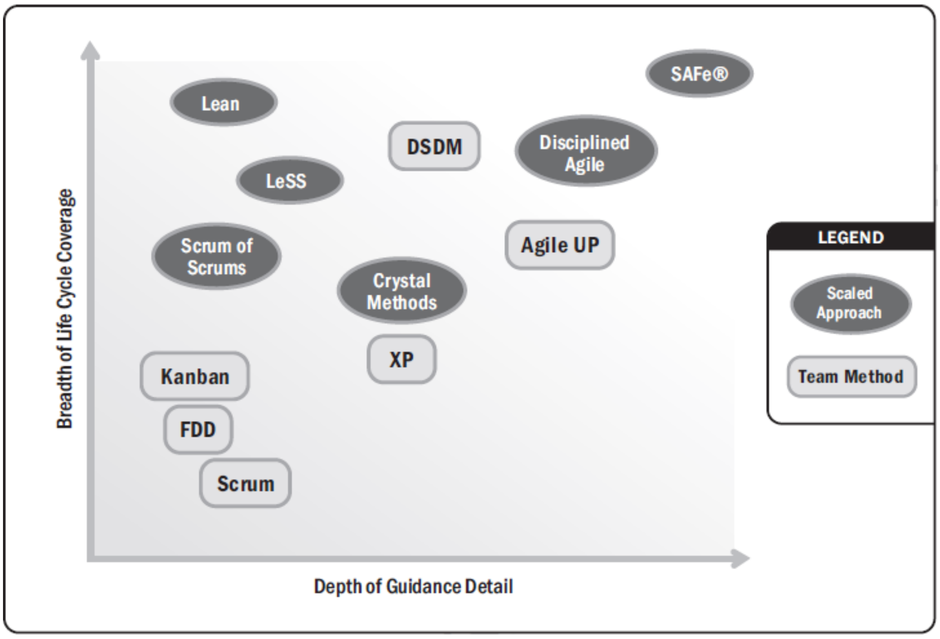


Fig. 8 - Agile Methodologies by Breadth and Detail [25]

Implementing a certain approach in an enterprise context is widely analysed with different focuses. Therefore, some steps must be required before a specific implementation. In order to identify an appropriate approach, the main necessities and the specific requirements of the organization should be considered in foreground. Preparing the enterprise for the selected approach succeeds the first step. Then, it is important to consider the integration of internal relationships and motivation of the project team in the adaptation process of the agile PM approach with the target to improve team effectiveness and self-organization, at the same time. Based on the characteristics of the enterprise, it is the phase of selection of the various methodologies that are most suitable for the project. Adaptation of the methodology will help to get better results before the actual implementation. During this phase conflicts between the selected methodology and enterprise principles or employees' character are analysed for necessary adaptations of the implemented methodology. Lastly, the final stage ensures the methodology implementation [30]. An overview of the implementation phases are detailed in Fig. 9.

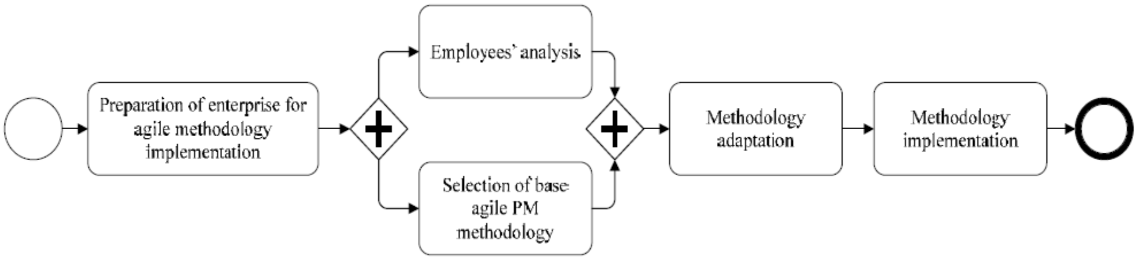


Fig. 9 - Implementation of agile approach [30]

#### 2.2.1.1 Scrum

Scrum is a single-team framework used to manage the project life cycle, running in intervals of one month or less. Scrum is an easy and simple method to handle agile by the whole team involved in the project, through properly tested product increments within short iterations. The short iterations are called Sprints, which have a fixed length, not exceeding thirty days, where a potentially releasable increment of product is produced [25, 31, 32]. Another important part of scrum is that it uses only three roles in managing the project: the scrum team is composed by the Product Owner (PO),the development team and the scrum master [25].

- The PO is responsible for maximising the value of the product;
- The development team is a cross-functional, self-organizing team consisting of team members who have autonomy regarding how to develop the increment;
- The scrum master is responsible for ensuring that the scrum process is upheld and works to ensure that the scrum team adheres to the practice and rules, as well as coaches the team on removing impediments.

To implement scrum, the team managing the project must communicate and collaborate during the whole process. In order to achieve this, scrum defines five types of meetings exhibited in Fig. 10, which must take place in a specific order and those three roles must plan and attend to [31 – 33]:

- Sprint planning meeting: At the beginning of each sprint, the PO and the team responsible for the meeting, negotiate which items are the most suitable for the business. Learning with previous sprints, the team plans how much work to obtain from the sprint and determines how to accomplish that work.
- Daily Scrum meeting: Meetings occur every day, where all the scrum roles must be present, with the purpose of demonstrating the progress of the work and enlightening possible impediments in completing the work.
- Sprint review meeting: Summits where apart from the scrum roles, some external participants are invited, essentially stakeholders, where the un/finished work is revealed. The invited participants play an important role, being encouraged for active interventions, giving feedbacks, and asking for clarifications, so as to add value to the final product.
- Sprint retrospective meeting: Similar to the sprint review, but only for the scrum team. It is assigned to the scrum master the main role, being responsible for collecting all impediments, uncertainties, questions and conflicts, which appeared during the sprint, confronting them with the team, and developing actions that will take the team and organizations to the next level.
- Backlog refinement meeting: It is not a required event, but a required activity that improves the scrum efficiency. It describes the product and what is necessary to achieve or just changes the priorities of the product backlog.

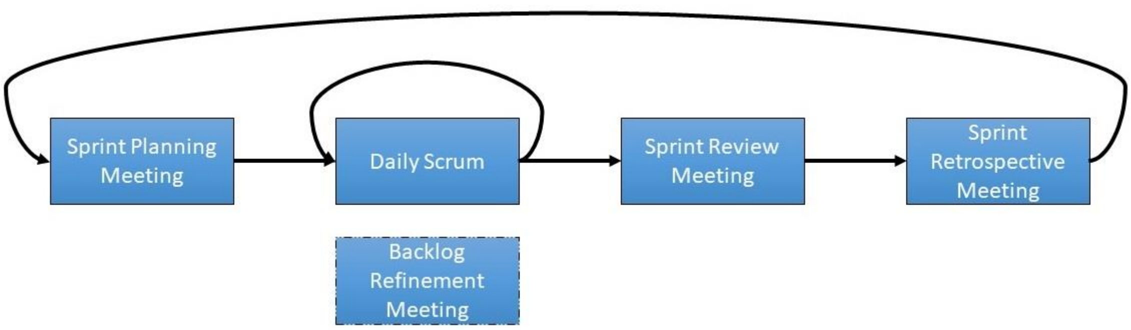


Fig. 10 - Scrum Meetings

### 2.2.1.2 Kanban

Kanban in lean manufacturing is a system for scheduling inventory control and replenishment. The literal translation of the Japanese word Kanban is “visual sign” or “card”. The Kanban method is used and applicable in many settings and allows for a continuous flow of work, being able to visualize that flow and limit Work In Progress (WIP), increasing value to the customer.

This method may be utilized when a team or organization desires to increase the efficiency, productivity and quality, with a higher flexibility of the performed work, when they are inserted in high uncertainty of workload and a continuous delivery environment, focusing in team members and reduction of waste.

A physical Kanban board with cards, as demonstrated in Fig. 11, provides clear perceptiveness to workflow, bottlenecks, blockers, and overall status, through the system for everyone to see. This information is made up of columns that represent the stages the work needs to flow through in order to get done. The simplest of boards could have three columns (*i.e.*, to do, doing and done), but it is adaptable to whatever stages are considered needed by the team utilizing it [25, 32].

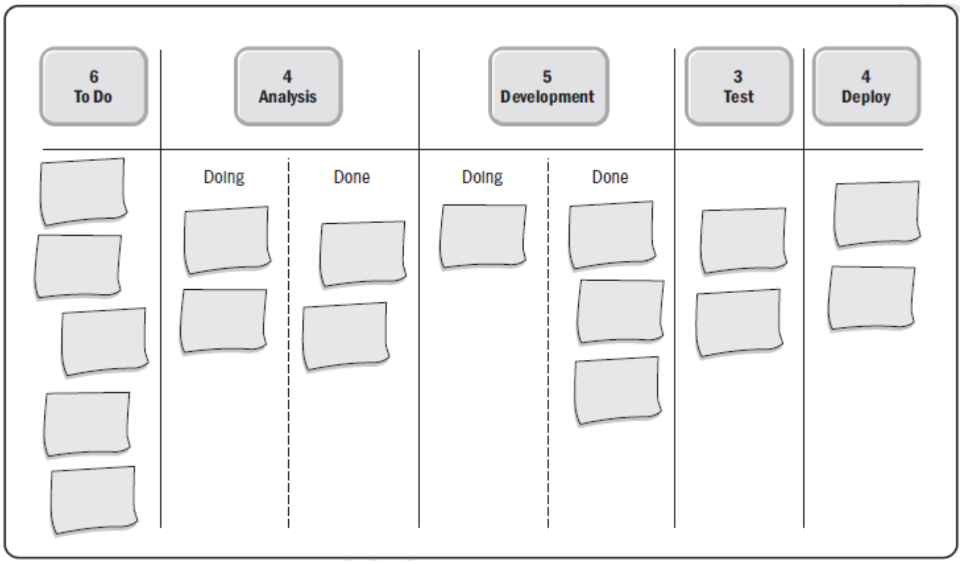


Fig. 11 - Kanban board [25]

### 2.2.1.3 Srumban

This methodology uses Scrum as a framework and Kanban for process improvement. Unlike scrum there are no predefined roles, where the team retains their current roles. The work is organized in small sprints and the meetings are still held, as daily meetings to maintain the collaboration between the team. In those meetings, Kanban boards are utilised, in order to visualise and monitor the work. The tasks are placed on the board and the team manages its works and plans what to do next [25].

Studies continually reveal that in certain situations and conditions, agile approaches and their methodologies have a positive result in projects. Due to the complexity of this approach some challenges arise. Table 3 describes the most important researched works in this specific theme, which attempt to give the best options for these problems.

Table 3 - Research regarding Agile Approaches

| Bibliographic References | Work Description |
|---|---|
| A. Rasnacis and S. Berzisa, "Method for Adaptation and Implementation of Agile Project Management Methodology", 2016 [30]. | As a result of the different type of approaches and high range of their methodologies, this paper has the intent to introduce a method and the best practices for implementation of the agile management approach, according to some aspects that can have an impact on that type of method. Project types, company and employee characteristics, their mutual relations and motivations, are some aspects that can have an impact on the success of the method of implementation. |
| A. Gal, I. Filip, and F. Dragan, "A New Vision Over Agile Project Management in the Internet of Things Era", 2018 [31]. | The constant increase of the network of the internet of things lets this article focus on team network by the improvement of the agile scrum methodology, increasing the efficiency of the process. The solution consists of involving all available smart devices, which can take work off scrum team members, improving their communication process, giving the team members more time to create features and improve the final product. |
| F. Freitas, F. Silva, R. D. S. G. Campilho, C. Pimentel, and R. Godina, "Development of a suitable project management approach for projects with parallel planning and execution", 2020. [34] | In the A/C maintenance sector, it is almost impossible to follow the project as planned, once the total failures can only be found in the ground analysis. This paper develops and implements a hybrid approach in an A/C maintenance company, where the planning and execution of the activities is ongoing in parallel. The result revealed a much more efficient management of the process and an increase of the quality of the PM processes |

### 2.2.2 Hybrid Approach

It is not necessary to use a single approach for an entire project. It is possible to combine approaches for a single project and within a single methodology, having in mind when it is better to use which approach. Both predictive and agile approaches have their advantages and disadvantages if compared to different project characteristics, as presented in Table 4. The challenge is to define which project characteristics are important to define the best methodology that fulfils the specific environment of the organization [25, 35].

The following characteristics demonstrate the different possibilities of mixing agile and predictive approach.

Table 4 – Comparing Predictive and Agile Approach [35, 36]

| Characteristics | Predictive Approach | Agile Approach |
|---|---|---|
| **Requirements** | Clear initial requirements; low change rate | Creative, innovative requirements |
| **Documentation** | Formal documentation required | Tacit knowledge |
| **Project Size** | Bigger projects | Smaller projects |
| **Team members** | Not accentuated; fluctuation expected; distributed team | Collocated team; smaller team |
| **Project plan** | Linear | Complex; iterative |
| **Budget** | The size of the project is important, and the costs are a variable quantity | The project has a fix budget out of which the highest value for the customer shall be developed |
| **Delivery scope** | At the end of the project or in several smaller units | Part by part in several repeated actions |
| **Collaboration with customer** | Not involved | Close and frequent collaboration |
| **Leadership** | The leadership is of a directive nature. | The leadership is carried out more in the form of motivation and coaching. |
| **Life cycle of development** | The product as a whole goes through all development phases from defining the requirements up to handing over to operation | The individual functional units in the framework of each iteration go through a life cycle similar to the classical project. |

#### 2.2.2.1 Agile development followed by a predictive rollout

The basic approach utilizes an agile development in the beginning of the project, followed by a predictive rollout phase, as depicted in Fig. 12. This approach can be used when there is uncertainty, complexity, and risk in an initial phase, followed by a defined, repeatable rollout phase [25].


Fig. 12 - Agile development followed by a predictive approach [25]

#### 2.2.2.2 Combined agile and predictive approaches

Fig. 13 illustrates this type of approach that combines agile and predictive throughout the project life cycle. It is applied when the team is transitioning to agile and uses some approaches like short iterations, daily meetings, and retrospectives, but other aspects of the project such as upfront estimation, work assignment, and progress tracking are still following predictive approaches [25].

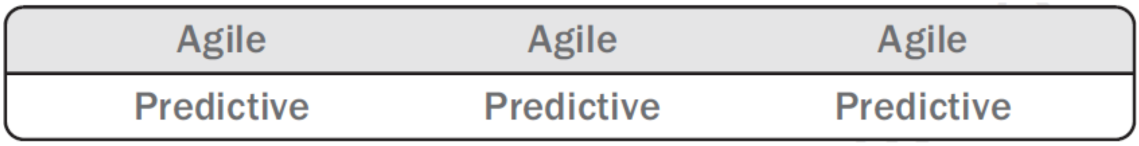


Fig. 13 - Simultaneously use of agile and predictive approach [25]

#### 2.2.2.3 A largely predictive approach with some agile components

In this case, a small agile element is incorporated in a major routine and predictable project, as demonstrated in Fig. 14. The project is being managed using predictive approaches, but a portion of them with uncertainty and complexity are being undertaken in an agile way [25].

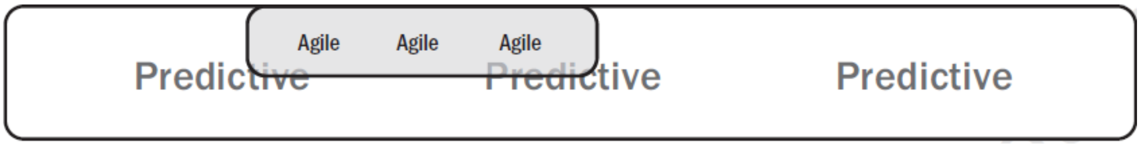


Fig. 14 - A largely predictive approach with some agile components [25]

#### 2.2.2.4 A largely agile approach with a predictive component

This approach might be used when a particular element is non-negotiable or not executable using an agile approach. Fig. 15 exemplifies a predominantly agile approach with a predictive component [25].

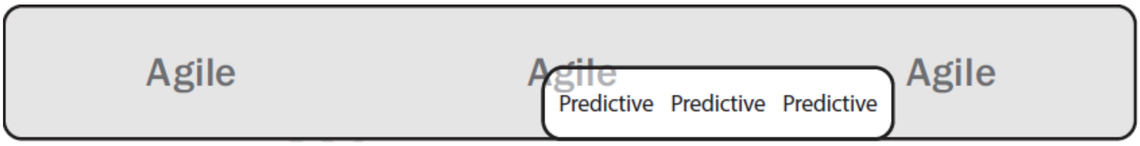

Fig. 15 - A largely agile approach with a predictive component [25]

Implementing an agile approach is a continuous challenge. Certain organizations apply hybrid frameworks to make a transition to agile. Others perform that type of approach in different contexts with a need of constant improvement and rapid deliveries. Empirical studies report that companies benefit when implementing hybrid approaches. Table 5, presents researched studies regarding this mixed approach, and the results that are originated from the implementation, in different types of industries and environments.

Table 5 - Research regarding Hybrid Approach

| Bibliographic References | Work Description |
|---|---|
| E. C. Conforto and D. C. Amaral, “Agile project management and stage-gate model—A hybrid framework for technology-based companies”, 2016 [37]. | Technology-based enterprises search new strategies that combine simplicity, velocity, and flexibility on developing new products. This study implements a hybrid approach in this type of industry, combining stage-gate model and agile PM practices, allowing flexibility and iterative development, using multiple planning and execution levels. The results indicate positive impact on the project and product development performance. |
| F. J. Brandl, M. Kagerer, and G. Reinhart, “A Hybrid Innovation Management Framework for Manufacturing - Enablers for more Agility in Plants”, 2018 [38]. | Manufacturing enterprises cope with fast changing, complex and turbulent environments during innovation projects. In this paper, a hybrid framework is created, integrating a stage-gate model and scrum methodologies, to enhance the company´s market position. |

| Bibliographic References | Work Description |
|---|---|
| E. Papadakis and L. Tsironis, "Hybrid methods and practices associated with agile methods, method tailoring and delivery of projects in a non-software context", 2018 [39]. | This research work intends to capture a global review and the current state of agile approaches and hybrid applications, identifying generic principles, success factors and challenges, by selecting the best methods. The review indicates that companies increasingly are making tailoring efforts combining traditional and agile practices in order to prepare the organization for innovative advancements and changeable environments, focusing on teamwork, customer interaction and involvement, productivity, and flexibility. |
| G. Fernandes, S. Moreira, M. Araújo, E. B. Pinto, and R. J. Machado, "Project management practices for collaborative university-industry R&D: A hybrid approach", 2018 [40]. | The main contribution of this paper is to help stakeholders involved in collaborations between universities and research and development industries to manage such collaborations, presenting a hybrid management approach. The research was based on a contingency theory and identifies practices that all programs must fulfil to ensure the program governance. |

## 2.3 Scaled Agile Framework (SAFe®)

SAFe® is a framework provided by © Scaled Agile, Inc. that focuses on offering, an online, knowledge base of patterns, integrated principles, practices, and competencies for scaling development work across all levels of the enterprise by implementing agile technics. SAFe® applies the power of agile, along with the contemporary knowledge found in systems thinking and agile product development to help businesses address the significant challenges of developing and delivering enterprise-class technology-based solutions with high quality and fast time-to-market. It is an online knowledge base of proven success patterns for achieving business agility. SAFe® supports the full range of development environments with four configurations, being able to select which are appropriate for a certain context [25, 41].

### Essential SAFe®

Essential SAFe® is the configuration which represents the simplest starting point for implementation and provides minimal elements for success [41, 42]. The framework of this configuration is illustrated in Fig. 16.

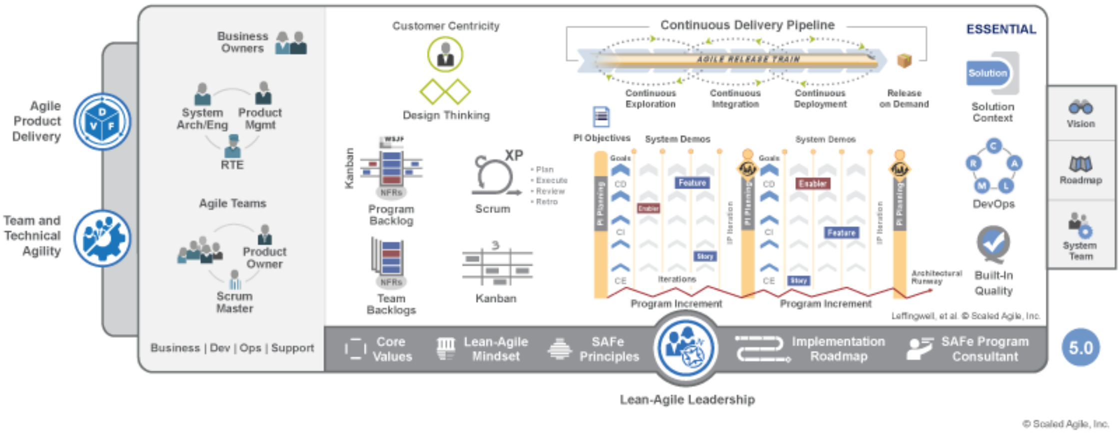


Fig. 16 - Essential SAFe® configuration [41]

### Large Solution SAFe®

This is a configuration for enterprises that are building large and complex solutions. Such solution development is common for industries like aerospace and defence, automotive, and government [41, 42]. The framework of this configuration is demonstrated in Fig. 17.

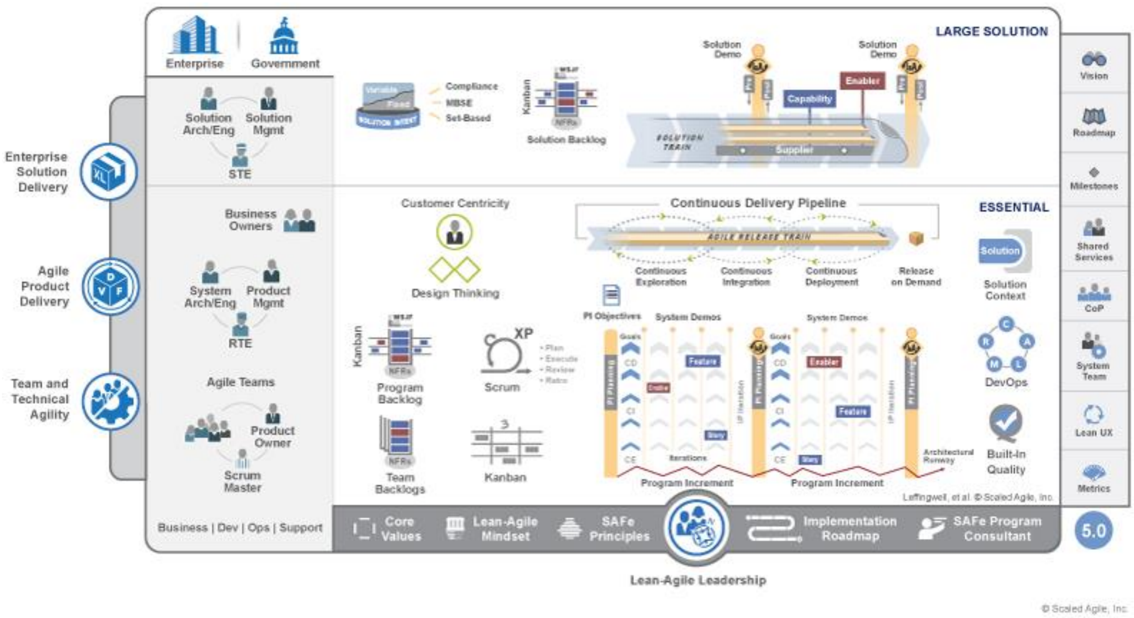


Fig. 17 - Large Solution SAFe® configuration [41]

## Portfolio SAFe®

This is as structure that is the minimum set of competencies and practices that can fully enable business agility in the lean enterprise. In addition, provides portfolio strategy and investment funding [41, 42]. The configuration is exhibited in Fig. 18.

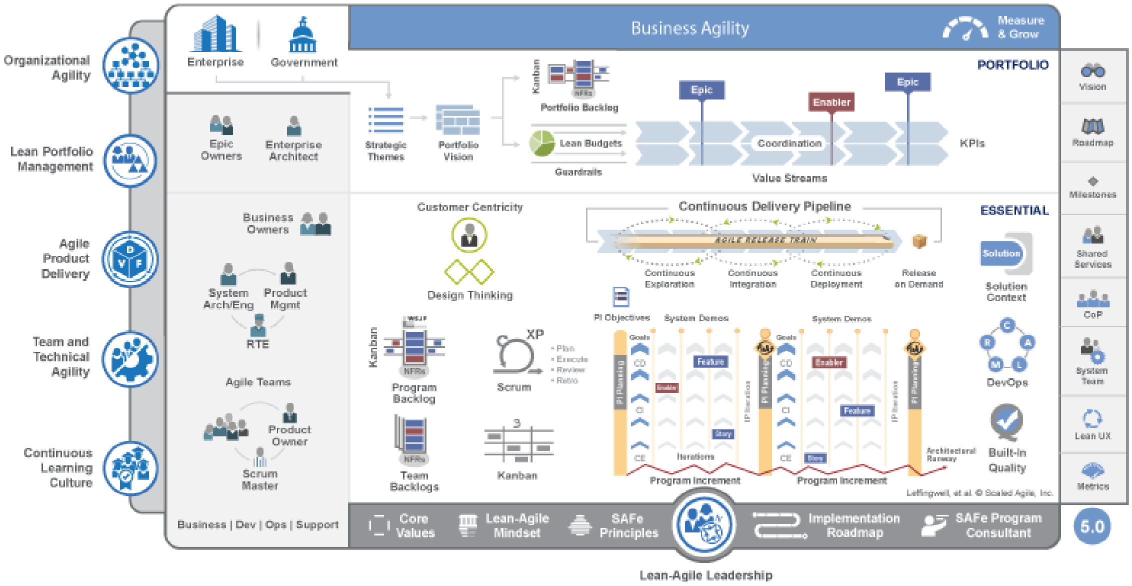


Fig. 18 - Portfolio SAFe® configuration [41]

## Full SAFe®

Full SAFe® represents the most comprehensive configuration. It supports building large, integrated solutions that typically require hundreds of people or more to develop and maintain [41, 42]. The pattern of the configuration is exhibited in Fig. 19.

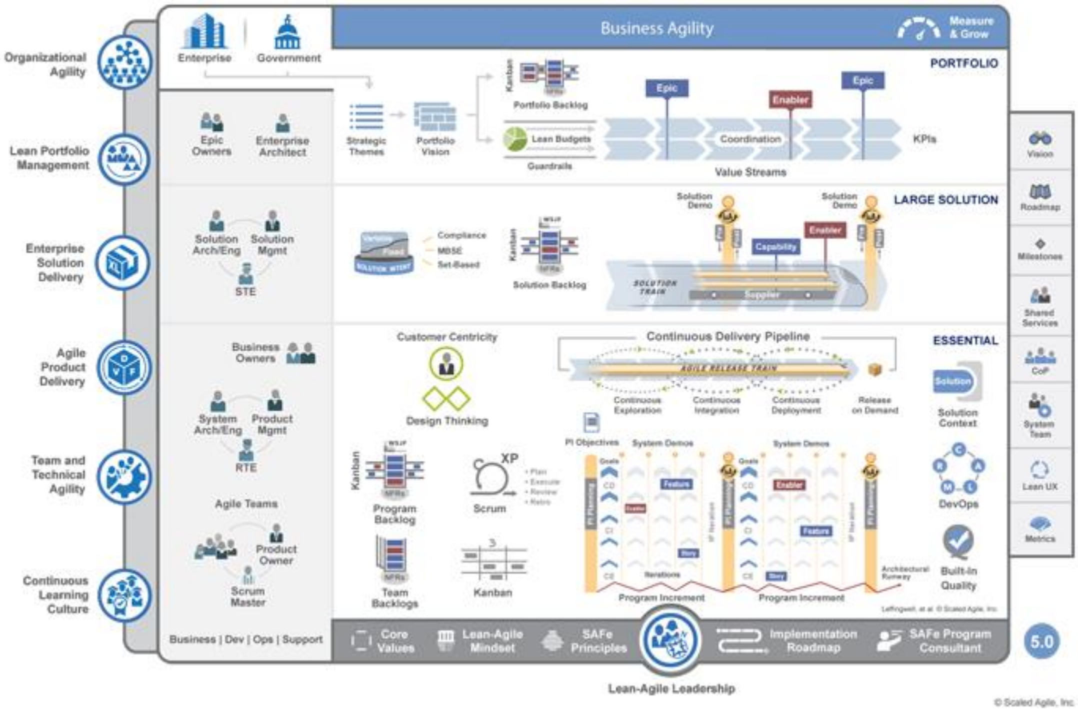


Fig. 19 - Full SAFe® configuration [41]

**Comparing SAFe® Configurations**

As can be perceived from the figures (Fig. 16, Fig. 17, Fig. 18, Fig. 19), each configuration contains a cluster of events, artifacts and roles to reach the Lean-Agile mindset, that may differ according to configurations. Essential framework is the simplest and the base for the upcoming complex solutions. The main difference among Large Solution and Portfolio relies in the quantity and complexity of value streams and ARTs, two major concepts in SAFe®. Portfolio SAFe® contains one or more development value streams and manages the enterprise strategy to portfolio execution around the flow of value, focusing on develop the right things with the appropriate level of investments. Whereas the Portfolio manages one or more value streams, a large value stream must be supported by multiple ARTs, applying the practices of SAFe® Large Solution creating a Solution Train (ST) to help coordinate the contributions of ARTs and Suppliers.

### 2.3.1 Value Stream

Value Streams are a sequence of steps implemented to generate a constant flow of value to a customer. In SAFe®, people are organized around value streams, that enables delivering the maximum customer value in the shortest sustainable lead time, accelerating the time for value (or market).

As exemplified in Fig. 20, one important event triggers the flow of value, possibly a request or order from a customer. The customer receives value when the enterprise executes all steps needed to accomplish this feat. The lead time is the time from the trigger to the delivery of value [41, 43].

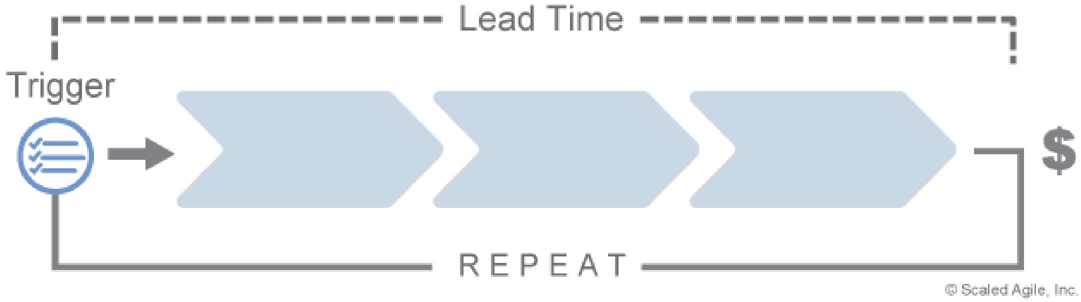


Fig. 20 - Value Stream [41]

SAFe® distinguishes two types of values streams.

- Operational value streams – Contain the steps and the people who deliver end-user value with solutions created by the development value streams. Most often these are physical solutions, or services that the company offers.
- Development value streams – comprise the steps and the people who develop solutions used by operational value streams.

The following illustration (Fig. 21) uses an example of a consumer banking loan to enhance the differences between the two value streams [41].

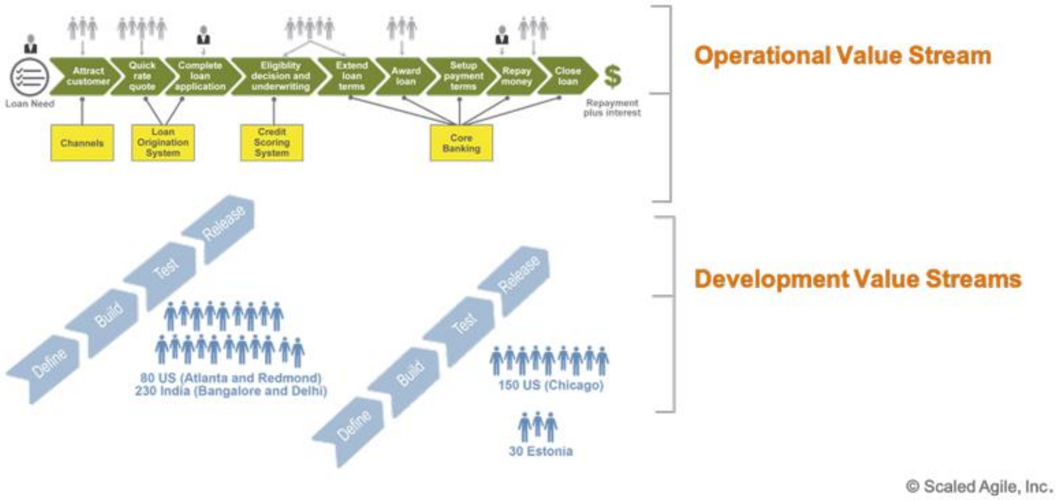


Fig. 21 - Example of a Value Stream [41]

### 2.3.2 Agile Release Train (ART)

ART is an agile team, that incrementally deploys and builds solutions that deliver benefit to the end user. ARTs are cross-functional and have all the people needed to define, deliver, and operate solutions, facilitating the flow of value.

ARTs are organized around the development value streams, given the size and complexity of the stream, for an organization matter, there are three patterns for ART design, as Fig. 22 exemplifies[41]:

- Multiple, smaller development value streams can fit within a single ART.
- Some development value streams can be implemented by a single ART.
- A larger development value stream must be supported by multiple arts.

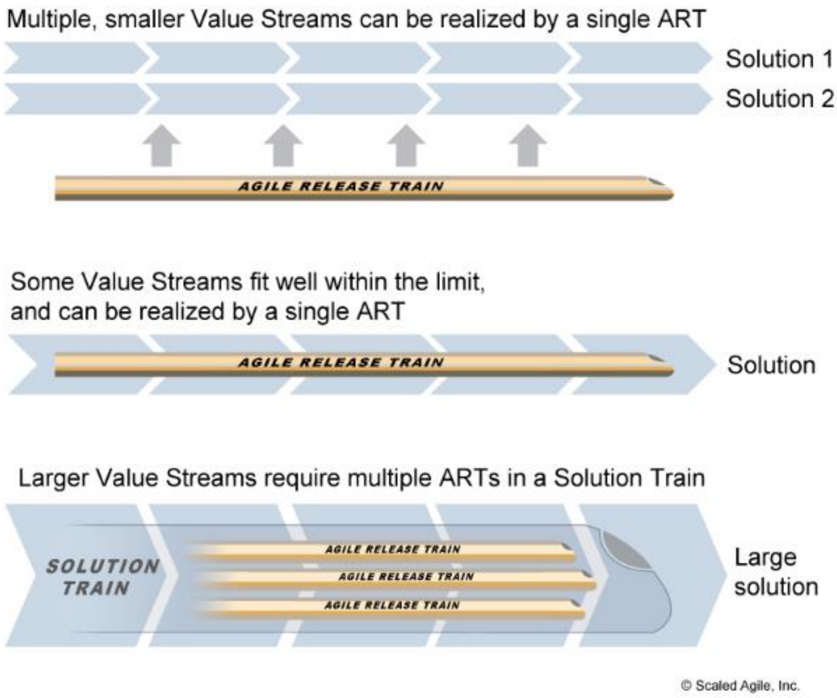


Fig. 22 - Possible scenarios for ART design [41]

### 2.3.3 Solution Train

As evidenced previously, multiple ARTs are required for large development value streams. The ST is the organizational construct created to help coordinate the contributions of ARTs to build and deliver large and complex solutions.

All development activities typically occur within each ART, contributing to the development of the large solution, as Fig. 23 illustrates [41].

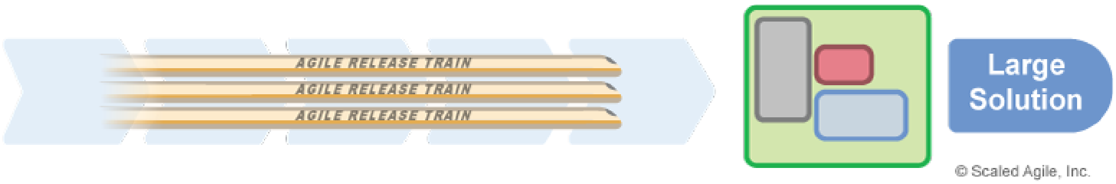


Fig. 23 - Contribution of ARTs in the ST [41]

### 2.3.4 Roles

#### *2.3.4.1 ART Roles*

##### 2.3.4.1.1 Agile teams

Agile teams are cross-functional teams within the ART that define, build, and test features and components, as well as those that deploy, release, and operate the solution, throughout agile practices, based primarily on Scrum and Kanban. According to SAFe®, each agile team has five to eleven dedicated individual contributors, covering all the roles necessary to build a quality increment of value for an iteration.

All agile teams incorporate two key roles, the Scrum Master, and the PO [41, 44].

- Scrum Master – is the leader of the team, assisting meetings, promoting agile behaviour, eliminating obstacles, and maintaining the team's focus.
- PO - is responsible for the team backlog, acts as a customer representation for developer questions, prioritizes the work, and collaborates with the Product Manager to plan and deliver solutions.

##### 2.3.4.1.2 Critical ART Roles

In addition to the agile teams, the following roles help ensure successful execution of the ART [41]:

- Release Train Engineer (RTE) - is a leader who facilitates program execution, removing impediments, managing the risks and dependencies, and promotes continuous improvement.
- Product Manager - is responsible for 'what gets built,' as defined in the Program Backlog. They work with customers and POs to understand and communicate their needs, and also participate in solution validation.

- System Architect/Engineering - is an individual or team that defines the overall architecture of the system. They work at a level of abstraction above the teams and components, and define Non-functional Requirements (NFRs), major system elements, subsystems, and interfaces.
- Business Owners - are key stakeholders of the ART and have ultimate responsibility for the business outcomes of the train.
- Customers - are the ultimate buyers of the solution.

Fig. 24 demonstrates the interactions between the most active roles on the development of the solution and how the information reaches the customer and vice-versa.

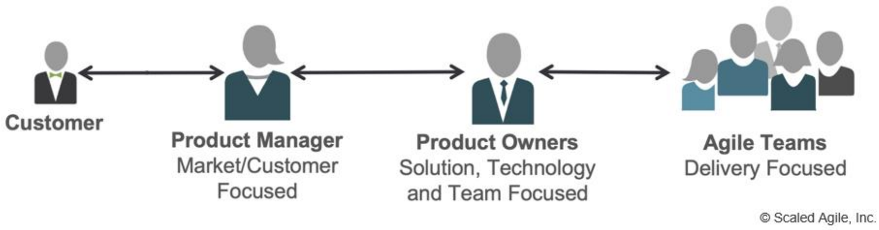


Fig. 24 - Interaction between roles [41]

### 2.3.4.2 Solution Train Roles

In addition to the critical ART roles, the following roles facilitate the execution of the conjunction of all ARTS in the Large Solution designated as ST [41]:

- Solution Train Engineer (STE) - is the leader of the ST. Their control allows the train to run smoothly by identifying and resolving issues across the entire solution. The STE facilitates the large solution-level events and monitors the solution Kanban. They also work with RTEs to coordinate delivery.
- Solution Manager - represents the customer's general needs across ARTs. They collaborate with the Product Manager of each ART to define capabilities and split them into features. The Solution Manager, is the primary content authority for the solution backlog, also contributes to the economic framework that governs the ARTs and Agile teams.
- Solution Architect/Engineering - defines collaboratively the technology and architecture that connects the solution across the ARTs. It works with the ART's System Architect/Engineering team to help guide their portion of the solution's design.
- Supplier - Is an internal or external organization that develops and delivers components, subsystems, or services that help STs and ARTs provide solutions to their customers.

### 2.3.5 Artifacts

#### *2.3.5.1 Solution Backlog*

The Solution Backlog is the holding area for upcoming Capabilities and Enablers, each of which can cover multiple ARTs and is intended to advance the Solution and build its architectural runway [41].

- Architectural Runway - consists of the existing code, components, and technical infrastructure necessary to implement short-term features, without the need for excessive redesign and delay.
- Enabler - supports the activities needed to extend the architectural runway and solutions that meet near and long-term goals. Some enablers correct existing problems with the solution. These enablers start out in the backlog, but after implementation, they may become NFRs which can be considered constraints on new development.
- NFRs - define system attributes such as security, reliability, performance, maintainability, scalability, and usability. They serve as constraints or restrictions on the design of the system across the different backlogs.
- Capability - is a higher-level solution behaviour that typically spans multiple ARTs. Capabilities are sized and split into multiple features (explained in the next subsection) to facilitate their implementation in a single Program Increment (PI).

#### *2.3.5.2 Program Backlog*

Program Backlog is the holding area for upcoming Features, which are intended to address user needs and deliver business benefits for a single ART. It also contains the enabler features necessary to build the Architectural Runway. Fig. 25 displays an example in which way a capability could be broken-down into features [41].

- Feature – is the service that fulfils a stakeholder need. Each feature includes a benefit hypothesis and acceptance criteria and is sized or split as necessary to be delivered by a single ART in a PI.

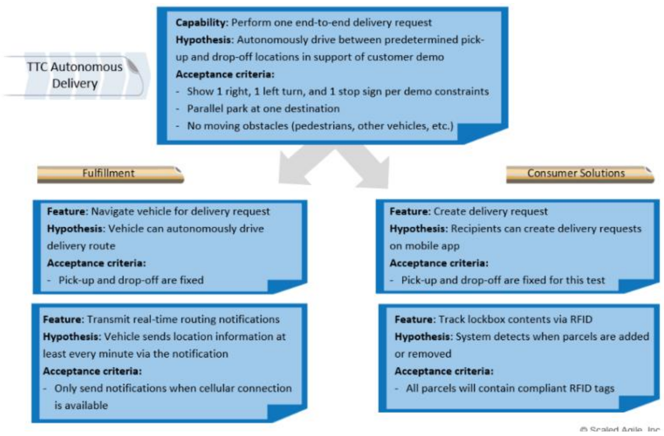


Fig. 25 - Capabilities split into Features [41]

### 2.3.5.3 Program and Solution Kanban

To work the backlogs, teams managed items through the Program and Solution Kanban, that follows certain processes as stated in SAFe®:

- Funnel;
- Analysing;
- Backlog;
- Implementing;
- Validating on standing;
- Deploying to production;
- Releasing;
- Done.

The work travels through the states of "funnel" and "analysing" and the highest-priority features and capabilities that were sufficiently elaborated and approved, move to the "backlog" state. Then, they are prioritized relative to the rest of the backlog to await implementation. When moved to the backlog, items are prioritized through Weighted Shortest Job First (WSJF). Items that can add more value in the shortest duration are selected first for implementation. WSJF is an algorithm, exhibited in the following equation, obtained through the quotient of the cost delays by the duration of execution of a certain feature or capability [41, 45].

$$\text{WSJF} = \frac{\text{Business value+Time criticality+Risk reduction/Opportunity enablement}}{\text{Job Duration (Job Size)}} = \frac{\text{Cost of Delay}}{\text{Job Duration}}$$

Equation 1 - WSJF

### 2.3.5.4 Team Backlog

Team Backlog contains user and enabler Stories that originate from the Program Backlog, specifically defined by splitting the features, as Fig. 26 illustrates, as well as stories that arise from the team's local context. It may include other work items as well, representing all the things a team needs to do to advance their portion of the system [41].

- Stories - are short descriptions of a small piece of desired functionality, written in the user's language. Agile Teams implement small, vertical slices of system functionality and are sized, so they can be completed in a single Iteration.

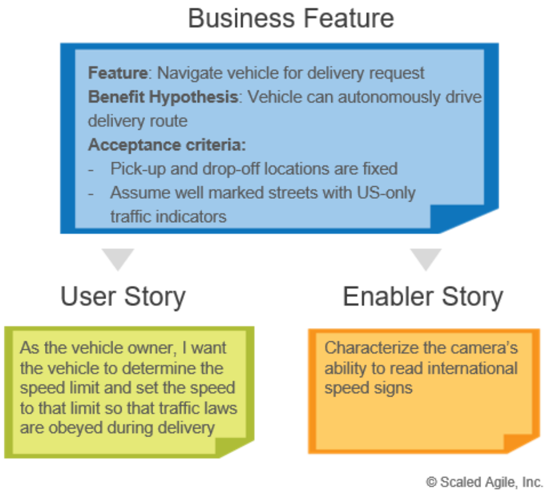


Fig. 26 - Features split into Stories [41]

## 2.3.6 Events

### *2.3.6.1 Program Increment*

A PI, as quoted by SAFe®, is the heartbeat of an ART. It is a timebox, typically eight to twelve weeks, during which an ART delivers incremental value. The PI is managed by the PDCA cycle. In SAFe® it is represented by specific ART events and activities. The planning step of the cycle is the PI Planning event, the execution of the PI is the do step, the System Demo is the Check step, and the Adjust step is called the Inspect and Adapt (I&A). The most common pattern for a PI is initiated by a PI Planning event, followed by four execution Iterations, concluding with one Innovation and Planning (IP) Iteration, as Fig. 27 illustrates [41].

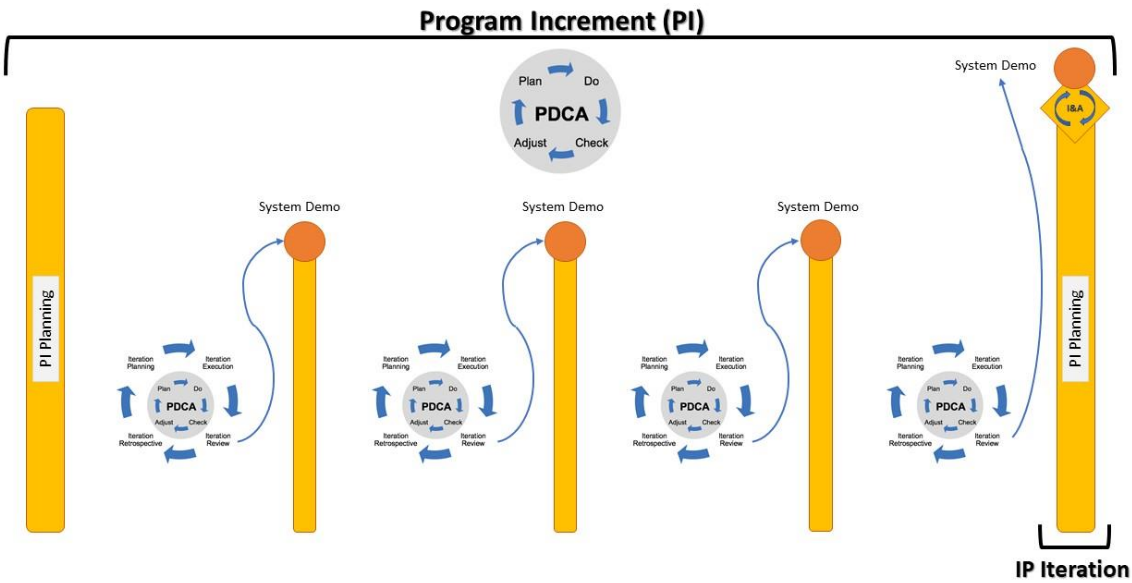


Fig. 27 - PI [41]

### 2.3.6.2 Solution Train Events

#### 2.3.6.2.1 Pre- and Post-PI Planning

A ST and its associated ARTs use the same PI cadence. However, for a ST there are two additional activities: pre- and post- PI planning, Fig. 28 shows the positioning of these events. These meetings manage dependencies between the various ARTs involved in the ST, creating a single plan across them all.

The pre-PI planning event is used to coordinate the context for the ARTs and suppliers to create their individual plans in their PI planning sessions.

The post-PI planning event occurs after the ARTs have ran their respective planning sessions, and is used to integrate and synchronize the results of ART planning and create the overall solution plan.

Attendees include, STE, solution manager, solution architect/engineering and also representatives from all ARTs, usually, RTEs, product managers and system architects/engineering [41].

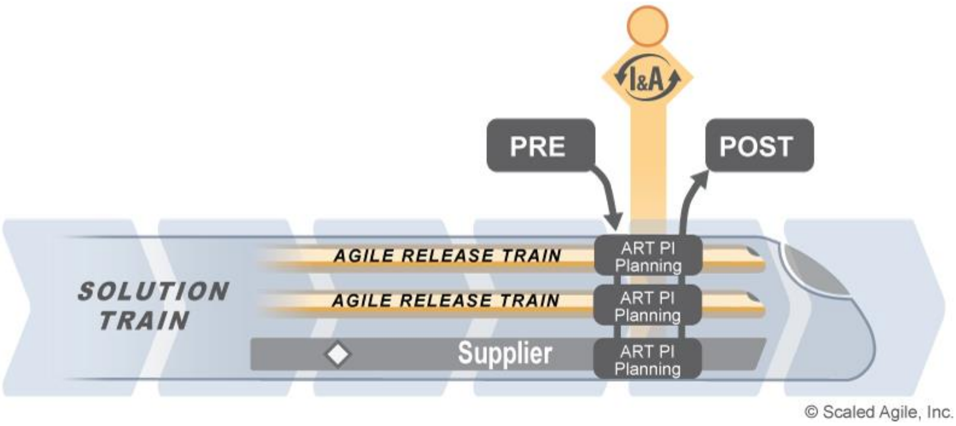


Fig. 28 - Pre- and Post- PI Planning [41]

#### 2.3.6.2.2 Solution Demo

A solution demo is scheduled at the end of each PI and after the IP iteration, providing critical and objective inputs for the pre- and post-PI planning events. It is a regular opportunity to evaluate a fully integrated solution across all ARTs, and presents the progress to customers and stakeholders.

The attendees of this event, hosted by the solution manager, are the same as the pre- and post- PI planning [41].

#### *2.3.6.3 ART Events*

##### 2.3.6.3.1 PI Planning

The ART events begin with the PI planning (Fig. 27), where teams create their plans and objectives for the upcoming PI. The business context and the top ten features are the inputs of this meeting. It is expected that, at the end, all participants commit themselves to a set of objectives that are created by each team with the business value assigned by the business owners, highlighting the new feature delivery dates, feature dependencies among teams and relevant milestones.

Facilitated by the RTE, this event includes all members of the ART. Attendees include business owners, product managers, agile teams, system, and solution architects/engineering, and other stakeholders [41].

##### 2.3.6.3.2 ART Sync

This event is the combination of two events that can be held separately but, for synchronization or schedule reasons, could be merged into one. When such a situation occurs, the RTE acts as a chief scrum master [41].

**Scrum of Scrums (SoS)**

SoS is a weekly event timeboxed for thirty to sixty minutes, facilitated by the RTE, who acts as a chief scrum master. This meeting helps to coordinate the dependencies of the ARTs and provides visibility into progress and impediments [41].

**PO Sync**

In a manner equal to the SoS, the event also occurs every week, timeboxed for thirty to sixty minutes, held for POs and product managers, facilitated by the RTE or a product manager. In the same way, the purpose is to get visibility into how well the ART is progressing toward meeting its objectives, to discuss problems or opportunities with feature development, and to assess any scope adjustments. The event may also be used to prepare for the next PI, and may include program backlog refinement and WSJF prioritization ahead of the next PI planning event [41].

##### 2.3.6.3.3 System Demo

The System Demo occurs at the end of every iteration (Fig. 27), with product managers and POs running the demo. It has as attendees business owners, customers, and system architect/engineering. It provides an integrated, comprehensive view of the new features delivered by the ART over the past iteration, and is giving feedback from the stakeholders about the effectiveness and usability of the system under development [41].

#### 2.3.6.3.4 Inspect and Adapt

The I&A is held at the end of every PI (Fig. 27) and consists of three parts where the current state of the solution is demonstrated and evaluated by the RTEs. The first part is the PI system demo where, similar to a regular system demo, all features developed over the course of the PI are shown. In the second part, teams review and measure quantitatively and qualitatively the objectives previously defined in the PI planning. In the end, teams identify significant issues, and analyse the causes of these problems with the purpose of improving backlog items.

Attendees include the agile teams, the RTE, system and solution architect/engineering, product manager and business owners [41].

### *2.3.6.4 Team Events in Iterations*

An Iteration is a basic building block of agile development. Each iteration is a standard, fixed length timebox, approximately two weeks, where agile teams deliver incremental value. Agile teams execute a full PDCA cycle with several team events. The planning step is the iteration planning, the do step is the iteration execution, iteration review is the check step and iteration retrospective is the adjust step, as illustrated by Fig. 29 [41].

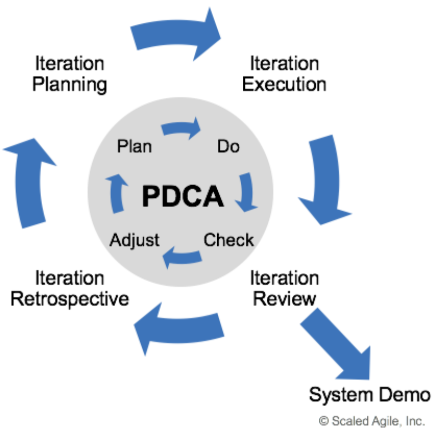


Fig. 29 - PDCA Cycle on Iterations [41]

#### 2.3.6.4.1 Iteration Planning

The iteration Planning aligns all team members to determine how much of the team backlog they can commit to deliver during the upcoming iteration based on the available team capacity. The team members are discussing each story and possible dependencies on other tasks. Once the team runs out of capacity stops are planned. At the end, everyone determines and commits to the goals of the iteration. All team members, including the PO and the scrum master, who acts as the facilitator for this event, attend to the meeting, as well as any stakeholder as required [32, 41].

#### 2.3.6.4.2 DSU Events in Iteration Execution

Iteration Execution is the core of the iteration, where everyone works together as an ART to achieve the planned objectives. Teams follow the progress of the iteration using story or Kanban boards and continuous communication and synchronization via Daily Stand Up (DSU) events, timeboxed to fifteen minutes, where certain questions are answered.

- What did I do yesterday to advance the iteration goals?
- What will I be able to complete today to advance the iteration goals?
- What is preventing us from completing the iteration goals?

DSU meetings, hence answering that questions improve the flow by managing WIP, building quality in, and continuously accepting stories throughout the iteration [41].

#### 2.3.6.4.3 Iteration Review

Iteration Review brings closure to the iteration timebox and provides an opportunity for the team to assess progress, as well as receive feedback to improve the solution under development by making adjustments ahead of the next iteration. In this event, facilitated by the scrum master, the agile team measures the progress showing a tested increment of value (working stories) to the PO, and other relevant stakeholders, and receive feedback on what they have produced. It allows team members to demonstrate the contributions they have made, and to take some satisfaction and pride in their work. The event finishes by refining the team backlog, based on the feedback received. Following the iteration review, the team prepares and participates in the system demo, as demonstrated in Fig. 29 as well as Fig. 27 [32, 41].

#### 2.3.6.4.4 Iteration Retrospective

The whole team participates in the retrospective, with the Scrum Master facilitating. The team evaluates the processes and reviews any improvement stories it had from the previous iteration. They also identify new and systematic problems and their causes that will need to be addressed at the next I&A event, as well as emphasizing bright spots, and create improvement stories that enter the team backlog for the next iteration [32, 41].

As reported in SAFe®, there are the following formats for the iteration retrospective[41]:

- Individual – Individually write Post-Its and then find patterns as a group;
- Appreciation – Note whether someone has helped you or helped the team;
- Conceptual – Choose one word to describe the iteration;
- Rating – Rate the iteration on a scale of one to five, and then brainstorm how to make the next one a five;
- Simple – Open a discussion and record the results under three headings;

- Conventional method - the Scrum Master simply puts up three sheets of flipchart paper labelled ‘What Went Well’, ‘What Didn’t’, and ‘Do Better Next Time’, and then facilitates an open brainstorming session.

#### 2.3.6.5 Innovation and Planning Iteration

IP iteration occurs every PI and serves multiple purposes. It acts as an estimating buffer for meeting PI objectives and provides dedicated time for innovation, continuing education, PI Planning, and I&A events.

Fig. 30 displays an example for an IP iteration calendar. This event, as cited above, is a concentration of certain meetings from the ARTs, as well as the ST. It is initiated by the ST pre-PI planning. During the progress of the event, the I&A meeting and the PI planning are held for each ART. The IP iteration ends with the ST post-PI planning, and the occurrence of this events is demonstrated in Fig. 27, as well as in Fig. 28 [41].

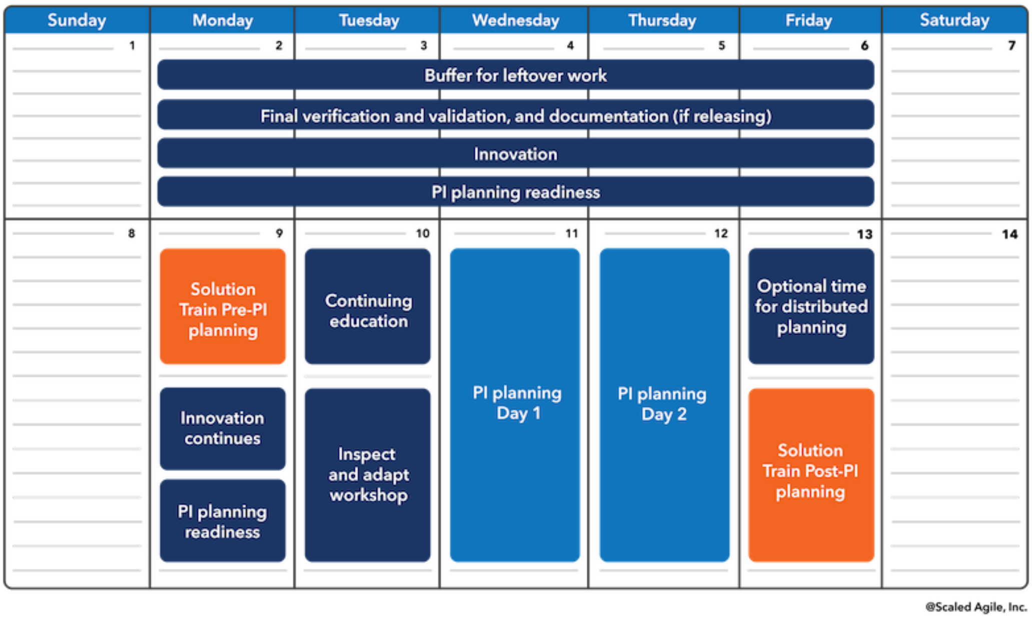


Fig. 30 - Example of an IP Iteration Schedule [41]

Literature lacks profoundly on studies concerning the usage and adoption of SAFe® in real circumstances and, subsequently, on the constraints and factors that influence that implementation, as well as advantages for organizations when they embrace this framework.

Table 6 presents several researched studies that attempted to provide an answer to overcome those shortcomings at bibliographic level.

Table 6 - Research regarding SAFe®

| Bibliographic References | Work Description |
|---|---|
| M. Paasivaara, "Adopting SAFe to scale agile in a globally distributed organization", 2017 [46]. | Case study of adopting SAFe® in two business lines of the same globally distributed company. The comparison of the two cases revealed divergent outcomes that allowed to identify challenges and success factors, to lead the implementation of the framework to good results. |
| O. Turetken, I. Stojanov, and J. J. M. Trienekens, "Assessing the adoption level of scaled agile development: a maturity model for Scaled Agile Framework", 2016 [47]. | As a consequence of the lack of a well-structured gradual approach for establishing SAFe®, this work developed a maturity model with the intent of guide organizations in providing the directions and practices to implement and establish SAFe®. Moreover, the effectiveness of the model was assessed by applying it in a large organization. As expected, the level of achieved agility practices tend to decrease towards higher maturity levels. |
| A. Putta, M. Paasivaara, and C. Lassenius, "Benefits and challenges of adopting the Scaled Agile Framework (SAFe®): Preliminary results from a multivocal literature review", 2018 [48]. | Towards to suppress the little literature on the benefits and challenges of the application of SAFe®, this paper performs an exhaustive search to collect the existing knowledge on this topic. The most salient benefit categories were: transparency, alignment, productivity, predictability, and time to market. The most frequently mentioned challenge categories were: change resistance, challenges with the first program increment planning and moving away from agile. |
| M. Laanti, "Characteristics and principles of scaled agile", 2014 [49]. | This study researches and examines the characteristics and principles upon how scaled agile can be built and attempts to merge such aspects of agility with SAFe®. As a result of the research, they were mentioned aspects of agility, despite being built on principles of lean thinking, SAFe® does not cover all the mentioned aspects. |

| Bibliographic References | Work Description |
|---|---|
| P. Kettunen and M. Laanti, "Future software organizations – agile goals and roles", 2017 [50]. | The tendency of most software companies is to become companies which have a profound impact on organizational designs, roles, and competencies, increasing new demands for more efficient organizational data processing. Despite modern scaled agile framework, such as SAFe®, they offer certain solution schemes. This paper develops the necessary future capabilities for such organizations and demonstrate them via real-life examples |
| S. Sreenivasan and K. Kothandaraman, "Improving processes by aligning Capability Maturity Model Integration and the Scaled Agile Framework", 2019 [51]. | This case study developed in a mid-size IT firm, combines the collection of best practices for process improvement of a maturity model with the elements provided by SAFe® on how to implement those practices. The implementation of the maturity model practices in a SAFe® environment resulted in a series of qualitative and quantitative benefits for the organization. Although productivity decreasing, there were improvements in achieving project objectives, such as meeting sprint commitments and reducing both defects and rework. |
| B. Mucambe, A. Tereso, J. Faria, and T. Mateus, "Large-scale agile frameworks: Dealing with interdependences", 2019 [52]. | With the constant increment of projects and programs, large-scale agile approaches are the way to respond to the demands of the business environment. In this research, different large-scaled frameworks were analysed and compared, including SAFe®, to identify how the methods deal with the interdependencies between teams. |

# DISSERTATION DEVELOPMENT

# 3 DISSERTATION DEVELOPMENT

## 3.1 Processes and Problem Characterisation

Generally, MRO organizations in aviation industry follow the plan described in Fig. 2. This program is no exception, the customer requests a proposal, including the work orders, the cost estimation and delivery dates. If the proposal is accepted, the operational phase proceeds where the major issues emerge. In this phase, the scope of the project is not fully defined, as unscheduled work is constantly present during the lifetime of the project. Throughout the project, during inspections and maintenance work, findings arise that were not expected and, therefore, were not introduced in the initial work orders in the proposal, the so-called Non-Conformances (NC). Whenever a NC is detected, a report is issued to enter in the electronic system that serves as database. If the NC is in the Technical Order (TO), which is a document with procedures to repair the finding, the production is able to execute the repair task. Otherwise, the report is handled by the engineering department, that classifies the NC as minor or major. In the case of minor NCs, the engineering department is capable of releasing a procedure to repair, to be performed by the production, while in major NCs the procedure needs to be approved by the customer. Only after acceptance, the production is able to execute the procedure. Fig. 31 clarifies the process.

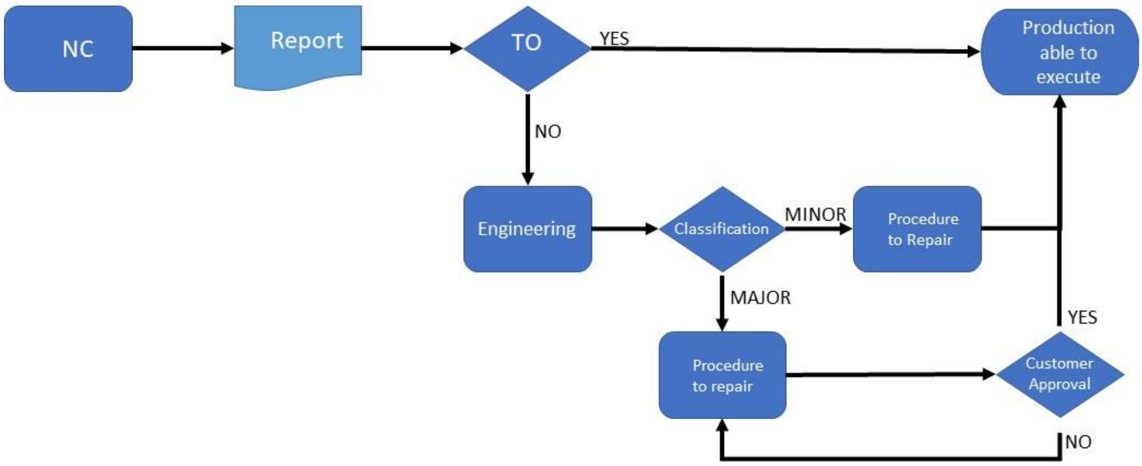


Fig. 31 - NC Process

The entire process is lengthy, and frequently several reports are emitted on a daily basis. Evaluating all the NCs and generating new procedures by the engineering, as well as the response from the customer is an extended practice, and often the procedure is not accepted at first attempt. Additionally, to this process, the material management department intervenes to be in contact with other parts, when it is necessary to replace certain components, to export or even to produce the inventory. Nevertheless, all decisions must pass through PM to plan quickly so as to follow the execution phase.

The departments and the people working on the shop floor must be in constant interaction and communication, working in conjunction.

Currently, in the shop floor the personnel are distributed per teams, *i.e.,* mechanics, electricians, people responsible for the structure, surface treatment, among others. Moreover, mechanics are allocated per A/C zone, for instance, landing gear, left wing, right wing, cockpit, fuselage, *etc*. To control and manage the work to be accomplished, each zone and team possesses a supervisor, namely a group leader and a team leader. The person in charge of the A/C is the A/C manager. The *gemba* organization, for a clear perspective, is depicted in Fig. 32.

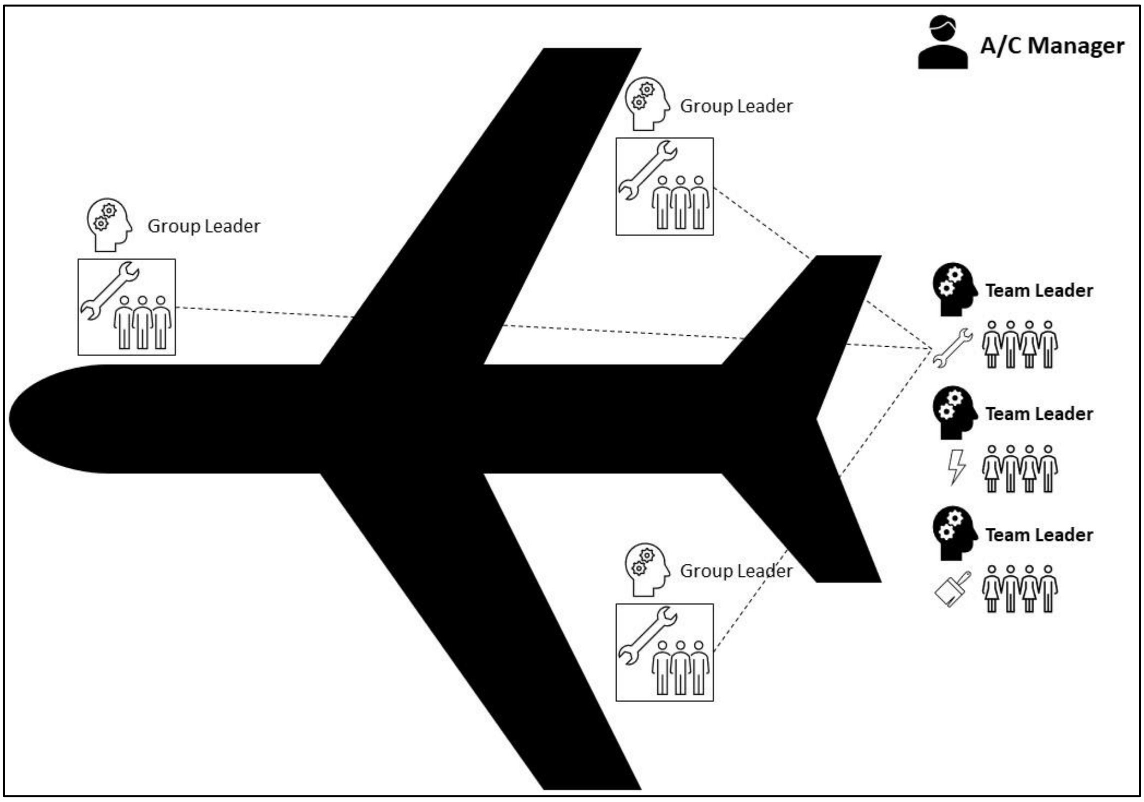


Fig. 32 - Shop Floor Organization

Daily meetings are held in an attempt to maintain the contact with all teams, manage and control prioritizing tasks. Attendees are more than twenty, including representatives from the engineering, material management and PM departments, as well as the A/C manager, team and group leaders. The meetings have revealed as exhaustive and extensive, not being the best solution to handle this situation.

In summary, by literature review as from the feedback from the company, a high customer dependency is observed, which generates an absence of schedule control, and the unplanned work, that besides having a responsibility on planning, engenders a significant impact on the cost control.

To address those main blocking points on the program, it is necessary to, predominantly, transform the unplanned work into planned, measuring the flow of the WIP, linking the key individuals through effortless interactions.

For the purpose of consummating the foremost challenges, SAFe® is a complete agile framework, that connects all events, with constant iterations where engineering and material management are able to develop solutions, while production focuses on daily high priority tasks, allowing a continuous work flow.

## 3.2 SAFe® Concepts Applied to Hardware Industry

SAFe® built under agility concepts. It was designed most frequently for software development organizations. However, the principles and behaviours of the lean-agile framework could apply to any type of industry, focusing on flexibility, acceptability of change, continuous improvement, and strong interaction.

Adapting the concepts is not always simple. Changes to regulatory standard of hardware are tumultuous, lead time is longer, which limits the length and number of iterations, late changes are hard to recover. Therefore, it is essential to avoid reversed or lack of decisions, incremental delivery, and faster feedback loops enable informed decisions and decrease the risk. Partial products cannot be tested, because testing requires the entire product to be functional, or delivered to the customer. Hardware systems are complex with interaction between subsystems and cannot be developed independently, breaking it down into features. Cross-functional teams are still a goal within high level of transparency and communication, although there is a large number of roles needed and functions that are not fungible, people with very specialized skills can provide support mostly in a sequential manner. Infrastructure resources (laboratories, equipment, as well as manufacturing) are expensive and cannot be replicated to support multiple development projects simultaneously.

## 3.3 Approach to be used

The approach to be used on the program cannot be a fully agile approach, only supported per iterations and scheduling the work during the development of the program. Despite the scope of the project not being totally defined, it is important to have a full picture of the scheduled maintenance for the customers to assess costs and have a perception of the accomplished dates. Moreover, even though the project team has experience with the program and are familiarised with agile methodologies, it is a transition phase, where workers, mainly the personnel working on the shop floor, are accustomed to a traditional approach.

The best suitable option is a hybrid approach, combining agile and predictive approach throughout the entire project life cycle, as Fig. 13 illustrates. The scope of the program will have a contingency plan for the unscheduled work, being supported by SAFe® and all the concepts that it entails.

## 3.4 SAFe® Application

As described in 3.2, the framework must suffer certain changes when applied to the hardware industry, although the principles and lean-agile mindset are constantly present. Furthermore, SAFe® was developed for enterprises as a whole. In this case, it will be attempted to implement in a single, however complex, program, within various projects ongoing at the same time, where the main product is a service instead of a physical deliverable. Hence, during iterations, there will be no derivable. In some cases, people will have, besides their main occupation (project manager, engineer, *etc*), more than one role, as there are a handful of people to integrate all the roles that SAFe® imposes. Therefore, every role, artifact and event needs to be tailored accordingly to the program circumstances.

In the following sections the most suitable concepts of SAFe® to be applied to the program are defined, and how they were adapted to fit accordingly to the program requirements.

### 3.4.1 Select Configuration

Before allocating and adapting SAFe® concepts into the program, it is necessary to select one configuration (Essential, Large Solution, Portfolio, Full) within the four that SAFe® offers.

Essential configuration is insufficient for the complexity of the program and Full configuration requires hundreds of people to develop and maintain. Consequently, both are excluded. After rejecting the aforementioned configurations, remains the Large Solution and Portfolio configuration, which differs by the quantity and complexity of value streams and ARTs. To determine, within the remaining two configurations, which is the most appropriate to implement in the program, it is essential to identify the value streams and the ARTs associated with the program.

#### *3.4.1.1 Identify the Value Stream*

The need for A/C maintenance triggers the flow of value, since the Request For Proposal (RFP) by the customer, following all the steps, until the delivery of the A/C, and consequently the invoicing, is which generates value on the program, as Fig. 33 (a) illustrates.

Certainly, throughout the operational value stream there are several development value streams. However, focusing on the operational phase, performing and developing maintenance solutions and implementing upgrades on the A/C, in the lowest lead time possible, avoiding a lengthy AOG, reducing the downtime cost, is the core of the problem. It is around this value stream that ARTs are organized. Fig. 33 (b) demonstrates the steps of the development value stream, since the arrival until the delivery of the A/C.

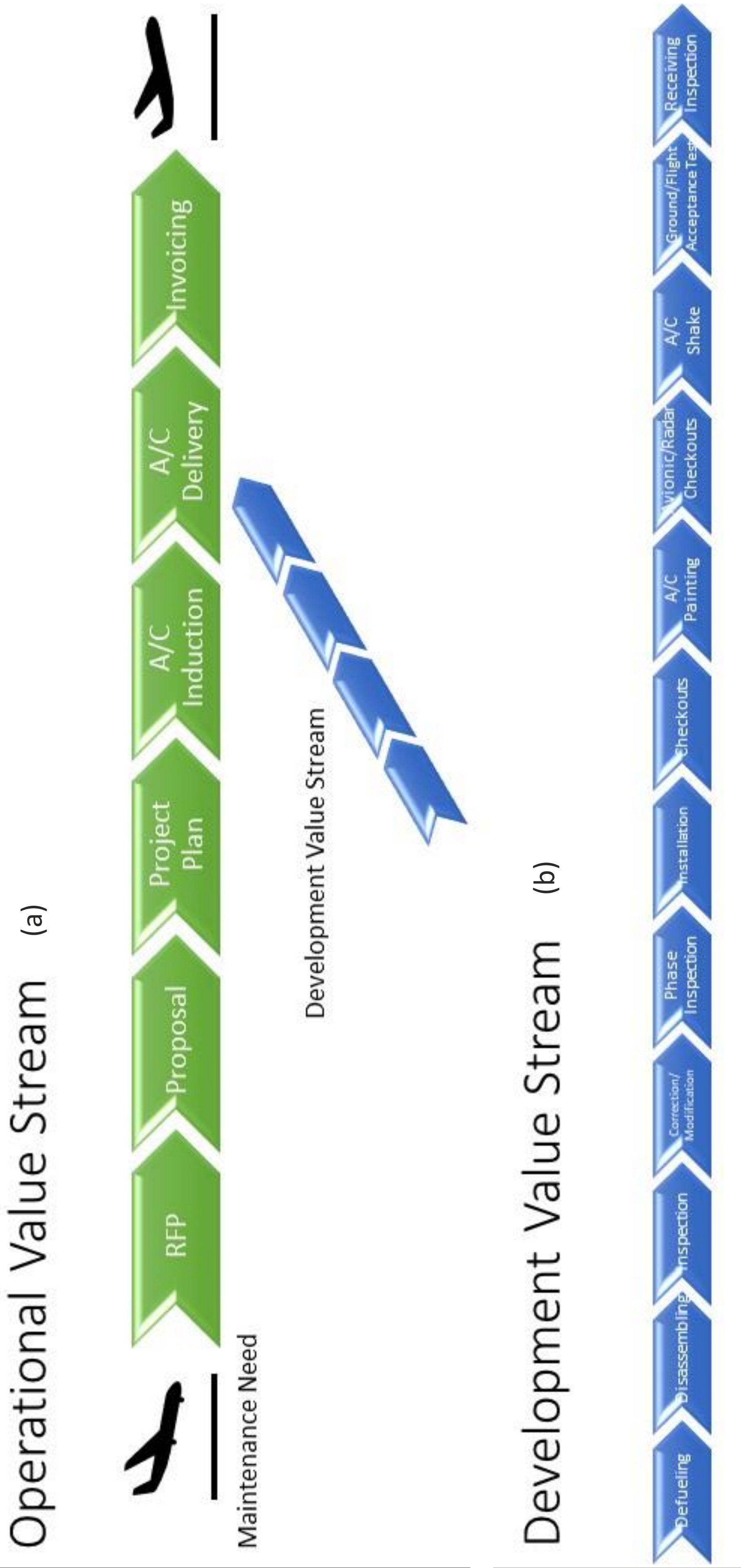


Fig. 33 - Operational and Development Value Streams in the Program

#### *3.4.1.2 Identify the ARTs*

Identified the development value stream, the final activity is identifying the ARTs that induce the value within the development value stream.

Three ARTs were identified, one major depot inspection, modifications and upgrades and other work under the frame contract, which corresponded to the projects associated to the maintenance program. Considering that the development value stream is a large value stream supported by multiple ARTs, it is required to create a ST to help coordinate the contributions of ARTs, illustrated by Fig. 34. Thus, in the context of the project, the adequate configuration is **Large Solution SAFe®** (Fig. 17).

**Large solution**

It is important to notice that, in the context of the program, each ART operates separately from the others, delivering solutions individually. However, working for the same purpose, reach the large solution. It is intended by large solution, delivering an operable A/C with all the MRO, modification and upgrade activities performed.


Fig. 34 - ARTs and ST in the Program

### 3.4.2 Solution Train

#### *3.4.2.1 ST Roles*

Accordingly to the responsibilities of the roles described in 2.3.4.2, the roles will be distributed to the individuals working on the program:

- STE – Someone at program level that possesses experience and knowledge in the program.
- Solution Manager – Similar to the STE, must be someone at program level that holds a major experience and knowledge in the program, possibly the program leader.
- Solution Architect/Engineering – This role is not applicable once there are no developments in the program.
- Supplier – Engineering, Material Management, Quality, Production, Manufacturing Engineering, Customer Support and Commercials are the main stakeholders. Considering that when stating “solution” in section 2.3.4.2 refers to supporting the customer in their capabilities, providing solutions for the problems that arise, for instance the NCs.

#### 3.4.2.2 Solution Backlog

As stated in section 2.3.5.1, solution backlog is the holding area for upcoming capabilities and enablers. The description of the artifacts are equivalent for the program. Items are managed through the solution Kanban, which is managed by the customers. Capabilities are provided by the customer, which also split into features for the project backlog. Afterwards, examples of the items presented in the solution backlog are specified.

- Enabler – Activities related to the process, such as, NC reports or material from the customer.
- NFRs – Cost constraints, maintenance procedures from the customer and requirements to use the customer's material.
- Capability – In general, every activity that provides airworthiness of the A/C ("make the A/C ready to fly again"). For instance, to be able to fly in the civil aerospace, the A/C requires certain avionics, as well as approvals from the competent authorities.

#### 3.4.2.3 Solution Train Events

Although the final product is the same, ARTs "develop" their work individually, therefore, in the program there is no necessity to monitor the work and development of the ARTs as a conjunction.

The program is distinct from the software industry where ARTs develop their portions of the software and in the end, they must deliver them as a whole. Thus, there is no need for Pre- and Post-PI Planning and Solution Demos, as a synchronization of ARTs. Solely, one meeting (ST sync) will be held, to measure the progression of the ARTs and possibly to refine the backlogs.

**Solution Train Sync**

Attendees:

- STE, acts as facilitator
- Solution Manager
- RTEs
- Product Managers
- Stakeholders

ST Sync is a weekly meeting with the purpose of reviewing the program objectives, measuring milestones progression, and possibly suggesting new definitions. Product managers will present the progress of the project backlog, as well as any issue related to the WIP, discuss the top features and potential dependencies with other trains. It is also a moment of refinement of the solution backlog, and solution management will review the capabilities and its compliance with NFRs.

In Fig. 35, it is illustrated how the information flows, as described above. It is in the ST Sync that all the matters related to the ST are discussed, as solution backlog refinement may occur, and the solution Kanban is managed by the customer, their approval to insert new items in the backlog is previously needed. Posteriorly, the capabilities are broken down into features, which are provided to the correspondent ART. Each ART owns a project Kanban and consequently a project backlog.

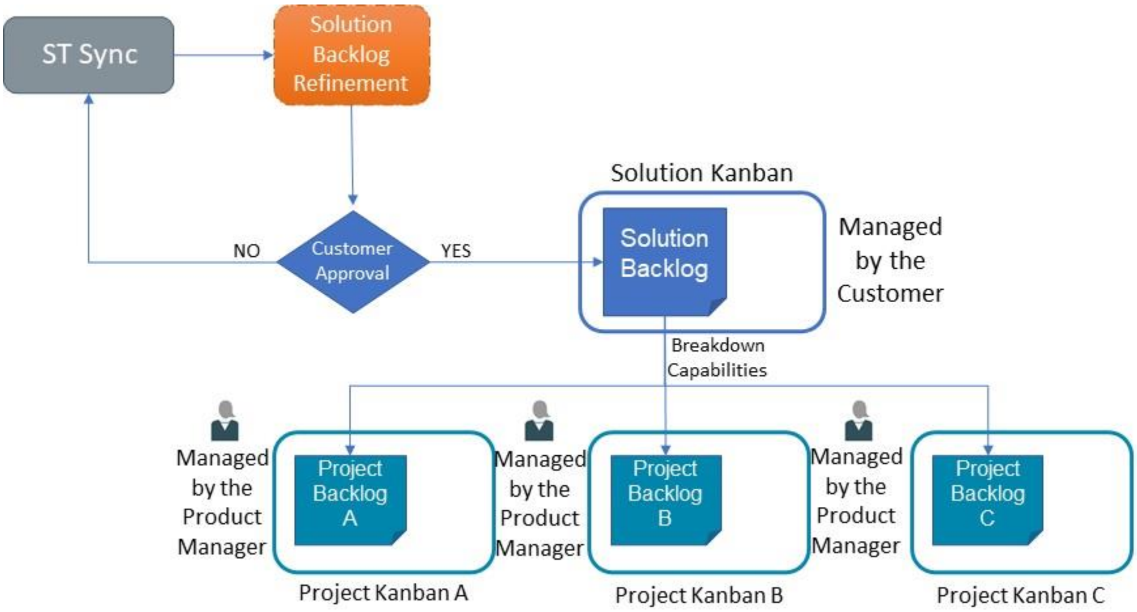


Fig. 35 - ST Diagram

### 3.4.3 ART: One Major Depot Inspection

To simplify the process of implementing the framework into the program, the ART that contains most problems related to unscheduled work was selected. The ART corresponds to one major depot inspection, also called D-check, which comprises disassembly and assembly of the A/C, repairs, overhaul or complete rebuilding and manufacturing of parts, technical assistance, and testing.

In the following subsections, the customized roles, events, and artifacts, incorporated in this ART are described, although they could be similarly adapted to the other ARTs.

#### 3.4.3.1 ART Roles

**Agile teams**

Agile teams are composed by people working on the shop floor. Thereby, the shop floor configuration will suffer some adjustments. Henceforward, group and team leader concepts cease to exist. Teams will be distributed per A/C zone, and each team comprises one PO, one scrum master and the repair teams that include, mechanics, electricians, people responsible for the structure and avionics, among others. In Fig. 36 the new configuration of the *gemba* is illustrated. The description of the roles follows what was once described in section 2.3.4.1.1, however, personalized for the project.

- Scrum Master – Someone at repair level that is flexible, confident, open minded and able to express himself, as well as, to listen.
- PO – Someone at repair level responsible for the whole repair in that zone, with a robust technical expertise, understanding A/C repair and maintenance, possibly a previous group or team leader.

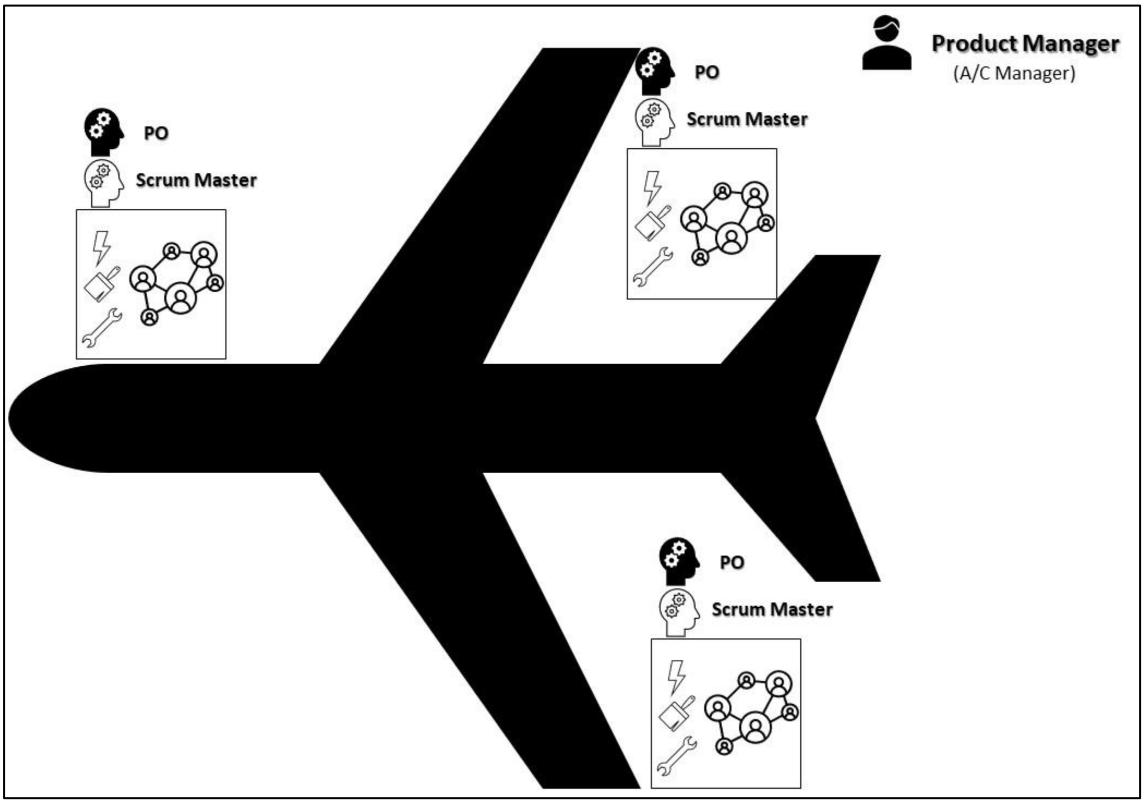


Fig. 36 - New Shop Floor Organization

**Critical ART Roles**

As asserted in section 2.3.4.1.2, the following roles ensure an effective execution of the ART, the explanation remains equal, however, tailored for the project.

- RTE: Someone at project level with a large knowledge and experience in the project, possibly the project leader.
- System Architect / Engineering: This role is not applicable, as there are no developments in the program.
- Product Manager: A/C Manager will act as the product manager. In addition to what is described in the mentioned section, they are accountable for the maintenance and repair.
- Business Owners: Engineering, Quality, Material Management.
- Customers: In this context, the ultimate "buyers" of the solution will be the project managers, once they are in an acceptance position of the generated development, in other words, all the work developed will pass through the project managers. Note that, henceforth, when in the meetings, it is stated "customers", it refers to these customers (project managers), and not the ones that request the proposal and own the A/C.

##### *3.4.3.2 Project Backlog*

Project backlog corresponds to the program backlog, stated in section 2.3.5.2. The change of the name occurs in order not to be confused with the backlog of the program, that is the solution backlog, once this one is applicable in one project inside the program. It is the holding area for upcoming features, though features are sized or split as necessary to be delivered by a single ART. It will not include benefits hypothesis and acceptance criteria. Example of features could be inspection tasks in the wings or in the body of the A/C. Items are managed through the project Kanban. Currently, the project team already possess a Kanban board, which will be used for easy implementation, managing the features throughout certain processes:

- To Do (backlog);
- In Progress;
- Blocked;
- Done.

The work travels through the different states. It begins in the "To Do" with the features provided by the customer. The features are prioritized relatively to the rest of the backlog to await implementation and the highest-priority features that were approved, move to the "In Progress" state. Blocked state is work that was already under progress, however some external constraints occur, for instance, NC procedure to repair acceptance from the customer, which stopped the WIP. The work in this state does not mean that it is entirely paused. In fact, PM, Engineering, Material Management work on this issue to solve it. The Product Manager (A/C Manager) must have an impact on the resolution, providing alternatives to overcome the blocked work; thus, agile teams could focus on other tasks.

### 3.4.3.3 Team Backlog

Team Backlog contains tasks that are features that are divided up and originate from the Program Backlog, as well as tasks that arise from the team's sprint review. It may include other work items as well, representing all the things a team needs to do to advance their portion of the system. Note that the name "stories" was changed to "task", as there is no point in this type of industry, as the concept of story was portrayed in section 2.3.5.4. The concept of tasks differs from stories as described below.

- Tasks – features that are broken down and originate from the Program Backlog. It may contain planned or unplanned work to be performed for one specific team. Features can be divided in to one or more tasks. Tasks based on the same feature could be distributed to different teams and are sized, so they can be completed in a single Iteration.

Teams follow their progress work from Kanban boards organized in the shop floor.

In Fig. 37, for a clear understanding, it is displayed a configuration of how the roles and backlogs are allocated.

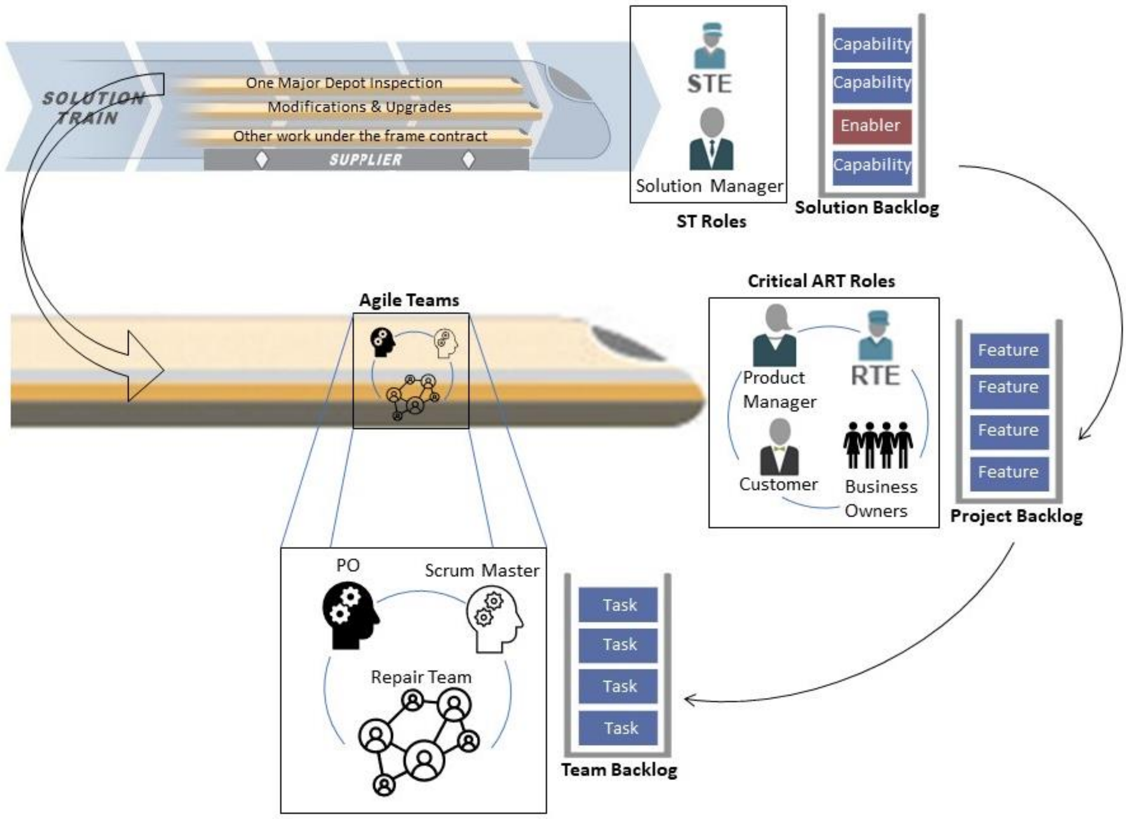


Fig. 37 - Applicable Roles & Backlogs in the Program

An example of broken down items regarding each backlog (capabilities split into features, and features breakdown into tasks), is demonstrated in Fig. 38.

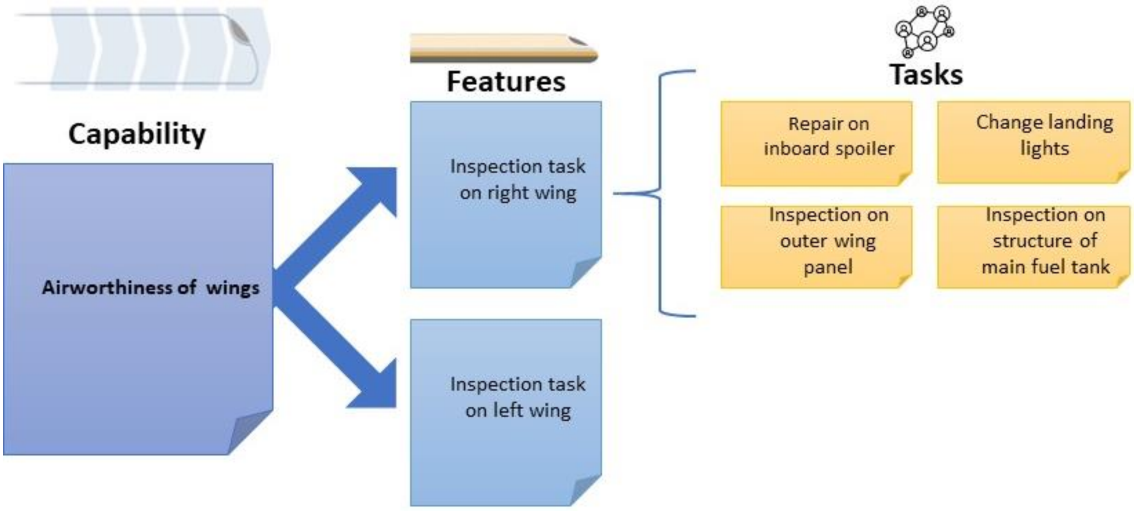


Fig. 38 - Example of broken-down Items into the Program

### *3.4.3.4 ART Events*

**Project Increment (PjI)**

Attendees:

- RTE, responsible for running the meeting.
- Product Manager and POs.
- Business owners and customers.

PjI is not related to PI stated in section 2.3.6.1. In fact, the concept is entirely different. It is assumed that the PI, as stated in the mentioned section, when applied into the program, instead of four sprints (the name of iterations was changed to sprints, which will be explained ahead) corresponds to one sprint. PjI occurs at the end of each sprint acting as an IP iteration, where within I&A, PI planning and a system demo are taking place. Briefly in this event, a review and a retrospective of the previous sprint, and a planning for the upcoming sprint arises.

It provides an integrated, comprehensive view of the features executed by the ART over the past sprint, and a feedback from the stakeholders is given about the effectiveness of the work.

The improvements and problems that arise from the teams' sprint retrospective are discussed in order to improve and redefine backlog items. One method to manage this situation could be, as declared in SAFe®, the retrospective and problem solving that complies certain steps. It begins with the agreement on the problem to solve. Afterwards, in order to identify the causes of the problem an Ishikawa's diagram is utilized; and to focus on the major causes, a Pareto's analysis is applied. Then the new problem is restated, subsequently to solve the problem, brainstorm solutions are suggested and, finally, improvement backlog items are identified.

For the upcoming sprint, a set of objectives and plans are created, highlighting the new features, feature dependencies among teams and relevant milestones. The sprint plans are delivered to the teams via PO and presented during the sprint planning.

**ART Sync**

Attendees:

- RTE, facilitates the event acting as a chief scrum master.
- Product Manager and POs.

For synchronization reasons, this event is the combination of the SoS and the PO Sync. ART Sync follows what is depicted in section 2.3.6.3.2. The meeting provides visibility into progress and impediments of ARTs towards meeting its objectives. Problems or opportunities with feature development (Blocked features in the project Kanban) are discussed, and any scope adjustments assessed. The event may also be used to prepare for the next sprint and may include program backlog refinement and prioritization ahead of the next sprint, mitigating the impact of the risks.

**System Demo**

Attendees:

- RTE, facilitates the meeting.
- Product Manager and POs.
- Business Owners and customers.

Contrary to the system demo stated in SAFe®, this event occurs at the end of the project to verify the alignment of the teams in the end of the project, before the delivery of the A/C, measuring the work quantitatively and qualitatively. Fundamentally, it is a review of the whole project and a retrospective for improvements for the next depot inspection.

#### *3.4.3.5 Team Events in Sprints*

In the project there are no deliverables. Therefore, the terminology of team events was altered to sprints, since the purpose of iterations is to deliver one product or solution at the end and improve it in the next iteration. The sprints continue to follow a PDCA cycle, illustrated in Fig. 39, and the description of the sprint remains as stated in section 2.3.6.4.

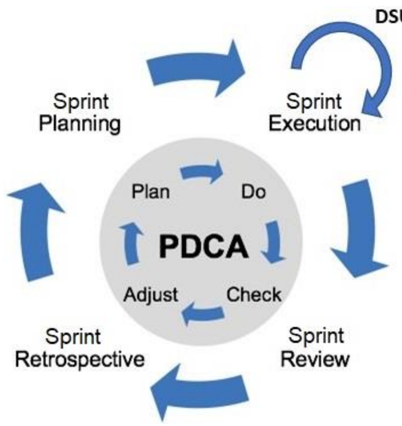


Fig. 39 - PDCA Cycle on Sprints

**Sprint Planning**

The sprint is planned in the ART Sync meeting, meaning that the highest priority features are communicated to the PO, who breaks them down into tasks. Those tasks are discussed in this event, facilitated by the scrum master and with every team member present, as well as the PO, elaborating an accomplishment plan and identifying dependencies within tasks. At the end, every person agrees and commits to the sprint goals.

**DSU event in Sprint Execution**

Sprint execution, as the name implies, is the execution of the tasks previously defined. The team follows the progress of the sprint using a Kanban board placed in the shop floor. Throughout the sprint execution, new tasks do not arise, and teams synchronize their work via DSU events, timeboxed to fifteen minutes, where specific questions are answered, as described in section 2.3.6.4.2:

- What did I do yesterday to advance the sprint goals?
- What will I be able to complete today to advance the sprint goals?
- What is preventing the progress of the sprint?
- What is preventing us from completing the sprint goals?

This last question arises, due to the fact that goals could be achieved at the end, even though something is preventing the progress. For instance, if what is preventing the progress of the sprint is a response from a department for a procedure to repair, and that response arrives on the last days of the sprint, the goals of the sprint could still be fulfilled at the end of the sprint, despite the progress being blocked at some point.

**Sprint Review**

Sprint Review, facilitated by the scrum master, brings closure to the sprint timebox where teams measure the progress by showing the completed tasks to the PO, who gives a feedback. The PO takes the information to the PjI to get feedback from the stakeholders. The event finishes by refining the team backlog, as the PO prepares to participate in the PjI.

**Sprint Retrospective**

This event, with the scrum master responsible for running the meeting, and with the presence of the PO, focuses on the improvement of the process, applying the conventional method to identify systemic problems that will need to be addressed at the PjI. The teams argue and answer three questions in an open brainstorming session:

- “What Went Well”;
- “What Didn’t”;
- “Do Better Next Time”.

The answers could be written down on a flipchart, labelled with these three questions.
Fig. 40 portrays the interconnections between the events and artifacts regarding the ART of one major depot inspection, as described in the aforementioned sections. After the capabilities being split into features and delivered to the correspondent ART, as Fig. 35 illustrates, the features are broken down into tasks to be included in each team backlog. Each team performs their sprints, and the team backlog could be refined in the sprint review. Through that timebox, two ART Sync meetings are ensued where project backlog refinement could occur. Moreover, the project backlog could be also refined at the end of the sprint, in the PjI, where the Product Managers and POs, as well as business owners and customers review the sprint, discuss the issues that arose during the sprint and are provided solutions for those problems.

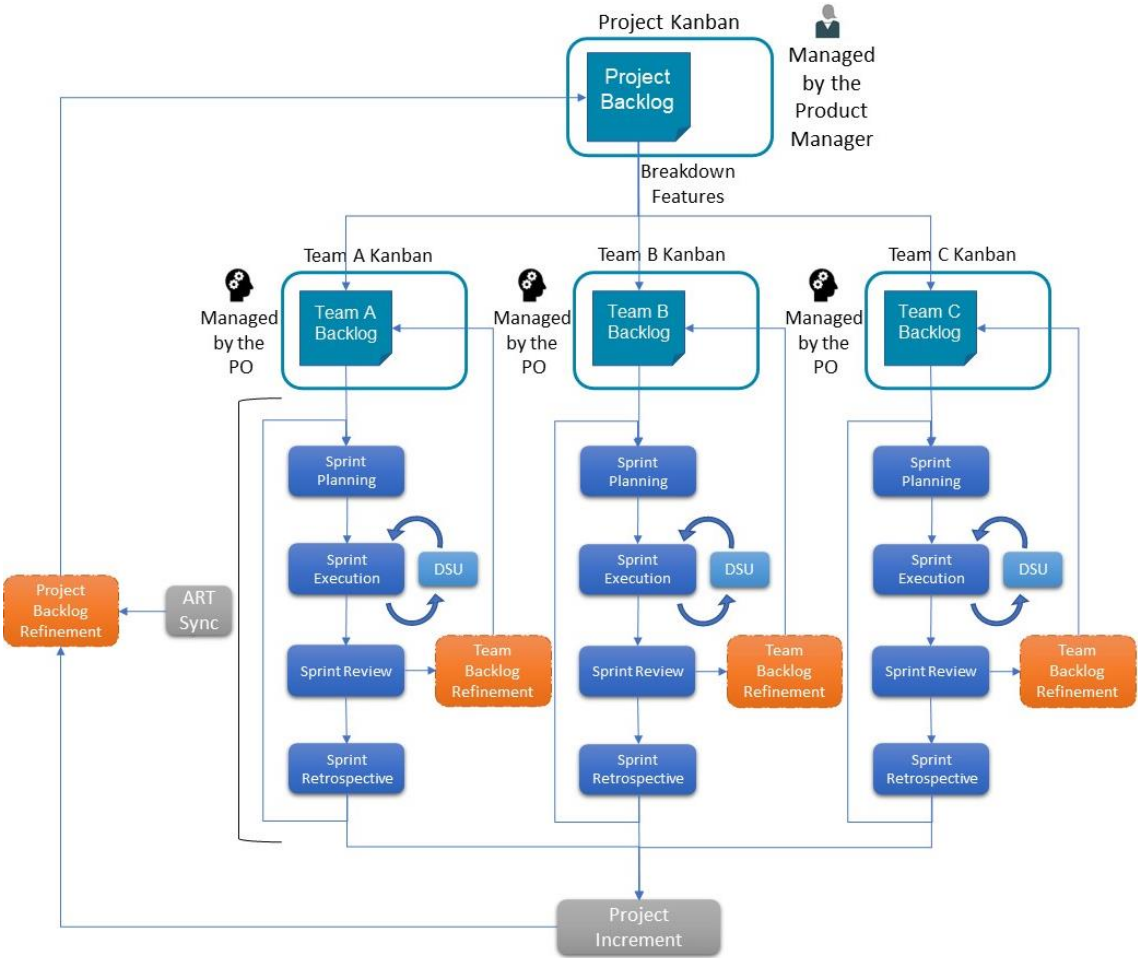


Fig. 40 - ART Diagram

It is throughout the sprint that the process depicted in Fig. 31 occur. There are two moments where the departments make contact with the information providing solutions. NCs detected during a sprint execution are approached in ART Sync or later by the agile team in the sprint review and communicated at ART level in the PjI, where they transmitted the solutions from the issues that arose from the previous sprint, and the new problems are discussed. Ideally, the process finishes with a positive response from the customer in the course of the sprint, otherwise the problem will be approached in the next sprint.

For instance, when a NC is detected and reported, it must be approached during the sprint in the DSU meeting or at the end of the sprint in the sprint review if the NC emerged close to the end of the sprint. If the NC is in the TO, the production is able to execute the repair task. Otherwise, the NC is approached in the ART Sync, during the sprint or in the PjI at the end of the sprint. It is in these meetings that the departments are informed about the issues. The engineering department classifies the NC as minor or major. In the case of minor NCs, the engineering is capable of releasing a procedure to repair, which will be performed by the production and disclosed in the ART Sync meeting throughout the sprints, or in the PjI at the end of the sprint; while in major NCs the procedure is revealed in ST Sync, where the customers are attendees and it needs to be approved by them. Only after acceptance, the production is able to execute the procedure, once more, disclosed in the ART Sync or at the PjI. It is important to note that, when the production is able to execute, it does not mean necessarily that they have to execute the procedure in the sprint where the procedure is revealed, it is in the PjI that the sprint is planned.

Fig. 41 displays the new NC process, described above, interconnecting the meetings and the processes to reach the repair execution.

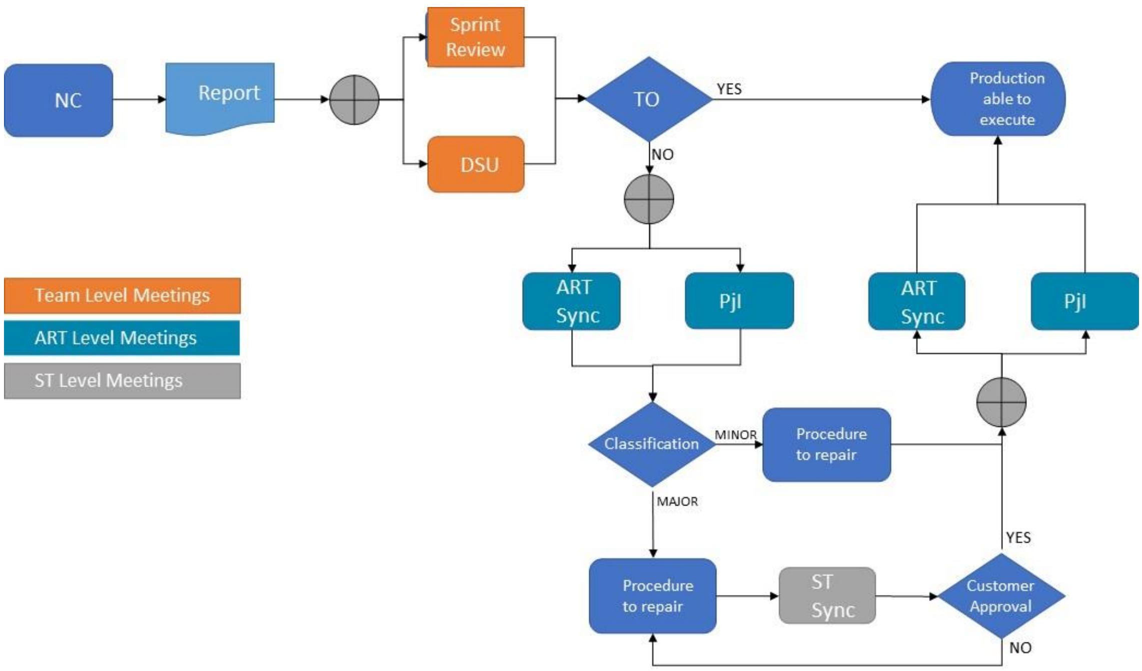


Fig. 41 - New NC Process

The departments are an integrated and an active part of this methodology, as they perform the roles of business owners and customers. However, besides applying SAFe®, the departments of the project have other tasks to accomplish on a daily basis. Therefore, they follow the work flow in their own Scrumban boards completed with the refined items discussed in the PjI and/or the ART Sync, and consequently integrated in the Program Backlog, as illustrated in Fig. 42.

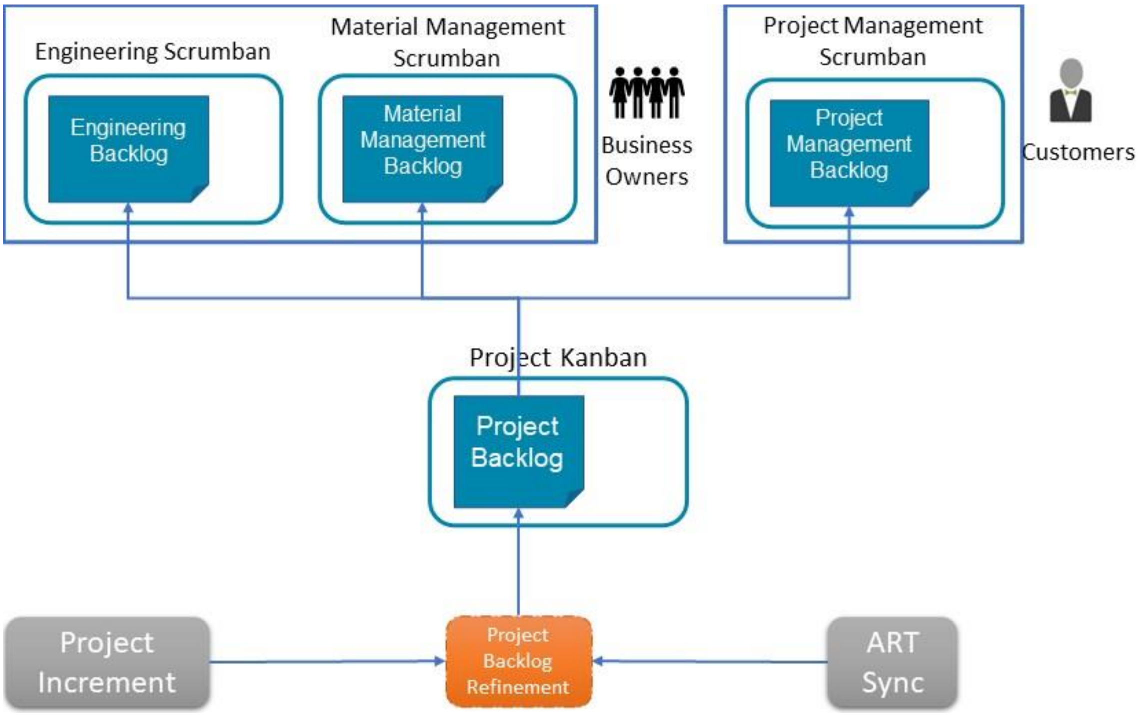


Fig. 42 - Departments Diagram

### 3.4.4 ART Framework

Every concept was tailored and described to be applied to the program. Subsequently, Fig. 43 enlightens the interconnections and the chaining of the events presenting a big picture of the ART for one major depot inspection.

The maintenance schedule is planned depending on A/C life cycle, comprising the planned work, provided by the work orders from the customer, and a contingency unplanned work based on experience of the project team. This planning follows the project throughout its development, giving it a perception of accomplished dates, as well as determining costs.

In a first phase, the first analysis established by the planned work initiates when the first findings are diagnosed, instigating the unplanned work. Every work goes to the program backlog (planned and unplanned) in the format of features.

The features are divided into tasks to be performed by teams, where each team holds a backlog. From this moment, in parallel, the planned and unplanned work is ongoing, each team execute sprints where they decide which tasks they are able to accomplish, based on periodization.

Sprints (one sprint corresponds to one PDCA cycle) act as a buffer of work, where engineering and material management have time to solve problems and wait for responses from the customer, while teams are focused on high priority tasks that arise from the previous sprint. For instance, when a NC is found, which will be addressed in the following sprint, engineering will attempt to solve it in the timebox of the current sprint. At the end of the sprint, backlog refinement in the sprint review event could occur.

Although Material Management, Engineering, and PM, possess integrated roles in SAFe®, they are separate entities that work separately to solve the problems and work on other daily tasks. They must follow the features on Scrumban boards, with tasks that emerge from the PjI or during the sprints from the ART Sync and consequently from the Program Backlog, thus, allowing the visualisation of the work flow.

Throughout the period of the sprints an ART Sync meeting arises, where backlog refinement could occur. PjI takes place at the end of each sprint where the last sprint is reviewed, and the next sprint is planned. At the end of the project, a System Demo meeting is ensued, with a purpose of a general review of the project.

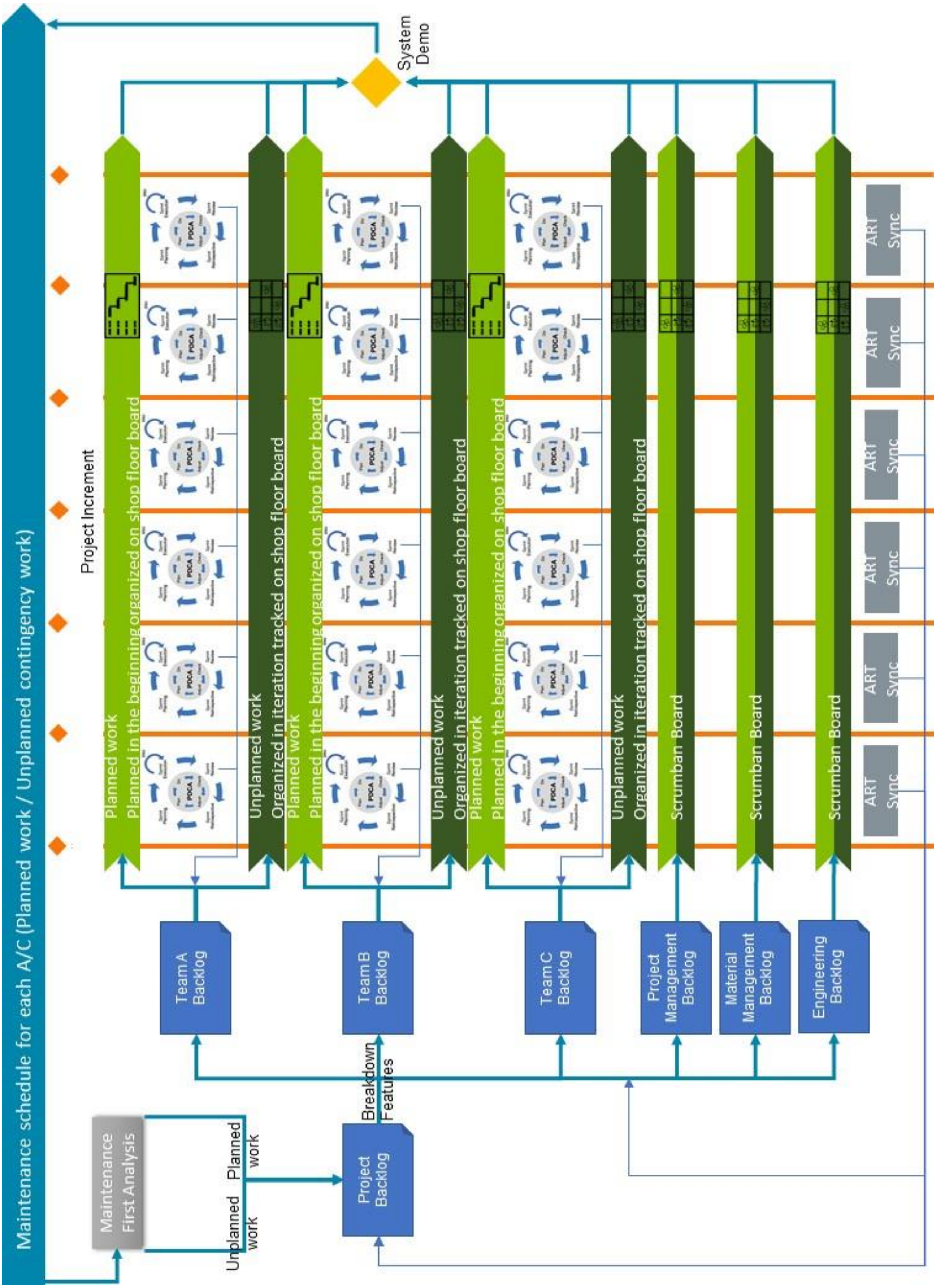


Fig. 43 - ART Framework

### 3.4.5 Events' Schedule

The sprints must be viewed as a whole. In this way, theoretically, the team does not lose any work, once when the team is not actually working, it is committed on finding solutions to improve the development of the process and, consequently, the work to be done.

In reality, the previously described is unsuitable in this type of industry, and specifically in this program. The teams cannot cease their work to attend extensive meetings, as their labour is continuous, obliging them to follow a plan and meet deadlines.

Fig. 44 illustrates the best solution to minimize the loss of work, providing a wide view of how the events are distributed during the sprint, displaying a schedule for one month, recognizing that for upcoming months the schedule is replicable. The calendar is divided per weeks, and the weeks into days, which are split in two moments, mornings (AM) and afternoons (PM). Considering that the labour hours per day are eight hours, mornings comprise the first four hours of the day and afternoons the last four. Furthermore, the meetings are allocated corresponding to the levels that they belong to.

In the morning of the first day of the sprint, the review and retrospective meeting take place simultaneously, turning it into one event, for about two hours or less, concerning the previous sprint. Following this meeting, the PjI occurs. Naturally, in the very first sprint of the program, the review and retrospective meeting is not performed, beginning the sprint with PjI, which is programmed for two hours, as well.

PO takes information from the PIj and attends a meeting (sprint planning) in the afternoon with the team, not exceeding the duration of two hours, since the morning is occupied with other meetings and the sprint is being planned.

The execution of the sprint lasts two weeks, with an everyday meeting at team level (DSU), for about fifteen minutes.

In order to prevent interruption of the work in the A/C while the PjI meeting is taking place, the team starts to work in the highest priority tasks defined in the last ART Sync (darker colour in the execution).

ART Sync occurs weekly in the last day of the week to provide the necessary time for the development of the execution and for concerns which may arise. Following this event, the ST Sync takes place, both of which with a duration not exceeding two hours. In the last ART Sync meeting of the sprint, the highest priority tasks to be done in the beginning of the next sprint are defined, as aforementioned. As the highest priority tasks could change during the PjI meeting, while the team is already working, the risks of the major issues are mitigated in this event.

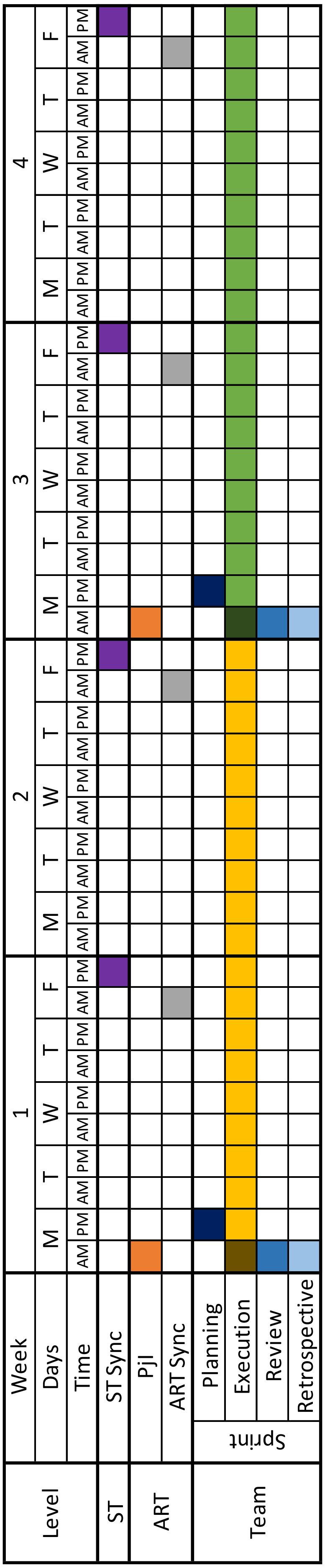


Fig. 44 - Events' Schedule

## 3.5 Critical Analysis

In general, the innovative character of the work that aims to be applied to the A/C maintenance industry is emphasized, due to the fact that there is absence of references of the described methodology employed in this sector. Hence, the unavailability of literature impedes the assessment of the proposed methods and application.

This work resulted in a theoretical application of a complex methodology, which has not meanwhile been implemented. Therefore, implementing an innovative and elaborate approach may lead to issues. Certainly, various factors will influence the application that presents itself as an arduous and gradual task. Following, limitations of the methodology and predicted constraints that may occur when applied are described.

The focal point is expected to be the people working on the shop floor, since they are unfamiliarised with agile methodologies, being accustomed to traditional approaches, and will suffer a radical disposition adjustment of the shop floor. Embracing agility and being adaptable to change is not necessarily easy, mentalities and attitudes must change in accordance with the selected methodology. Consequently, the implementation must be gradual to provide the necessary time for people, less familiarised with the new methods, to progressively adapt. Definitely, in the first stages of the implementation, the productivity will decrease, although always with the perspective to meet the outlined objectives. First meetings are predicted to be disorganized, as everyone will not realize the objectives and understand their responsibilities. The two weeks timebox of the sprint could reveal insufficient to solve issues and wait for a response from the customer. Furthermore, in team events, the attendees, more precisely the repair teams, are not used to and comfortable at exposing the problems which could became an issue. Indeed, communication is a key point of agile methodologies, nevertheless providing excessive independence to teams could result in incoherent decisions. Organizational problems may arise on the shop floor, once each team, allocated at the several A/C zone, possess one Kanban boards. Hence, there will be numerous boards on the shop floor. Although being the best-found solution in the schedule, the teams will not work continuously, as they must cease the work, not exceeding the two hours per sprint, for the review and retrospective meeting.

Concerning the distributed roles and considering that SAFe® is applied to organizations, in this case, it was customized to be implemented in one single program. Despite being complex, the over-allocation of roles will be constantly an issue, since, alongside their main activity, the members of this project shall take into account other responsibilities, which may influence the development of the program and, consequently, the application of agile methodologies. In the agile teams, the people responsible for those roles of PO and scrum master may not fulfil the requirements of that roles. Moreover, as PO and Scrum Master are an integral part of the repair team, it may occur conflict of interests, among other circumstances, on tasks distribution.

It is important to notice that, for the implementation of the ART framework, it is necessary to define how the departments manage the Scrumban boards, as well as describing every concept that it implies. Therefore, it is essential to acquire a deep knowledge of the program, to recognize the structure behind each department, the roles and responsibilities performed. That situation was not the focus of this work, but only a general solution that allows the departments to follow the WIP and visualise diverse tasks.

The application of SAFe® was not employed in the whole program. The tailored principles were applied to one ART within an ST identified as crucial, since most of the unplanned work problems occur, thereby, enabling to overcome the main impediments.

A SWOT analysis is displayed in Fig. 45, resuming all the main points of the application of SAFe®.

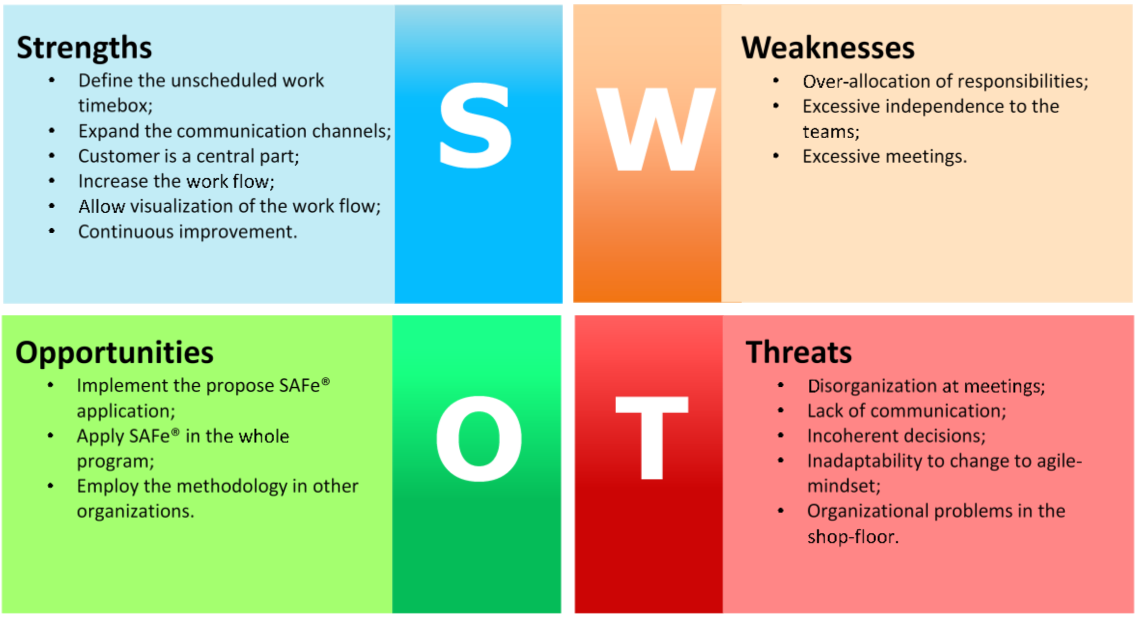


Fig. 45 - SWOT Analysis of SAFe® application

# CONCLUSIONS

# 4 CONCLUSIONS AND PROPOSALS FOR FUTURE WORKS

## 4.1 Conclusions

This work arose in attempting to overcome the main difficulties of planning MRO activities in the A/C maintenance sector, by implementing an agile framework. The main problems were identified based on literature review related to A/C maintenance, as well as, from the feedback provided by the company.

The unplanned work through the life cycle of the projects, proved to be the major issue in this sector, not allowing to define a full scope of the project and to control the costs. Particularly in this program, in addition to the problem of the unscheduled work observed in this industry, a high dependency on customer was identified. Moreover, during the project, approvals are required from the customers for the procedures to repair of the findings that emerge. For instance, an airline that performs itself MRO activities will not have the customer dependency problem. However, an airline that contracts an MRO facility to perform this type of tasks, additionally to the unscheduled work problem, the contracted organization will have a high dependency on the airline. In these cases, the MRO organizations need to be in constant communication with the customer, from the RFP until the end of the project, as in the beginning it is necessary to reach a contractual agreement, and throughout the project. Due to the unscheduled work, new tasks may arise, requiring authorizations to be performed.

Knowing the positive implementation's background of agile methodologies in the program, the application of SAFe® was proposed to overcome the main issues, presented as a well-structured tool, which by implementing agile methodologies, interconnects all people and provides customer centricity.

The application of this framework was going to be guided by literature concerning this complex topic, which revealed to be scarce, rare in hardware industries and totally absent in the A/C maintenance sector. Hence, the application needed to be tailored and self-developed, accordingly to the particularities of the project.

Initially, the most suitable PM approach was selected, considering that SAFe® applies fully agile methodologies. Nonetheless, due to the characteristics of the project, it could not be a totally agile approach. A combination between agile and predictive approach (hybrid approach) is the best option. The scope of the project is defined, guiding the project through its life cycle, while SAFe® supports and helps to overcome the main concerns that will emerge.

Considering the complexity and the number of value streams and ARTs within the program, the best SAFe® configuration was elected, being the large solution SAFe®. Subsequently, the root of the main issues was found, being inserted in the ART one major depot inspection, and all the concepts were customized within that ART.

The people employed on the program, hereafter instead of working around the project, will work around ARTs, allowing more communication channels. Moreover, the new configuration of the shop floor will increase the flow of the work, once people in different functions are working at the same time for the same purpose. Within the self-developed sprint methodology, based on the one that SAFe® provides, it is possible to plan the unplanned work, while during the sprint the departments are occupied to solve issues from the previous sprint. Meanwhile the personnel on the shop floor are working on high priority tasks, previously defined, and on the findings detected in the previous sprint that already have a procedure to repair. At the end of that sprint, they must commit to the goals, being feasible to observe a timebox.

The framework of the ART was developed to define the interconnection between roles, artifacts, and events, in other words, how all the concepts work together in the project. Despite not being implemented so far, it proved to be one of the best options to handle SAFe® within the complex project, and comprehend how the project will unfold with the new approach's application.

This dissertation is a theoretical work that may function as a guide for the company when implementing the framework. The dissertation is the base for the real implementation, all concepts are defined and described in detail, thus, it is solely necessary an implementation plan.

## 4.2 Outlooks

Considering the main constraints and limitations referred in the critical analysis (section 3.5), this section takes an outlook for the implementation. Despite what was described previously, certainly the real issues will arise during the actual implementation and on the first stages after implementation.

Before the physical implementation, and after the implementation plan being fully defined, it is advisable to organize seminars and meetings to make everyone embrace agility, knowing their responsibilities and realizing how the project will develop within the new approach. The implementation must be progressive, so that everyone will follow the implementation at the same time, and provide time for the less familiarized to become accustomed.

The physical implementation could begin with the launch of the critical ART one major depot inspection. After an experimental period, it is important to assess and measure the results, so as to adjust the application accordingly to the found impediments. That evaluation contributes to realize what this new approach actually contributed, for instance, by satisfaction inquiries, whether the coordination between roles is being well managed or whether the time of sprints is appropriate.

Following the launch of the first ART, and this being on track for a long period of time, it is possible to identify more ARTs within the same development value stream (besides the ones already identified). Thus, applying and customizing the concepts similarly to the ones performed and described in this dissertation. For the new ARTs that can be identified in the project, some people will have accumulation of roles. Probably, the role of STE or solution manager will be shared by the same person for as other ST identified.

Similar to the first ART, and following the application of the concepts, the launch of the new ARTs may occur, possibly with the experience earned from the first, an easier implementation can be reached.

Proved the benefits and the positive results from the new approach at project level, improvements at program level may begin, identifying more development value streams through the operational value streams and, consequently, ARTs, clustering it in STs. The application and implementation are analogous to that described, starting with adaptation of the concepts to the new identified ARTs, then the launching of the ARTs, and finally the assessment and adjustments of the approach.

In this case there is more than one development value stream, therefore it is meaningful to attempt to move to portfolio SAFe® configuration. After the attempt, it is important to assess if it is feasible to upgrade the configuration, if there will be over-allocation of resources and whether it is beneficial for the program.

Fig. 46, illustrates the proposed process of implementation, above described.

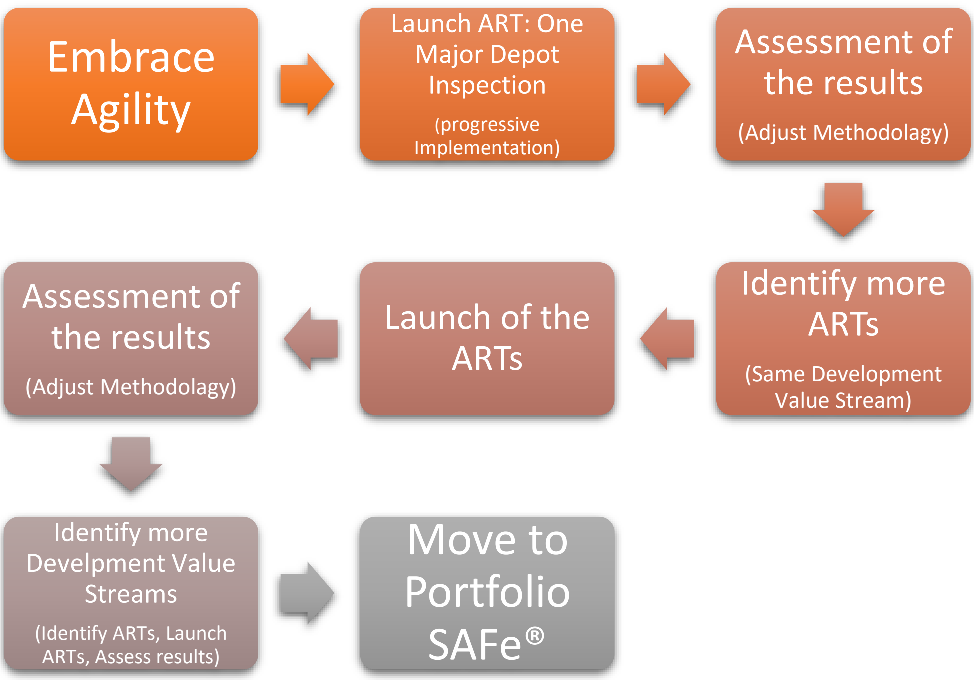


Fig. 46 - SAFe® implementation scheme

Regardless this of work, more research case studies regarding the application and implementation of SAFe® on the hardware industry in several branches would be important. Not only in organizations, but in projects, in order to understand how the concepts can be tailored, which benefits, and how to implement them. To reach a consensus and verify if there is a pattern to follow, or if it is necessary to adapt to each organization's characteristics.

## 4.3 Critical Review

This work was properly organized and planned, once all the objectives were accomplished. Understanding the characteristics and getting involved in a complex project, in a specific and fascinating sector that is the aviation, proved to be challenging. However, it would be important to know in detail more about the project characteristics, to explain in a consistent way all interconnections between departments and how the information flows between them. The knowledge concerning PM, the diverse approaches, and more precisely, the agile approach and their methodologies has been deepened, in order to understand a recent and revolutionary agile framework that could lead to significant improvements in organizations. Comprehending how a complex tool, not developed for this type of industry, and a complex project could correlate, and taking the best of the adaptation to suppress the identified blocking points revealed itself as an arduous task. In conclusion, this work was a source of knowledge, as it comprises concepts that were previously unknown or slightly studied.

# REFERENCES AND OTHER SOURCES OF INFORMATION

# 5 REFERENCES AND OTHER SOURCES OF INFORMATION


[1] A. Crespo Marquez and J. N. D. Gupta, “Contemporary maintenance management: Process, framework and supporting pillars,” *Omega*, vol. 34, no. 3, pp. 313–326, 2006.

[2] M. C. A. Olde Keizer, S. D. P. Flapper, and R. H. Teunter, “Condition-based maintenance policies for systems with multiple dependent components: A review,” *Eur. J. Oper. Res.*, vol. 261, no. 2, pp. 405–420, 2017.

[3] X. Zhao, K. N. Al-Khalifa, A. Magid Hamouda, and T. Nakagawa, “Age replacement models: A summary with new perspectives and methods,” *Reliab. Eng. Syst. Saf.*, vol. 161, pp. 95–105, 2017.

[4] B. de Jonge and P. A. Scarf, “A review on maintenance optimization,” *Eur. J. Oper. Res.*, 2019.

[5] H. Löfsten, “Measuring maintenance performance - in search for a maintenance productivity index,” *Int. J. Prod. Econ.*, vol. 63, no. 1, pp. 47–58, 2000.

[6] Y. Qin, Z. X. Wang, F. T. S. Chan, S. H. Chung, and T. Qu, “A mathematical model and algorithms for the aircraft hangar maintenance scheduling problem,” *Appl. Math. Model.*, vol. 67, pp. 491–509, 2019.

[7] K. K. H. Ng, C. K. M. Lee, F. T. S. Chan, and Y. Qin, “Robust aircraft sequencing and scheduling problem with arrival/departure delay using the min-max regret approach,” *Transp. Res. Part E Logist. Transp. Rev.*, vol. 106, pp. 115–136, 2017.

[8] C. K. M. Lee, K. K. H. Ng, H. K. Chan, K. L. Choy, W. C. Tai, and L. S. Choi, “A multi-group analysis of social media engagement and loyalty constructs between full-service and low-cost carriers in Hong Kong,” *J. Air Transp. Manag.*, vol. 73, no. August, pp. 46–57, 2018.

[9] K. K. H. Ng, C. K. M. Lee, F. T. S. Chan, and Y. Lv, “Review on meta-heuristics approaches for airside operation research,” *Appl. Soft Comput. J.*, vol. 66, pp. 104–133, 2018.

[10] C. Cusano and P. Napoletano, “Visual recognition of aircraft mechanical parts for smart maintenance,” *Comput. Ind.*, vol. 86, pp. 26–33, 2017.

[11] D. Dinis, A. Barbosa-Póvoa, and Â. P. Teixeira, “A supporting framework for maintenance capacity planning and scheduling: Development and application in the aircraft MRO industry,” *Int. J. Prod. Econ.*, vol. 218, pp. 1–15, 2019.

[12] R. Cobb, “Modeling aircraft repair turntime,” *J. Air Transp. Manag.*, vol. 2, no. 1, pp. 25–32, 1995.

[13] J. A. Erkoyuncu, S. Khan, A. L. Eiroa, N. Butler, K. Rushton, and S. Brocklebank, “Perspectives on trading cost and availability for corrective maintenance at the equipment type level,” *Reliab. Eng. Syst. Saf.*, vol. 168, pp. 53–69, 2017.

[14] R. Saltoglu, N. Humaira, and G. Inalhan, “Scheduled Maintenance and Downtime Cost in Aircraft Maintenance Management,” *Int. J. Aerosp. Mech. Eng.*, vol. 10, no. 3, pp. 602–607, 2016.

[15] Q. Deng, B. F. Santos, and R. Curran, "A practical dynamic programming based methodology for aircraft maintenance check scheduling optimization," *Eur. J. Oper. Res.*, vol. 281, no. 2, pp. 256–273, 2020.

[16] S. P. Ackert, "Basics of Aircraft Maintenance Programs for Financiers: Evaluation & Insights of Commercial Aircraft Maintenance Programs," pp. 1–23, 2010.

[17] D. Rengasamy, H. P. Morvan, and G. P. Figueredo, "Deep Learning Approaches to Aircraft Maintenance, Repair and Overhaul: A Review," *IEEE Conf. Intell. Transp. Syst. Proceedings, ITSC*, pp. 150–156, 2018.

[18] Project Management Institute, *A Guide to the Project Management Body of Knowledge*, Sixth edit. Project Management Institute, Inc, 2017.

[19] R. Picciotto, "Towards a 'New Project Management' movement? An international development perspective," *Int. J. Proj. Manag.*, 2019.

[20] T. Seymour and S. Hussein, "The History Of Project Management," *Int. J. Manag. Inf. Syst.*, vol. 18, no. 4, p. 233, 2014.

[21] M. Hällgren, A. Nilsson, T. Blomquist, and A. Söderholm, "Relevance lost! A critical review of project management standardisation," *Int. J. Manag. Proj. Bus.*, vol. 5, no. 3, pp. 457–485, 2012.

[22] G. Silvius, "Sustainability as a new school of thought in project management," *J. Clean. Prod.*, vol. 166, pp. 1479–1493, 2017.

[23] C. Bredillet, J. . Turner, and F. . Anbari, "Exploring Research in Project Management: Nine Schools of Project Management Research," *Proj. Manag. J.*, vol. 39, pp. 28–42, 2008.

[24] J. R. Turner, F. Anbari, and C. Bredillet, "Perspectives on research in project management: the nine schools," *Glob. Bus. Perspect.*, vol. 1, no. 1, pp. 3–28, 2013.

[25] T. Falkmer, A. Siren, L. Hakamies, and S. Breker, *Agile Practice Guide*. Project Management Institute, Inc, 2017.

[26] E. C. Conforto, D. C. Amaral, S. L. da Silva, A. Di Felippo, and D. S. L. Kamikawachi, "The agility construct on project management theory," *Int. J. Proj. Manag.*, vol. 34, no. 4, pp. 660–674, 2016.

[27] J. Highsmith, *Agile Project Management: Creating Innovative Products*, Second. 2010.

[28] B. Boehm and R. Turner, *Balancing Agility and Discipline: A Guide for the Perplexed*, Seventh. Addison-Wesley, 2009.

[29] J. Erickson, K. Lyytinen, and K. Siau, "Agile Modeling, Agile Software Development, and Extreme Programming: The State of Research," *J. Database Manag.*, 2005.

[30] A. Rasnacis and S. Berzisa, "Method for Adaptation and Implementation of Agile Project Management Methodology," *Procedia Comput. Sci.*, vol. 104, no. December 2016, pp. 43–50, 2016.

[31] A. Gal, I. Filip, and F. Dragan, “A New Vision Over Agile Project Management in the Internet of Things Era,” *Procedia - Soc. Behav. Sci.*, vol. 238, pp. 277–285, 2018.

[32] H. Lei, F. Ganjeizadeh, P. K. Jayachandran, and P. Ozcan, “A statistical analysis of the effects of Scrum and Kanban on software development projects,” *Robot. Comput. Integr. Manuf.*, vol. 43, pp. 59–67, 2017.

[33] M. James and L. Walter, “Scrum Reference Card - A Management Framework,” *CollabNet, Inc*, p. 6, 2010.

[34] F. Freitas, F. Silva, R. D. S. G. Campilho, C. Pimentel, and R. Godina, “Development of a suitable project management approach for projects with parallel planning and execution,” *Procedia Manuf.*, vol. 00, no. 2020, 2020.

[35] M. Špundak, “Mixed Agile/Traditional Project Management Methodology – Reality or Illusion?,” *Procedia - Soc. Behav. Sci.*, vol. 119, pp. 939–948, 2014.

[36] K. Buganová and J. Šimíčková, “Risk management in traditional and agile project management,” *Transp. Res. Procedia*, vol. 40, pp. 986–993, 2019.

[37] E. C. Conforto and D. C. Amaral, “Agile project management and stage-gate model—A hybrid framework for technology-based companies,” *J. Eng. Technol. Manag. - JET-M*, vol. 40, pp. 1–14, 2016.

[38] F. J. Brandl, M. Kagerer, and G. Reinhart, “A Hybrid Innovation Management Framework for Manufacturing - Enablers for more Agility in Plants,” *Procedia CIRP*, vol. 72, pp. 1154–1159, 2018.

[39] E. Papadakis and L. Tsironis, “Hybrid methods and practices associated with agile methods, method tailoring and delivery of projects in a non-software context,” *Procedia Comput. Sci.*, vol. 138, pp. 739–746, 2018.

[40] G. Fernandes, S. Moreira, M. Araújo, E. B. Pinto, and R. J. Machado, “Project management practices for collaborative university-industry R&D: A hybrid approach,” *Procedia Comput. Sci.*, vol. 138, pp. 805–814, 2018.

[41] © Scaled Agile Inc, “Scaled Agile Framework,” 2020. [Online]. Available: https://www.scaledagileframework.com/. [Accessed: 07-Jan-2020].

[42] D. Leffingwell, R. Knaster, I. Oren, and D. Jemilo, *SAFe 4.5 Reference Guide: Scaled Agile Framework for Lean Enterprises*. 2018.

[43] A. Lugert, K. Völker, and H. Winkler, “Dynamization of Value Stream Management by technical and managerial approach,” *Procedia CIRP*, vol. 72, pp. 701–706, 2018.

[44] C. Loiro, H. Castro, P. Ávila, M. M. Cruz-Cunha, G. D. Putnik, and L. Ferreira, “Agile Project Management: A Communicational Workflow Proposal,” *Procedia Comput. Sci.*, vol. 164, pp. 485–490, 2019.

[45] D. Reinertsen, *Principles of Product Development Flow: Second Generation Lean Product Development*. Celeritas Publishing, 2009.

[46] M. Paasivaara, "Adopting SAFe to scale agile in a globally distributed organization," *Proc. - 2017 IEEE 12th Int. Conf. Glob. Softw. Eng. ICGSE 2017*, pp. 36–40, 2017.

[47] O. Turetken, I. Stojanov, and J. J. M. Trienekens, "Assessing the adoption level of scaled agile development: a maturity model for Scaled Agile Framework," *J. Softw. Evol. Process*, 2016.

[48] A. Putta, M. Paasivaara, and C. Lassenius, *Benefits and challenges of adopting the Scaled Agile Framework (SAFe): Preliminary results from a multivocal literature review*, vol. 11271 LNCS. Springer International Publishing, 2018.

[49] M. Laanti, "Characteristics and principles of scaled agile," *Lect. Notes Bus. Inf. Process.*, vol. 199, pp. 9–20, 2014.

[50] P. Kettunen and M. Laanti, "Future software organizations – agile goals and roles," *Eur. J. Futur. Res.*, vol. 5, no. 1, pp. 1–15, 2017.

[51] S. Sreenivasan and K. Kothandaraman, "Improving processes by aligning Capability Maturity Model Integration and the Scaled Agile Framework®," *Glob. Bus. Organ. Excell.*, vol. 38, no. 6, pp. 42–51, 2019.

[52] B. Mucambe, A. Tereso, J. Faria, and T. Mateus, "Large-scale agile frameworks: Dealing with interdependences," *Proc. 33rd Int. Bus. Inf. Manag. Assoc. Conf. IBIMA 2019 Educ. Excell. Innov. Manag. through Vis. 2020*, pp. 3109–3119, 2019.