Agile Product Line Engineering: The AgiFPL Method

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Abstract: Integrating Agile Software Development (ASD) with Software Product Line Engineering (PLE) has resulted in proposing Agile Product Line Engineering (APLE). The goal of combining both approaches is to overcome the weaknesses of each other while maximizing their benefits. However, combining them represents a big challenge in software engineering. Several methods have been proposed to provide a practical process for applying APLE in organizations, but none covers all the required APLE features. This paper proposes an APLE methodology called AgiFPL: *Agile Framework for managing evolving PL* with the intention to address the deficiencies identified in current methods, while making use of their advantages.

1 INTRODUCTION

Over the past years, the software industry has been searching for methods, processes and techniques to increase the delivery of high quality software while reducing development costs. Several paradigms have been proposed in order to fulfil this target. *"Agile Software Development"* (ASD) and *"Product Line Engineering"* (PLE) are well-known approaches proposed by researchers and practitioners for dealing with the growing complexity of information systems and handling competitive needs of the IT industry (da Silva et al., 2011). The popularity of both approaches and their positive results have motivated researchers to find ways for integrating them (Farahani, 2014) leading to *"Agile Product Line Engineering"* (APLE).

The main goal of APLE is to maximize the benfits of each individual approach and to fulfil their common goals (Hanssen, 2011). Moreover, combining ASD and PLE presents a significant advantage in terms of "synergy" in which, each approach addresses the weaknesses of the other. But, among the proposed APLE methodologies, only few have proposed a specific process for this combined approach, and can hence be actually referred truly to as APLE methodologies (Asadi, and Ramsin, 2008).

After reviewing the literature on APLE and anlysing, comparing and evaluating the relevant APLE methodologies, each method can be considered as presenting strengths and weaknesses. Furthermore, the study of the existing APLE methods has revealed that no single method covers all the needed APLE features.

In this context, this paper proposes an APLE methodology called AgiFPL *(Agile Framework for managing evolving SPL*). The intention behind the definition of this APLE method is to address the deficiencies identified in current methods, while making use of their advantages.

1.1 Research Method

In order to achieve our target we started by identifying, studying and evaluating the relevant APLE methodologies that exist in the literature. (Díaz et al., 2011) and (da Silva et al., 2011) have already surveyed several APLE methods in their systematic literature reviews. (Farahani and Ramsin, 2014) have presented a recent study in which they surveyed and analyzed APLE methodologies in a more precise and systematic manner through using *"criteria-based evaluation"*. Based on that, we made an iterative evaluation of the methodologies based on a *"criterion set"*. The results of the evaluation performed in each iteration have allowed us to obtain a deeper insight into the features of the methodologies. The results are therefore used to identify new criteria and thus enriching the criterion set. Indeed, the results of this criteria-based

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evaluation have highlighted the strengths and weaknesses of each methodology, have specified the features expected of APLE methodologies, and have identified the shortcomings of methodologies. Thus these results could be used for improving current and future APLE methodologies.

Secondly, we have studied and evaluate some ASD methodologies such as, Scrum (Cohn, 2013), XP, Scrumban (Ladas, 2009). We aim with this evaluation to identify methods or reusable method chunks that could help us to produce our intended APLE. The results of this evaluation are used as a basis for selecting and assembling reusable method chunks, instantiating abstract process frameworks, and extending existing methodologies in order to define the bespoke APLE methodology.

Thirdly, after designing and defining the proposed APLE we aim to validate it by establishing an exhaustive *case-study* that shows the applicability of the bespoke APLE. Due to lack of space, we only present a short illustration in this paper.

1.2 Contributions

As said this paper is an effort to propose an adequate APLE method that addresses the lacks and deficiencies (see Section 4) of classical APLE methods. For this purpose, we focus on the agile methods Scrum (Cohn, 2013) and Scrumban (Ladas, 2009) as basis for AgiFPL as they adapt well to software evolution and they are widely used by the agile community. In addition, we focus on the requirement engineering disciplines of I-Tropos (Wautelet, 2008) (i.e. Organizational modeling and Requirement Engineering) in order to define the RE process of AgiFPL.

According to (Asadi et al., 2012) and (Hersari et al, 2010) software development methodologies consist of two integral parts: a *"modeling language"* and a *"process"*. The modeling language part provides the syntax and semantics used for expressing the products, whereas the process prescribes the flow of activities that should be performed and explains how the products should be produced, enhanced and exchanged along this flow. The agility feature of APLE methods has deemphasized the role of modeling, and hence the modeling language. In the proposed APLE, we presented an adequate Requirement Engineering (RE) process for both Domain Engineering (DE) and Application Engineering (AE). The proposed RE process of AgiFPL make a trade-off between the requested RE elicitation and the agility feature. The target of this RE process is to introduce a suitable reuse strategy and reduce the upfront design during the AgiFPL development process. Moreover, for the process part AgiFPL integrates Scrumban for the DE and Scrum for the AE.

The paper is structured as follows. Sections 2 and 3 overview PLE and ASD. Section 4 highlights the nowadays context of APLE. Section 5 presents our AgiFPL framework. Section 6 introduces an illustration with part of case study. Finally we conclude the paper in Section 7.

2 PRODUCT LINE ENGINEERING

Software Product Line Engineering or *Product Line Engineering* (SPLE or PLE) provides an efficient way to build and maintain portfolios of systems that share common features and capabilities.

There are two essential phases to develop SPLs: Domain Engineering (DE) and Application Engineering (AE) (Pohl et al., 2005).

DE is the phase of creating a set of reusable assets for building systems in a specific problem domain (Díaz et al., 2011). It determines the scope and handles the commonalities and the variability, i.e. defines the core-assets, points of variations, and expected variants for all the products of the PL (Kang et al., 2010). DE is summarized in the following set of activities or practices (O'Leary et al., 2009):

1. Domain Identification and Scoping;
2. Requirements Engineering;
3. Feature Modelling;
4. Architecture Design;
5. Core-Assets Development;
6. Traceability Management;
7. Evolution and Maintenance.

The AE phase consists of developing products through systematic reuse of core-assets by deriving the PL variability points, i.e. reusable assets are extended from variability points with the selected variants for a specific product (Clements and Northrop, 2001 ; Pohl et al., 2005). AE is summarized in the following set of activities and practices (Díaz et al., 2011):

1. Release Planning (plan for product applications);
2. Product Configuration (model application, architecture application, platform application);
3. Product Development;
4. Test, Integration and Deployment;

5. Traceability Management;
6. Evolution and Maintenance.

Figure 1 shows a framework for PLE, which divides the product line into DE and AE.

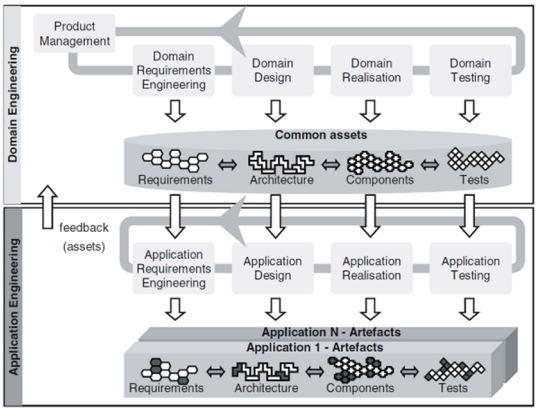

Figure 1: The Software Product Line Engineering framework (Pohl et al., 2005).

3 AGILE DEVELOPMENT

Agility is an umbrella term for a variety of agile methods that are based on the Agile Manifesto (Shore and Warden, 2007) principles and values. Agile Software Development (ASD) is an approach that is intended to enable rapid and flexible development of small-scale software solutions from scratch, usually addressing a single, well-defined customer (Sommerville, 2011). Documentation, including plans, is kept at a minimum, and work is organized in short iterations developing the software product in increments, which is continuously tested in collaboration with customers and potentially refactored (See Figure 2).

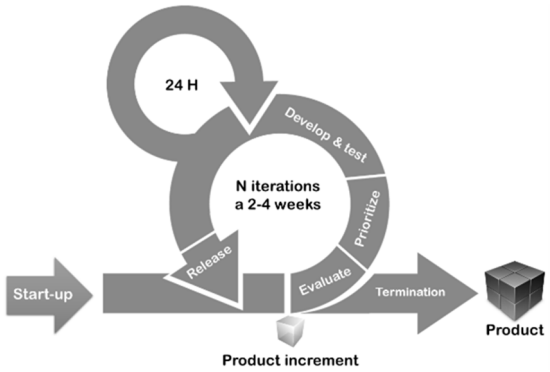

Figure 2: Basic ASD process (Shore and Warden, 2007).

External stakeholders such as clients and third-party actors participate in nearly the whole period of a development project (Larman, 2003).

All these methods, such as Scrum, XP, and Scrumban implement iterative incremental life cycles, share common values, and principles with each one of them defining their own practices. We only focus in on Scrum and Scrumban since we will use them in the design of AgiFPL.

3.1 Scrum

In Scrum, projects move forward through aggressive deadlines via a series of iterations called sprints to implement dynamic requirements pulled from a backlog. Each sprint is typically two to four weeks long, at the end of which, the performed work should create something of tangible value to the stakeholders (Chon, 2013; Kenneth, 2013). Each sprint has a *sprint-planning meeting* at the sprint beginning in which the *Product Owner* and *Team* plan together about what to be done for the sprint. The result is the sprint backlog, a list of *User Stories* and *tasks* that must be performed to achieve the sprint goal.

3.2 Scrumban

Scrumban proposes a transition method for moving software development teams from Scrum to a more evolved development framework. Since the introduction of Scrumban, organizations have layered the Kanban Method alongside Scrum to help them achieve several different kinds of outcomes (Ladas, 2009 ; Reddy, 2016).

4 AGILE PRODUCT LINE ENGINEERING

There has been growing interest in whether the integration of Agile and PL could provide further benefits and solve many of the outstanding issues surrounding software development (da Silva et al., 2011).

The following methods are proposed as APLE methods and are considered as relevant:

- Component-Driven Development (CDD) – (Ramsin and Paige, 2008 ; Wang, 2005);
- Extend FAP – (de Souza and Vilain, 2013);
- RiSE Process for Product Line Engineering (RiPLE-SC) – (Balbino et al., 2011);
- A-Pro-PD – (O'Leary et al., 2010);

- Tailoring the Scrum Development Process to Address APLE – (Díaz Fernández et al. 2011);
- An Iterative Model for Agile Product Line Engineering – (Ghanam and Maurer, 2008);
- Extreme Product Line Engineering – (Ghanam and Maurer, 2009);
- Agile Approach for Software Product Lines Scoping – (da Silva, 2012);
- Agile PuLSE-I – (Carbon et al., 2006);
- Agile product line planning – (Noor et al., 2008);
- Reactive Variability Management in Agile Software Development – (Ghanam et al., 2010).

The main shortcomings (deficiencies) (Farahani, 2014) of these methodologies concern the following groups of criteria:

1. General criteria (e.g. modelling language, the process);
2. Criteria related to the characteristics of agile methods (teams, flexibility, leanness etc.);
3. Criteria related to the PL characteristics (DE activities, AE activities, core assets, scope, features, etc.);
4. Criteria related to the common goals of agile and PL (on-time software delivery, software quality, HR management, management of changes in requirements, etc.);
5. Criteria related to issues arising due to the combination of the two approaches (Reuse approach, basis of the methodology, etc.).

Reviewing the existent APLE methodologies shows the need of a new approach that cover all the following APLE characteristics (Díaz et al., 2011; Farahani and Ramsin, 2014):

7. Full coverage of the generic software development lifecycle;
8. Comprehensive and precise definition of the methodology;
9. Sufficient attention to the non-SDLC activities (umbrella activities);
10. Prescription of a specific modeling language;
11. Provision of model examples;
12. Attention to learning at project and portfolio levels;
13. Attention to active user involvement;
14. Management of expected and unexpected changes.

5 OUR AGIFPL FRAMEWORK

The intention behind our AgiFLP framework is to develop a proper APLE methodology which combines agility with PLE effectively, and embodies the advantages of both approaches.

This section presents how our APLE is tackled by means of a tailored Scrum, and Scrumban in which the DE and AE processes are performed in an iterative and incremental way. To overcome the PL-architecture challenge and reducing the upfront design, it is necessary to define the mechanisms and strategies to be applied during the APLE development process. This is why our contribution is based on two main aspects: *requirement engineering (RE)* and *development process*. In fact, using a goal-oriented requirement engineering approach (GORE) such as i*, will provide the mechanism to easily evolve PL-architectures in an agile context and will establish a suitable reuse strategy. Furthermore, adopting Scrumban and Scrum for the development processes in DE and AE will establish the agility of our method.

AgiFPL is thus an agile methodology designed to improve the agility within the PLE and to meet effectively any new emerged business expectations. The main goal of AgiFPL is to move teams from the classical approach to a more evolved APLE framework.

In addition, the proposed approach adopts forecasting and metric models and some project management practices in order to address some management issues.

In other words, on the one hand, for the DE stage, AgiFPL implement an iterative process that uses i* approach with Scrumban. On the other hand, for the AE stage, AgiFPL implement also an iterative process that use the Scrum approach with i*.

AgiFPL is a two a tier framework where the first layer modelled in Figure 3, is dedicated to the Domain Engineering (DE) and the second one, modelled in Figure 4, is dedicated to the Application Engineering (AE). Moreover, the framework considers two spaces i.e. *Problem Space* and *Solution Space*. Note, that each process of AgiFPL is based on an *iterative* and *incremental* development.

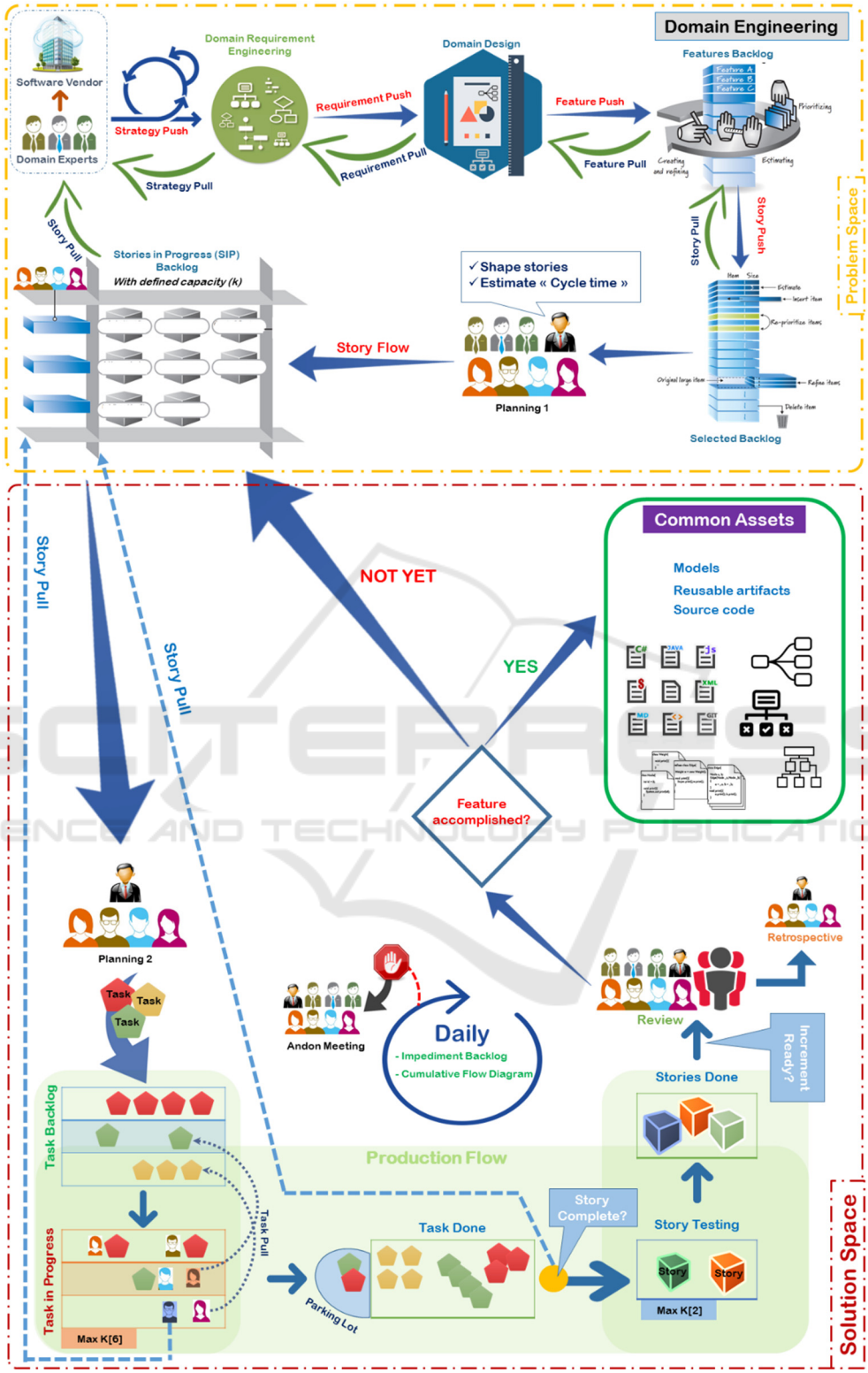

Figure 3: Domain engineering (DE) process according to AgiFPL.

5.1 De Tier

The DE tier is detailed in Figure 3. First, the *"Software Vendor"* has a business strategy for the domain. This strategy is built from market trends, potential investment opportunities and core-business improvements. The domain strategy constitutes the main base to define the scope of the domain and start the phase of *"Domain requirement engineering" (DRE)*.

The strategy pushes to start the *DRE phase*, first step in the problem space. DRE is a sub-process that aims to understand the problem space by studying the settings of the organizations related to the domain. Roles involved in this sub-process are "Domain Experts", "Domain Sensei" and "Development Team". During this sub-process, the people involved model the target domain in terms of social actors and their intentions. In addition, when the "Software Vendor" adopts a new or modified strategy, the "Domain Experts" pull this strategy and upgrade the "Domain Requirements".

After receiving all the documentations and models delivered at the end of the DRE phase, the *"Domain Design" (DD)* phase starts. The *DD phase* takes the reference RE models as input and creates a reference architecture for the product line's platform, which gathers the common assets. At this phase, the scope of the domain and the architectures have to be determined, i.e., decide which products should be covered by the product line and, consequently, which features are relevant and should be implemented as reusable artefacts. The DD phase contains two primary tasks: *domain scoping* and *domain modelling*.

Once commonalities and variabilities are identified and *feature models* are generated at the DD phase, "Domain Experts" defines the *"Features Backlog" (FB)*. During this phase, the persons involved document features in *"User Stories" (US)* format (Cohn, 2004). At this stage, stories contain rough estimates of both business value and development effort. At the end of this stage, the "Domain Experts" build a *"Selected Backlog" (SB)* with defined capacity from the FB. The SB represents a list of work the "Development Team" must address next. It has a defined capacity limit. As soon as capacity is available, it is filled up with user stories/features from the top of the FB.

After building the SB, the "Domain Experts" and "Development Team" hold the *"Planning 1"* meeting in order to shape stories and estimate "Cycle Time". "Planning 1" is considered as the "WHAT": Whenever the "Domain Experts" pulls new user stories into the SB. After this, the "Development Team" should understand the different features. Therefore, the team is able to estimate the complexity of each user story.

Once "Planning 1" takes place, the "Development Team" structures the *"Stories in Progress Backlog" (SIP Backlog)* with defined *capacity (K[n])*. The SIP Backlog is a list of user stories, which the development team currently addresses. Team members pull user stories from the selected backlog when there are no more remaining tasks in the task backlog.

After structuring the SIP Backlog, the "Domain Sensei" and "Development Team" hold the *"Planning 2"* meeting. With "Planning 2" starts the *"Domain Implementation or Production of Common Assets" phase*. The "Planning 2" is considered as the "HOW": Whenever team members pull new user stories into the production flow. During the "Planning 2" meeting, the team establish the *"Production Flow"* consisting of the following components:

1. Task Backlog;
2. Task in Progress with defined capacity (max k[6]). Once the "Task in Progress" is done, team members pull tasks from "Task Backlog".
3. Task Done with "Parking Lot". Once the story is completed (Story complete?) "Development Team" members pull user stories from the "SIP Backlog".
4. Story Testing with defined capacity (max k[2]);
5. Stories Done;

During the "Production Flow", the "Domain Sensei" and "Development Team" hold a *"Daily" meeting,* which is a short, time-boxed meeting, taking place every day at the same time.

Whenever the team ships an increment *(Increment Ready?)*, the "Domain Experts", "Domain Sensei" and "Development Team" hold a *"Review" meeting* in order to review the work accomplished. The team uses this meeting to present and review the work it has completed since the last delivery. Usually, it also includes a demonstration of the features created during the latest increment or iteration. Once the features are implemented as reusable artefacts (Models, Source Codes,…), these are placed in the *"Common Assets Warehouse"*.

After any "Review", the "Scrumban Sensei" holds the *"Retrospective" meeting* to reflect on the past production cycle in order to ensure continuous process improvements. The "Domain Sensei" always asks two questions in the retrospective:

1. What went well during the last cycle?
2. What should improve in the next cycle

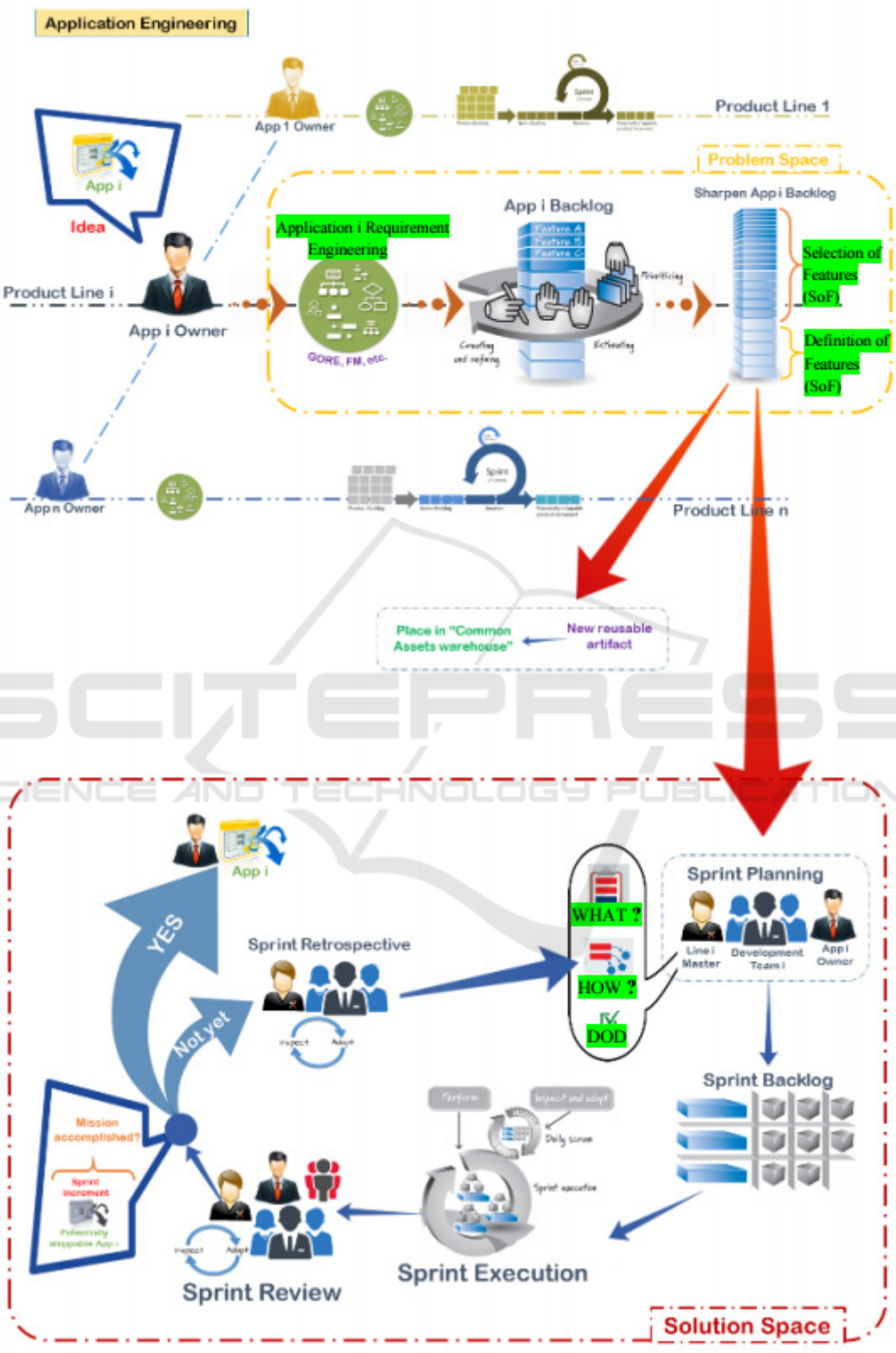

Figure 4: Application engineering (AE) process according to AgiFPL.

During the "Production Flow", whenever a problem occurs, the "Domain Sensei" organizes an *"Andon" meeting* whenever problems in the production flow occur.

5.2 AE Tier

The AE tier, represented in Figure 4 includes several product lines where the outputs are client applications (products). At this stage, *"App i Owners"* and *"App i Stakeholders"* are more involved in the development process.

Hereafter, we describe the AgiFPL proposition for the *"Line i"* which deliver at the end the *"App i"*. In fact, AgiFPL propose a simple agile. Each line of the AE tier will follow this process.

First, an "App i Owner" comes with an idea of what he/she wants to create. The App Line process starts and lunches the *"App i Requirement Engineering" (ARE i) phase*. This phase has two main missions:

1. The "App i Owner", "App i Stakeholders", "Line i Master", and "Development Team i" study the "Organization i" in order to understand the motivations and rationales that underline the "App i" requirements.
2. The "App i Owner" idea could be large, therefore, through an activity called "Grooming"; it is broken down into a set of features that are collected into a prioritized list called the *"App backlog"*.

The requirement assets produced in "Domain Engineering" constitute some basis, but they will not satisfy all "App Owners" and "App Stakeholders" requirements. The gap between what is available and what is required must be analysed, and a trade-off decision has to be taken for each unsatisfied requirement. At the end of the ARE phase two types of features coexist:

1. Features that exist and could be selected from the "Common Assets Warehouse". The set of these is called *"Selection of Features" (SoF)*.
2. Features that are required for the development of the application and does not exist in the "Common Assets Warehouse". Since these features are defined during the ARE phase, the set of these is called *"Definition of Features" (DoF)*.

Consequently, the building of the "App backlog" is finished and it contain an ordered list of documented US that the team maintains for an "App". Note that all *new reusable artefacts* issued from the AE process have to be classified in the "Common Assets Warehouse".

Once the "App backlog" is finished, the work is performed in "Sprints" up to a calendar month. The work completed in each sprint should create something of tangible value to the customer or user. The "Sprint" starts with the *"Sprint Planning"* (WHAT? And HOW?). The "App i Owner", "Line i Master" and "Team Development i" perform the "Sprint Planning" in order to determine the most important subset of "App backlog" items to build in the next sprint. During the sprint planning, the "App i Owner" and "Development team i" agree on a sprint goal that defines what the upcoming sprint is supposed to achieve.

At the end of the "Sprint Planning", the "Sprint Backlog" is defined and the *"Definition of Done" (DoD)* list is established. In fact, DoD is a checklist of activities required to declare the implementation of a story to be completed.

Once the concerned people consider the "Sprint Planning" as finished and agree on the content of the next sprint, the "Development Team i", guided by the "Line i Master" coaching, performs all the task-level work necessary to get the tasks done. This step is called *"Sprint Execution"*.

Every day during the sprint, ideally at the same time, the "Development Team i" members hold a time-boxed *"Daily" meeting*. This *"inspect-and-adapt" activity* is sometimes referred as the daily stand-up.

The "Sprint" results are considered as a *"Potentially shippable App increment"*, meaning that whatever the "Development Team i" has agreed to do is really done according to its agreed-upon definition of done.

At the end of the "Sprint", there are two additional "inspect-and-adapt" activities:

1. *"Sprint Review":* The goal of this activity is to inspect and adapt the product that is being built. Critical to this activity is the conversation that takes place among its participants. The conversation is focused on reviewing the just-completed features in the context of the overall development effort.
2. *"Sprint Retrospective":* This activity frequently occurs after the sprint review and before the next sprint planning. Whereas the sprint review is a time to inspect and adapt the product, the sprint retrospective is an opportunity to inspect and adapt the process.

Once the "Sprint Retrospective" is completed, the whole cycle is repeated again — starting with the next sprint-planning session, held to determine the current highest value set of work for the team to focus on. At the end of the "Sprint" the "Line i Master",

"Development Team i", and "App i Owner" perform a "Backlog refinement": (max. 60 min) used to introduce and estimate new backlog items and to refine existing estimations as well as acceptance criteria. It is also used to break large stories into smaller ones.

After an appropriate number of sprints have been completed, the "App i Owner's" vision will be realized and the solution can be released.

6 ILLUSTRATION

In order to validate our proposed APLE method, we suggest introducing briefly a case study based on the Odoo open source ERP platform (Odoo Inc., 2017). In fact, Odoo offers an *All-in-one* ERP management software which fits small and medium companies and our APLE method (AgiFPL) could be applied within Odoo.

Due to lack of space, we only present a simple example concerning "NST Shipping" which is a maritime transporter that Odoo to implement their cross functional business processes. In the requested ERP, several modules and application are needed for supporting NST activities, e.g. "Invoicing Application" and "eTracking service".

Odoo has an initial huge "Common Assets Warehouse". Among the reusable artefacts of Odoo we found the "Invoicing Module". Therefore, several modules of NST ERP would be found in Odoo's common assets warehouse.

Once NST signs the contract of the NST ERP implementation with Odoo, the Odoo "Line Team" will proceed following the AE phase of AgiFPL. Based on the results of the "ARE step" and "NST App Backlog" the "Line Team" will recognize that the requested "eTracking service" does not exist in the "Common assets Warehouse" and there are no similar artefact among the reusable ones. Therefore, the "Line Team" will start the process of developing this service. In other words, the team will transform the related requirement model (See Figure 5) into a feature model and then into USs and organize these USs in the App Backlog. Then they will follow the process until delivering the final version of the NST ERP.

Following AgiFPL method, this "Goal Model" of the eTracking service will be transformed into a feature model (FM). Figure 6 shows the FM for the eTracking service" module.

As said above, this FM for "eTracking Service" will be transformed to USs in order to define the "App Backlog". According to the "Planning" the development of this App will take a "Sprint" of 2 weeks. *Table 1* shows the "Sprint" plan.

At the end of the sprint the final version of the "eTracking service App" will be integrated to the NST ERP. In addition, all reusable artefacts generated from this step will be stocked on the "Common assets warehouse".

7 CONCLUSIONS

As mentioned in this paper, our contribution is to propose a new proper APLE approach that addresses the deficiences identified in current APLE methods, while making use of their benefits. The proposed APLE approach is called *AgiFPL (Agile Framework for managing evolving PL)*.

In order to design this APLE approach we have reviewed the most relevant APLE approaches from the literature. In addition, we present as an illustration part of a case study in order to show how we intend to validate our approach.

Further work undergoing to complete AgiFPL approach. For instance, we are working on adopting and developing metrics for performance. Furthermore, we are developing tools that will facilitate the implementation of AgiFPL. Also, we try to simplify the RE processes by adopting adequate frameworks that fit the agility of our proposal.

Table 1: Sprint plan.

Week 1	One of the first days	Meeting with NST stakeholder Sprint post-mortem
	1 Monday	Technical meeting
		Development sprint kickoff
	2 Tuesday	Development
	3 Wednesday	
	4 Thursday	
	5 Friday	
Week 2	1 Monday	
	2 Tuesday	
	3 Wednesday	Internal demo
		Sprint "planning 2" and review meeting
	4 Thursday	Fix change requests
	5 Friday	Retrospective
		Project Status Meeting

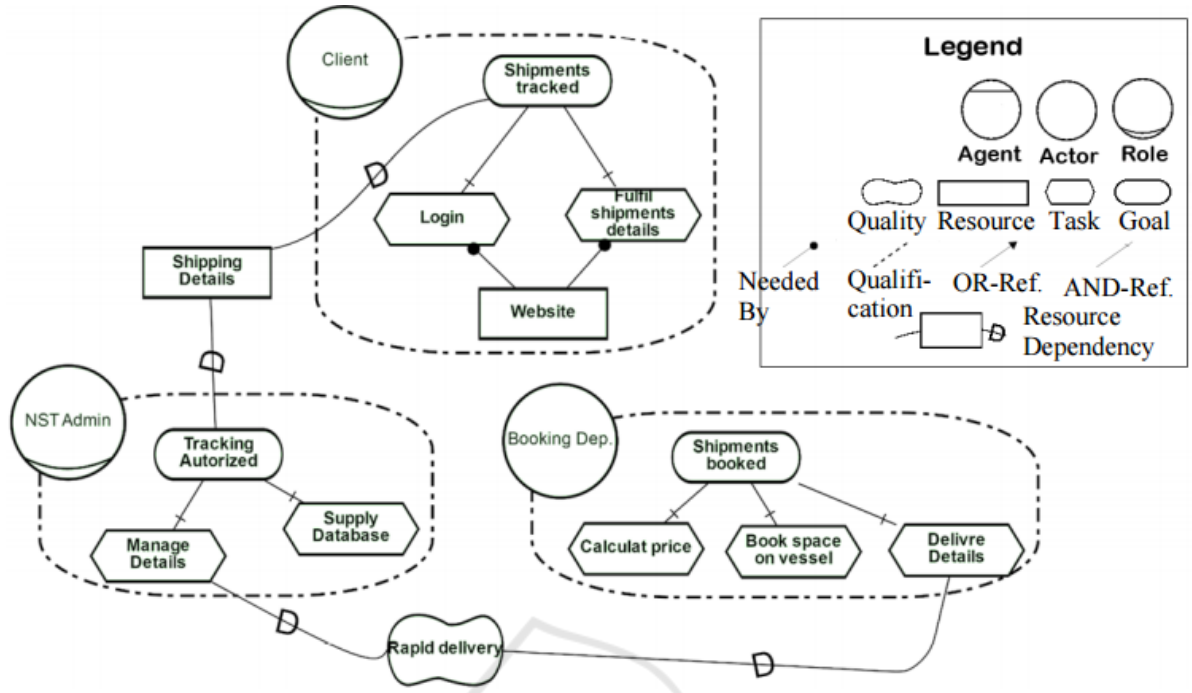

Figure 5: Goal Model (i* SR model) for *eTracking service.*

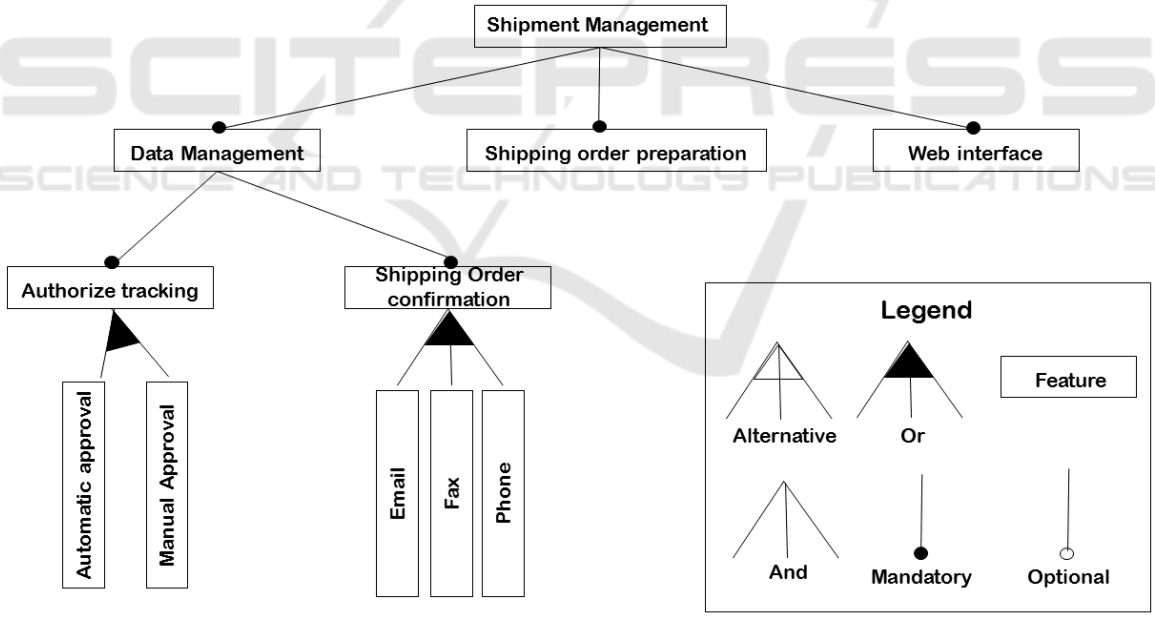

Figure 6: Feature Model for eTracking Service.

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