AHAA –Agile, Hybrid Assessment Method for Automotive, Safety Critical SMEs

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ABSTRACT

The need for software is increasingly growing in the automotive industry. Software development projects are, however, often troubled by time and budget overruns, resulting in systems that do not fulfill customer requirements. Both research and industry lack strategies to combine reducing the long software development lifecycles (as required by time-to-market demands) with increasing the quality of the software developed. Software process improvement (SPI) provides the first step in the move towards software quality, and assessments are a vital part of this process. Unfortunately, software process assessments are often expensive and time consuming. Additionally, they often provide companies with a long list of issues without providing realistic suggestions. The goal of this paper is to describe a new low-overhead assessment method that has been designed specifically for small-to-medium-sized (SMEs) organisations wishing to be automotive software suppliers. This assessment method integrates the structured-ness of the plan-driven SPI models of Capability Maturity Model Integration (CMMI) and Automotive SPICE™ with the flexibleness of agile practices.

Categories and Subject Descriptors

Software and Software Engineering

General Terms

Management, Performance, Reliability, Security, Standardization.

Keywords: Software Process Improvement, Agile Practices, CMMI, Automotive SPICE™, Assessment Methods, Safety-critical.

1. INTRODUCTION

Due to the nature of the final product, many software industries are expected to produce high-quality software through the use of processes. For example, regulations within the medical device industry have existed for many years and the automotive industry is now moving in that direction. In the last decade, there been a significant growth in the production of automotive software – a growth which is expected to continue – and this software must be developed faster and in a more cost effective way, but still in a quality environment. It is expected that the industry markets will require process maturity levels from companies to demonstrate the quality of their software.

In many countries (Ireland and Finland are the focus of this paper), there is a vibrant software industry with many small-to-medium sized enterprises (SMEs). The European Union definition states that a SME has less than 250 employees, turnover of less than €50million and is less than 25% owned by a non-SME. However, to survive and grow SMEs, must be aware of software opportunities. One such industry is the automotive industry. As software is becoming more safety-critical, automotive software suppliers need to aware of safety considerations such as those described in ICE 61508 [22], ISO WD 26262 [24] and DIN 31000 [10].

Assessments provide a valuable mechanism to start improvement initiatives towards achieving high quality software. The agile, hybrid assessment method for the automotive industry (AHAA) presented in this paper supports the integration of agile practices with the more traditional plan-driven practices that are associated with SPI in safety-critical companies. The paper presents how this method was used within a SMEs software development organization and illustrates how "goal-based" improvements may be achieved through adopting a combination of plan-driven and agile based recommendations. Whenever automotive software is not safety-critical it is feasible for the AHAA to recommend a combination of both plan-driven and agile based practices. However, in the case of safety-critical automotive software development (complying with ICE 61508 and ISO WD 26262) the AHAA will only recommend plan-driven practices.

In section 2, process within automotive software SMEs is discussed. Section 3 presents the need for AHAA, the assessment method we developed. Section 4 describes its development, while Section 5 presents the implementation of the assessment method within an SME, AutoSoft. In Section 6 we discuss feedback from the company, with conclusions presented in Section 9.

2. SOFTWARE IN AUTOMOTIVE SMEs

According to [35] software was first introduced into cars in 1976 and in recent years, there has been a substantial increase in automotive software. The number of electronic control units (ECUs) is increasing – consequently, more interfaces need to be developed between these ECUs. While much automotive software is not

ICSE'08, May 10–18, 2008, Leipzig, Germany.

safety-critical, for example, software within navigation and infotainment systems, safety-critical functions, such as braking, are becoming more software dependant. Furthermore, the driver requires some safety-critical information, for example, the speed at which the car is travelling. While the driver can intervene in the execution of these functions, the increase in software dependence requires that operational safety must be accounted for when developing automotive software.

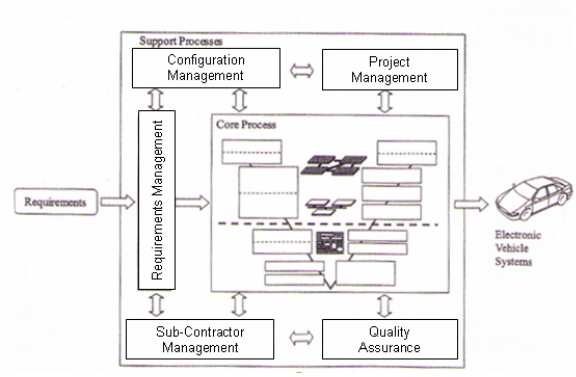

Figure 1 – Support processes for Electronic Systems and Software Development (Adapted from Schauffele and Zurawka, [39])

This has resulted in the imposition of safety regulations (for example, DIN 31000 within the automotive industry and many automotive companies have already faced challenges to develop complex software where the goal is to achieve high quality safety-critical software components. The implementation and improvement of software processes can be used to support the development of automotive software as illustrated in Figure 1. While core development processes are required, there is also a need for support processes such as configuration management, project management (including risk management), requirements management, subcontractor management and quality assurance. Due to the challenges of controlling the increased complexity that innovations bring, a HIS (Herstellerinitiative Software) process assessments working group was "funded to establish a common approach for determining software capability/maturity of suppliers" [18]. Consequently, there is an increasing requirement for the quality of software to be monitored and assessed throughout the development process.

2.1 Importance of the SME sector

In Europe, and specifically in countries such as Ireland and Finland, where the researchers are based, there is an increasing emergence of the small firm as a key component of the industrial profile of individual countries.

Information and Communications Technology is a growth sector which has been recognised strategically by Government as important to the Irish economy. The success of the growth of this sector is attributed to a number of factors which include low corporation tax, an English speaking workforce, the availability of a highly qualified and educated workforce, a strong indigenous firm base and deployment of EU structural and cohesion funds to Ireland [12,13, 15, 44]. With 760 indigenous software companies employing over 11,100 people, they provide 47% of employment in the Irish software sector [13].

In Finland, software companies employ over 13,000 people [43]. Revenue in Finnish software companies increased at 2005 by 24.2 % [41] and again in 2006 by 13 % [38]. In Finland, these increases can be attributed to both large and small software companies [41]. However, many SMEs are carrying out sub-contract development and are supporting the needs of large embedded product development companies [30]. Evaluations have also shown that the critical success factor of the Finnish software industry will be support, increased know how and internationalization, especially, among the SME sector [30].

The increasing need for software in the automotive sector provides opportunities for SMEs to become software suppliers to the large automotive organizations. Our research has demonstrated that SMEs who wish to take up this opportunity need to demonstrate that their process is capable of producing high-quality software. Thus, they require a cost-efficient assessment which supports their business requirements.

2.2 Use of SPI Models

SPI initiatives can be based on various models such as the Capability Maturity Model (CMM) [31], more recently CMMI [7] or process standards such as ISO 15504 [23] and ISO 9001 [1, 42]. Implementation of changes identified during SPI assessments enable organizations to reduce software development costs and time-to-market [1,16, 42]. For example, 400 projects reported increased productivity and software development speed due to CMMI based improvement programs [16]. According to this study, 12% of the overall lead time in software product development and 49% reduction in defects was obtained using CMM or CMMI based improvement programs. However, many companies have refused to adopt the assessment part of these models as they tend to be too heavy and expensive for SMEs [14]. Furthermore, several organizations have adopted time consuming SPI programmes, the benefits of which will take a long time to be realized [17].

In the automotive sector, a challenge that faced the HIS process assessment working group was that each manufacturer had a different approach to evaluating suppliers' capability/maturity [19]. For example, BMW and Porsche used an internal questionnaire [19]. Based on the different requirements for a common assessment method, ISO/IEC TR 15504 [23] (SPICE) has been adopted for supplier assessment within the HIS. From 2001 to 2006, HIS members have executed some 200 ISO 15504 assessments [18]. According to [3] "the focus on software capability assessment has already provided significant business benefits for its use, but at the same time has highlighted the scale of the potential problem, particularly with suppliers of safety-critical embedded software system components".

Automotive SPICE™ is an initiative of the Automotive Special Interest Group (SIG), which is a joint special interest group of The SPICE User Group, and the Procurement Forum together with major automotive manufacturers [3]. One of the reasons behind this initiative is that the experience (gathered during assessments) indicates that there is a demand for an automotive specific guidance of the standard [19]. Automotive SPICE™ consists of a Process Assessment Model (PAM) and a Process Reference Model (PRM) [3]. The Automotive SPICE™ Process Assessment Model is based on the ISO/IEC 15504-5 [23]. Thirty-one of the processes from ISO/IEC 15504 were selected for inclusion in Automotive SPICE™. Furthermore, from 2007, all HIS members will perform and accept only Automotive SPICE™ assessments. Therefore

automotive assessments based on ISO/IEC TR 15504 will be replaced by Automotive SPICE™. The results of the assessments can be used for the identification of process improvements for a supplier as well as a criterion for supplier selection [3].

2.3 Suitability of Agile Approaches

Agile approaches such as eXtreme Programming [4] and Scrum [40] have been increasingly used in companies as a way of addressing key problems in software development [25] such as: "software takes too long to develop, costs too much and has quality issues upon delivery" [21]. Although, agile software development practices have benefited some companies producing safety-critical software [11, 46], Boehm and Turner [6] have argued that plan-driven approaches are better suited to these situations. However, the way forward may be to combine suitable agile practices as part of a company's current plan-driven software development activities [6, 33]. Although assessments are often characterized as a plan-driven technique for SPI and are rarely used within agile practices, Paulk [32] argues that "Adopting the two methods (CMMI and agile) can create synergy, particularly in conjunction with other good engineering and management practices."

The first step in engaging in SPI is to assess the current state of the software development practices. A SPI path may be developed based upon a combination of this starting point and the business goals of the organisation [28]. Processes in SMEs must be catered for in a different manner than within large companies [37] as existing SPI assessment methods are very heavyweight and are not suited to the needs of SMEs. Furthermore, they do not consider both plan-driven and agile practices. Small companies need specialized assessment methods because they do not have the same ability to invest in SPI as the bigger enterprises. However, they require high quality software and fast software production. [26].

Organizational maturity indicators like CMMI levels, SPICE ratings or specific ISO standards have become important for software development. Customer organizations often rely on them when selecting a supplier as the results of these assessments can serve as indicator of process maturity. At the same time, agile methods continue to gain popularity due to increasing speed and quality demands. It has been argued that the CMMI model is too heavy-weight for software development projects adopting agile practices [36] and that its use would lead to an undesirable document-driven software development approach [9, 20]. This presents a challenge to enable organizations relying on CMMI as an indicator for process maturity (which is supposed to translate into product quality) to also benefit from using agile methodologies like XP and Scrum.

This paper presents how a lightweight assessment method (AHAA) has been developed for the automotive industry. This method provides software development SMEs an assessment of how their existing software development practices will be required to change in order to become automotive software suppliers. The AHAA integrates the plan-driven SPI models of CMMI and Automotive SPICE™ with agile practices. It has been specifically developed to provide a low cost way of introducing software development SMES to the requirements of the automotive industry.

3. NEED FOR AHAA

One of the main goals of Lero (the Irish Software Engineering Research Centre) is to develop an automotive software development industry within Ireland. Additionally, VTT (the Technical Research Centre of Finland) is interested in investigating the advantages that agile practices can bring to automotive software development. The Adept method [28] was previously developed to provide a light-weight assessment of software processes (mainly against the generic SPI model of the CMMI [7], with some reference to ISO/IEC 15504). In parallel to this, an agile assessment approach [33, 34] was developed to provide a way to identify agile based improvement solutions for Finnish software companies. The Adept method has now been integrated with this agile assessment approach, taking Automotive SPICE™ process areas into account, producing AHAA. The overall objective is to encourage software SMEs to enter the automotive software supply market.

AHAA enables software development organisations to gain an appreciation of the fundamental process areas from the CMMI® and Automotive SPICE™ SPI models through diagnosing strengths and weakness in their software development practices. It is different from other assessment methods as it also provides an organization with a combination of plan-driven and agile-based improvements. AHAA was designed to adhere to 8 of the 10 criteria outlined by Anacleto et al. [2], for the development of lightweight assessment methods: low cost, detailed description of the assessment process, guidance for process selection, detailed definition of the assessment model, support for identification of risks and improvement suggestions, conformity with ISO/IEC 15504, no specific software engineering knowledge required from companies' representatives, and tool support is provided. The two exceptions to the criteria outlined Anacleto et al. [2], are that no support is provided for high-level process modeling and only the authors currently have access to method. AHAA also shares the following requirements with Adept: improvement is more important than certification, a rating is not required, preparation time required by the company is minimised; assessment time is minimized, and companies should be enabled to select assessment in process areas that are most relevant to their business goals.

While the focus of AHAA is to encourage software SMEs to become automotive software suppliers, the method provides an ideal opportunity to educate software SMEs in terms of generic SPI. Therefore, the assessment should not become "a waste of time" if the company decided not to become an automotive software supplier. Consequently, AHAA provides automotive specific and non-automotive specific recommendations. The assessed company was supplied with feedback in relation to both CMMI® and Automotive SPICE™ process models which enables such companies to decide whether they wish to follow a CMMI or an Automotive SPICE™ SPI path. Additionally, AHAA suggests agile based improvement solutions for automotive companies coping with high quality complex software development within the automotive business environment. AHAA provides the assessed company with a findings document presented in terms of CMMI®, Automotive SPICE™ processes and agile practices.

4. DEVELOPMENT OF AHAA

As AHAA is based upon relevant CMMI® process areas, existing Adept questions were used as the foundation for the AHAA. Questions were added to enable coverage of relevant Automotive SPICE™ processes and agile practices. Even though each assessment component adopts a CMMI® process area name, it also contains questions providing coverage of Automotive SPICE™ and agile practices.

A key decision in the development of AHAA was 'what process areas are most applicable?'. Process areas were included because:

A. Based on our previous research, they are process areas which provide a significant level of benefit to Irish SMEs software development organisations [5, 8, 29, 45];
B. They have been highlighted within automotive engineering literature as fundamental to the development of efficient software development [39];
C. They have process area counterparts included within the HIS subset of 15 process areas [19];
D. They were previously included in the Adept method [28];
E. They were previously included in the agile assessment approach [33, 34].

Each of the CMMI® process areas was analysed (See Table 1).

Table 1. Suitability of CMMI® process areas for inclusion in AHAA

CMMI® Process Area	A ?	B ?	C ?	D?	E ?
Requirements Management	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***
Project Planning	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***
Project Monitoring & Control	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***
Configuration Management	***Yes***	***Yes***	***Yes***	***Yes***	
Measurement & Analysis				*Yes*	
Process & Product QA		*Yes*	*Yes*	*Yes*	
Supplier Agreement Management		*Yes*	*Yes*		
Requirements Development				*Yes*	*Yes*
Technical Solution			*Yes*	*Yes*	*Yes*
Verification				*Yes*	*Yes*
Product Integration			*Yes*	*Yes*	*Yes*
Validation				*Yes*	*Yes*
Organisational Process Focus					
Integrated Supplier Management			*Yes*		
Organisational Environment for Integration					
Organisational Process Definition					
Organisational Training					
Integrated Project Management					
Risk Management				*Yes*	
Decision Analysis & Resolution			*Yes*		
Integrated Teaming					
Organisational Process Performance					
Quantitative Project Management					
Organisational Innovation & Deployment					
Causal Analysis & Resolution					

Table 1 illustrates that only three of the twenty-five process areas from the CMMI® model satisfied all five factors and these were therefore included in the first release of AHAA. As Configuration Management satisfied four of the five factors it was also included in this release. In addition to AHAA focusing on four CMMI® process areas, related Automotive SPICE™ processes and agile practices must also be assessed. Selection was as follows:

Step 1. Serially scan the chosen CMMI® process areas against the following list of 15 HIS process areas and select related Automotive SPICE™ processes:-

- System requirements analysis; System architectural design; Software requirements analysis; Software design; Software construction; Software integration; Software testing; System integration; Software testing; System integration; System testing; Quality assurance; Configuration management; Problem resolution management; Change request management; Project management; Supplier monitoring.

Step 2. Map relevant agile practices against the process area.

As a result of performing these steps AHAA will provide coverage of 4 CMMI® process areas, 5 Automotive SPICE™ processes and several agile practices as illustrated in Table 2.

To encourage uptake of AHAA assessment by software SMEs, on-site interviewing is restricted to one day [28] thus minimising the time and cost associated with the assessment.

Table 2. CMMI®, Automotive SPICE™ and agile linkages

CMMI® Process Area	HIS Automotive SPICE™ Process	Agile Practices
Requirements management	Software requirements analysis Change request management	Stories; Product Backlog; Planning Game; Daily meetings; On-site customer; Self-organizing teams
Project Planning Project Monitoring & Control	Project management Problem resolution management	Planning Game, Small releases, Tasks, Estimations, RetrospectivesUser Stories, Small Releases, Daily Stand Up Meetings Retrospective
Configuration management	Configuration management	Continuous Integration

4.1 Scripted AHAA Questions

Table 3 illustrates the breakdown of the scripted AHAA questions. When developing the interview questions we examined the base practices, checking the relevant interview questions from the Adept method to ensure coverage of their counterparts in agile and Automotive SPICE™. There is some commonality between related processes in CMMI®, agile and Automotive SPICE™. However AHAA questions based solely upon a process within one model will not (in isolation) provide full coverage of this process within the other two models (this is illustrated in figure 2 for the project planning process).

Table 3. Breakdown of Scripted AHAA Questions

AHAA Interviews	No. of Adept (CMMI) Questions	No. of New Questions	No. of AHAA Questions
Project Planning	65	15	80
Project Monitoring & Control	36	17	53
Requirements management	23	37	60
Configuration Management	29	6	35
Total No. of Questions	***153***	***75***	***228***

4.2 Project Planning

Within Adept 65 questions were used to provide coverage of the specific goals of the CMMI® *Project Planning* process area. AHAA is more comprehensive in its coverage of Project Planning and has 80 scripted questions for Project Planning (see Table 3). AHAA not only contains CMMI® based questions but also 2 additional questions that are specifically related to the Automotive SPICE™ *Project Management* process. Only the planning part of the Automotive SPICE™ *Project Management* process may be mapped against the CMMI® *Project Planning* questions. Five additional questions evaluate the company's suitability to adopting an agile based approach to project planning, and 8 questions that are common for Automotive SPICE™ and an agile based approach to project planning are also included. The key difference between plan-driven and agile-based project planning is that in the agile approach, planning is done iteratively during the software development life cycle [27]. Figure 2 illustrates that out of the 65 scripted questions that are applicable to the CMMI model, 7 are also applicable to both the Automotive SPICE™ model and agile practices, 32 are applicable to the Automotive SPICE™ model, 19

are applicable from an agile based perspective, and 21 are only applicable to the CMMI model.

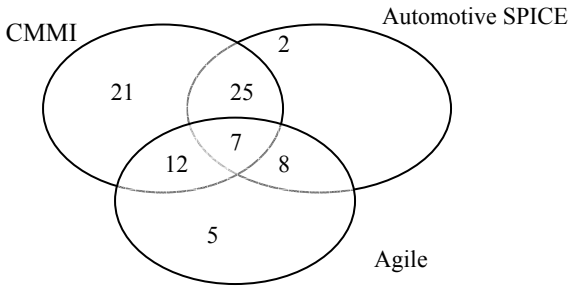

Figure 2. Breakdown of Project Planning Questions

For example, estimating the scope of a project is an important part of project planning. The AHAA has 15 scripted questions that are asked to gain an understanding of the company's procedure for estimating the scope of a project (see Table 4).

These questions provide coverage of this topic in CMMI, Automotive SPICE™ and agile. Six questions are asked which are only applicable in relation to agile practices and these questions are asked to determine if the scope of the project is estimated in an iterative manner and to gain an understanding as to who is involved. Two questions are asked that are based solely on the CMMI model and these are used to determine if consideration has been given to either adopting 3rd party components or reusing existing components. Two questions are asked that are based solely on the Automotive SPICE™ model and these are used to determine how the scope of the project was defined and what interfaces exist for the project. Three questions are applicable to CMMI, Automotive SPICE™ and agile practices and they probe the size and suitability of tasks. A single question is applicable to both CMMI and Automotive SPICE™. This is used to gain an understanding of the boundaries of a project. One question which ensures that the task sizes are appropriate for regular monitoring, is common to both Automotive SPICE™ and agile. Project Monitoring and Control, Requirements Management and Configuration Management questions were analysed in the same manner, providing a list of 53, 60 and 35 scripted questions respectively

4.3 AHAA Stages

AHAA is composed of eight stages (see Figure 3). The assessment team consists of two assessors who conduct the assessment between them.

Stage 1 (*Develop Assessment Schedule and Receive Site Briefing*) involves a preliminary meeting between the assessment team and the software company wishing to undergo a SPI assessment. The assessment team discusses the main drivers for the company embarking upon an AHAA and establishes whether the company is interested in becoming an automotive software supplier. During **stage 2** (*Conduct Overview Briefing*) the lead assessor provides an overview of AHAA for members of the assessed organisation who will be involved in subsequent stages. This session is used to remove any concerns that individuals may have.

Stage 3 (*Analyse Key Documents*) provides a brief insight into project documentation. The primary source of data for AHAA is through a series of process area interviews conducted during **stage 4**. In this stage key staff members from the assessed organisation are interviewed. There are 4 interviews, one for each process area.

Table 4. AHAA Questions for Estimating project scope

Question	CMMI	Automotive SPICE™	Agile
How was the scope of work defined?		Yes	
What view do you have of the project overall scope (features that needs to be done)?			Yes
How often is the scope of the project re-planned and updated?			Yes
How do you determine the boundaries of a project?	Yes	Yes	
How do you define the features for the overall product? Who is responsible?			Yes
How do you prioritise the features for the overall product? How often is this updated?			Yes
What features are defined in the next release, release after that etc.?			Yes
Do you decompose the project into a set of tasks? (how often, for each release, for whole product)?	Yes	Yes	Yes
Who participates in the task definition? Who has responsibility?			Yes
How do you decide on suitable tasks?	Yes	Yes	Yes
What size are tasks decomposed to?	Yes	Yes	Yes
Are the tasks of a manageable size, to ensure that adequate monitoring is possible ?		Yes	Yes
Do you consider the acquisition of 3rd party components?	Yes		
What interfaces do you have (both with sub-projects, suppliers and other parts of the organization) ?		Yes	
Do you consider the potential reuse of any products from this project?	Yes		

Each interview is scheduled to last approximately 1.5 hours. Each interview involves two assessors, and at least one representative from the company is present for each process area interview. **Stage 5** (*Generate Assessment Results and Create the Findings Report*) is a collaborative exercise between the assessors to develop the findings report using interview notes for each of the four assessed process areas. The resultant findings report consists of a list of strengths, issues and suggested actions for each of the process areas evaluated. **Stage 6** (*Deliver the findings report*) involves presenting the findings report to participating staff in the organisation. **Stage 7** (*Develop a SPI Path with the Company*) involves collaborating with staff to develop a roadmap. This will provide guidance to the assessed company presenting practices that will provide the greatest benefit in terms of the company's business goals. Companies wishing to become automotive suppliers are recommended to focus upon establishing working practices that will assist them in future Automotive SPICE™ assessments. **Stage 8** (*Re-assess the SPI Path and Produce a Final Report*) involves revisiting the assessed company approximately 6 months after the completion of stage 7 and reviewing progress against the SPI path. The outcome of this stage is an updated SPI path and a final report detailing the progress that has been accomplished along with additional recommendations. This stage provides feedback and assistance to the assessed company after a period of time and also assists in compiling research material in terms of SPI experiences.

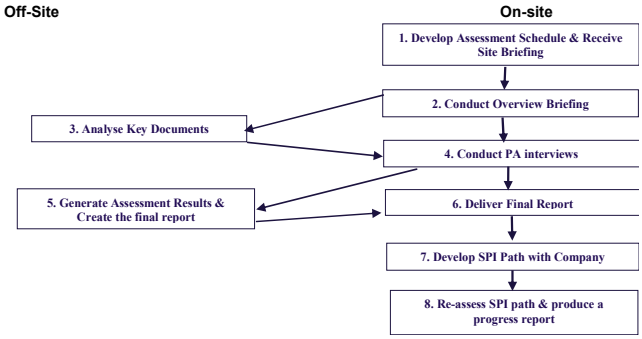

Figure 3. Stages of AHAA

5. AHAA IMPLEMENTATION

We implemented AHAA in an Irish software development SME, AutoSoft (a pseudonym). AutoSoft currently has 8 software development staff and works closely with its larger parent company in Denmark. However, AutoSoft develops non-automotive safety-critical software and plans to enter the automotive sector in the near future. They want to understand their current software development practices and the extent to which these practices would have to change when entering the automotive software industry. They also sought a low-cost method to obtain guidance as to how they could deliver higher quality software in a more timely manner. AutoSoft was an ideal candidate for an AHAA.

During stage 1 of the AHAA, the goals and schedule of the AHAA were determined, involving the assessment team (2 people), the managing director and 2 project managers from AutoSoft. During stage 2 the lead assessor provided an overview briefing of the AHAA to the AutoSoft software development staff. The assessment team briefly inspecting a sample project plan, a requirements document, sample minutes from a project review meetings and a configuration management document (Stage 3). This enabled them to gain a basic understanding of documentation procedures within AutoSoft, which assisted the assessors in developing additional questions for the process area interviews. All eight of the AutoSoft software development staff participated in stage 4 of the AHAA, with the assessment team interviewing 4 staff within each of the process area interviews.

During Stage 5, held off-site, assessment team wrote a findings report, listing strengths and issues for each of the 4 process areas. It combined plan-driven and agile based recommendations to address these issues which were based on the business goals that were highlighted in stage 2. The main business goal that emerged was that high quality software should be developed in a shorter time-frame than was currently the case. The findings report was then presented to AHAA participants (stage 6).

5.1 Project Planning Findings

The Project Planning process area contained more questions (80 scripted questions) than any of the other process areas. Therefore, it was no surprise that the most strengths (10), issues (22) and recommendations (13) were produced for this process area (see Table 5). The action part of the table illustrates how plan and agile based suggestions (PPAct1-13) were provided to address each of the issues (PPIss1-22) that arose during the AHAA.

Table 5. AHAA Project Planning Findings

Strength	**Description of Strengths**		
PPStr1	Evidence of high-level planning		
PPStr2	Project is decomposed into suitable tasks –"Splitting tasks into daily units"		
PPStr3	Involvement of development staff in developing project plans		
PPStr4	Known resources are allocated into the project plan		
PPStr5	Risk is considered during the planning phase		
PPStr6	Risks are identified on the critical path		
PPStr7	Good informal communication channels		
PPStr8	Understanding of interfaces and boundaries		
PPStr9	Efficient use of 3rd Party Components		
PPStr10	Some evidence of component reuse		
Issue No.	**Description of Issues**		
PPIss1	No evidence of requirements in the Project Plan		
PPIss2	Little evidence of the Project Plan being updated e.g. to include change requests as the project progresses, scope etc.		
PPIss3	Limited evidence of formal estimation approaches		
PPIss4	Historical data is not used		
PPIss5	Estimates based solely on knowledge/familiarity of system components		
PPIss6	Insufficient linkage between project budget and estimates		
PPIss7	No usage of short iterations and milestones		
PPIss8	The initial project plan does not contain the full set of resources required		
PPIss9	Requirements are not always defined in the initial set of resources		
PPIss10	No use of continuous integration approaches		
PPIss11	Fixed price projects – so no flexibility for planning – not based on any estimates		
PPIss12	No systematic way of managing risk		
PPIss13	No common risk list		
PPIss14	Little evidence of mitigation at the planning stage		
PPIss15	Little evidence of formal communication channels		
PPIss16	Staff utilization load not properly understood e.g. how realistic is it to plan for an 7.5 hr day?		
PPIss17	Knowledge and skills are not recorded and managed		
PPIss18	Due to resourcing issues external skills are sought rather than providing training		
PPIss19	Reactive rather than planned approach to resourcing		
PPIss20	Resources not always costed into the project plan		
PPIss21	Resources tend not to be allocated in a timely manner		
PPIss22	There is no strategy for component reuse		
Action No:	**Description of Actions**	**Addresses Issue No: PPIss***	**Plan-driven or Agile**
PPAct1	Consider the use of historical data as input into the estimation process	4, 5, 6, 11	Plan
PPAct2	Consider the use of daily estimation procedures e.g. Make use of useful metrics	3	Plan
PPAct3	Plan on the basis of a shorter – more realistic (actual working time) day e.g. set aside time for "skilling up" etc.	3,16	Plan
PPAct4	Consider using incremental release delivery	7, 10	Agile
PPAct5	Perhaps use a senior member as an internal customer	7	Agile
PPAct6	Update the project plan iteratively	2	Agile
PPAct7	Link requirements to the project plan	1	Plan
PPAct8	Perhaps use Scrum product Backlog, sprint backlog and Sprint Planning e.g. Scrum would also assist with formalising communication procedures	7, 15	Agile
PPAct9	Consider the development of a risk management strategy e.g. include a common risk list and mitigations for risk items	12, 13, 14	Plan
PPAct10	Consider developing a skills database	17	Plan
PPAct11	Provide training opportunities for staff to skill-up	18	Plan
PPAct12	Consider resources at the planning stage	8,9,14, 19,20, 21	Plan
PPAct13	Consider strategy for the reuse of standard components	22	Plan

As AutoSoft develops safety-critical software it is important that the software developed is traceable throughout the lifecycle and therefore this lends itself to the plan-driven aspects of the AHAA and therefore it is no surprise that 9 out of the 13 actions that were outlined as a result of the AHAA are plan-driven. The suggested plan-driven actions will improve the project planning areas of task estimation, requirements linkage, risk management, resourcing and component reuse.

As AutoSoft also wishes to improve the time-to-market of its software agile project planning related actions were provided in order to improve this aspect. Therefore 4 agile actions were provided (PPAct4/5/6/8), see table 5. For example, the agile practices provided a systematic continuous planning procedure based on the time boxed iterations.

> *"Software development life cycles need to be shorter in the whole automotive industry and it would be better if the whole company were involved in the change management process"*

This was suggested by project members to assist them in keeping plans up-to-date and communicating them more systematically to the project stakeholders.

5.2 Project Monitoring and Control Findings

The Project Monitoring and Control area was performed well (though informally) by AutoSoft producing 6 strengths, only 3 issues and 6 actions from the AHAA (largely based upon the 53 scripted questions).

From a project monitoring and control process perspective, 4 plan-based and 2 agile-based recommendations were provided as a result of the AHAA in order to address the 3 issues that were highlighted. The plan-driven recommendations were produced to address formalizing the project monitoring and control procedures of AutoSoft by tracking actual effort against planned effort and recording any deviations for future reference. The agile-based actions encourage the usage of daily meetings and burn-down charts. Scrum practices were, for example, suggested as a mechanism to measure the project status, and to improve estimation and daily risk management in the software development projects.

> "*There is no formalized approach for project monitoring" "there are no metrics…it would be useful to compare plans against results to understand how accurate the current estimation process is, at the moment, getting such feedback can be difficult*"

5.3 Requirements Management Findings

The Requirements Management area was highlighted as an area of concern for AutoSoft. A representative from AutoSoft stated the following when asked about their requirements capture procedure:

"*A list of requirements are provided by the parent company in the release document…we were not involved making this list…requirements produced by AutoSoft are our interpretation of these requirements*"

This issue arises because AutoSoft currently applies a highly plan-driven approach that does not involve direct interaction with the customer. In practice, this means that the customer requirements are defined by the parent company and delivered to AutoSoft in the form of a requirements document plus informal, ad hoc communications between the parent company and AutoSoft (see Figure 4). Even though, projects were generally well planned, the requirements were often at a high level and were not prioritized. Additionally, as the requirements are initially gathered by the parent company from the customer and this interpretation is then interpreted by AutoSoft there is a risk that incorrect requirements will be collected by AutoSoft. This causes a significant risk, as any misconception may not be highlighted until the customer provides feedback six months later, at which time six months may have been wasted developing the "wrong" product.

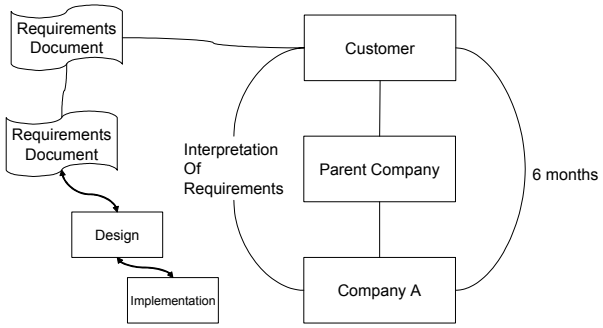

Figure 4. Plan-driven adopted by AutoSoft

As a result of performing the AHAA on the requirements management process we produced 3 strengths, 14 issues and 7 actions (largely based upon the 60 scripted questions) to address the highlighted issues.

AHAA provided 7 actions to address the 14 issues that were highlighted during the assessment of the requirements management process within AutoSoft. Five plan-based recommendations were provided to enable the company to improve their: requirements traceability; the quality of the requirements captured; handling of change requests (CRs); mechanism for ensuring that requirements records are updated. Additionally, two agile-based recommendations practices were provided. During the assessment analysis, it was found that customer requirement management and change request management are key challenges for the company.

5.4 Configuration Management Findings

Upon assessment of the Configuration Management process within AutoSoft using AHAA, 8 strengths, 3 issues and 3 actions were identified (largely based upon the 35 scripted questions).

Configuration management was generally a well applied process in AutoSoft. All work products were managed and controlled, although manually. The 3 actions that were suggested in order to resolve the 3 highlighted issues consisted of 1 plan-driven and 2 agile-based suggestions. The plan-driven suggestion encouraged AutoSoft to perform audits on the descriptions entered when items are changed in the Configuration Management system to ensure that meaningful and standardized comments are always added. Additionally, we encouraged the usage of continuous integration and scrum as agile-based recommendations to improve the configuration management process in AutoSoft.

5.5 Summary of the Findings

Upon analysis, the AHAA assessment revealed that AutoSoft may be able to significantly improve their software development practices by adopting a combination of plan-driven and agile based recommendations. As AutoSoft develops safety-critical software it is important to ensure that sufficient documentation is in place so that components may be traced throughout development and therefore plan-driven practices are required. However, as the company desires to increase its productivity, reduce the length of its

software development lifecycle and become more competitive, AHAA suggests adopting a more hybrid approach. Twenty-nine recommendations were provided as to how AutoSoft could improve their software development practices, with 19 of these recommendations being plan-driven and 10 agile based. An assessed company can decide whether they will implement plan-driven recommendations only, agile based recommendations only or a combination of both.

For example, as a result of the AHAA recommendations we could amend some of AutoSoft's current project planning, project monitoring and requirements management practices by combining both plan-driven and agile based recommendations. AutoSoft currently does not have an efficient estimation procedure in place and therefore we would encourage them to combine the plan-driven practices of making use of historical data and planning on the basis of a shorter working day, and combining this with introducing daily stand-up meetings and burn-down charts (agile based practices) so that actual effort can be compared against planned effort on a daily basis. This will enable any deviations to be monitored very closely and historical records of the actual task times may be recorded for future project estimation. This therefore will reduce the risk of both current and future projects.

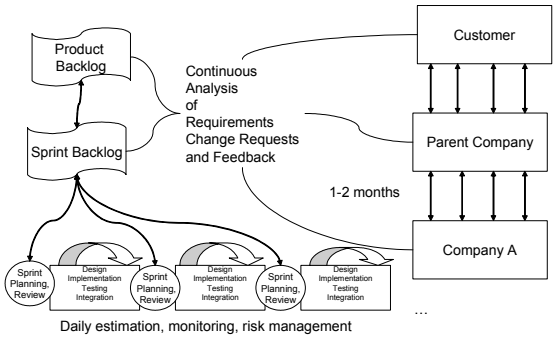

Figure 5. Agile-based improvement suggestions for AutoSoft

Figure 4 illustrated that requirements management causes problems for AutoSoft. The AHAA recommendations enable this to be resolved through adopting a combination of plan-driven and agile based actions. For example, AutoSoft may adopt plan-driven practices such as introducing requirements capture templates (to ensure that requirements are complete and verifiable) and developing a procedure for handling CRs, in addition to introducing the agile based practices of iterative software development cycles, backlog-based requirements databases, continuous requirements analysis and continuous requirements prioritisation with the customer and parent company (Figure 5).

6. FEEDBACK FROM AUTOSOFT

During the findings presentation, both management and developers agreed that the highlighted strengths and issues were an accurate reflection of company's software development practices. Both the management and developers of AutoSoft acknowledged that the AHAA recommendations were achievable and if implemented they could bring benefit to both AutoSoft and the parent company (particularly as they both want to embark upon automotive software development in the future). As AutoSoft develops fixed price projects the AHAA improvement suggestions for increasing the quality of their software whilst decreasing their development time through adopting a combination of plan-driven and agile-based practices were of particular interest. Furthermore, as AutoSoft is an SMEs, resource is a precious commodity and they welcomed the fact that the assessment did not require any preparation time from them.

Senior management from AutoSoft commented that the AHAA improvement recommendations were relevant and important to them for several reasons. First of all, they were satisfied that the AHAA provided them with realistic suggestions as to how customer satisfaction might be improved using both requirements and project management. Secondly, the suggested movement towards incremental software development (encompassed regular iteration planning, daily team meetings and iteration reviews) will enable the company to respond better to change requests from the customer and the parent company. Additionally, AutoSoft's future success depends upon being able to correctly estimate future projects. Adopting an incremental development approach combined with suggested plan-driven practices for sizing the effort of project tasks could enable the company to develop a capability for providing realistic estimates for future projects.

The senior management from AutoSoft also stated that they intended championing these improvements and then rolling them out to their parent company so that the overall organisation could benefit from incorporating the new plan-driven and agile-based practices into their existing software development practices.

Following the AHAA findings presentation, AutoSoft representatives met internally to discuss developing a SPI path. They reviewed and prioritised all the AHAA recommendations, planning how they will be implemented in a new project (stage 7 of the AHAA). Having gone through this assessment cycle, senior management realised the importance of such assessments. Therefore, a criticism of the AHAA which they made was that they were only assessed 4 process areas. We have agreed to engage in an additional assessment involving other software process areas (i.e. 2nd release of AHAA). They also have requested that we re-assess their software processes within 6 months (perform stage 8 of the AHAA) so that they may obtain feedback in relation to their progress along their SPI path. This will also provide the assessment team with an opportunity to validate their improvement suggestions.

7. CONCLUSION

Automotive industries cope with the challenging demands of safety criticality and the increasing amount of electronic component software. This creates the opportunity (especially for SMEs) to become software suppliers to large automotive companies. Therefore, SMEs need to adopt SPI approaches to assist them in improving the quality of software, the speed of software delivery and their ability to respond to change requests.

Software process assessments can assure quality of development processes. Unfortunately, assessments are often too time consuming and expensive for SMEs. Another difficultly in adopting software process assessments is deciding which SPI model the company should be assessed against, as different manufacturers may adopt different SPI models and therefore have a different approach to evaluating the capability/maturity of a potential supplier. Both CMMI and SPICE are internationally adopted reference models for SPI. However, Automotive SPICE™ has now been published to specifically meet the demands of automotive industry. In addition, agile software development methods have been shown to provide significant benefit in assisting organizations to respond to changes,

to increase their software development speed and to increase customer satisfaction.

This paper presented a lightweight method for software process assessments which integrates CMMI, Automotive SPICE™ and agile practices in an assessment method called AHAA. The goal of AHAA is not to provide a certification rating but to provide a low-resource assessment method which indicates to companies: the current state of their software processes; recommendations as to how they might improve; the status of their software processes both in terms of CMMI® and Automotive SPICE™; and their suitability to becoming automotive software suppliers.

From a research point of view AHAA enables both VTT and Lero - the Irish Software Engineering Research Centre to:

- Gain an understanding as to whether existing software development practices within companies are more CMMI® or Automotive SPICE™ based;
- Gain an understanding in relation to the strengths (profile) that both Irish and Finnish software companies possess particularly in relation to supplying software to the automotive industry;
- Increase their knowledge of how to combine improving the time to market with the quality of safety-critical software;
- Use some parts of AHAA within companies that are already following a path towards certification in CMMI or Automotive SPICE™ but wish to use agile methods;
- Use some parts of AHAA within companies that are already using agile methods but wish to follow a path towards certification in CMMI or Automotive SPICE™.

This paper presents how the AHAA was conducted in a safety-critical software company. The company has since prioritised actions and are currently engaged in adopting a number of the recommendations as part of their software development practices. It also describes the 1st release of the AHAA, providing coverage of 4 CMMI® process areas, 5 Automotive SPICE™ processes and relevant agile practices. In the future we plan to extend the number of process areas that may be assessed. We will initially extend the assessment to provide coverage of the remaining two process areas that are listed as being fundamental to the automotive industry [39]. These process areas will be Process and Product Quality Assurance and Supplier Agreement Management. The medium term aim will then be to provide coverage of each of the 15 Automotive SPICE™ processes included in the HIS, with a long-term goal of providing coverage of all 31 Automotive SPICE™ processes.

8. ACKNOWLEDGMENTS

This research is supported by the Science Foundation Ireland (SFI) funded project, Global Software Development in Small to Medium Sized Enterprises (GSD for SMEs) grant number 03/IN3/1408C within Lero - the Irish Software Engineering Research Centre (http://www.lero.ie), the SFI Stokes Lectureship Programme, grant number 07/SK/I1299 and the ITEA Flexi project, funded by TEKES and Nokia Foundation in Finland as a part of VTT, Technical Research Centre of Finland

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