An Empirical Study on Software Process Improvement in Automotive

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Abstract. This paper presents the results of an empirical study on process improvement initiatives linked to management of software developments for the automotive industry. In this context the software development is mainly demanded to specialized software suppliers that are required by car makers to improve and measure the process quality of their projects by applying process models such as Automotive SPICE®.

The authors, as Automotive SPICE assessors, have directly observed and analyzed specific software process improvement opportunities during a significant number of assessments performed at several organizations.

This paper, that focuses specifically on the project management process, is the initial step of a wider study. Such a study aims at identifying common weaknesses in industrial projects having negative impact according Automotive SPICE. The study relies on data taken from several assessments performed world-wide and it shows the most occurring weaknesses in terms of the project management process base practices – such recurrent weaknesses that are then clustered appropriately and analyzed to provide insight in this crucial process.

Keywords: Software process improvement · Automotive · Automotive SPICE® · Project management

1 Introduction

Car OEMs (Original Equipment Manufacturer) are now turning their vehicles from mechanical devices into elaborated electronically controlled systems. As a result the software (with increased demand in terms of size and complexity) is a crucial car component since it is part of embedded systems called Electronic Control Units (ECU) that control electronically a large number of the vehicle functions. The number of ECUs, both for economic to luxury vehicle models, is remarkably increased during the last fifteen/twenty years.

In general, the software development is demanded to software suppliers that range from small-medium organizations to large and structured ones. It is remarkable to notice that small and medium organizations represent currently a significant part of the players in this challenging arena. In such a context project management and software engineering, initially underestimated sides of the ECU development projects,

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are today considered as crucial in the automotive industry. Software projects are required to meet increasingly demanding timing and quality objectives - it is interesting to remark that budget efficiency is also important but mass production can partially mitigate this aspect in some circumstances. In particular, the market expectations (it is a fact that the bulk of car issues currently come from electronics and software issues) and technology advances have produced a real need for improvement at managerial and technical levels in order to keep software developments on track, especially for SME small and medium-sized enterprises (SME).

In automotive, beyond the complexities of the embedded development, SW suppliers needs to accommodate tights schedules and the peculiarities of the vehicle development process that at very high level reflects the following paradigm:

Fig. 1. High-level paradigm of vehicle development phases

The aim of this paper is to present the results of an empirical study conducted using the data from a sample of assessments performed on twenty-three (23) organizations by the authors worldwide in the last five years. The empirical study is aimed at making explicit and analyzing commonalities in Automotive SPICE assessment findings observed by the authors related to project management process as it is a key aspect of development.

More specifically this paper focuses on a specific area (i.e. process) of the software development as described later. The paper is structured as follows:

- Section 2: Notes on Automotive SPICE®
- Section 3: The Methodological Approach
- Section 4: Empirical Study Results
- Section 5: Conclusions

2 Notes on the Automotive SPICE™ Model

SPICE (Software Process Improvement and Capability dEtermination) is an acronym that identifies the ISO/IEC 33000 standard series (that recently substituted the former ISO/IEC 15504 standard) [3]. In early 2000s an initiative was launched by the Procurement Forum with the principal European Car Makers, their assessors and representative bodies to address the problems related to software assessments in automotive. In the framework of this initiative, a Special Interest Group (SIG) has been founded with the aim to design a special version of the SPICE model (called Automotive SPICE) tailored on the needs and peculiarities of the automotive business area. The first results of the initiative was to create consensus on commonality of approach in order to avoid that suppliers face multiple assessments from multiple manufacturers using different models and criteria and consume resources that put additional pressure on delivery times. Furthermore, the focus on software capability determination by means of software process assessment has determined a common trend among the European Car Makers in using Automotive SPICE™ as a mean for determining a supplier's qualification mechanism.

Nowadays Automotive SPICE®, as a de-facto process standard, is used by car makers to push software process improvement among their ECU and software suppliers [4], [5]. Many of the car makers are using also this standard to assess supplier capabilities and are requiring the achievement of specific rating. Thus it provides both a scheme for evaluating the capability of software processes and a path for their improvement. In extreme synthesis the four basic pillars of Automotive SPICE® are: Process Reference Model (PRM) [2], Process Assessment Model (PAM) [1], Measurement Framework and Assessment Scope:

1. **PRM**: it is a model comprising definition of processes in a life-cycle described in terms of "process purpose" and "process outcomes", together with an architecture describing the relationships between processes. In practice, the PRM contains the set of the descriptions of the processes that should be assessed.

2. **PAM**: it is a model suitable for the purpose of assessing process capability, based on one or more PRMs with a two-dimensional view. In one dimension, it describes a set of process entities that relate to the processes defined in the specific PRM (it is called Process Dimension); in the other dimension the PAM describes capabilities that relate to the process capability levels and process attributes.

3. **Measurement Framework**: The rating of the "capability" starts from the lowest level (Level 0) means that not all processes in the scope are adequately performed. In Level 1 all important documents are available, in Level 2 everything is systematically planned and tracked, in Level 3 there are uniform guidelines for the complete organization, and in Levels 4 and 5 the processes are statistically measured and optimized. It is interesting to highlight that current industrial requirement ranges from Level 1 to Level 3. The determination of the capability of a process is obtained by means of the rating of process attributes (some process specific – the Base Practices - and others generic – the Generic Practices). The scale of such a rating is composed of four values: N (Not achieved), P (Partially achieved), L (Largely achieved), and F (Fully achieved).

4. **Assessment Scope**: it is a subset of the processes contained in Automotive SPICE® where each process is associated with a target process

capability level. In particular the Hersteller Initiative Software (HIS) Scope is a subset of the processes contained in Automotive SPICE®, which will be assessed by each manufacturer. In the meantime, the HIS Scope of the Automotive SPICE® has been adopted by other industries as a reference for process improvement initiatives and scope for assessments.

The following picture highlights the HIS scope of Automotive SPICE® in the context of all ISO/IEC IS 15504 and Automotive SPICE® processes.

In Table 1 the whole Automotive SPICE PRM is presented, the processes in bold are those belonging to the HIS assessment scope.

Table 1. HIS Assessment Scope

Process Id.	Process Name	Process Id.	Process Name
ACQ.3	Contract agreement	**SUP.8**	**Configuration Management**
ACQ.4	**Supplier monitoring**	**SUP.9**	**Problem resolution management**
ACQ.11	Technical requirements	**SUP.10**	**Change request management**
ACQ.12	Legal and administrative Requirements	PIM.3	Process improvement
ACQ.13	Project requirements	**ENG.1**	**Requirement elicitation**
ACQ.14	Request for proposals	**ENG.2**	**System requirements analysis**
ACQ.15	Supplier qualification	**ENG.3**	**System architectural design**
MAN.3	**Project management**	**ENG.4**	**Software requirements analysis**
MAN.5	Risk management	**ENG.5**	**Software design**
MAN.6	Measurement	**ENG.6**	**Software construction**
SPL.1	Supplier tendering	**ENG.7**	**Software integration test**
SPL.2	Product Release	**ENG.8**	**Software testing**
SUP.1	**Quality Assurance**	**ENG.9**	**System integration test**
SUP.2	Verification	**ENG.10**	**System testing**
SUP.4	Joint Review	REU.2	Reuse program management
SUP.7	Documentation		

From Table 1 results that processes in Automotive SPICE® (the ones with marked with the letter A on the left) are conveniently grouped and large in number. The rational behind the HIS scope is to limit the impact on the practitioners by selecting the core of the engineering processes and only other few fundamental processes. As a matter of fact MAN.3 is the only process in management process group.

3 The Methodological Approach

During the last five years the authors, in the capacity of qualified Automotive SPICE Principal Assessor (according to the IntACS international assessor certification scheme) [6], have performed more than thirty Automotive SPICE assessments of several organizations producing software-intensive systems for the automotive industry.

Typically these Automotive SPICE assessments have targeted the HIS scope (or variants of HIS scope) in several domain (e.g. body electronics, lighting, closures...) and they had one or more of the following purposes:

- Perform Gap Analysis for benchmarking
- Measure the progress after a SW Process Improvement effort
- Supplier process capability rating

as the typical software process improvement path follows the following pattern:

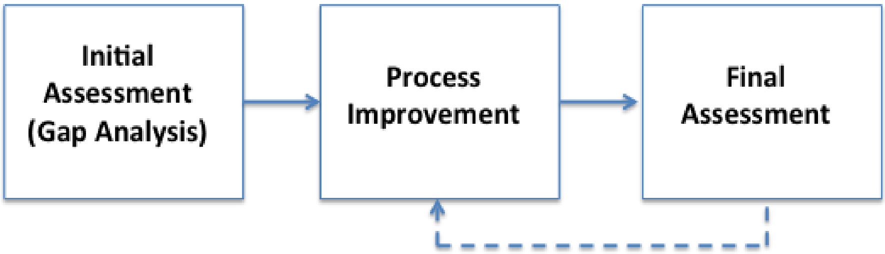

Fig. 2. Typical process Improvement path

Table A.1 in Annex A summarizes in anonymous way the database that supports this study – although the number is limited in number (23) and geographical distribution (Italy 18, China 2, Korea 2, Israel 1) it can be considered meaningful by all means due to the nature of the subject under analysis. Yet the following outcomes have not a statistical validity and are based on empirical observations.

It is key to remark that the organizations have been assessed:

- Before and after improvement (10 organizations) for a total of 21 assessments
- Before implementing a structured improvement initiative (6 organizations) for a total of 6 assessments
- After implementing a structured improvement initiative (7 organizations)

targeting a total of 42 projects (some of them with ISO 26262 norm requirements [8] for functional safety of road vehicles). From a size point of views the organizations ranges from small (6), medium (11), large (6) ones.

This empirical study, that focuses on Project Management process (MAN.3) only, represents the starting point of an wider analysis aiming at getting a complete "in practice" view of the software process improvement internals in the automotive industry.

During the assessments, data on the processes in scope are collected in different ways, including interviews and document analysis and these data are assessed (using their expert judgment) against a set of indicators provided by the Automotive SPICE model itself. These indicators are the so-called Base Practices (process-specific) and the Generic Practices (applicable to all processes). In context of process improvement it is important to remark that the assessment activity is not limited to a mere rating of process indicators, but it includes also the provision of high-level improvement guidance for the projects under assessment. Assessments also enrich the assessors by exposing them to precious "behind-doors" experience of real projects.

The following step-wise approach has been adopted in this study:

> ***S.1*** the organizations assessed by the authors are classified in terms of product domain, organization size (omitted from annex A for confidentiality), location, and type of assessment.
>
> ***S.2*** the assessment results have been analyzed in order to identify those Base Practices rated unsatisfactorily (N or L). Such Base Practices have been reported in tabular format.
>
> ***S.3*** The rationales of Base Practices weaknesses have been investigated and clustered, when possible, following homogeneity criteria.

Confidentiality issues has been considered and carefully addressed.

4 Empirical Study Evidences and Results

According to what stated in Section 3. in this paper the gaps related to the Project Management process (MAN.3) are taken into account. The Project Management process is a key process for an organization developing software because it addresses the "*identification, establishment, planning, co-ordination, monitoring and control of the activities, tasks, and resources necessary for a project to produce a product and/or service, in the context of the project's requirements and constraints*" [1], [7]. Consequently, this process allows an all-around view of the activities dealing with software development projects (in fact, MAN.3, usually the initial process to be addressed in a Automotive SPICE assessment, is used by assessors to get the complete picture of the project).

Table 2 reports the Base practices of the Project Management process (MAN.3) that have been found not fully achieved in the assessment performed on the Organizational Unit (OU) belonging to the study sample. The 'X' in a cell indicates that the rating of the corresponding Base practice has been not "Fully Achieved" or "Largely Achieved".

The weaknesses indicated in Table 2 have been analyzed in detail, according to the step S.3 of the study's methodological approach, and then the most recurrent one are linked to a clustering system built using the common basis of such process weaknesses that the authors call Gap Clusters (GC).

The data reported on Table 2 show a concentration of weaknesses for the following Base practices:

MAN.3 BP.3: Determine and maintain estimates for project attributes;

MAN.3 BP.6: Define and maintain project schedule;

MAN.3 BP.8: Establish project plan;

MAN. 3BP.10: Monitor project attributes.

Table 2. Best Practices weaknesses for MAN.3 process

OU Id.	MAN.3 Project Management											
	BP1	**BP2**	**BP3**	**BP4**	**BP5**	**BP6**	**BP7**	**BP8**	**BP9**	**BP10**	**BP11**	**BP12**
1	P	P	P	P	L	P	L	P	L	P	P	L
2	F	P	P	P	L	P	L	P	L	P	L	L
3	F	F	L	F	F	F	F	F	F	F	F	F
4	F	F	L	F	F	F	F	F	F	L	F	F
5	F	F	L	L	L	F	F	F	L	L	F	F
6	F	F	P	P	F	P	F	F	F	L	F	F
7	F	L	L	L	F	L	F	F	F	P	F	L
8	F	P	P	F	F	P	F	F	F	L	F	F
9	P	P	P	F	F	F	L	P	L	L	P	F
10	F	F	L	F	F	F	F	F	F	L	F	F
11	F	F	L	F	F	P	F	F	F	L	F	F
12	P	P	P	P	L	P	L	P	L	P	P	L
13	F	P	P	P	L	P	L	P	L	P	L	L
14	F	F	L	F	F	F	F	F	F	F	F	F
15	F	F	L	F	F	F	F	F	F	L	F	F
16	F	F	L	L	L	F	F	F	L	L	F	F
17	F	F	P	P	F	P	F	F	F	L	F	F
18	F	L	L	L	F	L	F	F	F	P	F	L
19	MAN.3 not in scope											
20	F	F	L	F	L	F	F	F	F	L	L	L
21	F	L	L	L	L	L	F	P	P	L	L	F
22	F	P	P	P	L	P	F	P	P	P	L	L
23	P	P	P	P	L	P	F	P	P	P	L	L

The investigation on the rationales of these Base Practices weaknesses on the basis of the assessment outcomes in Assessment Reports, determined the following gap clusters (GC):

GC a) Operative scheduling definition and control is informal [MAN,3 BP.6].

GC b) Poor project planning update and dissemination [MAN.3 BP.8].

GC c) Lack of estimations [MAN.3 BP.3].

GC d) Poor effort management [MAN.3 BP.8, MAN.3 BP.10].

In the following, the clusters listed above are discussed:

The gap clusters a) and b) are mainly due to the adoption of inadequate approaches, tools and means to support the planning and the monitoring of project activities are a substantial source of process issues. In fact such an inadequate infrastructural support often leads to a general habit to separate the actual project planning and control (performed informally and with few evidences) with respect to the documented project planning and control (documents and charts are not always used in practice and often are just maintained for process compliance reasons or for interfacing the customer). Such a habit causes two negative effects: 1) lack of evidences and poor availability of information about the actual planning (re-planning) and control of the project activities and tasks; 2) waste of effort for maintaining formal document and charts, not always actually used.

The cluster c) is primarily due to the fact that an estimation process is not explicitly established and made available. In particular, the estimations are often made (but not documented) by senior staff on the basis of their experience only, without any support of estimation methodologies nor historical data.

The cluster d) is mainly due to neglecting the effort (intended as man hours/days) as fundamental project attribute to control and predict the project performance; focus is often just on addressing timing and cost aspects of the projects.

In order to discuss the frequency of the Clusters above, their occurrence in the outcomes of the gap analysis/assessments performed on the OU belonging to study sample is represented in the Table 3. With reference to the Table in Annex A, the X means that, for a specific organization unit (OU) corresponding to a column some gaps related to the corresponding Gap Cluster (GC) have been pointed out during the gap analysis/assessment.

Table 3. Clusters occurring in OU assessment/gap analysis results

G	OU																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
a)		X		X	X		X	X	X	X			X		X	X						X	X
b)		X		X	X	X	X	X	X				X		X	X		X			X	X	X
c)	X	X	X	X	X	X	X	X	X				X		X	X		X			X	X	X
d)	X		X	X	X			X	X							X						X	X

5 Conclusions and Next Steps

This paper contains the results of an empirical study aimed at identifying, on the basis of a sample of Automotive SPICE assessments, some common weaknesses related to the performance of the Project Management process (identified as MAN.3 in the Automotive SPICE terminology).

The study relies on data taken from a sample of 23 assessments performed by the authors world-wide, and follows a well defined the methodological approach.

The analysis of the most occurring weaknesses in terms of Base Practices rating allowed the identification of clusters of rationales of such weaknesses. The resulting set of rationales represent an useful insight (given the fact that related literature is almost totally missing) that can be beneficial for whole software process improvement community, because it can be used as a reference for process improvement efforts.

The study reported in this paper is to be considered as the starting point of a wider study involving, not only the MAN.3 process, but also the other processes belonging to the HIS scope of Automotive SPICE. Once the results of the full study will be available they may represent the first extensive analysis of improvement drivers for the automotive software community.

One of the objectives of the future deployments of this study is to extend the approach and the corresponding clustering, by including also additional dimensions such as the OUs and of the project types used in the assessments (as for instance the size of the OU, the geographical location, the domain of the projects).

References

1. Automotive SPICE, Process Assessment Model (PAM) v2.5 (2010)
2. Automotive SPICE, Process Reference Model (PRM) v4.5 (2010)
3. ISO/IEC 33000 – Information Technology – Process Assessment, International Organization for Standardization (2013)
4. Hoermann, K., Mueller, M., Dittman, L, Zimmer, J.: Automotive SPICE in Practice: Surviving Implementation and Assessment. Rocky Noor (2008). ISBN 978-1933952291
5. Fabbrini, F., Fusani, M., Lami, G., Sivera, E.: A SPICE-based Supplier Qualification Mechanism in Automotive Industry. Software Process Improvement and Practice Journal. **12**, 523–528 (2007). Wiley InterScience
6. www.intacs.info
7. Project Management Institute: A Guide to the Project Management Body of Knowledge, 4th edn. Project Management Institute, ANSI/PMI Standard 99-001-2008 (2008)
8. ISO 26262 - Road Vehicles - Functional Safety, International Organization for Standardization (2011)

Annex A

Table 4. A.1 Synthetic representation of the empirical study sample.

OU Id.	Product Domain	OU Size	Project Team Size	Company Size	Location	Gap An. Assessm.	Year Scope
1	Body electronics	10	7		Italy	YY	2013 ENG.4, ENG.5, ENG.6, ENG.8, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
2	Infotainment & Telematics	27	12		China	NY	2014 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.9, ENG.10, MAN.3, MAN.5, MAN.6, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
3	Electric vehicle Control	1000	15		South Korea	YY	2014 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
4	Electric vehicle Control	18	15		South Korea	YY	2014 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.9, ENG.10, MAN.3, SUP.8, SUP.10 (CL2)
5	Electric Steering	10	5		Italy	YN	2014 ACQ.4, ENG.1, ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, MAN.3, MAN.5, SUP.1, SUP.4, SUP.8, SUP.9, SUP.10, SPL.2 (CL2)
6	Body electronics	5	5		Italy	NY	2013 ENG.1, ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, MAN.3, MAN.5, SUP.1, SUP.4, SUP.8, SPL.2 (CL2)
7	Body electronics	31	12		Italy	NY	2012 ACQ.4, ENG.1, ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.9, ENG.10, MAN.3, MAN.5, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
8	Cooling Fan	10	8		Italy	YN	2011 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
9	Motor Control	15	10		Italy	YN	2011 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
10	Cooling Fan	10	9		Italy	YY	2013-2014 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
11	Lighting Control	10	6		Italy	YY	2013-2014 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL3)
12	Window lift	50+	10		China	YY	2014 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
13	Driving Assistance	100+	20+		Israel	NY	2013 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
14	Closures	10	7		Italy	NY	2013 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, MAN.5, MAN.6, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
15	Electric Pumps	10	7		Italy	YY	2013 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
16	Cooling Fan	5	5		Italy	YY	2012 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, MAN.5, MAN.6, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
17	Instrument Cluster	6	7		Italy	NY	2011 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
18	Body electronics	20	7		Italy	NY	2012 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6,, ENG.7, ENG.8,, ENG.9, ENG.10, SUP.1, SUP.8, SUP.9, SUP.10, MAN.3 (CL3)
19	Window lift	5	4		Italy	YY	2012 ENG.4, ENG.5, ENG.6, ENG.7, ENG.8 (CL2)
20	Electric vehicle Control	20	8		Italy	YY	2010-2012 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL2)
21	Instrument Cluster	10	5		Italy	YN	2010 MAN.3, SUP.1, SUP.8, SUP.9, SUP.10, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8 (CL1)
22	Instrument Cluster	10	5		Italy	YN	2010 MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 ENG.2, ENG.3, ENG.9, ENG.10 (CL1)
23	Electric vehicle Control	10	6		Italy	YN	2010 ENG.2, ENG.3, ENG.4, ENG.5, ENG.6, ENG.7, ENG.8, ENG.,9, ENG.10, MAN.3, SUP.1, SUP.8, SUP.9, SUP.10 (CL1)