Software Process Improvement in Inter-departmental Development of Software-Intensive Automotive Systems – A Case Study

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Abstract. This paper presents a software process improvement (SPI) initiative conducted at two automotive companies, focusing on the inter-departmental interplay between manufacturing and product development, which are central players in automotive development. In such a complex environment with multiple departments with varying challenges—the planning of improvement possibilities was considered as mission critical to get support for changes in the companies. This paper reports the results of the SPI efforts following the process assessment, namely specifically the improvement planning step, which is often overlooked in empirical reports. We also thoroughly describe and report on lessons learned from employing our tailored planning method involving 41 professionals.

We found that requirements engineering, early manufacturing involvement and roles and responsibilities were prioritized as main challenges to address. Furthermore, our and the involved professionals' experiences of the used SPI (planning) method, showed that it was useful, giving valuable decision support for the planning of the improvement.

Keywords: Empirical Software Engineering, Software Process Improvement, Case Study, Automotive, Process Improvement Planning.

1 Introduction

Software is becoming an increasingly important component and seen as the main enabler of innovations in a number of traditionally hardware-focused industries (e.g., automotive and aerospace) [1]. For example, the worldwide value of automotive software-intensive systems is expected to rise from 127 billion Euros in 2002 to 316 billion Euros in 2015 [2]. In these organizations, but generally in large organizations, the software-intensive

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systems are commonly developed in the context of large-scale development, where software constitutes only one, but important, part of the whole [3, 4].

With the development of such systems follows many challenges, among which the needed interaction between different competencies and departments is critical [5, 6]. Using an automotive vehicle manufacturer as a case, coordination and communication between individuals and groups (e.g., system owners. architects and developers) within a department (intra-departmental issues) is critical. But also across departments (inter-departmental issues). In particular, the inter-departmental interaction between Product Development (PD) and Manufacturing (Man) has been recognized in research and industry as a key challenge [7-11].

For increasing efficiency and quality when creating software-intensive products, both industry and researchers have acknowledged the importance of software process improvement (SPI) by continuously assessing and improving processes and practices [12-14].

The work presented in this paper is part of a SPI project focusing on the inter-departmental interaction between PD and Man in large-scale development of software-intensive automotive systems. PD concerns development of software-intensive automotive systems (e.g., development of power train and chassis control systems for vehicles). Man concerns managing these systems when producing vehicles (e.g., vehicle manufacturing operations affected by power train and chassis control systems). The inter-departmental interaction in our definition includes all the phases of development, from concept (e.g., exploration of requirements and solutions) to design, implementation and validation, but also manufacturing involving pre-production verification and validation of the manufacturing processes cf. [11, 15, 16]. In a new car model project, these activities commonly span over three to four years [15], [16].

The SPI was undertaken at two Swedish automotive companies: Volvo Car Corporation (VCC) and Volvo Truck Corporation (VTC) utilizing the iFLAP framework (improvement Framework utilizing Light weight Assessment and improvement Planning) as described in [17]. This paper presents a study on the improvement planning (IP) of nine improvement issues identified in the prior process assessment (PA) step in iFLAP reported in [11]. The main purpose of this study is to establish a realistic planning of the development and implementation of improvements determined from priorities and dependencies between the nine issues, as well as risk and cost of implementation, and time to return on investment (TTROI).

The main contributions of this paper are twofold. First, even though the IP has only been performed within two automotive companies, we believe the results can be valuable for practitioners that want to improve the inter-departmental interaction, at least between PD and Man in the automotive domain. This because many of the characteristics of VCC and VTC are typical for automotive companies. Furthermore, to enhance the validity of the results, data were collected both in workshops and as a web survey, where professionals (subjects) at VCC and VTC gave priority to each issue and mapped their dependencies. In total 41 subjects participated. Of those, 80% had at least 6-10 years experience of development of software intensive automotive systems.

Second, no studies on SPI efforts targeting the process area of inter-departmental interaction in large-scale software development have been found. For helping researchers and practitioners to perform IP in such process areas, we thoroughly describe and demonstrate how the use of improvement issue packaging as a method for IP was applied in practice. We also report the results of a questionnaire-based evaluation of the method, our concrete lessons learned, and the required effort used.

The paper is organized as follows. Section 2 presents related work and motivations and needs. Section 3 describes the IP method used and how it was evaluated. The results of the IP step are presented and analyzed in Section 4 and Section 5 discusses lessons learned. Finally, conclusions are presented in Section 6.

2 Related Work and Motivation

There are a few empirical studies focusing on the PD/Man interface [18]. Vandevelde and Van Dierdonk [18] claim that formalization and empathy on the part of PD towards manufacturing are contributors to a smooth start of production. Formalization entails clear goals, roles and responsibilities. Empathy means that the product developers consider manufacturing aspects during the design stage through building a better understanding of each other's work in the different development stages. Similarly, Nihtilä [4] and Lakemond et al. [19] emphasize the need for formalization and empathy and observed that such as early and active Man involvement, balanced recruitment between PD and Man, and continuous communication are critical factors in the PD/Man interface. An interesting conclusion in [4] is that due to the increased amount of software in products, there is emerging need for integrating software development operations to the project as a whole, indicating an important direction in future research. Earlier work on large-scale software development projects also show that the success is largely depending on the effectiveness of communication and coordination in the company [6], especially when it comes to requirements engineering (RE) across organizational boundaries [5].

There are several studies on Lean Product Development (LPD) at Japanese automakers (e.g., [8-10]) that have had a strong influence on approaches that have been developed to reinforce communication and coordination across departments in the PD process. Several of them can be explicitly associated with inter-departmental interaction between PD and Man. For example, to accelerate the PD process, Wheelwright and Clark [10] emphasize the necessity of understanding how problem solving is carried out across PD and Man and Sobek et al. [9] present Set-Based Concurrent Engineering. Even though lean principles and practices have been translated to the context of software development [20] it is not clear to what extent they have been applied and studied in large-scale software development [21, 22].

Three main factors motivate the work presented in this paper. First, the rapid growth of software in vehicles and the increasing demands on effective launches of new vehicle programs in manufacturing indicate an industrial need of investigating the inter-departmental interaction between PD and Man in the development of software-intensive automotive systems. Second, empirical research addressing the PD/Man interface in PD is limited [18] and SPI initiatives performed in the industrial setting studied here, has not been found. Even though above mentioned literature is relevant, it is important to understand and adopt specific organizational needs in the search for solutions to industrial problems that have been identified [23].

Third, during the PA step we realized that there was an explicit need to enable planning, but also inherently building a consensus on an inter-departmental level. That is, when we knew what parts needed to be improved (results from the PA step) we needed not only to establish changes yielding most potential benefit, but also the rationale of the improvement order and priority needed to be conveyed and anchored in the organizations.

3 Methodology

This section presents the improvement packaging method used for the IP. We also present the design for evaluating this method and validating its results

The SPI methodology used in this study is based on iFLAP [17] and its predecessor [12, 13]. IFLAP was chosen mainly because of two factors: (1) iFLAP and its predecessors have been proven to be scalable and useful in industry, especially in the automotive domain [17, 23], and (2) concerns the studied organizations' limitations in allocating the necessary resources for the SPI project. Commencing top-down SPI effort such as CMMI [24] or Automotive SPICE [25] would not have been possible due to the large amount of resources required [26].

The underlying research strategy when employing iFLAP is case research [27, 28]. IFLAP takes a bottom-up approach and its process consists of three main consecutive steps (see Fig. 1): (1) Selection—includes selection of relevant cases, such as organizations, projects, roles and subjects for the PA, (2) PA—embodies data collection and analysis by using multiple data sources such as interviews and documents that are triangulated, yielding a set of confirmed improvement issues, and (3) IP—involves prioritization and dependency mapping of the established improvement issues that generate packages of improvement issues, and aims to establish a road map that describes an appropriate way of developing and implementing improvements on the basis of specific organizational needs.

Fig. 1 shows the overall process for the SPI project, and the sub-steps used in this study for the IP in Step 3, each detailed below. The selection and PA (Steps 1 and 2) are reported in [11].

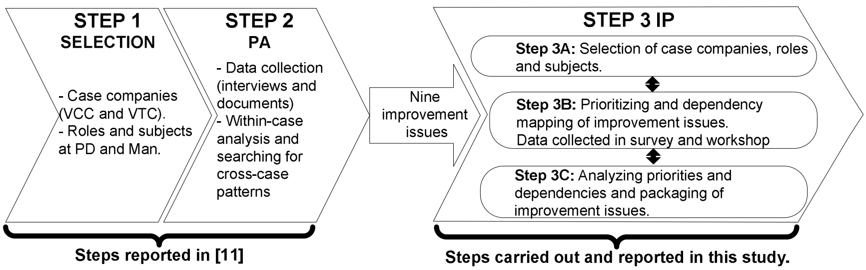

Fig. 1. Overall process overview for the SPI project (note Step 3 IP is reported in this paper)

The main output from the PA (Step 2) to the IP (Step 3, in Fig. 1) were the nine improvement issues identified (see Appendix A[1]), but also such as practical restrictions and cost limitations, and important roles and subjects, and documents (e.g., process descriptions) relevant to the process area assessed. As methods for collecting data in Step 3 and the evaluation, we used self-completion questionnaires in a web survey and workshops (see Appendix B[1] and C[1], and Table 2 in Section 4.2) The workshops and the survey were carried out during the period of January 2010 to June 2010. The duration of each workshop varied between two and four hours. How each of the sub-steps of Step 3 (see Fig. 1) were used to plan the improvements in the SPI-project is detailed below, as this is the focus of this paper.

3.1 Step 3A – Selection

The strategy for selecting case companies and subjects participating was based on a non-probability quota sampling, mainly because the underlying purpose of the inquiry presented in this paper is to set the baseline for subsequent development and implementation of improvements in the companies assessed. Consequently, subjects from VTC and VCC were selected based on the roles identified in the previous steps (Step 1 and 2).

VCC is a premium car manufacturing company and has approximately 22,000 employees all over the world and produces roughly 450,000 cars per year (2011) [29] VTC is a global automotive company that focuses on the development and production of medium and heavy-duty trucks. The number of employees is about 17,000 and approximately 75,000 trucks are produced in 16 countries (2010) [30]. Both companies are organized as matrix organizations and uses a traditional plan-based approach including a stage gate model for governing the development of the complete car and the V-model to present an overview of design and verification of inherent software-intensive systems [11, 15]. Currently, this approach is commonly used in the automotive industry [3, 31] and thus should strengthen the possibility to generalize some of the findings reported in this paper, at least to the automotive domain.

A central concern underlying the selection of subjects was to cover all the roles and competences that are involved in the assessed area. The subjects' experiences of development of software-intensive automotive systems were also considered.

Special considerations were taken regarding the team set-up in the workshops. To save time (selecting and introducing the subjects to the improvement initiative at each workshop) and obtain continuity and commitment, the intention was to use the same workshop team throughout the improvement work. Consequently, the selected subjects had to be available for the workshop series. Furthermore, putting together managers, who were identified as having an important role, and subordinates was another concern, since there is a risk that subjects in a superior position become dominant and suppress everyone else's voice in the group.

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[1] This can be downloaded via the URL:
`http://www.cse.chalmers.se/~pernstal/publications/2012Pernstal_IP/pernstal_2012_iFLAP_IP.html`

To obtain the right team set-up in the workshops and ensure the subjects' availability, senior management at the companies were informed about the purpose and planning of the workshop series and involved in the selection of the subjects. Some of the senior managers were also members of the steering group of the SPI project, ensuring that management was involved and committed. Table 1 in Section 4.1 shows the main characteristics of the subjects.

3.2 Step 3B – Prioritizing and Dependency Mapping

The data for prioritization and dependency mapping were collected through a web survey and in a workshop. Combining these two data sources provided a broader set of data from a larger sample size, which increases the analysis possibilities, especially in relation to be able to do statistical tests (e.g., [32, 33]). Using two methods for measuring the priorities and identifying dependencies also alleviated the risk for measurement bias as data can be analyzed across methods [34].

A major challenge in the creation of the survey and workshop instruments (self-completion questionnaires) was the choice of prioritization techniques. The choice of technique for the workshop and the survey was mainly based on the capability of each technique to fulfill desired granularity, scalability and applicability to different analysis methods. Most of the analysis methods, such as disagreement and satisfaction charts [35], and principal component analysis (PCA) [36] are possible to utilize when the relative prioritization techniques, cumulative voting (CV) [37] and Analytical Hierarchy Process (AHP) [38], are used, while the techniques based on an absolute grading poorly support the analysis methods [35, 36].

In AHP, the validity of the resulting priorities can be checked by calculating the consistency ratio (CR) for each subject, which makes AHP less sensitive to judgment errors compared to the CV technique. On the other hand, a common criticism of AHP is its limitations regarding scalability, since the number of comparisons increases dramatically with the number of elements. Prioritizing the nine improvement issues in this study gave 36 comparisons. In comparison to AHP, CV is a more straightforward and easy prioritization technique, and its scalability is better [17, 37]. As AHP brings the benefits of consistency checking but with limited scalability it was chosen for the workshop while CV (100$-test) was chosen for the survey due to the fact that simplicity and completion time are critical factors for the response rate on survey questionnaires [39].

Owing to the deviating interests of PD and Man, it was specifically important to agree upon the criteria of what to base the prioritizing on. As the underlying goal of the improvement initiative was to improve the interaction between Man and PD, it was agreed that the priorities should be assigned regarding how the subjects perceive the importance of each improvement issue for the interaction between PD and Man in development of software-intensive automotive systems.

The dependency mapping aims at establishing a scheme for the interdependencies between the improvement issues, where the dependencies between the issues are identified by a sample of subjects. It is preferable to allow the same subjects as were involved in the prioritizing also to identify the dependencies between the improvement issues, because other factors (e.g., practical restrictions and costs) than the priorities of the improvement issues that influence the order in which improvements are best implemented can be better uncovered. Thus, the dependency mapping was carried out in conjunction with the prioritizing in both the workshop and the survey.

To ensure that the survey and workshop instruments were comprehensible and unambiguous, and could be completed relatively quickly (one hour or less was the target for the survey instrument), drafts of them were iteratively reviewed and piloted several times. The workshop and survey instruments are shown in Appendix B[1] and C[1].

3.3 Step 3C – Analyzing and Packaging

The data from the prioritizing and identification of dependencies were analyzed within each, but also across the workshop and survey. The analysis of the prioritizing consisted of three main parts: (1) ordering of priority of the improvement issues based on the assigned priorities (2) visualizing the dispersion of priorities (disagreement) among the subjects for each improvement issue in disagreement charts, and (3) displaying how well each subject's or subject group's ranking of the improvement issues corresponds to the resulting priority order of the improvement issues in satisfaction charts. To further analyze discovered disagreements, PCA and statistical tests were used to reveal whether there are groups of subjects (e.g., PD and Man, and roles) that have opinions deviating from the rest of the subjects.

Each of the assigned dependencies were listed and given a relative weight in order to identify dependencies. We calculated the weight by dividing the number of subjects that had identified the dependency by the total number of subjects. Next, a threshold was set and the dependencies with a lower weight than the threshold were removed, the others above the threshold were considered as 'confirmed'. The threshold for the workshop and the survey was set to 3, that is three independent subjects had to have identified the same dependency. Furthermore, to discern valid and invalid relationships (e.g., due to misinterpretations or too vague motivation), each dependency was scrutinized to assure that the rational specified in relation to the dependency was non-trivial and corresponded between the subjects.

The overall idea of the packaging of the improvement issues is to enable the organizations to focus their improvement efforts on the most critical issues first, while taking priorities and dependencies into account. In addition, we considered the subjects' and senior company representatives' view on importance and dependencies utilizing their knowledge of critical aspects in the IP. For example, their views on risks and costs of implementing too many improvements at once and the TTROI.

3.4 Evaluation

The evaluation process consisted of three main activities. First, the research team gathered in follow-up meetings where their shared experiences were discussed and recorded after applying each of the IP Steps 3A, 3B and 3C. During the execution of each step required effort in terms of time spent was also measured.

Second, to ensure the quality of the packaging, it was presented in a second workshop, where the workshop subjects and the research team reviewed and evaluated the results. Furthermore, the subjects were asked to evaluate the IP method used with regard to their perception of some of the main concerns in SPI (commitment, and involvement), reliability, usefulness of the method, and validity of the results [13, 17]. For this we developed and used a self-completion questionnaire (see Table 2 in section 4.2). The self-completion questionnaire used a five-point Likert scale, representing levels of agreement from "do not agree at all" to agree completely, and usefulness from "useless" to "very useful".

Third, we reviewed and evaluated the results also among senior company representatives at a steering group meeting. The results of the evaluation are reported in terms of lessons learned from using improvement packaging as a method for IP (see Section 5).

4 Results

This section presents the main results of the IP (Steps 3A, 3B and 3C) of the nine improvement issues and the evaluation.

4.1 Results of the IP (Steps 3A, 3B and 3C)

In total, the sample consisted of 77 subjects from VCC and VTC. The survey was sent to 64 subjects, of whom 28 responded (response rate 44%), and the workshop involved 13 subjects, yielding 41 responses in total. Of these, 16 subjects belonged to Man (39%) and 25 were organized in PD (61%). Unfortunately, only four responses were received from VTC. This mainly because the sample of VTC (11 subjects) was lower than that of VCC due to lack of resources for identifying and selecting representative subjects at VTC. Table 1 summarizes the main characteristics of the subjects in the survey and the workshops. Furthermore, 80% (33 out of 41) of the subjects had at least 6-10 years experience from development of software-intensive automotive systems, and 40 of the subjects had been working at the companies for more than six years.

Table 1. Characteristics of the subjects

Characteristic	Survey (Number of subjects)	Workshop (Number of subjects)
Company	VCC (26); VTC(2)	VCC(11); VTC(2)
Function	PD(18); Man (10)	PD(7); Man (6)
Role	Line Manager(10);Program Manager (1) Design Engineer (6);Manufacturing Engineer (9);Process Developer (2)	Line Manager (0);Program Manager (2); Design Engineer (4); Manufacturing Engineer (4);Process Developer (3)

The consistency of the collected data from the workshop was checked by calculating the subjects' CR values. Following the recommendation by [38] of 0.10 would have excluded all of the subjects except one, which was not practical. Therefore, a CR of 0.3 or less was judged to be a practical compromise, as it on one hand forms a relatively large group (eight out of 13 subjects) that is balanced between Man and PD, and on the other hand it sorts out results with very high inconsistency. Moreover, the group covers all the roles included in the workshop.

The aggregated results of the prioritizing of the nine improvement issues identified in the PA (Step 2) from the workshop (eight subjects) and survey (28 subjects) are given in Fig. 2. The issues are sorted from left to right with respect to their assigned priorities (normalized priorities). It also visualizes the dispersion of priorities (disagreement) among all subjects in the workshop and the survey for each issue.

Fig. 2 shows that Issue 1 (Requirement Engineering) has the highest priority (0.173) and Issue 8 (Adoption of New Technologies) was given the lowest priority (0.076). There are disagreements among the subjects for all of the issues and the level of disagreement varies. For example, the subjects disagree more on the resulting priority for Issue 7 (77%) than on Issue 1 (57%). However, the level of disagreement is quite uniform, varying between 50% and 77%, and there is no indication that those issues with high priority are related to a high level of disagreement.

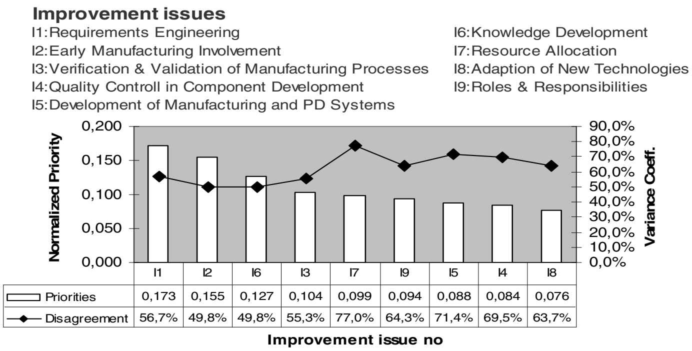

Fig. 2. Aggregated priorities and disagreements

Furthermore, the satisfaction charts (not included in this paper due to space limitations) showed that a majority of the subjects (37 out of 41) were satisfied with the resulting ranking of the issues (spearman rank-order correlation >0). This indicates a possibility to reach consensus on the planning of improvements.

Differences in assigned priorities between PD and Man were also analyzed. There were relatively small differences between these two groups of subjects and a Mann-Whitney test (data did not have normal distribution) showed that there were no significant differences at a significance level of 0.05.

The nine improvement issues were packaged (according to dependencies and priorities, risks and costs, and TTROI) into four separate improvement packages. The resulting packaging is presented and motivated in Appendix D[1]. Improvement package 1 were deemed most critical and should be addressed first in the further improvement work, and consisted of three improvement issues: Issue 1—Requirements Engineering, Issue 2—Early Manufacturing Involvement, and Issue 9—Roles and Responsibilities.

4.2 Results of the Evaluation

During the second workshop 11 of the 13 invited subjects attended. Of these, six subjects represented PD and five belonged to Man. Apart from the manager role, all the other roles were covered. Overall, the subjects agreed upon that the issues in Improvement package 1 are the most critical and must be dealt with first.

In Table 2, the questions and answers of the questionnaire based evaluation are given (levels given zero answers are not shown). For example, 73% (eight out of 11) of the subjects agreed and 18% (two out of 11) of them agreed completely to Q1, whereas 9% neither agreed nor disagreed (one out of 11), 0% disagreed, and 0% did not agreed at all.

In the steering group meeting, eight senior company representatives participated. There was no disagreement on the results, since the overall view among them was that the results closely reflected their 'gut feeling' of what was most important and beneficial to improve. However, in order to identify causes for the issues in Improvement package 1, it was suggested to decompose them into smaller and more targeted problems.

Table 2. Results from evaluation questionnaire

Question	Answer format
Q1: The method makes you feel involved in the development work.	Neither agree nor disagree (9%) Agree (73%) Agree completely (18%)
Q2: The method gives you the possibility to influence the improvement development work.	Neither agree nor disagree(18%) Agree(64%) Agree completely(18%)
Q3: The method makes you feel committed to the improvement development work.	Neither agree nor disagree (27%) Agree (55%) Agree completely (18%)
Q4. The method is reliable.	Neither agree nor disagree (36%) Agree (45%) Agree completely (18%)
Q5: The method is capable of finding out what need to be improved.	Neither agree nor disagree (9%) Agree (45%) Agree completely (45%)
Q6: Do you agree with the resulting list of what needs to be improved?	Neither agree nor disagree (9%) Agree (55%) Agree completely (36%)
Q7: What is your overall opinion of the usefulness of the used method to achieve efficient improvement development?	Useful (73%) Very useful (27%)

The effort (time spent), for the steps of the IP and for the evaluation was in total 196 man-hours. Of those, 24 hours were used in Step 3A, 110 hours were used in Step 3B, 22 hours were used in Step 3C, and 40 hours were used in the evaluation.

The effort of the research team was 72 hours and the company effort was 124 hours where the company hours used was mainly dependent on the number of participating subjects in the workshop and the survey. Roughly, 40 % (30 out of 72 hours) of the research team effort was spent on developing the instruments where a major part (~25 hours was used for elaborating the web layout of the survey instrument.

5 Lessons Learned

5.1 Results of Using the IP

Overall, our study indicates that there is an agreed view among staff and managers in the organizations about what the most critical issues are, and what their improvement efforts should focus on. The results of the prioritizing show that the level of disagreement among all the subjects for the issues with high priorities is not higher than for those issues with low priorities. There are also no significant differences for the assigned priorities given by the groups of subjects belonging to PD and Man. In addition, the answers to Q4, Q5 and Q6 in Table 2 indicate a good confidence in the method for producing reliable and valid results among the subjects. Despite the consistently positive attitude toward the method, any conclusions from the answers should be drawn with a great deal of caution mainly because of the relatively small sample representing the organizations investigated and since the answers might have been biased by the agree/disagree questions, as some people tend to agree regardless of their real opinion [39].

The packaging of the nine improvement issues resulted in four improvement packages among which Improvement package 1 includes the three issues that were found most important to deal with first in the SPI project: Issue 1—Requirements Engineering, Issue 2—Early Manufacturing Involvement, and Issue 9—Roles and Responsibilities. This is much in line with earlier studies even though these studies have other focus than our study and have been performed in other contextual settings. In requirements engineering, Curtis et al. [5] found that requirements communication is a crucial part in enabling stable requirements and a correct understanding of them, but that for large software systems development organizational boundaries impede the communication. Active involvement of Man in early phases of the development has in previous work been identified as one of the most critical factors for achieving flawless launches as well as cost efficient and quality assured production [4, 7-11, 19]. For example, Daetz [7] shows that 75% of the production costs are determined early in the development of products. Earlier field studies on the PD/Man interface point out the importance of establishing clear roles and responsibilities, which become more critical in later development phases [18, 19].

5.2 Results of the Evaluation

Using expert judgment by relying on industrial representatives showed out to be an efficient way to perform the selection of subjects. However, relying on the judgment of industrial representatives, and not be able to critically evaluate the selection can introduce bias (e.g., the subjects have been selected so they conform to a specific view). It is difficult to avoid this but it can be alleviated by discussing and anchoring the selected subjects among the managers in the project steering group. Furthermore, the research team should have done their homework by scrutinizing the results of the PA (Steps 1 and 2 in Fig.1), and collecting and analyzing additional information that is accessible and needed. This in turn may disclose the originators who could be excellent candidates for further participation.

When selecting the subjects, the overall strategy was to cover all the roles identified in the assessed process area. The experience of the identification of roles is that the results of the prior PA must be considered. For example, in the IP (Step 3), the process developer role was added to obtain a better coverage. Furthermore, including managers in the workshops was, however, deemed a risk factor as it could threaten the goal of allowing everyone to contribute their experiences and ideas in the improvement work. Here the survey made it possible to capture the views of the managers with regard to priorities and dependencies of the improvement issues without jeopardizing further improvement development carried out by the team selected for the workshops. In order to involve management, the most concerned senior managers were also represented in the project steering group.

Using also the survey as data collection method, increased the sample size of the workshop from 13 to 41 subjects. This made it possible to perform further analysis through PCA and statistical tests, revealing whether there were significant differences between groups of subjects (e.g., Man and PD, see Section 4).

A disadvantage of collecting data through both workshop and survey was the relative increase in effort of the research team mainly because of elaborating the survey instrument. Furthermore, online questionnaires limit the possibilities to discuss and clarify obscurities in the instrument. This was reflected on when discussing the results and the IP method in the second workshop. The subjects found it difficult to carry out the prioritization and dependency mapping mainly because of difficulties in getting an overview of the improvement issues and interpreting them. These difficulties are probably related to the fact that it is hard to describe the issues only through written text. The value of discussing and clarifying the improvement issues before letting the subjects prioritize and identify dependencies is pointed out in [13, 17]. Thus, the aim of obtaining validity between the workshop and survey by not providing additional information about the improvement issues in the workshop can be questioned.

Applying AHP in industrial settings commonly results in CR higher than 0.1 [40]. Apostolou and Hassell [41] suggest that it is possible to use responses with CR >0.1 without affecting the overall results. For example, Gorshek and Wohlin [13] included subjects having a CR of 0.2 or less and showed that if subjects with CR>0.2 also were included the priority of the improvement issues did not substantially change. When analyzing the impact of excluding the five subjects with a CR of 0.3 or more, it could be observed that there were minor differences except for Issue 3, which showed a moderate change where the ranking dropped from fourth to seventh place.

Attaining commitment is one of the most important success factors in any improvement initiative [42, 43]. The answers to Q1, Q2, and Q3 in Table 2 indicate that a majority of the subjects felt committed to the SPI effort according to. However, as mentioned above the answers might have been biased. On the other hand, as the IP was done jointly, there was a larger joint commitment to perform improvements, thus enabling the continuation of the SPI project.

Finally, according to the answers to Q7 in Table 2, all of the 11 subjects perceived the method to be either useful (73%) or very useful (27%), which indicates a strong support for its usefulness.

6 Conclusions

SPI is an important enabler for effectively developing software-intensive products with competitive edge. Many of these products are complex and developed in large organizations where inter-departmental communication and coordination are critical.

This paper reports on a study focusing on improvement issue packaging as method for IP, which was applied to an SPI project performed at two Swedish automotive companies. The SPI project focuses on the inter-departmental interaction between PD and Man in large-scale development of software-intensive automotive systems. The overall aim was to establish decision support, based on organizational needs, for the further planning of the improvement work at the companies.

This study makes two main contributions. First, we believe there is an industrial value of the results of the IP for practitioners aiming at improving in similar industrial setting. In total 41 subjects at the companies, assigned priorities and dependencies in both a survey and a workshop. Based on the outcome of the packaging three issues were deemed most important: Issue 1—Requirements Engineering, Issue 2—Early Manufacturing Involvement, and Issue 9—Roles and Responsibilities.

Second, we tailored and applied IP to inter-departmental interaction in large-scale software development, which differs from earlier studies on SPI. We provide a detailed description and demonstration of using improvement packaging as an IP method and report our lessons learned and feedback from professionals on its industrial usefulness. This information is most likely helpful for practitioners wanting to conduct SPI in similar industrial settings as investigated here.

An overall conclusion related to the use of our IP method is that it is useful and has the capability of identifying the most critical issues and sorting them into feasible packages. However, the benefits of extending iFLAP by using a survey can be questioned mainly due to increase of resources and higher risk of misinterpretations among the participating subjects.

The companies presented in this paper intend to continue the improvements based on the results presented here, which includes using iFLAP and the IP method.

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