Analyzing Requirements Engineering Processes: A Case Study

Frank Houdek
DaimlerChrysler AG
Research and Technology
P.O. Box 23 60
D-89013 Ulm, Germany
frank.houdek@daimlerchrysler.com

Klaus Pohl
University of Essen
Software Systems Engineering
Altendorfer Str. 97-101
45143 Essen, Germany
pohl@informatik.uni-essen.de

Abstract

Thorough process improvement starts with an analysis of the current situation. This is also true for requirements engineering processes. The goal of cooperation between DaimlerChrysler and the department of Software Systems Engineering at the University of Essen is to establish a framework for such RE process analysis in the area of car manufacturing.

In this paper, we report on our first analysis using a traditional interview techniques and the results obtained. We compare the major findings with existing research and other experiences, identify a set of challenges and provide an outlook of our future investigations.

1. Introduction

The increase of software and systems complexity, more frequent changes and shorter time to market forces organization to establish better requirements engineering processes. Thus, improving RE processes with respect to organization specific needs is becoming a crucial challenge for many organizations. Most mature improvement approaches, e.g. quality improvement paradigm, PDCA, TQM, AMI [1; 7; 4]) are based on the Plan-Do-Check-Act Cycle proposed by Steward 1939 and made popular by several quality improvement frameworks like TQM [3]. Consequently, they consist four main steps:

(1) assessing the current situation;
(2) selecting areas of improvement and defining improvement activities;
(3) implementing the improvement activities (in pilot projects);
(4) determining whether the improvement achieved the desired effects.

Do to its success, we propose to adapt the four-step approach to the improvement of RE processes. In this paper we mainly deal with the first step, namely assessing and analyzing RE processes. In literature, mainly high-level assessments for RE processes are described (see for instance [11; 10; 9]). In order to make achieve a detailed analysis and to make the analysis more valuable, more domain specific assessments and analysis techniques are required (cf., e.g. [9]).

In this paper, we report our RE process analysis activities at DaimlerChrysler passenger car development. High-end cars today contain more than 70 software based control units with several megabytes of software running on them. Development is both done in-house or in collaboration with external suppliers. Software development is always part of larger system development activities and many stakeholders are involved in the development of a single control unit. In particular, we worked together with the instrument cluster group (see Section 2) to improve their RE process. In our first assessment exercise, we used traditional interview techniques and tried to elicit a complete picture of the current RE process situation. Reflecting this assessment, we identified several shortcomings. To overcome the shortcomings we established a collaboration between DaimlerChrysler Research and the department of Software Systems Engineering at the University of Essen to improve RE process analysis techniques for the passenger car development domain.

In Section 2, we briefly describe the context of the analyzed RE process. Section 3 characterizes the overall process improvement paradigm followed in our cooperation and identifies the information expected from an analysis of the current practice. In Section 4 we outline the method used to gather those information in the context of the car manufacturing.

The main findings of our case study are summarized in Section 5, which also compares the findings with existing research. Section 6 summarizes our observations, makes some recommendations and outlines our next steps planned for the cooperation.

2. Instrument Cluster Development at DaimlerChrysler

The case study was performed with a team of engineers responsible for the design and realization of the instru-

0-7695-0680-1/00 $10.00 © 2000 IEEE

ment cluster for passengers car at DaimlerChrysler AG. An instrument cluster is the panel element behind the steering wheel displaying various status information about the car, like current speed, rotations per minute, warnings (e.g. parking break activated) and outside temperature. Modern instrument clusters contain a display to show more detailed information about the car, like time to next service, distance to drive with currently available fuel or detected defects (e.g. indicator lamp front right is defect). Figure 1 provides a schematic sketch of an instrument cluster.

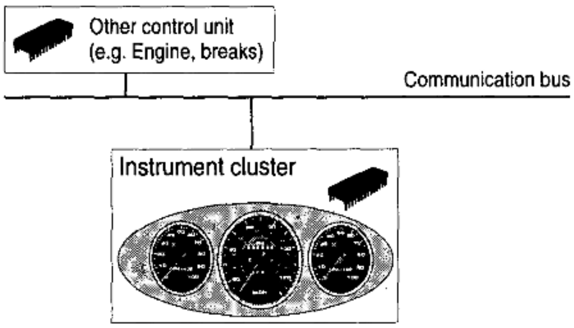

Figure 1. Schematic sketch of an instrument cluster together with some communicating control units.

Instrument clusters are typically jointly developed between external suppliers and DaimlerChrysler leaving DaimlerChrysler with the responsibility to provide and define system and software requirements. The development of instrument clusters itself is a part of a complete passenger car development process. Thus, there are many interrelationships with other groups participating in car development many of them having stakes for the instrument cluster development. Those stakeholders include control instrument designers, marketing people, people responsible for other control units, end users, chief designers, hardware specialists, chief executives as well as researchers and suppliers. The quality requirements for the instrument clusters are high – as for all other parts of a car. In other words, instrument cluster must be highly reliable and perform their functions in real-time.

3. Improvement Paradigm

As discussed in the introduction, process improvement should never be goal of its own but always related to an organization's particular improvement goal. It is necessary to

(1) identify the actual improvement goals of the organization and the people performing the process;
(2) assess the current practice and thereby identify good practice, pitfalls and potential improvement areas;
(3) define those parts of the current practice which must be changed to achieve some of the goals identified in (1);
(4) suggest and implement process modifications;
(5) evaluate the applied modification;
(6) start again with step (1)

These steps are common to many bottom-up related improvement paradigm like Quality Improvement Paradigm, Experience Factory, PDCA, AMI or TQM [1; 7; 4]. Since there is always a risk in modifying current practice, improvement suggestions (process modifications) are typically implemented in pilot projects first. Obviously, this generic improvement approach is applicable to RE processes. It was chosen as basis for our cooperation.

For the analysis of the current RE situation we slightly adapted the objectives of the assessment steps:

- identify existing steps in the RE process, define which products are consumed and produced by those steps and who is participating with which responsibilities;
- indicate subjective defects, i.e. areas (steps) of the process which are recognized as "difficult", "problematic" or "immature" by project participants;
- identify those defects where the steps are "in control" of DaimlerChrysler and where an improvement is more likely to be effective;
- establishing a qualitative (or even quantitative) baseline for future evaluation of process improvement activities;

The aim of our analysis activity was thus twofold. On the one hand, we aimed in identifying the actual improvement goals of the organization and the people involved in the actual process. On the other hand, we aim in collecting information about the current practice.

Both information is essential to select the "best" improvement areas and to plan appropriate improvement activities.

4. Process "Assessment"

We performed the analysis activities in the instrument cluster group with semi-structured interviews. The main reason for choosing this technique was the high workload of the involved instrument cluster developers which required that the assessment exercise could only take several hours (not days or even weeks). To get as many different views as possible we interviewed each developer separately. We analyzed the interviews and used the results to prepare a second interviewing round. In the second interview, we confronted assessed detail information and confronted each interviewee with statements from other developers from the first interview round.

Table 1 shows an outline of the questionnaire used. This questionnaire was build using several assessment questionnaires described in literature [10; 11] with additional questions according to our knowledge of the domain we were working with. Altogether, all major areas of RE processes were covered. However, the interviewer was free to ask additional questions or skip questions, were appropriate. The interviewer and one additional person wrote the protocol online.

Table 1. Structure of the RE process assessment questionnaire. Each section contained 5 to 20 questions.

1	***Administrative information***: Interviewer, interviewee, experience of interviewee
2	***Environment***: Interfacing groups, project goals, project owner
3	***Start-Up***: Stakeholders involved, provided documents, kick-off meeting, project estimation
4	***Requirements documentation:*** SRS structure, evolution of the SRS structure, verification
5	***Requirements elicitation***: Stakeholders, communication channels, negotiation, validation
6	***Change management:*** Reasons for changes, change management process, responsibilities
7	***Project finalization*** Quality gates, wrap-up meeting
8	***Tools used***: Which tools are used for what?
9	***Subjective judgment:*** Best practice, pitfalls and improvement suggestions

Additionally, a context diagram depicting the interfacing groups of the project was created during the interview. One interview consumed about two hours. The interviewed persons were instrument cluster SRS responsibles in various car development projects.
Altogether, we interviewed three developers. Each interview tooked about 2 hours. The interviewees were project responsibles for instrument clusters in different car projects. Each of them had several years of knowledge in instrument cluster development.
During the interviews, we also collected information not covered by our questionnaire. We incorporated information related to the RE process into the protocol.
After performing all interviews, we tired to consolidate the acquired information to a consistent picture of the overall RE process applied in this domain. As already indicated in the introduction, we failed to develop a consistent picture. Main reasons for this was the diversity in the information, the nonexistent of clear process roadmap and obvious gaps between the different activities identified and characterized.

5. Findings

Next, we describe our main findings gained from the assessment performed. To ensure confidentiality, we can not provide all the details of our observations. We thus name the main insights and provide, where possible, an illustrating example which is as close as possible to reality.

5.1. Requirements Engineering activities are heavily intertwined

Numerous researchers have identified important requirements engineering steps (tasks) like validation, elicitation, documentation and negotiation (cf., e.g.[5; 11]).
Observation: We tried to characterize the information gathered in the interviews according to those requirements engineering tasks. As a result, we experienced that the activities, especially the elicitation and validation of requirements, where not perceived as separate activities by the interviewees.
Example: Some control units in the car need information which should be calculated by the instrument cluster based on several input data received from several sensors or control units. This triggers a "micro-process" of clarifying and refining the requested information, performing a feasibility study (e.g. using simulation tools), negotiating whether the calculation function can be incorporated in the instrument cluster, writing a change request to the supplier, deciding upon additional cost estimates and modification of the SRS. Almost each step of this "micro-process" covers elicitation, negotiation, documentation, and analysis activities.
Relation to research: Based on our analysis experience, we agree with those research proposals who argue that the requirements engineering steps, like validation and elicitation, are heavily intertwined. Our investigations further raised the question if a differentiation between those activities has benefit, especially since we where not able to clearly relate our observations to those steps. For future research we would like to see more advise on how to observe real process to obtain information (and which) for each of the RE steps.

5.2. Defining a comprehensive model of an RE process is impossible.

The vision of our assessment activities was to gain a thorough understanding of the RE process related activities in the observed environment, eventually manifested in a RE process model describing all activities, involved roles, produced and consumed artifacts, and responsibilities.
Observation: In each interview we tried to decompose the existing RE process into smaller pieces to identify activities and their interrelations. We never succeeded. In general, at least the process we observed, was an amorph object, without a clear structure. However, we were able

to identify some "micro-processes" which can be defined in quite detailed.
Example: We identified several "micro-processes", e.g., "getting a decision", "evaluating a prototype", "performing an inspection", "setting up and performing a kick-off meeting".
Relation to research: This observation supports previous work on RE processes which argues that RE process can not be described as monolithic processes and should, instead, be defined as process chunks [7; 8]. We also collected numerous examples which illustrate that the execution of those chunks heavily depends on the actual situation the developers are in and the current goal they try to achieve. To elicit those type of information (situations in which a step is being performed and under which goal this step is performed in a given situation) our observations suggests to use events and event-reactions as focusing elements in a third interviewing round.

5.3. Most detailed information is in the interface area

The RE process analyzed was embedded into a larger development context. As a consequence, there exist several information exchange activities with various stakeholders playing different roles in other processes.
Observation: Gathering detailed information about the interfaces of the RE process with other processes was pretty easy.
Example: The interviewees could, e.g., explain in detail the information exchange which takes place during the start-up of a new instrument cluster project and information exchange with other development units, e.g., responsible for defining a control unit. We mainly obtained "interface" information in cooperatively writing a context diagram during the interview. In contrast to information used insight the process, most of the information given to other stakeholder was explicitly documented, i.e. each artifact exchanged was somehow defined. This might be the main reason for the ease of gathering information exchanged via process "interfaces".
Relation to research: We are not aware of any publication indicating the effort to be spend or the techniques to be used best, for assessing different type of RE process information, like interface information.
Variation in subjective estimates is low
The questionnaire included some questions about relative subjective estimates, like reasons for changes and frequency of changes.
Observation: We observed only minor differences in the collected answers concerning the frequency and reasons for changes.
Example: Table 2 depicts the ranges of the answers showing that there was a low variation across the interviewees.

Table 2. Reasons for requirements changes.

Wrong requirement, contradicting requirements	10% - 20%
Modified user (e.g. marketing, other control unit) requirements and/or priorities	50% - 60%
Technical issues, schedule, cost	10% - 20%
Environment	5% - 20%

5.4. Document archaeology helps to prepare process analysis

Observation: Examining the final requirements specification documents produced, but also intermediate reports, helped us to prepare the interviews. They provided an invaluable source for examples which we used to clarify open topics and to raise clarification questions like "who has to agree on the optic shape of the control display for function xyz?" or questions to identify the role of external stakeholders like "who provides you with information about related to electromagnetic compatibility the instrument cluster has to fulfill?". Comparing the documents with the process definitions (if there are some) also helps to identify information which is missing or only roughly covered by the documents. In most cases, the lack of information identified a process area which was immature.
Example: Analyzing different versions of the specifications we identified some parts which remained unchanged across several versions.
Asking the interviewees for the reasons why this parts where so stable (,in contrast to all others) we figured out that the unchanged parts are provided by different stakeholders and are only updated based on complicated official change regulations. Of curse, they where out of date.
Review: Product measurement is the basis for most of the improvement approaches. Ideally such measurements should be qualitatively. For the case of RE processes we are not aware of any suggestions for establishing such measurements in general and specifically for the car industry.

5.5. Assessment has to be tailored

Observation: A successful RE process assessment has to be domain-dependent. To be able to perform the assessment with short time resources, the interviews have to be very goal directed which could only be achieved through a domain-dependent specialization.
Example: In our case, questions on project goals, relationship to business goals, or feasibility studies did not make much sense since the car development is a core activity of an automobile manufacturer and an instrument cluster is mandatory for each vehicle. On the other hand,

considering documents which are primarily produced outside the instrument cluster group (e.g. plans showing configuration information for production) helps to identify micro-processes (here: negotiating these information) which would otherwise have not been identified.
Review: Again, we are not aware of any suggestion how to tailor RE assessment to the application domain.

6. Conclusions

RE process assessment and analysis is crucial for successful RE process improvement. Yet, only a few contribution for the problem of assessing RE process exist [2; 6; 9; 10; 11]. Based on this literature, we performed an RE process "assessment" within the DaimlerChrysler passenger car development unit. Our initial goal was to obtain a comprehensive picture of the current RE process. Briefly, we failed to achieve this goal.
We experienced that it seems to be infeasible to define a comprehensive process model for the current practice and to differentiate between classical RE activities (e.g. elicitation, validation and tracing) from a process point of view, i.e. those activities where never performed as process steps with a clear input and output; instead they where heavily intertwined.
Based on our experiences we identified first insights which might be useful for other RE process assessments:

- Build a context model of the development and RE process mentioning all involved parties, produced and consumed information, information media, structure and delivery intensity. Thereby you get at least a clear picture of the context which helps you in understanding and identifying shortcomings in the "internal" RE process within a department.
- Identify triggering events (e.g. change request by graphical designers or upper management) and try to capture all "micro-steps" performed to achieve the changes (i.e. a more or less sequential description of subsequent activities, stakeholders involved and artifacts produced or consumed).
- Analyze existing documents before interviewing the stakeholders and use them to analyze the information gathered, e.g., during interviews.

Based on our experiences, we will perform a third interviewing round in which we will focus on the identification of process chunks and their characterization, instead of trying to define a comprehensive process model. Moreover, we aim in illustrating those process chunks with concrete scenarios to make them easier to understand and to validate.
Beside this, we will also implement two concrete improvements of the current process in areas where significant shortcomings have already been identified. We can not name those activities here, but will be able to report on the experience made in implementing improvements in industrial RE processes.

7. Acknowledgements

We would like to acknowledge to contributions of the colleagues at the instrument cluster group at DaimlerChrysler, especially Armin Stähle. This work has been partially funded by the ESAPS project (Eureka Σ! 2023 Programme, ITEA project 99005).

8. References

[1] V. R. Basili, "The experience factory and its relationship to other improvement paradigms", *Proceedings of the 4th European Software Engineering Conference (ESEC)*, 1993, pages 68-83.
[2] Caputo, *CMM Implementation Guide: Choreographing Software Process Improvement*, Addison Wesley, 1997.
[3] W.E. Deming, *Out of the Crisis*, Massachusetts Institute of Technology, Center for Advanced Engineering Study, Cambridge, 1986.
[4] F. Houdek, *Empirically Based Quality Improvement – Systematic Adaptation of External Experiments in Software Engineering*, Logos Verlag, Berlin, Germany, Ph.D. theses (in German), 1999.
[5] G. Kontonya, and I. Sommerville, *Requirements Engineering: Processes and Techniques*, John Wiley & Sons, West Sussex, UK, 1998.
[6] Paulk, M.C., Weber, C.V., et al., *The Capability Maturity Model – Guidelines for Improving the Software Process*, Addison Wesley, Reading, MA, 1995.
[7] K. Pohl, *Process Centered Requirements Engineering*, Research Studies Press Ltd., Taunton, UK, 1996.
[8] C. Rolland, "A Comprehensive View of Process Engineering", *Proceedings of the 10th Conf. On Advanced Information Systems Engineering*, Springer-Verlag, Pisa, Italy, June, 1998.
[9] C. Smith, "Using a quality model framework to strengthen the requirements bridge", *Proceedings of the 3rd International Conference on Requirements Engineering (ICRE)*, pages 117-125, 1998.
[10] I. Sommerville, and P: Sawyer, *Requirements Engineering: A Good Practice Guide*, John Wiley & Sons, Chichester, UK, 1998.
[11] Wiegers, *Software Requirements*, Microsoft Press, Redmond, WA, 1999.