Change management methodologies trained for automotive infotainment projects

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Abstract. An Automotive Electronic Control Units (ECU) development project embedded within a car Environment is constantly under attack of a continuous flow of modifications of specifications throughout the life cycle. Root causes for those modifications are for instance simply software or hardware implementation errors or requirement changes to satisfy the forth-coming demands of the market to ensure the later commercial success. It is unavoidable that from the very beginning until the end of the project "requirement changes" will "expose" the agreed objectives defined by contract specifications, which are product features, budget, schedule and quality. The key discussions will focus upon an automotive radio-navigation (infotainment) unit, which challenges aftermarket devises such as smart phones. This competition stresses especially current used automotive development processes, which are fit into a 4 Year car development (introduction) cycle against a one-year update cycle of a smart phone. The research will focus the investigation of possible impacts of changes during all phases of the project: the Concept-Validation, Development and Debugging-Phase. Building a thorough understanding of prospective threats is of paramount importance in order to establish the adequate project management process to handle requirement changes. Personal automotive development experiences and Literature review of change- and configuration management software development methodologies led the authors to new conceptual models, which integrates into the structure of traditional development models used in automotive projects, more concretely of radio-navigation projects.

1. Introduction

Evaluating the development of an Electronic Control Units (ECU) in the specific area of automotive engineering and focusing for example on todays Electronic-Infotainment-System, which is divided into several Network-Community partners such as the Main-Unit, display, telephone and several comfort and driver assistance units, as shown in Figure 1. Especially complex are Network-Partners or Content-Provider, which are connected via Internet (e.g. navigation-information or Plug & Charge of electro-mobility Systems). Each ECU will be assigned and development by a specialized automotive supplier. It is common practice, not only in the automotive business to develop complex projects with partners "to respond quickly to the changing need of customers" [1] or market requirements and concentrate on the core business competency [1].

The objective of this paper is to examine the question how to handle automotive requirement changes in general and taking into account the challenging aftermarket driven infotainment development life cycle, the side effects of multi-partner-relationships, and most important to suggest such an automotive specific Change-Management (CM) process. This paper contributes to several

papers and books [1-5] dealing already with CM processes, but commonly neglecting the consideration of the faced risk of requirement changes. and human resource management. Thus, the 2nd focus is deliver a Risk-Assessment-Model embedded within such a CM construction, which is the key to meet the adjusted objectives to be ready as expected. The research will aim to drive a simple to use guided-tour to judge the risk, which is carried by each single change and as well as reviewing the total risk at a particular milestone. Another key issue to discuss is how to handle the impact of a must-have RfC, which appears at the final stage (i.e. Preparation of Production) of the project. Literature research of agile software development methodologies have led the authors to new conceptual supportive models, which integrates into the structure of the investigated automotive specific change management process. The graphical visualization of the RfC inflow with respect to the development phase will give a description of the critical issues the project is facing and possible remedies to sustain control of the project. The result of the analysis will provide instruments to judge the Risk and control the inflow of RfC's to meet the agreed project objectives.
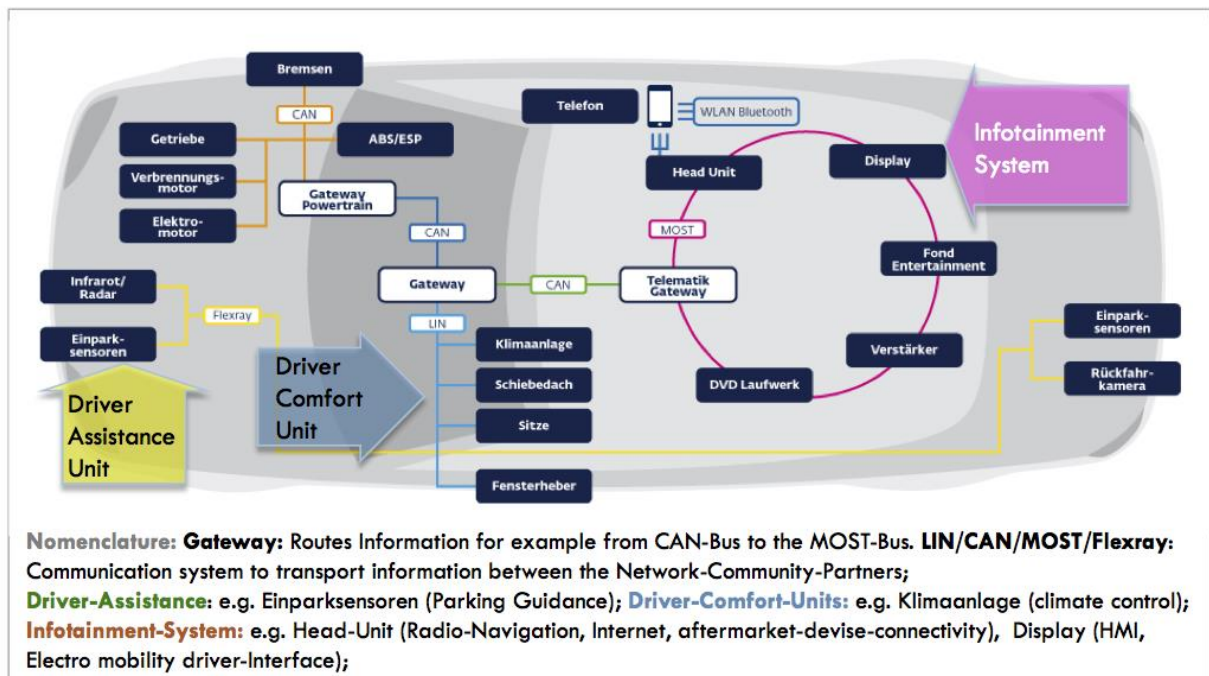

Figure 1. ECU Network Community [6]

2. Research Environment

Automotive systems are broken down into specialized project areas. Considering for example todays Electronic-Infotainment-Systems (p.r.t. Figure 1), which are divided into several Network-Community partners. Each ECU will be assigned and development by a specialized suppliers [1] section "Requirements for collaborative, multi-company ECM" [1]. The research project assumes that that all project partner have proven their potential to meet the project objectives which is part of an initial project launch supplier assessment, proving their company Management- and "domain knowledge in your own field" [7]. The supplier selection is part of the Supplier agreement management; but only the 1st tear supplier (i.e. navigation system developer) will be reviewed. The 2nd tear supplier (i.e. CPU supplier) might be assessed as well but is within the contractual responsibility of the 1st tier supplier. The innovation target will a risk, but must be also considered during supplier selection [7]. Supplier management is most certainly important [7] and will be part the Risk-Management investigation.

All modifications of the requirement specification must be evaluated regarding all possible impacts, s as development schedule, budget and especially possible side effects, including impacts to

of the network community partners. Another key issue to discuss is how to handle the impact of a must-have RfC, which appears at the final stage (i.e. Preparation of Production) of the project.

3. Project life cycle of Automotive Projects

At this point it is not necessary to describe the complete automotive product development phases of a car manufacturer, but the key milestones of an ECU development. The titles and descriptions of the project milestones vary with the OEM (Original Equipment Manufacturer), understanding the story and the to-do's behind the milestones is of utmost significant to appreciate the variations of possible negative effects of RfC's and their dependencies, i.e. at which HW/SW release timing of the modification appears in the project schedule. If for example, the implementation of an RfC is release 1st time just after the debugging phase (see Figure 2) and the verification required intensive test drives, it might be hardly possible to solve possible negative side effect or bugs before the 0-bug sample.

The following description will only briefly outline the process steps required until finally the ECU (or Use Case) will meet the customer; in addition explain the terminologies used the following discussion. The original OEM milestone expressions and schedules are not used due to arrangements of confidentiality and especially to prevent that the research's findings are bound to be valid only for a particular OEM.
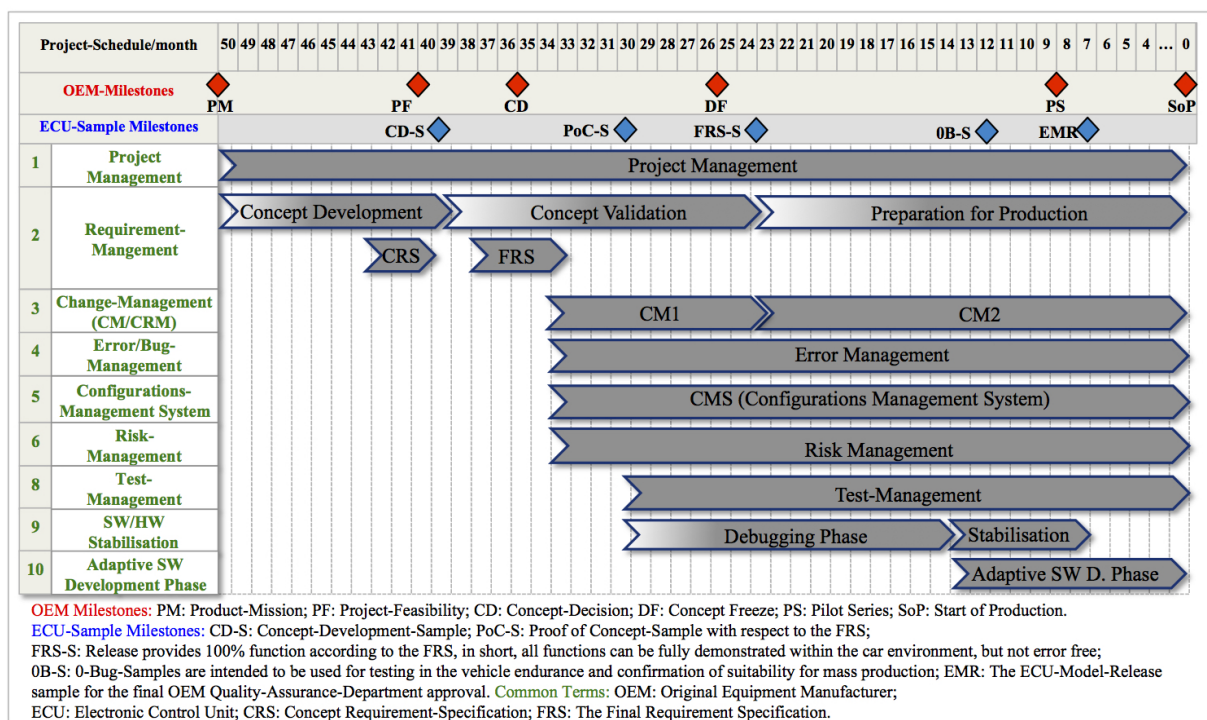

Figure 2. Automotive Project Milestone-Plan with Process-Introduction and Deliverables (adapted after [8], [9])

Figure 2 shows the development life cycle of automotive projects can be divided into three main parts such as Concept-Development, Concept-Validation and finally Preparation-of-Production.

3.1. Concept-Development

The start of the Concept-Development phase is marked with the Project-Mission (PM) milestone and ends with the Concept-Development-Sample (CD-S), [8]. The goal of this phase is to develop upon a Requirements-Brief, stating for example the market positioning, technology and finances the Concept-

Requirement-Specification (CRS). The final review of the Concept-Requirement-Specification will be based firstly upon a feasibility study (PF) and finally lead to a Concept-Development-Sample which could be a first ECU sample or just a computer simulation.

3.2. Concept Validation

The Concept-Validation phase lies in between the Concept-Development-Sample (CD-S) and the Final-Requirement-Specification-Sample (FRS-S), or more precisely the concept sample will reach within this period 100 % functionally. The task of the FRS-Sample is to show all (final customer) features in the car according to the Final-Requirement-Specification (FRS). The FRS is the baseline for the nomination of the supplier of the ECU. All contractual agreements such as functional content, schedule, finances and quality targets and so on are fixed within this document. In fact, the FRS is the INPUT of the supplier mission or contract given to several prospective suppliers for quotation and the FRS-Sample the OUTPUT.

The Concept-Validation phase has two noticeable deliveries, the Proof-of-Concept-Sample (PoC-S) and as already explained the Requirement-Specification-Sample (FRS-S). The question of this paper is how to deal with possible changes of specification, which could not be seen while compiling the FRS, but sprung into life after the commercial agreement with the supplier, and cannot be ignored for reasons stated already in the paper. The worst-case scenario is when the Requirement-Specification-Sample (FRS-S) milestone must be shifted to realize a redesigned of the Final-Requirement-Specification. Automotive projects have shown that even adequate requirement documentation reviews cannot prevent the appearances of specification limitations. Reviews are most certainly useful, but the dynamic behaviour of a car network and market demand changes are not all foreseeable. This paper must therefore define the period to allow FRS changes and the research must clearly identify the side effect.

3.3. Preparation of Production

The start of the Preparation-of-Production phase is marked by the acceptance of the OEM of the Requirement-Specification-Sample (FRS-S). The initial aim of this period is to locate all hardware, software and system problems and meet finally FRS defined quality targets. Thus, found problems require to be handled with according a to be defined process and solved until the 0-Bug-Sample (0B-S).

4. Automotive Tailored Change Management (CM) including Configuration Management.

"Is there an ideal requirements engineering process? No- processes must be tailored to organizational needs" [3]. The following definitions and responsibilities have to be clarified to setup an automotive specific change management process shown in Figure 3a/b. The outlined process does not show all required "RfC-questionnaire" formal or technical reviews for the sake of simplicity. However, the essential task of the shown CM process is to establish and sustain a relationship with the stakeholders regarding the status and access of the RfC's which respect to the documentation database (CMDB), [3] and current service transition (see Figure 3a/3b).

4.1. Definition of the Input parameters or RfC-input:

a) New requirements due to must have changes to satisfy the strong demands of market to ensure the later commercial success. b) Secondly, requirement changes due to insufficient or faulty function description of the FRS. c) Finally, software or hardware implementation errors.
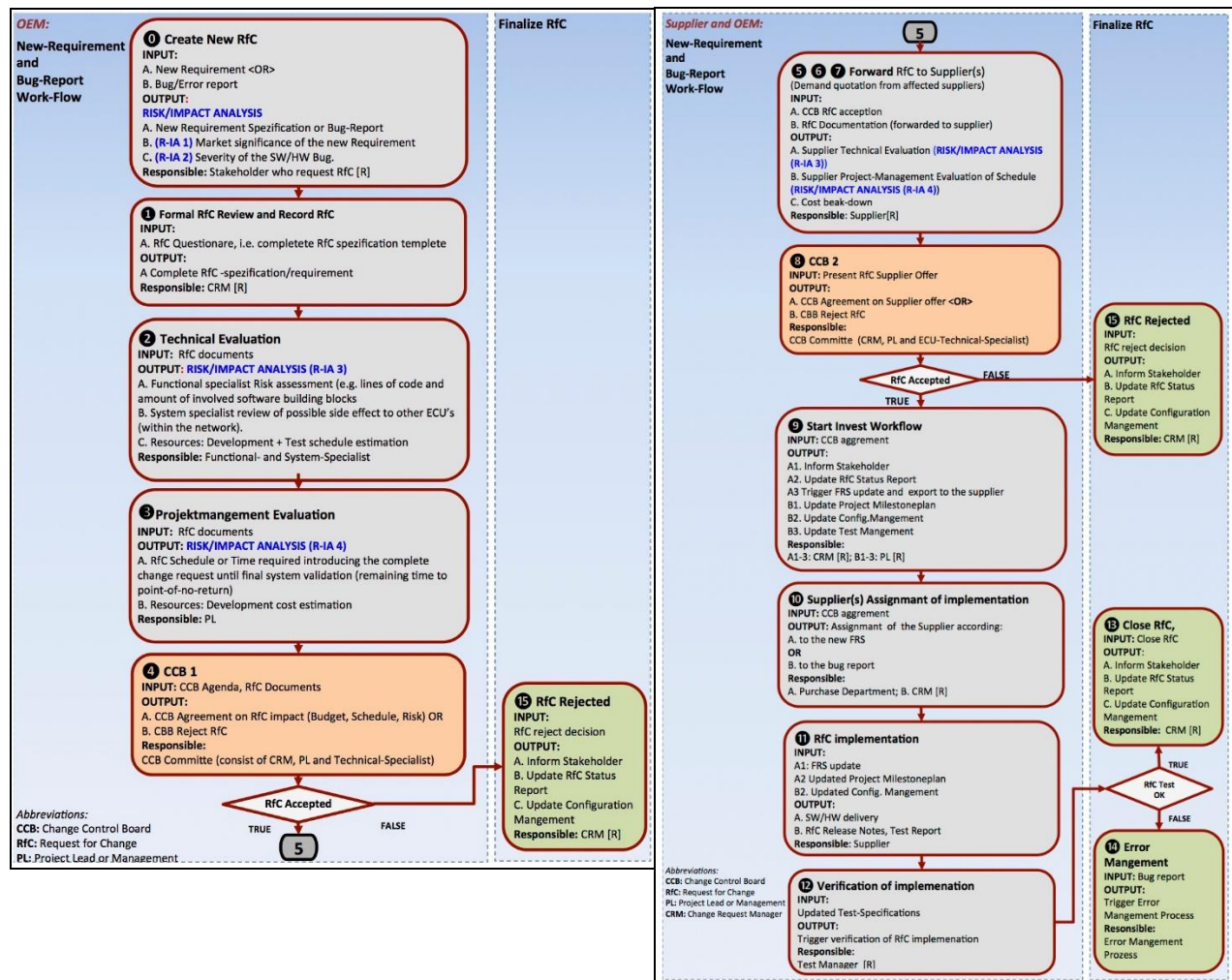
Figure 3a. Automotive Change Management (CM) Work Flow [11]

Figure 3b. Automotive Change Management (CM) Work Flow [11]

4.2. Start of the Change-Management (CM) process

From Figure 2 can be seen that it is suggested to start with the CM process at the start of the CM1 or alternatively at the CM2 phase. This discussion sets the CM start point at CM1, which is directly after the Final Requirement-Specification (FRS), since the FRS is used as the requirement base line to start with the development. In addition, the Configuration Management System (CMS), [3] will run simultaneously with the CM (see Figure 3c) to record all relevant data (CI), [3]. The benefit to start at CM1 phase is simply that all discussion, test result finding are feedback into the FRS. Secondly and may be more important is introduction of risk or impact analysis (see chapter 5). In addition, the consequence of neglecting to finalize the required change on contractual basis is the commercial impact review or influence is neglected. Thus the discussion might be concluded with a solution, which is not cost effective and due to budget limitations impossible to implement. Lessons-learned workshops of previous automotive projects state clearly that CM1 should be the trigger for the CM Work Flow in order to document all agreed specification changes. Without this process all other activities such as deriving a test specification based upon an invalid FRS is pointless. In addition, the CM Workflow must insure that all possible stakeholders or other departments are included in the RfC review process to insure not to neglect possible side effects.

4.3. Change Management (CM) Work Flow

The presented CM Work Flow in Figure 3 follows the concept of combining the requirement changes and bug report within the same CM work flow. Consequently the formal treatment of RfC for both cases must be harmonized in the way that the tooling (GUI) or RfC questionnaire using the same parameter such as priorities.

4.4. CM Work Flow transitions ('0'-15' see Figure 3: CM Work Flow)

In order to prevent or at least reduce delays and effort spent waiting for decisions from the Change Control Board (CCB), [2] or quotations from suppliers the transition timings should be defined.

4.5. RfC Status Report

The Status report will summarize the following parameters: a) RfC-in: New RfC; b) RfC-out: RfC is closed if the SW or HW change is delivered, implemented and in car successfully tested; c) RfC-Rejected; Rejected CR's will be added to the RfC-out count; d) RfC-active/open CM process step ('2'-'12'): The number of RfC-active/open corresponds with all RfC (RfC-in – RfC-out), which are still active; e) RfC-new workflow process step ('0'-'1'): The RfC will be taken for the RfC Status after the review of the CRM.

In addition, "the change record holds the full history of the change, incorporating information from the RFC and subsequently recording agreed parameters such as priority and authorization, implementation and review information." [5].

4.6. Automotive - Configuration Management System (CMS)

The Configuration Management System (CMS) is the backbone of Change-Management and "should prevents changes from being made to IT infrastructure or service configuration baseline without valid authorization." [2]. The CMS Workflow and CI (configuration item [3] or entities [4]) dataflow is shown in figure 3c. The CMS applied for automotive system should at least provide the following services:

a) A definition of the configuration database (CMBD), which relevant CI's to be recorded [4]

b) "Support for CIs of varying complexity, e.g. entire systems, releases, single hardware items, software modules" [2]

c) "Hierarchic and networked relationships between CIs; by holding information on the relationships between CIs, Configuration Management tools facilitate the impact assessment of RfCs" [2]

d) "Integration of problem management data within the CMS, or at least an interface from the Configuration Management System to any separate problem management databases that may exist" [2]

e) "Ease of interrogation of the CMS and good reporting facilities, including trend analysis (e.g. the ability to identify the number of RFCs affecting particular CIs)" [2]

f) "Ease of reporting of the CI inventory so as to facilitate configuration audits" [2]

g) "Flexible reporting tools to facilitate impact analyses" [2]

h) "Assign people to each role and maintain the assignment in the service (CMS)" [2], [4]

The RfC authorization should be recorded within the Configuration Management Database (CMDB) at least by the time that the change is implemented. The Software "Integration- and Delivery-process" should only be started, if all Configuration-Items (CI) of the CMDB are reviewed and approved by all significant stakeholders. The Integration-Call (stakeholder meeting, see Figure 3c) can give a final valid authorization for implementation if all stakeholders are present.
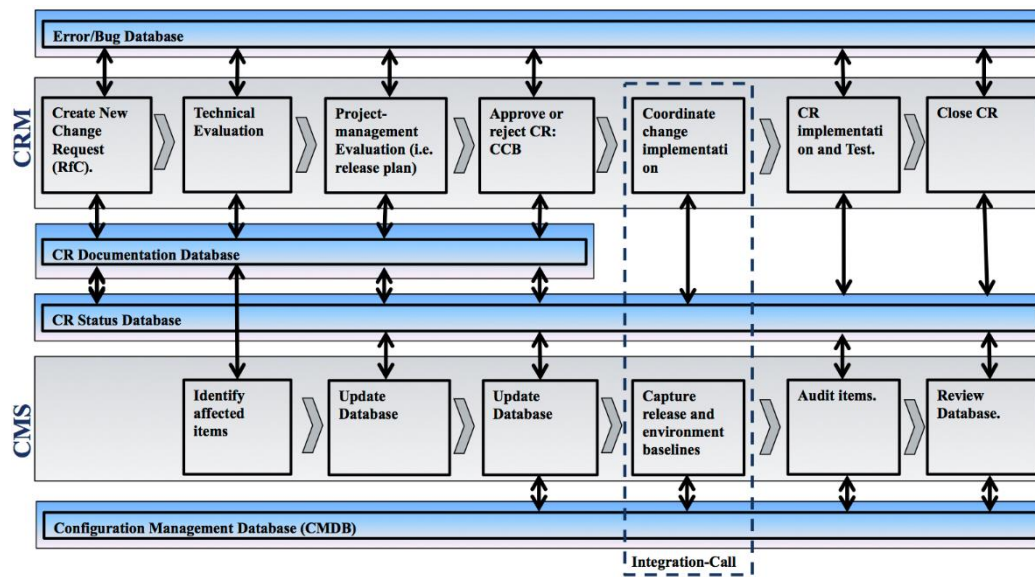
Figure 3c. Automotive Configuration Management System (CMS)

5. Implementation the of Change Management Process in combination with Risk-Management Assessment Simulations

The demand is how to evaluate the risk or impact of a change request (RfC) to the project and to enable the project management to decide a) to implement c) postpone to a later release or c) reject the deviation of the initial requirement specification. The following discussion will assume the CM Process is implemented as discussed.

5.1. Practical analysis. Total of valid RfC in-flow w.r.t. the project schedule (time)

For the analysis of the effects of a continuous in-flow of RfC's (New-Bug/-Req.) throughout the development life cycle until SoP the previous discussion has recognized:

   a) The start-point of the Change-Management (CM) process should be CM1, which is the milestone of the freeze of the contract specification (FRS).

   b) As also previously mentioned, this FRS is after nomination of the supplier the base line of the requirement (and CMDB) to be developed and handed over to the supplier via the purchase department.

   c) The end-point of the analysis (of this paper) will be the SoP.

   Utilizing the explained Automotive development key milestones (FRS-S, PoC-S, FRS-S, 0B-S and EMR) and the RfC-in and consequently the RfC-out flow the graphs shown in figure 4 (RfC-in/-out/-active) can be drawn along the milestone FRS to EMR or SoP. The trend of simulated RfC-in and RfC-out flow corresponds to lessons-learned of previous projects [8].

   The visualization of the in- and out-flow of RfC w.r.t. time shown in Figure-4 is already common practice [8]. From the shape of the simulated RfC in-/out-flow graph shown in figure 4 (RfC-in/-out/-active) can be deduced:

   a) The amount of active RfC shows the maturity of the ECU or of the concept and final specification. Bearing in mind the agreed expectations (fixed by contract) of the ECU quality defined and scheduled by the key milestones (FRS-S, PoC-S, FRS-S, 0B-S and EMR). If the quality goals are not meet countermeasure might be necessary. The countermeasures depend on the root cause of the RfC, therefore a precise remedy will depend upon the analysis result of the technical specialists.

   b) The FRS-S milestone marks the 100% feature complete ECU maturity expectation. Moving towards the 0B-S (0-bug Sample) milestone the RfC inflow should decrease as a statement of functional stability. The expectation is that the RfC inflow and the RfC total will be 'zero' at the 0B-S milestones. It is an unfortunate fact of life that software and hardware is never error free and any bug

solution might inflict another or several bugs into the system. Therefore it is important to introduce a SW/HW stabilization phase (just before the 0B-S - until the EMR-milestone) [8]. The described procedure only cultivates the RfC active curve into a fever (quality) chart of the project or a particular milestone. The graphs give no risk assessment support.

5.2. Risk-Management Assessment via RfC-Forecast Model

It is common practice at the beginning of a project to describe within the Project-Brief the required Project-Infrastructure, see "Infrastructure Management Process" [10]. The Project-Brief describes the demanded "resources for the achievement of project objectives" [10]. In order to estimate the required project infrastructure such as human resources or budget, similar projects can be used as a baseline and compared to be project at hand. Thus, data or the amount of requirement changes and bug report experienced in on-going or closed project can be use to derive a graph to be used as a Forecast or expected RfC inflow. In fact this data can be used to establish and reason the Project-Briefs statement of required resources. Figure 5 shows such estimated RfC-Forecast graph.

Reviewing the RfC-Forecast and the RfC-in graph with respect to the given milestone plan the following observations could be made, bearing in mind the maturity expectations of the ECU key milestones. If the inflow excites the forecast, countermeasures might to be necessary to return to the planned inflow (forecast).
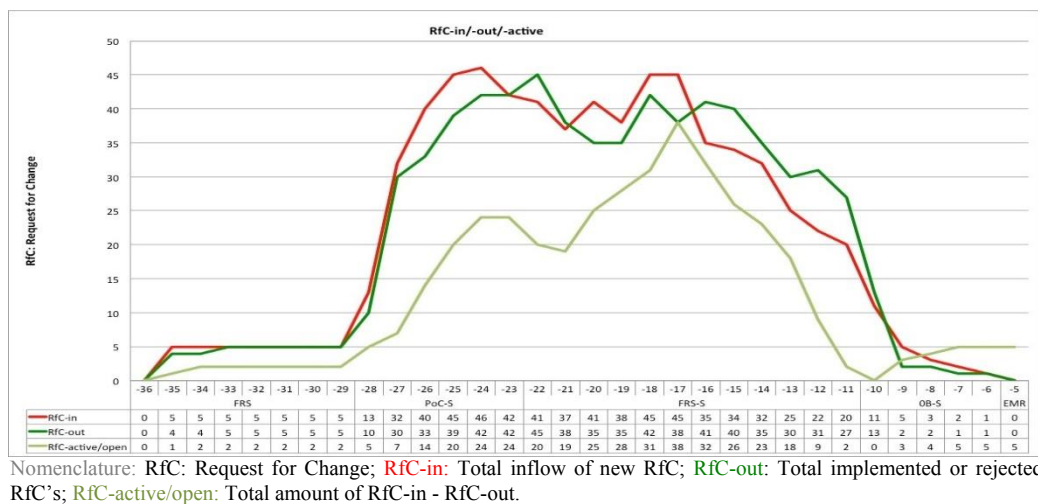

Nomenclature: RfC: Request for Change; RfC-in: Total inflow of new RfC; RfC-out: Total implemented or rejected RfC's; RfC-active/open: Total amount of RfC-in - RfC-out.

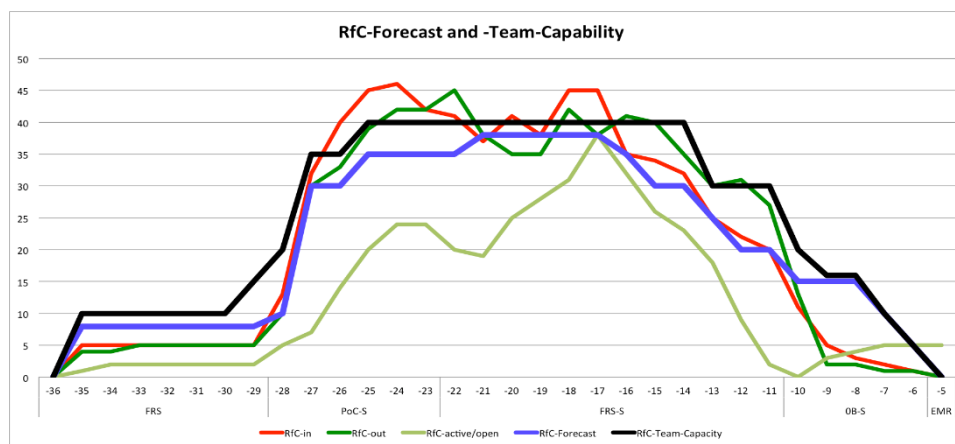**Figure 4.** RfC-in/-out/-active [8], [11]

Figure 5. RfC-Forecast Model [8], [11]

5.3. Risk-Management Assessment via RfC-Team-Capacity Model

The shape of the simulated RfC in-/out-flow graph shown in figure 4 (RfC-in/-out/-active) can be observed reviewing the data of several representative automotive projects [8], as stated in the previous chapter. Utilizing the data of such projects it is possible to construct the forecast model, most likely RfC inflow. Ideally the shape of the forecast curve must not be adjusted over the life cycle of the project, which is also a weakness of the Forecast-Model. The Forecast-Model take not into account the typical alterations of e.g. human resources and skills available. In order to improve the forecast model a "Human Resource" graph could be added to show the maximum team capacity to deal with the project requirements, i.e. "Human Resource Management Process" [10].

Plainly the graph must show the maximum human resources and skills available over time. Thus, the resulting team capacity must be able to produce the required RfC outflow to meet the project milestones. Introducing the described risk management control mechanism into figure 4 will conclude to figure 5 (RfC Forecast and Team Capacity). The data for forecast curve is idealized and leads to the shown curve. The data for the Team Capacity were derived as follows: During the early and the final phase of the project the Team-Capacity was set to equal or slightly larger values as the RfC-Forecast. During project phases were the probability growths that the RfC-inflow increases as described in chapter 'Timeline and Constraints of valid RfC inflow' the value of the Team-Capacity was set to at least 10% higher than the value given by the forecast as a save guard. The resulting data should be reused in the project brief, which "assures the providing of a supply of skilled and experienced personnel qualified to perform life cycle processes to achieve organization, project and customer objectives." [10].

5.4. Risk-Management or Control of RfC inflow via Priority and Impact-Analysis Model

The Team-Capacity-Model curve states the maximum inflow of new RfC's, which the total available project members at a specific time can handle. All previous discussed simulations only view amount of new changes requests, but not the impact of the bug or new requirement regarding: a) Market significance or consequences of introducing the feature at a later release; b) Severity of the SW/HW Bug to the customer or vehicle; c) Functional specialist Risk assessment (e.g. lines of code, amount of involved software building blocks); d) Project-Management Evaluation of Schedule impact, such as Time required introducing the complete change request until final system validation; e) Remaining time to until SW Freeze or SW stabilization; f) It is important to investigate the impact of an RfC to possible involved Network-Partners (see Figure 1) as discussed in the previous chapters; g) Implementation cost.

The question is therefore how to improve the discussed models to take the above stated possible arguments in to account, adding the impact of each argument to each single RfC. This Impact-Analysis (IA) is identifying or estimating the potential consequences and modifications to realize the change request.

Table 1 shows an example of Impact-Analysis (IA) items (R-IA 1 to R-IA-6) and the corresponding assessments focus for each impact analysis item; whereas each items links to a rating or score (IA Score):

a)   R-IA 1, R-IA 2 and R-IA 6 (IA: 4) gives the project management team a risk evaluation if the RfC is not implemented, with respect to market issues and to customer complaints. If the IA results into the highest impact sore, there is are very limited choices of not implementing the RfC as reasoned and shown in Table 1. The Change Management (CM) Work Flow (see Figure 3a.) suggests how to systemize or schedule the impact analysis R-IA 1 and R-IA 2. Responsible for the scoring is the stakeholder who initiates the RfC.

b)   R-IA 3 and R-IA 4 gives the project management a risk evaluation if the RfC is implemented, with respect to engineering or SW/HW implementation effort, including involving of network partner. The CM Work Flow (see Figure 3a.) suggests how to systemize or schedule the impact analysis R-IA 3 and R-IA 4. Responsible for the scoring is the technical group that evaluates the RfC from the OEM point of view (see CW workflow step '2' and '3'). The scoring is might be

adjusted after the suppliers review of the RfC via the supplier technical specialist (see Figure 3b, CM process step '5')

c)   R-IA 6 states the implementation cost. It is of vital importance that a new requirement is only realized after commercial agreement; otherwise the HW/SW implementation work might be stopped or even dismantled. Loss of budget and resources are the consequence. The implementation costs are part of the CMS/CI tracking.

Table 1. Impact-Analysis (IA) Items and Assessments [11]

Risk (R)	IA Focus	IA Priority: Assessments Description	IA Score
R-IA 1	Market significance of the new Requirement	1. Immediate: *Meets legislative requirements"* [2]. 2. High: "*Responds to short term market opportunities or public requirements; Supports new business initiatives that will increase company market position"* [2]. 3. Medium: "*Maintains business viability; Supports planned business initiatives"* [2]. 4. Low: "*Improvements in usability of a service"* [2]	1. IA: 4 2. IA: 3 3. IA: 2 4. IA: 1
R-IA 2	Severity of the SW/HW Bug	1. Immediate: Car Immobility expected (low battery), *Putting life at risk* [2]. 2. High: Customer complaint to be expected; *Severely affecting some key users, or impacting on a large number of users* [2]. 3. Medium: "S*everely affecting some key users, or impacting on a large number of users* [2]. 4. Low: "*No severe impact, but rectification cannot be deferred until the next scheduled release or upgrade"* [2].	1. IA: 4 2. IA: 3 3. IA: 2 4. IA: 1
R-IA 3	Technical Evaluation	1. Immediate: High and Network-Partner are involved 2. High: High SW/HW implementation risk, without Network-Partners involvement or else jump to the next risk level. 3. Medium: Medium SW/HW implementation risk, without Network-Partners involvement or else jump to the next risk level. 4. Low: Low SW/HW implementation risk, without Network-Partners involvement or else jump to the next risk level.	1. IA: 4 2. IA: 3 3. IA: 2 4. IA: 1
R-IA 4	Project-Management Evaluation of Schedule impact*	1. Immediate: RfC implementation during and after the stabilization phase. 2. High: RfC implementation during the Preparation of Production phase, but before the SW/HW stabilization phase. 3. Medium: RfC implementation during the Concept Validation-Development phase 4. Low: RfC implementation during the Concept-Development phase *RfC SW/HW realization, test and final system implementation.	1. IA: 4 2. IA: 3 3. IA: 2 4. IA: 1
R-IA-5	Network-Partner are involved	1. RfC Propagation: RfC on hold until Risk Analysis or Risk Impact of Network-Partner available. Critical Path Analysis: Worst Case Scenario! 2. No Network-Partner is involved	1. IA: 1 2. IA: 0
R-IA 6	Budget management	1. Required budget not available (no commercial agreement)! Consequently, the RfC is rejected, i.e. not realized. 2. Implementation cost evaluation necessary. Risk: Los of time due to evaluation and commercial agreement. 3. No Implementation cost, only control for CMS/CI tracking.	1. IA: 4 2. IA: 1 3. IA: 0

5.1. Combination of RfC-Team-Capacity Model and Impact-Analysis Model

RfC priorities [2] as explained for R-IA 1 and R-IA 2 are partially known in the IT. The impact priorities listed for R-IA 2 are common practice in the automotive developments. R-IA 1 and R-IA 2 states the severity of the problem to be solved if no solutions is found or implemented.

Figure 6 shows for each new RfC the impact evaluation result according to table 1, utilizing the R-IA 3 and R-IA 4 priorities. R-IA 3 and R-IA 4 are considering the impact from the SW/HW/System-implementation threats and schedule perspective inflicted to the team. The advantage of preassigned priorities to each RfC are as follows:

a)   The project development team can operate the implementation and test order in accordance to the priorities, i.e. 1st the RfC with highest IA score.

b)   For the configuration management the top score (immediate) RfC can influence the decision to release a SW or postpone a SW/HW release until this particular problem is solved, depending as well on the issue. However, the pre-marked top problem is marked to be especially treated with to priority and easily traceable.

c)   From the shape of the simulated Team-Capacity graph shown in Figure 6 (RfC-in/-out/-active) in combination with the total impact analysis can be observed that if the maximum calculated impact comes near by or even crosses the Team-Capacity border appropriate management activities neat to be in place. "Resources utilization against capacity" [2] needs to be considered. Figure 6 shows that for month '-26' until '-17' the resources will be sufficient to release all RfC's.

Consequently, several obvious management decisions are possible:

a) The RfC' marked with the Low priority need to be postponed or re-evaluated to reject candidates.

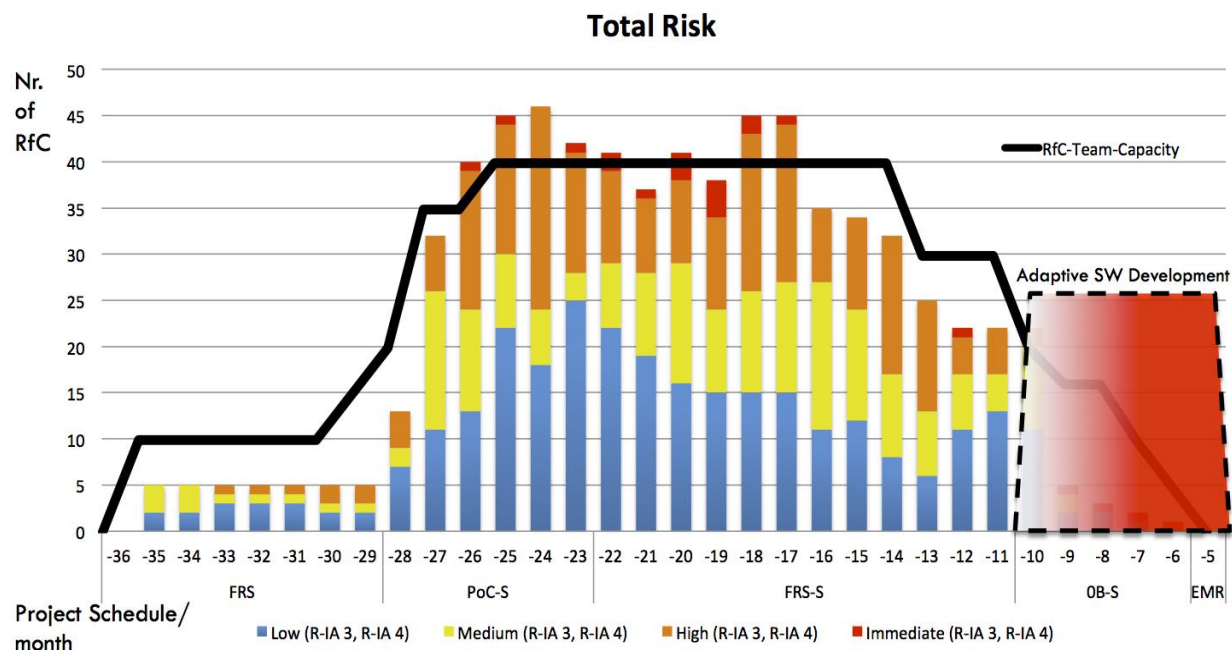b) The team capacity needs to be upgraded until the month '17' (see Figure 6).

Figure 6. Total (Implementation) Risk-Analysis and Team-Capacity (adapted after [8], [11])

6. Conclusions

6.1. Configuration Management System (CMS) and Change Management (CM)

The discussion suggests that the 'Change Management' (CM) process" in automotive ECU development projects starts directly after the freeze of Final Requirement-Specification (FRS), which

is the basis of the contract between OEM and supplier. The real benefit of the CM process is to collect the data describing the changes request and guide them through all the CM transitions steps necessary to prepare the information required to take the adequate decisions with the best possible confidence and benefit for the business.

The CMS and CM process secures the effective handling of RfC's from the initial need to change a requirement until the delivery and test of the adopted functionality. Summarizing the services of the described CM workflow as shown in figure 3a-c will lead to the following conclusion: The CM Process is a service, which collects all the predefined information at defined transition steps, as well as triggering supportive processes such as requirement-, configuration-, risk-management (impact analysis) and CCB (Change-Control-Board). The specification of the data required depends on the specific field of development. The RfC information (CI) required and collected by the CMS service should be defined by the (technical and project lead) project team. Involving the team in defining the CM process will serve to define the best practice relegated RfC questionnaire and getting familiar with the goals and purpose of the service.

The CMS/CM service requires to be maintained via a change request manager, which is required for both parties, for the OEM and the supplier to lead all stakeholders along a defined CM steps, providing data or information at the right time to the matching RfC stakeholder(s).

6.2. Risk Management

The shown Risk-Management Model depends completely on the quality of information (i.e. CI) gathered by the CM service. The Forecast- and Team-Capacity processes depending also on the data gathered of previous projects and on the team member transferring the data to the new project (-brief). The Impact-Analysis Model depends especially on the engineering expertise of the stakeholders judging and deciding on the IA score. Clearly, this is the weakness of all risk models discussed, for example the impact score decision might not be reproducible for any specific RfC. The suggested remedy for the IA scoring of 'R-IA 3 Technical Evaluation' and 'R-IA 4 Evaluation of Schedule impact' is the review of the scoring (see Figure 3b). However, the marking of 'R-IA 1 - Market significance' and 'R-IA 2 - Severity of the Bug' are depending on personal experience and possibly fondness on a use-case or customer feature.

However the Risk-Management Models are still valid supporting tools for the project-lead and especially for the CCB to judge and to decide to implement or reject the RfC. The Team-Capacity Model is particularly important at the end of the project timeline, since misjudgments of RfC inflow rates are more difficult to compensate. In addition, the graph of figure 5/6 could help at this point to argue against reduction of resources if the total amount of new of RfC requires the opposite.

6.3. Boundaries of the discussed models

Considering the following Use-Case of new requirements (RfC), with an Impact-Analysis (IA) assessment results (according to Table 1):

a)   R-IA '1' (Market significance of the new Requirement) with IA: 3 (High: Responds to short term market opportunities) and

b)   R-IA '4' (Project-Management Evaluation of Schedule impact) with IA: 3 (Immediate: RfC implementation during and after the stabilization phase).

If the CCB decides to pro-actively to integrate the RfC, due to the must have change to satisfy the strong demand of market (i.e. to ensure commercial success), the models can support with CM or Risk analysis processes, but not with the successful integration and final test which fits into the former explained automotive project life cycle concept of to meet the defined quality targets which can only be confirmed with long-term endures-test. Thus, during the stabilization phase the integration of a RfC require a revised software design and test process with will minimize the risk of lost development an endures-test time.

6.4. Further research (Adaptive Software Development Phase)
The key issue of infotainment systems is that there are embedded within the 4 years car development cycle against a one-year update cycle of an aftermarket devises such as a smart phones. Unfortunately the smart phones are already part the infotainment system. From personal automotive project experiences, the discussed CRM methods are useful for requirement changes, which appear before stabilization phase or 0-Bug sample (see Figure 2). The discussed methods are beyond those milestones still valid to give support to judge the risk, but this does not help the team to deliverer the most wanted feature (RfC) after the planned 0-bug sample; and to be integrated for SoP. Further research is necessary to establish "Adaptive Software Development" methods at the beginning of the automotive development life cycle.

References
[1]   K. Rouibaha and K. R. Caskey 2003 Change management in concurrent engineering from a parameter perspective, *Computers in Industry* **50** 15-34
[2]   ITIL3 *Service Transition* 2007 ISBN 978 0 11 331048 7
[3]   ITIL® *glossary and abbreviations* English 2011
      http://www.itilofficialsite.com/InternationalActivities/ITILGlossaries_2.aspx, ITIL,
      www.itil-officialsite.com/InternationalActivities/TranslatedGlossaries.aspx, ITIL®, Last
      access, 12.03.2014
[4]   Sommerville I 2004 *Software Engineering*, 6th Edition, Addison-Wesley
[5]   Kotonya G and Sommerville I 1998 *Requirements Engineering - Processes and Techniques*, First Edition, Wiley Publishing, Chichester, UK
[6]   https://www.telemotive.de/fileadmin/user_upload/content/Grafiken/Engineering/Bussysteme.png, last access 06.06.2016
[7]   Ebert C 2007 *Optimizing Supplier Management in Global Software Engineering*, IEEE Computer Society Press
[8]   ***Primary Source: Automotive OEM. The OEM Terminology, graphics and data are altered; the original OEM Company-Name, milestone expressions and schedules are not used due to strict arrangements of confidentiality. The examples are based on personal experience
[9]   Volker S, Prostean G and Hutanu A 2016 Research of Automotive Change Management and Supportive Risk Management, *Soft Computing Application* **357** 1097-1108
[10] ***INTERNATIONAL STANDARD 2008 *Systems and software engineering - Software life cycle processes*; ISO/IEC 12207; IEEE Std 12207-2008; Second edition 2008-02-01
[11] Volker S and Prostean G 2016 Research of Automotive Change Management and Combined Risk-management Models, *Procedia - Social and Behavioral Sciences* **221** 395–404