Impact of agile methodologies on team capacity in automotive radio-navigation projects

G Prostean, A Hutanu and S Volker
Politehnica University of Timisoara, Faculty of Management in Production and Transportation, Remus str., no. 14, 300191 Timisoara, Romania
E-mail: andreihutanu@yahoo.com

Abstract. The development processes used in automotive radio-navigation projects are constantly under adaption pressure. While the software development models are based on automotive production processes, the integration of peripheral components into an automotive system will trigger a high number of requirement modifications. The use of traditional development models in automotive industry will bring team’s development capacity to its boundaries. The root cause lays in the inflexibility of actual processes and their adaption limits. This paper addresses a new project management approach for the development of radio-navigation projects. The understanding of weaknesses of current used models helped us in development and integration of agile methodologies in traditional development model structure. In the first part we focus on the change management methods to reduce request for change inflow. Established change management risk analysis processes enables the project management to judge the impact of a requirement change and also gives time to the project to implement some changes. However, in big automotive radio-navigation projects the saved time is not enough to implement the large amount of changes, which are submitted to the project. In the second phase of this paper we focus on increasing team capacity by integrating at critical project phases agile methodologies into the used traditional model. The overall objective of this paper is to prove the need of process adaption in order to solve project team capacity bottlenecks.

1. Introduction
The development of automotive radio-navigation projects became even more complex because of the impact of peripheral components development processes. The integration of new communication protocols, which are used for new developed smartphones or IT components, into automotive project raised the necessity to harmonize the processes used in the development of different system components area. As the project has a strict deadline and the success factor depends also on the number of resources involved, not only the harmonization of processes will decide the success of projects. In order to achieve project success by implementing the critical factors like time, cost, scope and innovation, the project leaders have to be careful on the influence of changes on project requirements. Applying changes on requirement will bring confusion and delays in such complex projects.

The objective of this paper is to analyse potential process adaption and their influence on team capacity while requirements changes in a fast manor. The requirement changes in projects using traditional development models endangers project objective. Current literature review shows that the main objective of study is the adaption of development processes used, without taking into...
consideration the team capacity factor. By assuring that the initial team capacity stays under the planned level, the financial factor will not overtake the initial planning. On the other side, by not fulfilling project capacity, initial planning will lead to the necessity of cutting project scope or opening an update-project.

2. Development models applied in complex automotive systems

Different automotive projects components derived from various areas implies the integration of the different development models used. While the V-cycle development model is used in the development of traditional in car ECUs (Electronic Control Unit), the peripheral components like servers, smartphone integration are developed using agile methodologies. The main differences between the two main development methodologies are presented in Table 1.

Table 1. Difference between traditional development model and agile methodologies (adapted after [1])

|                     | Traditional                                                                 | Agile                                                                 |
|---------------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------|
| Fundamental Assumptions | Systems are fully specifiable, predictable, and can be built through meticulous and extensive planning. In automotive projects the planning of full implementation has its roots in production processes. | High-quality, adaptive software can be developed by small teams using the principles of continuous design improvement and testing based on rapid feedback and change. |
| Control | Process centric | People centric |
| Management Style | Command-and-control. Every sub-area of one automotive project has a leader whose responsibility is to plan, command and track the project. | Leadership-and-collaboration |
| Knowledge Management | Explicit | Tacit |
| Role Assignment | Individual—favours specialization | Self-organizing teams—encourages role interchangeability |
| Communication | Formal | Informal |
| Customer’s Role | Important, still in automotive projects some decisions are taken even if customer does not agree to them. | Critical |
| Project Cycle | Guided by tasks or activities | Guided by product features |
| Development Model | Life cycle model (Waterfall, Spiral, or some variation). In automotive projects most often the V-cycle model is used. | The evolutionary-delivery model |
| Desired Organizational Form/Structure | Mechanistic (bureaucratic with high formalization) | Organic (flexible and participative encouraging cooperative social action) |
| Technology | No restriction. Particular to radio-navigation system projects, the object-oriented technology is used. | Favours technology object-oriented |
| Acceptance of changes | Rigid, requirement changes are hard to implement | Flexible, easy to implement changed or new requirements |

The use of traditional development models in automotive projects is based mainly by historical car manufacturing reasons. The automotive software projects appeared on a later time than production
processes. The inexistence of software processes pushed the project leaders to use production processes, which are based mainly on the V-cycle model.

In comparison with automotive traditional development models, the automotive peripheral components are developed using agile methodologies. According to literature the most popular agile methodologies used are:
- SCRUM;
- Extreme Programming;
- Crystal;
- ASD (Adaptive Software Development).

3. Change management methods applied in automotive projects

During our research we found several papers regarding change management. There are some opinions on requirement changes during project development. For example Muhammad Nabeel Mirza et al. [2] said that a requirements should not change during project development, while De Bakker et al. [3] affirmed that initial requirements will certainly change. From our practice experience and also according to Milosevic D. and Patanakul P. [4], citing Eisenhardt [5], said that a fast developing environment abounds in fast requirements changes.

The main reason for requirement changes are:
- Changing technologies during project development. “The life cycle of products does not respect anymore the profile of the classic curve, this curve turned in the profile of a saw tooth. Before ending the phase of introducing the product on the market, the product is considered already outdated” [6];
- Unclear specification [7];
- Incomplete specification [7];
- “New requirements due to must have changes to satisfy the (strong) demand of market to ensure the later commercial success” [8];
- Improvement for robust design. [8];
- Project has a big temporal pressure [9];
- Project client does not want to inform all project details in the early phases of the project [9];
- Developing an innovative and complex system for the first time [9].

While changes will certainly occur during project development and organization of changes needs to be done, the practice taught us that change management processes need to be used. It has to be distinguished at this point between change management - and error tracking processes as “the tracking of errors is a separate process, with the objective” [10] “to ensure that all discovered problems are identified, analysed, managed and controlled to resolution” [9]. The purpose of the change request management process is to ensure that change requests are managed, tracked and controlled” [9]:
- “Managing the approved changes when and as they occur, by regulating the flow of requested changes” [11];
- “Controlling and updating the scope, cost, budget, schedule and quality requirements based upon approved changes, by coordinating changes across the entire project” [12].

The decision to implement a change request is taken mostly depending on the following factors [7]:
- “Market significance”;
- “Number of lines of code which has to be modified”;
- “Number of modules which have to be adapted in order to implement the change”;
- “Time required for complete change request until final system validation”.

Beside controlling and documenting changes, the change management process has the role to minimize project risk. Taking into consideration the tight project schedule of automotive project, the later the changes appears into the project, the greater will be the implementation risk. Particular to the automotive industry, the objective of change management process “is to establish and sustain a relationship with the stakeholders, to support all with up-to-date information such as the RfC (Request
for Change) transition status (i.e. reject, planned, implemented) and impacts to the initial agreed objectives, which are features, budget, schedule and quality” [8].  

Volker et al. [12] described the change management process applied in automotive projects according to Figure 2. The same way the effects of changed requirements have been described by Prostean and Volker [8]. By changing requirements the whole project structure is “under attack”.

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.

First of all, the project timeline is endangered and automatically the risk of overtaking project budget increases with every changed requirement. In the practice of automotive projects not holding project milestone can have an immense impact on one company’s business. The risk grows even more by delaying the market entry of the product which can lead to the loss of market shares, as the product does not fulfil the innovation characteristic. For this reason before starting the change management process, the project responsible have to estimate the number of change requests which can be implemented by current project team and structure (Figure 1).
As team capacity is essential in reaching project goals, the authors tried to find solutions to protect the team capacity workload. The authors observed in their practical experience that a project cannot be successful if the team capacity is overwhelmed for a long period of time. Figure 3 presents the impact of RfCs (Request for Change) on team capacity during project development.

Figure 2. Automotive Change Management Process [12]
4. Improvement of team capacity by applying agile methodologies

While the most automotive project are struggling keeping initial project planning, we identified a way to reduce team capacity workload by keeping the same amount of requirements. As automotive products have to preserve fix delivery dates to production, the first condition is to keep the actual structure of models used. As the greatest challenge is the fast evolution of requirements which tend to become obsolete [13], [14] the authors recognized the solution with respect to the project constraints:

- Keep the structure of traditional v-cycle model;
- Other methods like e.g. Goldratts Critical Chain [15] does not bring the required improvement.

Based on the V-cycle model the authors changed the essential phases of the traditional model with agile methodologies. The objective is to reduce the implementation of unnecessary software. The phases changed in the traditional V-cycle development model are:

- Requirement specification;
- System specification;
- Architectural design;
- Implementation.

The agile methodologies used in the new development model are:

- ASD (Adaptive Software Development), the collaboration phase;
- SCRUM.

The main advantages of using agile methodologies in the phase of requirement-, system specification and architectural design are:

- All requirements are matched with customer wish;
- The architecture is build change tolerant;
- All requirements are implemented following a priority list agreed with the customer;
- Better collaboration between project teams and between customer and project supplier;
- Better customer monitoring on current project status by participation on the SCRUM sprint reviews [16];
- Better possibility to predict and prioritize which requirements have to be implemented first.

![Figure 3. Team Capacity compared to RfC-input (adapted after [8])](image-url)
5. Discussion on integration of agile methodologies into traditional development models

The new resulted development model brings several advantages with it. Still the new development model has to prove his usefulness by removing the disadvantage of traditional models and solving the defined problem. In this particular case, the issue followed was the protection of team capacity while the project is confronted with a lot of requirement changes. The way of verifying models effectiveness is to compare the performance with regard to team capacity of the v-cycle model and the integrated agile model.

We decided to use this two models in two different projects and analyze the impact of changed requirements on team capacity. The first validation phase of the model was the evaluation of the first two specification phases (Figure 5). We compared every sub-phase and noticed that the project running with the integrated agile methodology managed to save 20.7% of time. By involving the client in the phase of specification, the project team saved time in the sub-phase of requirement analyzation. It is a known practice method that while using agile methodology the requirement phase is accompanied by supplier and customer. The savings arise mostly from the sub-phase of requirement analysis, requirement review and requirement adaption as a result of requirement review.

Our result was confirmed also by literature review, where savings have been measured between 15% [17] and 75% [18].
In the next phase we compared the phases of architectural design (Figure 6). Even if according to our measurements applying agile methodologies did not save time, we faced the advantage of building a change tolerant architecture which allows future requirement changes.

![Figure 6. Comparison of architectural design phase (only ASD circle from [19])](image)

Most important and time consuming phase in the development of project is the implementation phase. While being in the construction phase of the project, the implementation order of requirements in V-cycle model projects where not determined by strategic grow of the project. On the other hand, while using the SCRUM methodology the prediction of risk of change played a major role for the future development of the project (Figure 7). By implementing at first the requirements with a low risk of change, the amount of scrap software was reduced to the minimum. Another reason for time saving was the agreed requirement implementation with customer and less task interruption. This kind of approach allowed project team to estimate an improvement of capacity by 20%. As in automotive projects the time allocated for the implementation phase is fixed, the time saving is used for the implementation of changed specification.

![Figure 7. Comparison of implementation phase [21]](image)
6. Conclusion
Our practical experience in project management using traditional development models and expertize on critical issues led us to this study. We observed in the past few years a continuous change of automotive projects environment and integration of even more peripheral components with different lifecycles and development models used. Additionally these differences bring with them a continually increasing amount of requirement changes in automotive projects. Car manufacturer projects are not intended to support a lot of requirement changes, not only due to the high quality or lifetime endurance standards and expectations of customers. Every requirement change brings a high pressure on team capacity, this being the reason for changing the project approach and integrating agile methodologies into automotive projects. Main advantages of using agile methodologies are:

- Project time savings;
- Financial savings due to time savings;
- Team capacity improvements and better project disposition due to precise requirements and less scrap software implementation.

Further work should handle all sub-phases of the traditional v-cycle model and try to establish and integrate new methodologies in order to achieve specific project objectives.

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