

EARLY PHASE PROJECT MATURITY CONTROLLING OF INNOVATIVE SYSTEMS IN THE AUTOMOTIVE INDUSTRY

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ABSTRACT

The development process of innovative systems, especially in the very early phase, is characterized by high uncertainty and still lacks harmonized methods and criteria for project evaluation and maturity controlling [1]. In particular, the very dynamic development process of innovative systems needs an efficient integration of project maturity controlling, objective controlling, knowledge transfer and decision processes. As a result of relatively short development cycles in the automotive industry, development staff hardly has the opportunity to learn from and to refine the development process. To find a remedy, a customized knowledge management system and a knowledge transfer process are necessary [2]. To cope with the increasing number of cross-organisational and cooperative development projects maturity is used as a controlling parameter, a project performance indicator and an input for risk assessment. At the project decision points, maturity reporting is used for decision support. This paper discloses an iterative project maturity controlling process for innovative early phase projects on the basis of a refined stage-gate process [3]. The maturity controlling method has been put into practice in form of a pilot on 39 early phase automotive projects. User acceptance and process advancement determine that the maturity controlling should proceed and allow further refinement of the practical implementation of the method.

Keywords: Innovation process, early phase, project maturity controlling, knowledge management, automotive industry, multi-project management

1 INTRODUCTION AND PROBLEM DEFINITION

The automotive industry faces a steadily increasing number of car models and derivatives. At the same time these derivatives come to market in shorter intervals. As life cycles shorten and the technological and competitive environment becomes tougher, there is special interest on converting new technologies into innovative products and processes quickly with high quality and in a way that customer needs are met.

A study by Koen et al. identified the early phase to play a key role in the product development process for large numbers of really new products introduced each year [4]. An extensive empirical study showed, that "greatest differences between winners and losers were found in the quality of execution of pre-development activities" [5]. Consequently high failure rates have often been related to insufficiencies at the early phase of product development.

At the early phase of product development quality, costs and schedules are mostly defined. The effort to optimize project outcome is low and effects on the whole innovation process may be disproportionately high. Figure 1 shows the typical characteristics of the early phase. The degree of freedom in design and influence in project outcome are high, whereas costs of changes are comparatively low. This early phase advantage is limited by the fact that the amount and quality of information is low compared to the later stages.

A focal point of the early phase project controlling is therefore the optimization of the information transfer from former project outcomes to the upcoming projects. As idea generation and concept

development are typical tasks of the early phase, there has to be sufficient room for creativity. Also, there is the need to systemize activities to enhance the efficiency of the pre-development activities.

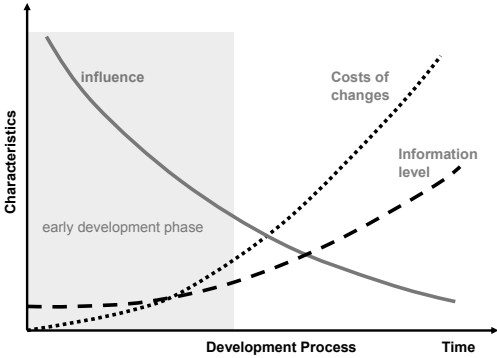


Figure 1. Characteristics of the “Early Phase” [4]

With the early phase project maturity controlling (PMC) an integrative approach to control the pre-development phase of technology-based industries is proposed. The objective of the early phase PMC is to provide an overview of the maturity of the innovation pipeline and to optimize resource allocation to the projects at a multi-project controlling level. On the single project controlling level, the maturity information is used to synchronize development with upcoming vehicle projects, to provide an organizational learning framework, to improve product development, to provide a framework of project goals and milestones, and to increase the integration possibilities. These benefits allow an increase in the transfer rate.

2 DEFINITION AND DIFFERENTIATION

The term “early phase” is used to describe the development range from the generation of an idea to either its approval for series development or its termination [6]. The underlying development process is split into the vehicle development process and the development process of innovative systems and components as charted in Figure 2. In this paper the early phase period starts with the pre-development of vehicle components and ends with the concept phase of the vehicle project.

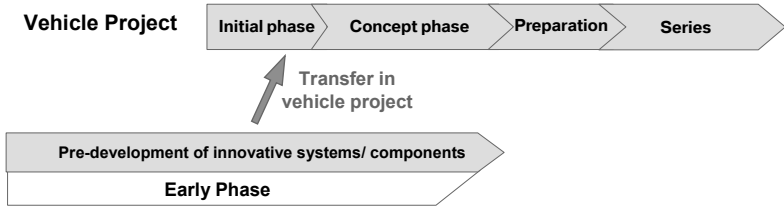


Figure 2. Development Process Synchronization

The upwards-pointing arrow indicates the transfer of the pre-developed components to an upcoming vehicle project. The new technologies or functionalities need to be mature enough to give evidence about the realization probability, cost and quality. The decision of further development activities or project hold/ kill is made at this point.

In the literature several terms for the description of the “early phase” are used, e.g. “pre-development” [5] “pre-project activities” [7], “fuzzy front end” and “pre-phase 0” [8]. In this paper the terms “early phase” and “pre-development” are used since this jargon has been widely established in the development process of the automotive industry.

A project is defined in DIN 69901 as a plan which is characterized through the singleness of the conditions. These conditions imply aims, limitations including those of a temporal, monetary, and personal nature, and the separation from other intentions and project specific organisations [9].

Projects discussed in this paper are used to gather information about undiscovered or new technologies or to develop new functionalities for vehicles. Project maturity implies therefore all intra- and extra-organizational efforts that lead to a successful completion of the target settings within all boundary conditions.

Different from the term project, maturity is not defined consistently in the literature from a technical point of view. Therefore, there is the need to clearly define and differentiate the meaning of the term “project maturity”. As a basis, maturity is described as the completion of development [10]. Derived from this statement the claim of a maturation stage is to create transparency of the project progress [11]. The degree of maturity is coupled with the achievement of specifically defined project goals – a defined final state [12], [13]. If a defined final state is reached, the reference maturity is reached. The whole complexity of a project is represented in the maturity indicators.

The term maturity can be seen as a state as well as a process value (see Figure 3). The degree of maturity is coupled with the achievement of predefined project goals, thus a defined final state [12], [13]. The reference maturity is reached, if the predefined final state is reached. In the case of maturity seen as a state value, the final state varies with the milestones. The progression of the project maturity is in this case not identical to the project progress. When the term maturity is used as a process value, it represents the gradual approach to predefined final project goals. This can be seen as the onward project progress [13].

The different characterisation of project maturity leads to two different visualizations [14]. If defined as a process value, project maturity takes the course of the project progress. The project progress takes a course of progressive or declining slopes which start at 0 percent at the beginning of the project until it finally approaches asymptotically to a maturity of 100 percent (see Figure 3). The maturity criteria remain the same during the project duration. The degree of fulfilment of these criteria steadily rises.

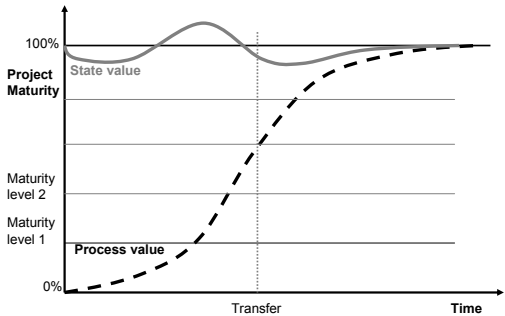


Figure 3. Maturity as a state and process value [according to 14]

If - in contrast to the project progress - the measurement criteria constantly change during the project progress, the project maturity is seen as a state. The maturity remains in the optimal case over the whole project duration at a horizontal line of 100 percent. The reporting is at all times measured against the 100 percent reference maturity. This means that the reporting is done in reference to the actual valid maturity criteria. The reported measure is therefore the amount of actual valid reference criteria already reached. This type of reporting makes it difficult to compare the overall maturity of a project, since the maturity is only significant in the context of the actual project phase and therefore the actual criteria set.

In the following, the maturity should be seen as a process value which is measured, traced and used as a controlling input. In contrast to the above drafted maturity measurement with high level overall project criteria, the criteria vary among maturity levels. The degree of maturity is reported in each maturity stage from 0% to 100%. When monitoring a single project, the maturity fulfilment in relation to the maturity goal is reported. In multi-project controlling, the maturity stage measurement is reported. This maturity overview is used for the synchronization of the two development processes and for the innovation roadmap.

Considering the above definitions of project and maturity, project maturity can be seen as the maturity in respect to the aimed success of the project goals' quality, cost, time, and recognized customer benefit. The project maturity strives for the correct, high quality product, developed for an existing customer and is producible with costs the customer will pay. The dimensions of function and customer benefit can be measured in maturity, whereas the dimensions of time and cost are controlling values within the project controlling.

The product maturity degree shows the degree of fulfilment of the product requirements [11]. In other words, the attributes of a product will be judged on the basis of predefined criteria. This assessment allows a concrete statement about the technical maturity and therefore the description of the functional requirements of a product [15] at any time of the development process. Besides the technical maturity indicators, criteria are included which assure the market or customer need, reflect the costs in context to the market and synchronize the development with the upcoming car series production programs.

The project controlling helps the project management with project planning and project monitoring and with the distribution of (cross organisational) information [16] in order to steer the project towards success. Therefore project maturity controlling can be defined as the controlling of the product maturity to provide the right high quality product for a real existing customer at the right time, which is producible with costs the customer will pay. Controlling includes the project planning, monitoring and steering in a multi project environment. Maturity controlling includes feasibility of the project and readiness for management decisions through its maturity criteria. This ensures clarification and risk reduction in the early phase development process and thus higher development efficiency.

3 STATE-OF-THE-ART

3.1 State-of-the-art of science

Most approaches to maturity measurement that are found in the literature pertain to the software industry where they explicitly refer to the control of coding quality. The necessity for a systematic maturity assessment is mentioned explicitly, but possible implementations are only sketched rudimentarily.

The most widely known concept for the maturity tracing is the "Capability Maturity Model" (CMM) of the Software Engineering Institute (SEI) of the Carnegie Mellon University [17]. Derived from the CMM is the more generalized project management approach, the "Project Management Maturity Model" (PMMM) [18]. The PMMM is a method to describe the process maturity. It depicts the development process itself and a company's ability to develop a product. The product itself is not considered at all by this method.

Another model to measure the degree of maturity, again from the software side, is the "business intelligence Maturity Model" (biMM), which is closely related to the CMM. The biMM treats the product in three main dimensions - business content, technology and organisational impact [19]. These three main dimensions are split into 94 sub-criteria. It only considers the end version of a (software) product and mostly disregards the development process with its different development steps.

A similar assessment can be made for the established method from Deelmann and Loss from the e-Business sector. The maturity indicators judge the maturity of solutions based on different views in a company (organizational view, data view, function view, performance view and the external view). Again, the development process is not integrated well and therefore for an early maturity assessment in the automotive industry not practical.

Fischer [20] proposes a method that derives maturity indicators from the specification, but he associates these specifications with the layer of the vehicle as a whole and does not separate them or break them down into their components. The chosen criteria are weighted to produce a single indicator that refers to the overall project. The evaluation and reporting is done in a predefined cycle (e.g. monthly) where the indicators are aggregated by their weights. The project progress is depicted in a diagram and prognoses for the project end are derived from prior project data.

Another academic effort to this issue is from Pfeifer [11]. His method represents, like Fischer's method, only the overall project layer with no further details. But he distinguishes between different kinds of maturity like economic-, time- or product maturity. Like in Fischer's method the indicators are valid for the overall project, and the group indicators are then split into single criteria for each

group indicator. The group indicators and the sub-criteria are weighted to indicate the influence in respect to the project.

A very adequate method is published by Wissler [13], who focuses on the requirements of plant engineering and construction. The product is split into components but the level of detail is not explicitly mentioned. After the selection of success critical components, the main indicators are defined (functionality, quality, costs...), which are derived from the product specification. Then the main indicators are split in sub-indicators (e.g. quality in FMEA-execution, safeguard analyses ...). The evaluation of the indicators is performed at predefined dates by an expert team and modelled on the basis of a traffic light measurement system. Depending on the evaluation, actions are discussed and adopted to correct the possible deviations. For the reporting, the aggregated single indicator evaluations are presented together with the suggested actions. This method leads to a higher transparency of the development progress and uses expert knowledge. The method works for the entire product development process (PDP).

Weinzierl introduced the broadest approach [14], which consists of a holistic maturity measurement system for vehicle projects in the automotive industry. The emphasis is on transparency of maturity management throughout the whole development process with the goal to minimize time consuming and expensive development loops in the series production. This method is designed for maturity controlling of the operative product ramp up. The front-loading idea with problem solving far ahead of the actual ramp up can be implemented with this method. But as yet, the method starts only after the pre-development activities.

There are several methods that deal with the later phases of the PDP to optimize the operative ramp up management. An example is described by Gentner [21], who has created development performance indicators to optimize product planning and steering in respect to cost, time and performance. He addresses the interfaces between series development and series production and suggests performance indicators to describe this changeover.

More methods can be found in the literature under the headings of logistics and time-to-market management. They mention maturity explicitly as an important steering value, but introduce no approaches for measurement.

3.2 State-of-the-art of technology

Mostly companies from the automotive industry have maturity-based project management set into practice. A driver for this method is the high efficiency potential, which is seen in the interface between supplier and OEM as well as in the development process [14].

An example is the Mercedes Car Group, which put the method from Fischer into practice [20].

VW tracks the product maturity with software called RGS-Online. The maturity is measured with a set of predefined criteria and reporting occurs at given quality gates [14]. Again, experts judge the maturity.

The company Magna Steyr monitors the maturity from their suppliers on the bases of check-lists at defined report cycles. The supplier and the customer agree on common criteria, which are then used to report the maturity.

All these methods have in common that they represent the overall project from the project management view and deliver decision support in terms of a report system [14].

The new maturity safeguard guideline for new component development from the German car manufacturer association (VDA) was released in November 2006. Throughout the PDP, maturity milestones are defined that contain maturity indicators and responsibilities. The maturity controlling process is driven from the quality department of the VDA and is used only for new product development. The criteria become more detailed with rising maturity. A focus is on the interaction with the suppliers [22].

4 TARGETS AND DEFINITION OF THE TASK

All methods, presented in the literature as well as those implemented in practice, address the maturity in the actual development process and not in the early project phase or pre-development. Therefore, the problem with high project failure rates is not addressed in new product development.

As the most innovative systems in the automotive industry are developed in form of a project, accurate project planning can significantly increase the effectiveness and efficiency of a pre-development project. Several studies point out the importance of project planning. A key element of project planning is the determination of goals [1]. These project goals are called milestones when tied to a specific completion date [1]. The maturity controlling method provides commonly agreed milestones for the project planning.

A special challenge in this early development phase is to keep the balance of freedom for creative and playful development to endorse innovative products with efficient development and the hard constraints in the automotive industry that ensure a possible transfer to the series development process. The challenge of the early phase is to give as much guidance as possible, yet facilitate a creative development environment and to push the projects from a fuzzy, dynamic, iterative creation process to a controlled development that prepares the projects to meet the hard quality and integration requirements of the series development process in the automotive industry.

Often the development of innovative components happens outside the standard (series) development process. In this setup, it is important to synchronize the two development processes to be able to transfer the projects from the pre-development into the standard development process. Therefore a function of the maturity controlling in the early phase is to manage a smooth changeover from the creative concept phase to the requirements-driven integration process in series development.

5 PROJECT MATURITY CONTROLLING

In the preceding sections, the need of an integrated maturity control and the deficits of current maturity measuring systems were pointed out. For that purpose project maturity controlling on the basis of maturity indicators to each maturity stage has been developed and a measurement method and reporting process have been created.

5.1 Requirements

Maturity criteria have to meet the following requirements to be a valuable maturity indicator. They have to be objective [14], non-ambiguous, complete, early indicating project goal deviations and deduction of response actions and economic maintainable [23].

During the realization process, practical requirements to raise the acceptance of the maturity controlling system were acquired. Since the VDA launched the maturity safeguard system at the end of 2006, compatibility with maturity controlling for the subsequent development phases has to be guaranteed. Innovation projects are characterised by high diversity and that future project matters are not predictable. Many different interest groups launch projects in this phase. A mapping of the requirements to these different interest groups is necessary to cover the full range of project types. The contents in the maturity controlling system must be traceable and responsibility must be allocatable. In other words, the execution of the maturity criteria must be controllable. The system is not meant to work as a stiff bureaucratic checklist to kill tricky projects. It is meant as a decision support system and to depict the ideal innovation process derived from what was learned in former successful projects.

5.2 Maturity Controlling Process

Maturity controlling is based on the following principals. An early phase product development project runs through five maturity levels until finally transferred into a vehicle project (see Figure 5).



Figure 5. Maturity level of the pre-development process.

A project normally starts at maturity stage 0 and obtains successive maturity stages by processing the maturity indicators. An example of a maturity indicator would be “the test specification is finished and reconciled in the steering board”. There are no global time guidelines. The maturity stages get tied to a date for each specific project. This process enables a flexible milestone and maturity planning for projects with different development speed. The maturity stages are shortly described in the following:

- **Maturity stage 0 „Idea Description“:** All project suggestions which are not examined sufficiently regarding the feasibility and suitability for the automotive industry.
- **Maturity Stage 1 „Pre-development Maturity“ (demonstrate feasibility):** The checklist for maturity stage 1 contains those criteria that must be fulfilled in order to receive the appropriate resources for the pre-development activities. The focus is on the fundamental technological economic feasibility on the generated customer use (also internal) and its marketing potential and on a plausible, challenging project planning and target agreement.
- **Maturity stage 2 „Proof of feasibility - qualitative“:** Alignment with the demanded requirements is completed for the focused, customer-oriented development.
- **Maturity stage 3 „Transfer maturity“ (Proof of feasibility - quantitative):** The questionnaire contains the goals that a project should reach to start the transfer into the vehicle project. For example, these can be quantified statements about electrical system loads, durability, changes in road performance, cost per unit estimation, etc.
- **Maturity stage 4 „Concept maturity“:** This maturity stage indicates a quantitative business plan with all business plan requirements. The business plan contains criteria to assess the economic and technological sustainability of the concept and consolidates risk estimations of the different releasing departments.
- **Maturity stage 5 „Integration maturity“:** The integration maturity is the last maturity stage of the early development phase. The main focus is the cost efficient and technological feasible integration of the innovation into the target vehicle under all hard automotive constraints.

A maturity level is defined through its maturity indicators. Therefore, each maturity level has a list with criteria which have to be met in order to reach the next maturity level - a checklist for the project manager. The maturity indicators can be seen as milestones in the project plan and are the key to a successful maturity controlling system. Therefore, the following lines draw special attention to the maturity indicator system.

As stated above, the early phase is a very dynamic and agile, yet creative development phase. Some critics even say that standardization should be excluded from this phase. However, when the research and exploration phase is over, the gap between having fancy ideas and efficient, cost saving realization has to be overcome. It is foolish to believe that one could set criteria in this dynamic process once and cover all new projects with this initial criteria set. Therefore, a learning system has to be established where the experiences from former projects are used to refine criteria that will become available to all upcoming project managers.

Pre-development projects may have different level of novelty [1]. The degree of uncertainty depends on the level of novelty and therefore different controlling approaches have to be applied. In general a high degree of novelty (cp. radical innovations) requires loose controlling to induce a creative environment. Incremental innovations such as product advancements can be controlled in a much more structured way [1]. For this reason all projects will be grouped based on the novelty so that the right controlling style may be applied. Novelty means, “New to the industry sector (branch)” – in this case the automotive industry. The two project groups that we consider are the radical innovations or projects with high uncertainty on the one hand and the incremental innovations or new products with a calculable risk on the other hand (see Figure 6). In the case of radical innovation, the emphasis is on gathering as much information as possible and therefore good knowledge management is very important. For incremental innovation, the emphasis is on getting it “right the first time”!

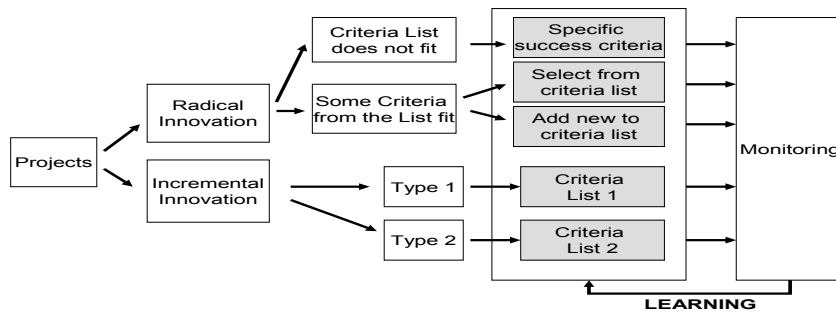


Figure 6. Classification of the projects and learning cycle

Since projects in the automotive industry are very different in their characteristics and project goals (cp. a pure software project compared with the development of a new combustion process in the engine), they will be clustered in correspond to comparable maturity indicators. In each project cluster the maturity criteria are the same. In Figure 6 two project types are depicted as an example.

The criteria for projects with high uncertainty pose special challenges, and a special approach is warranted. First the criteria list is checked if it fits a specific project, if not, an individualized target system is created. Later in this process, the criteria will be checked if they are of interest to other projects as well. If so, they will be added to the criteria list. If even only some of the project maturity indicators meet the project requirements, then this set is used to generate as much commonality with other projects as possible.

Controlling complex products requires a huge amount of maturity indicators to be a helpful guide for the project members. To reduce the complexity for low risk and low budget projects, a hierarchic maturity indicator system has been created. The project designers have to carefully balance the quality benefits against the administrative effort to keep this system up to date and thus the resources (costs) and assistance. The goal is to keep the steering intensity in the optimal zone [1].

At this point, the maturity indicators are aggregated on three hierarchic levels. The degree of detail rises from level 1 through level 3. Level 1 contains the high-level maturity indicators. These high-level indicators are the main success factors and constitute an abstract of the indicators. Level 2 indicators particularize the main maturity indicators in a way a project leader can use them to plan and control the project. The level 3 indicators are component, or department-specific, and draw attention to component specific challenges. Different interest groups need the information in a specific level of detail which can be represented through the hierarchies.

To calculate a maturity index and determine the maturity stage an aggregation algorithm will be introduced. Before this is done, the two project views are recalled. There is the project view to control the maturity and generate a target system for the early phase, and second there is the multi-project view where the overall project maturity of the innovation pipeline is of interest.

Therefore, two maturity measurements are implemented. The first measurement reflects the project's maturity stage and the second measurement reflects the extent of fulfilment of the referenced criteria in each maturity level. The latter measure is termed the maturity index.

In a normal project progression, a project finalizes all maturity criteria of a maturity stage and then reaches the next stage. The project aims are the maturity indicators of the actual stage. Since pre-development is not predictable and other project influences like e.g. unavailable test benches may occur, a flexible maturity measurement system is needed.

Before the maturity measurement is explained in more detail, the differences of the maturity indicators itself has to be explained. Some maturity indicators are unique to its maturity level (e.g. customer's input has to be gathered mostly at the beginning of a project) and some are constituents of each other (e.g. first risks have to be analysed and than fall back solutions can be worked out for the determined risks). So if a maturity indicator that is a constituent of a higher maturity level has been skipped but is finalized in the higher maturity level than all indicators in the lower level are automatically achieved

as well. But a maturity criterion that is unique gets assigned to the reference of the next maturity level. If a criterion of this kind is not evaluated at all, it leads to a maturity index below 100 %.

In each maturity stage a maturity index of 100% can be achieved. The maturity index is calculated through the degree of the fulfilment of the maturity indicators. Each maturity indicator has a specific weight relative to its importance. Generally, only the most important indicators are used in this system. But most experts believe that not all maturity indicators are equally important and therefore, the maturity measurement would be inaccurate. Another reason for using indicator weights is the possibility of maturity indicators controlling the development activities in the multi-project setup. A high weight signals importance and will be most likely processed at a higher priority. This is discussed in more detail later. The weight over all maturity indicators is standardized to 1. This standardization is necessary because in the hierarchical system the weightings must have the same total at each of the three levels. The algorithm to calculate the maturity is:

$$w_{I,MS,HL} = \frac{W_{I,MS,HL}}{\sum W_{I,MS,HL}} \quad (1)$$

$$MI_{MS} = \frac{\sum w_{I,MS,HL} \cdot P_{I,MS,HL}}{N_{I,MS}} \quad (2)$$

The relative weight (w) from an indicator (I) from a maturity stage (MS) and a hierarchy level (HL) is the weight divided by the sum of all weights in this hierarchy level. The maturity index then is the sum of the relative weight of a maturity indicator multiplied by the performance (P) of that indicator divided by the number (N) of the maturity indicators of that maturity stage. The performance is measured through a traffic light rating where red indicates that no action has taken place yet to fulfil this maturity indicator. Yellow states that the work has started but is not yet completed. And finally, green signals the criteria requirements are fully met. This representation was selected due to the confidence and acceptance that it enjoys within the enterprise. For the calculation the three states are coded so that green is 1, yellow is 0.5 and red is 0. A maturity stage is reached, if all maturity indicators of this stage are processed successfully.

At project start the maturity controlling intensity is fixed. The controlling intensity is dependent on the indicator hierarchy level. With higher indicator levels, the intensity rises. If there is discordance about the fulfilment of a maturity criterion, the criteria from lower levels are consulted or elevated to clarify. The criteria from all hierarchy levels are accessible to the project members to provide as much guidance and organizational learning as possible. The monitoring and reporting is based on the determined hierarchy level.

The maturity levels themselves get more detailed as maturity rises. So in the beginning of a project the team can work with less constraint in a creative environment. The more the project matures, the more maturity indicators have to be fulfilled and the indicators become more concrete.

All projects start at maturity level zero. There are no global time standards for reaching the next maturity level. This is determined project by project. Some projects go very fast through the maturity levels, some need years. The synchronisation with the vehicle series development is the focus when assigning the maturity milestones and sub-milestones.

6 EVALUATION

The maturity controlling method has been tested in 39 pre-development projects of a German automobile manufacturer. The projects varied from technology scoping to software and controller development, to the development of new components or systems, with crossed organisational teams. The budgets were from 100 to 7.000 T-Euros. The team sizes ranged from one person to 34 project members. 15 projects aimed for new functions/systems in the car, 11 projects were for concept development, 6 projects were studies, method development or configuration projects and 7 projects could not be allocated in the above named groups, since they dealt with special topics. Within the

company, the projects were distributed over different departments: 10 projects from the motor division, 19 projects from the vehicle concept department, 5 projects from the electronic department, 2 projects from the chassis department and 3 projects that dealt with the car body.

The maturity stage 3 was used as a test maturity level. A criteria list has been developed through an expert survey involving all departments that participated in the development process. The criteria were condensed to a list of 28 and a final reconciliation with all departments was accomplished.

Experts rated these projects between maturity stages one and four. This means successful projects in level 4 should have fulfilled all stage 3 maturity criteria where as projects in maturity stage 1 and 2 would be overstrained with the given criteria.

The criteria had been presented through an online-survey software tool, which was modified for the maturity measurement. Each project leader got a personalized link via email, which granted access to the online maturity survey. The answers were stored in a central database and could be accessed by the project members through the personalized link any time up to a final date, which was shortly before a personal project review in form of an interview. The interviews for all 39 projects took place over three successive days.

Each criterion could be labelled in four different ways. As described above, these are the three traffic light colours red, yellow and green and a fourth possibility “not relevant”. The “not relevant” category is used to filter out criteria, which are not suitable for a specific project type. In this setup there was only one criteria list with no distinction between different project types. If a criterion is not relevant in the whole course of the project, it is set to not relevant (e.g. software code does not pneumatically interact with other systems in the car). This answer had to be carefully reviewed, since some project members misunderstood the answer as “not actually planned”. As an effect the maturity index improved wrongly. The project answers were either corrected or excluded from the maturity analyses. The “not relevant” answers were later used to define different project groups for a better maturity indicator fit. The maturity index for the maturity stage 3 had been calculated with formulas (1) and (2) with equal weight for all criteria.

The survey contained a second part, where questions about the maturity measuring system itself were asked. Here the user could judge the system in different categories for acceptance or rejection. Fields for comments provided users the opportunity to make suggestions for improvement, write about mistaken verbalizations and express displeasure or encouragement. The main categories of this second part of the survey are the needed time for the maturity evaluation, helpfulness and implementation aspects, innovation degree and the overall personal opinion to the maturity controlling process.

7 RESULTS

Table 1 shows the outcomes of the maturity measurement. In the columns the pre-development projects got grouped according to the vehicle in which the project work will be implemented. The numbers in brackets behind the vehicles indicate the number of projects. Start of series development progresses from vehicle 1 to vehicle 3. Projects for vehicle 1 are already finished and used as a reference for the criteria catalogue. The projects for vehicle 2 are straggling, which can be seen at the elapsed project time of only 51 %. Compared with the transfer synchronisation point of the vehicle project, the projects should be at least between 70 % and 80 % of the project duration. The projects for vehicle 3 should be around maturity stage 3 and represent the projects which should be actually measured with the criteria set. The percentages express the degree of fulfilment of the criteria of maturity stage 3.

	Vehicle 1 (2)	Vehicle 2 (5)	Vehicle 3 (32)	Total (39)
Calculated Average in %	91%	71%	52%	57%
Estimated Average in %	90%	53%	45%	48%
Elapsed project time in % (basis: end of predevelopment)	100%	51%	52%	54%

Table 1. Maturity Measurement of 39 sample projects

In addition to the maturity criteria the project members and the steering committee estimated the maturity of the projects from an expert point of view (second row). This should provide a reference for the calculated maturity index.

On average it took the participants only approximately 3 minutes longer to answer the maturity criteria check list rather than filling up the old, individual system with project monitoring information. Through standardized reporting, projects can be compared easily. In the old system with free text documentation, each justification had to be read and interpreted by an expert.

The average over all answers for the question "Does the system help to communicate the requirements to a pre-development project more transparent?" was 4.09. The answer scale was from 1 = does not apply to 6 = very well. The more maturity criteria that could be set to green, this means projects with maturity stage 3 or more, the better the evaluation turned out. The evaluation measure got up to an average of 4.67 for all projects with a maturity index over 70 %.

For the question about the value of the maturity controlling concept itself, the answers had an average of 4.0 over all projects and 4.5 for projects with a maturity index over 50 %. The answer scale was the same as described above.

These results and the comments from the test participants lead to the conclusion that the maturity criteria fit their maturity stages, were accepted by the project members, provided guidance, and drew the attention to key challenges in new product development. Improvement is still necessary to cover strongly networked projects with much interdependence. In this case different project members need to evaluate the maturity criteria for their specific responsibility. A system that gives assistance for this networked evaluation has to be established.

8 CONCLUSION

The outcome of the pilot maturity measurement of maturity stage 3 consolidates the assumption that the proposed project maturity measurement provides the necessary results and will be accepted by the project members.

The maturity controlling system creates a common understanding of definitions and content. This understanding leads to higher information quality and facilitates cross-organisational comparability. For project success, important participants (marketing, production, development...) are involved early and major challenges can be solved in early stages where product changes are relatively inexpensive. The method leads to early uncovering of goal deviations and thus allows guiding the projects on the right track again. Therefore the project maturity controlling can be utilized as a management tool. The criteria can be used to draw special attention to development activities, e.g. more customer orientation. The system helps the alignment of different processes within a company through the criteria in each maturity stage (e.g. with a criterion like "Are all projects known in the patent department?"). Insights into general (integration) problems from former automotive projects are transferred through the maturity criteria to upcoming projects. The importance of systematic learning from past experience is supported by several studies, e.g. [7].

This Framework enables frontloading problem solving, which is defined as a "strategy that seeks to improve development performance by shifting the identification and solving of problems to earlier phases of a product development process" [24]. Here project-to-project knowledge transfer comes into effect. The automotive industry is called a "mature industry" in respect to its products. Hence most projects can be called incremental innovations where the system has its strength. The project-to-project learning and standardization has the best effect.

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