DEVELOPMENT OF AN EVALUATION FRAMEWORK FOR IMPLEMENTATION OF PARAMETIC ASSOCIATIVE METHODS IN AN INDUSTRIAL CONTEXT

Vahid Salehi, Chris McMahon
University of Bath, Bath, UK

ABSTRACT

This paper presents a study of the evaluation phase of a project that developed a new method to support parametric and associative computer-aided design, PARAMASS, in an automotive design context as an example of the systematic evaluation of new methods in design research. The evaluation employed qualitative and quantitative techniques to obtain the reaction of practising designers to the new method and to identify the time benefits of the application of the method in the design of automotive engines. The paper first presents a general overview of quantitative and qualitative methods, and describes systematic evaluation approaches in other domains especially software application. It then presents the evaluation of the PARAMASS approach using qualitative evaluation based on the Goal-Question-Metric approach, questionnaires and interviews of designers, and the qualitative evaluation based on the Use Case approach. Considerations in the planning and implementation of the evaluation procedures are presented.

Keywords: parametric associative design, method development, method evaluation, evaluation framework, goal-question-metric, use case approach

1 INTRODUCTION

Global competition forces automotive companies to develop vehicles in less time and to produce their products at low cost with high quality. To assist, different methods have been developed to support product development activities. In general, methods are systematic procedures that are intentionally applied in product development in order to improve the product development processes (PDPs) l [1]. A number of general methods such as Quality Function Deployment (QFD) [2], Failure Mode and Effects Analysis (FMEA) and Design of Experiments (DoE) [3] have achieved much interest and awareness in recent times as means to improve PDPs and the resulting products [3], and new methods are being developed all the time. Different industrial companies have integrated these approaches in their product development processes, but there exist varying views about the evaluation, benefits and implementation. The successful application of methods depends on different factors e.g. the amount and usage of the methods by the process participants. The evaluation of the impact of a new method is thus one of the most important and challenging parts of method implementation [1]. The significance of evaluation is addressed in several publications such as [4], [5] and [6]. To assess the impact of a method fundamentally means to determine the result and effect that the methods have or will have on the PDP. In general, the objectives of method evaluation can be for example greater satisfaction, shorter development times and in some cases reduced product development costs [6].

This paper describes the evaluation framework for a new method for parametric and associative computer-aided design (PA CAD) in an industrial context, as an example of the systematic evaluation of a new method. The method, called PARAMASS, builds on work previously presented by the authors which identified the industrial need for a new method and subsequently developed and tested the new method [7]. The next sections will first explain briefly the general aspects of quantitative and qualitative evaluation approaches and general approaches to evaluation before the results of the evaluation of PARAMASS are presented.

2 QUALITATIVE AND QUANTITATIVE EVALUATION

This section describes the important aspects and characteristics of qualitative and quantitative research studies. The main methods used for monitoring and evaluation come directly from other science research methods (e.g. social science) and can be divided into:

i) Qualitative methods, which include in-depth case studies, questionnaire surveys, rapid assessment, and participatory assessment [8]. The characteristics of a qualitative study are that (a) it generates 'working hypotheses' that can be further examined through quantitative research with specific pre-defined questions; (b) it can relate local to global performance (c) it explains and supports analysis of trends and patterns; and (d) it triangulates (verifies or refutes) results [8]. Furthermore, qualitative evaluation can be used to get information from those studied to gain their perspectives in words and other actions. Therefore, qualitative evaluation is an interactive process involving the researcher and those studied, to evaluate and understand their experiences and to learn about their feelings [9].

ii) Quantitative methods which produce numerical data in contrast to the textual data of qualitative research [9]. The key characteristics of quantitative approaches are [8]: a) control of the activities, to assist in enabling the scientist to identify the causes of observations, and in providing unambiguous answers to questions concerning relationships, cause and effect and so on; b) the operational definition of terms by the steps used to measure them (to eliminate confusion in meaning and communication); c) the importance of replicability in ensuring the reliability of results.

There is debate about the relative merits of qualitative and quantitative evaluation, and indeed there are strong advocates of each approach, especially coming from different research traditions [10]. The present work has sought to combine approaches, as advocated by Carvalho [11], while being aware of the comparative advantages of the two. In summary, quantitative methods produce data that can be aggregated and analysed to describe and predict relationships while qualitative research helps to probe and explain those relationships and to explain contextual differences. Carvalho's approach to combining the best of qualitative and quantitative approaches involves (1) integrating methodologies for better measurement, and (2) sequencing information [11].

3 GENERAL APPROACH OF METHOD EVALUATION

This section presents a summary of related approaches which have been developed for the evaluation of different kinds of software, tools and methods. Wigand tried to evaluate the indicators of implementing a "cost and performance measurement method", noting that relevant criteria in monetary and non-monetary terms are needed, focusing on inadequacies identified during method implementation process [12]. Aside from technology related cost and performance measures, a number of other effects like the organisation effects, qualification effects, human effects, and external effects need to be considered. According to Usher [13] the need for a company to be effective in selecting and applying measurements and criteria is critical. Measurements and criteria should be simple to determine, easily obtained, precisely defined, robust, and should appropriately evaluate the objectives and facilitate an understanding and prediction of the process [13]. But these aspects are also very challenging because the criteria are in some cases interrelated and therefore complex for the evaluation process [14]. Mittelmann [15] stated that for processes with a low level of structure and/or maturity, 'soft' criteria, which can be adapted to the situation, are much more appropriate than 'hard' measurements which can easily mislead. Another approach, presented by Reichwald [16], is the evaluation of information and communication methods and technologies based on the so called 'networked efficiency thinking'. The basis for evaluation in the final analysis of this approach is the extent of effectiveness. The concept of efficiency and effectiveness broadly corresponds to the concept of product development productivity proposed by Duffy [17]. In software development, an approach called the Goal/Question/Metric (GQM) is widely used for evaluating processes, especially for tailoring and integrating the objectives of an organisation into measurement goals and their refinement into measurable values. This approach was developed by [18] and successfully applied in industry by, amongst others, [19] and [20]. Fuggetta [20] reports that the application of the GQM approach offered improved data collection practices, better interpretation of the data and an enhanced motivation for data collection. The core element of the GQM approach is the GQM plan, which contains three parts [18]:

1. Goal: a goal describes the measurement purpose. This is described according to a template with five dimensions expressing the object of measurement, the purpose of measurement, the measured property

of the object, the subject of measurement (viewpoint) and the context and environment of the measurement.

2. Questions: a set of questions that refine the goal and characterize the object.

3. Metrics: a set of measurements associated with each question.

One of the biggest assets of the GQM approach is that it contains different levels which are interconnected with each other and therefore there is a clear target for every question. The approach can be used to describe the circumstances and boundaries in which the questions are created, and it is possible to describe what is the purpose of the question, what is going to be asked and who is involved. For these reasons the GQM approach was adopted in the work reported here to evaluate the PARAMASS method.

4. DEVELOPMENT OF THE EVALUATION FRAMEWORK

This section describes the framework used to evaluate the implementation of the PARAMASS method. The framework can be divided into two sections (see Figure 1). The first section describes the qualitative criteria which were based on the GQM approach. A questionnaire was used to evaluate usability aspects of PARAMASS such as learnability, applicability and satisfaction. The second section describes the quantitative evaluation criteria which were based on the Use Case approach (as will be explained in section 4.4). The quantitative indicators are characteristics of the application of PARAMASS which can be measured, for example, by the means of determining the time needed for performing a method step or measurement of time elapsed for tasks which have been defined in the Use Cases.

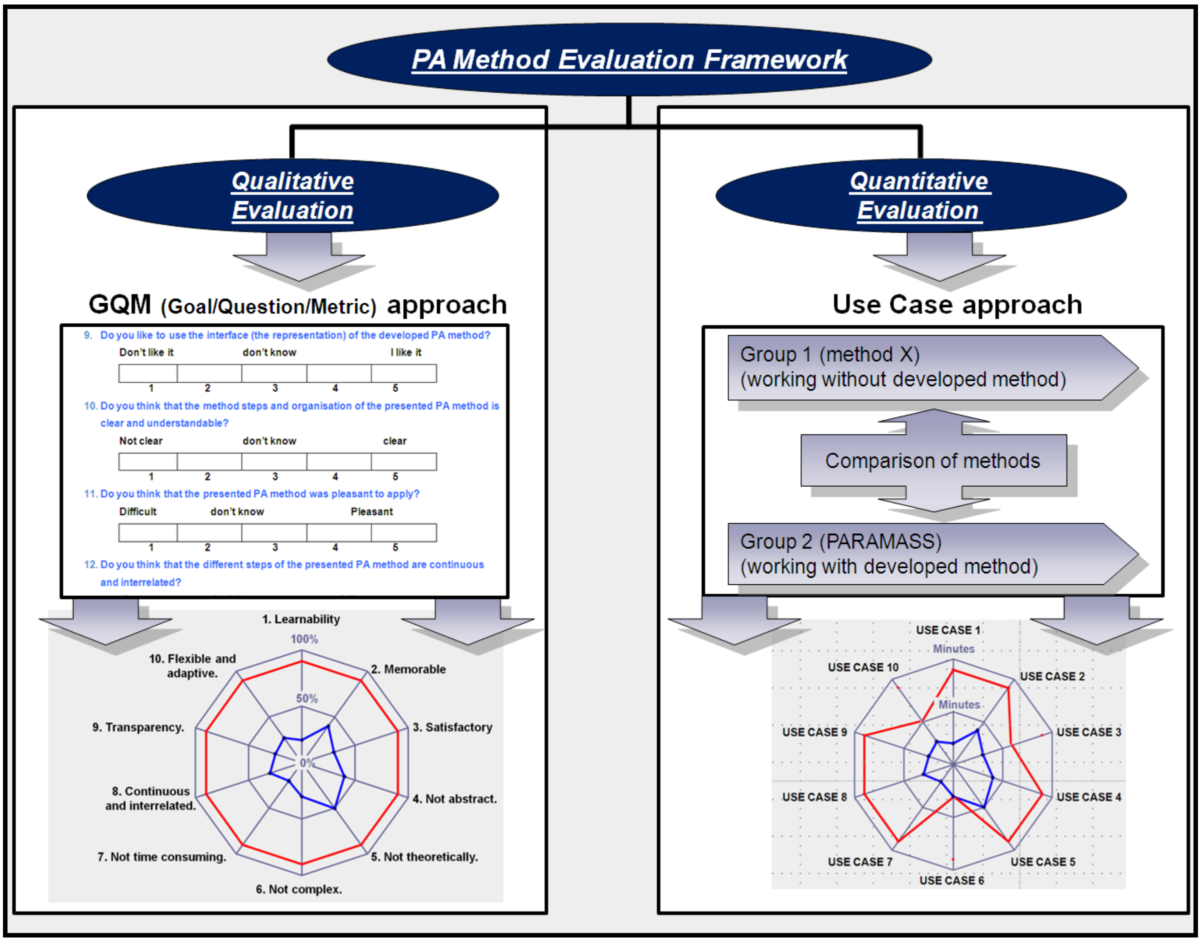


Figure 1: Evaluation framework of PA design methods

4.1 Qualitative evaluation of the PA approach from Usability aspects

Before starting to describe the qualitative aspects of the developed evaluation framework it is important to explain the usability measurements aspects, especially the origin and the definition of the term ‘usability’, which was evaluated by use of a questionnaire. According to Lindgaard [20], Usability concerns the ease of learning and using computer systems from the experienced and inexperienced user's point of view, but classifications of Usability evaluation methods differ from author to author. Lindgaard defined that "Usability is a narrow concern compared to the larger issue of system acceptability, which basically is the question of whether the system is good enough to satisfy all the needs and requirements of the users and other potential stakeholder, such as the user's clients and managers". The overall acceptability of a system or method is a combination of its social and its practical acceptability. Given that a system is socially acceptable, we can further analyse its practical acceptability within various categories, including traditional categories such as cost, support, reliability, compatibility with existing systems, etc., as well as the category of usefulness [20]. Furthermore usefulness is the issue of whether the system can be used to achieve some desired goals. According to Grudin [21] Usability has multiple components and is traditionally associated with five Usability attributes which were explored in the questionnaire:

<u>Learnability:</u> a very important attribute. Systems need to be easy to learn, especially by inexperienced users.

<u>Efficiency:</u> the system should be efficient to use, so that a high level of productivity is possible. Efficiency should be studied for users of different skill and experience levels

<u>Satisfaction</u>: again very important, subjective satisfaction refers to how pleasant it is to use a certain system or method.

<u>Memorability:</u> the system should be easy to remember.

<u>Errors</u>: the system should encourage a low error rate by users.

The first part of the qualitative evaluation of the PARAMASS approach was based on a questionnaire which has been carried out by asking 61 designers about their experience after the application of the approach. The questionnaire comprised a mixture of closed and open questions, divided into two parts. The basic conditions of descriptive studies are listed in Table 1.

Environment	Automotive Industry and suppliers
Participants	61 power train engineering designers from automotive company
Collection methods	Questionnaires and interviews
Time constraints	100 minutes for 30 questions
Team size	Groups of 10 people in different CAD design workshops
Number of cases	61 questionnaires
Total duration	6 Months

Table 1: Basic conditions of the questionnaire

The second part of the qualitative evaluation consisted of questions related to the investigation and clarification of the Usability issues of the approach. Semi-structured interviews with participants were undertaken to supplement the questionnaires to explore Usability aspects such as learnability, effectiveness, satisfaction and memorability. The results of the study demonstrated that the designers realized subjective improvements through the application of the developed PA CAD approach. 76% of the respondents agreed that the new approach is easy to learn, reporting in particular that this was because the method has only three main phases which are easy to understand. Users also considered the approach easy to apply. 69% of the respondents agreed that by means of the new approach it is easier to identify and determine relevant parameters (an important part of model development and editing). In addition it was also possible to observe that most of the designers have a high satisfaction with the application of the approach, because they were able to realize benefits during the identification, presentation and determination of the relevant parameters and associative relationships. Only the designers inexperienced in PA CAD had difficulties accepting that working with PA CAD systems requires a certain methodology. They stated that they are surprised that "A new PA CAD system which should ease their work needs a certain approach to work". Related to the aspects which are defined for the evaluation of the PA approach steps it was possible to observe that the subjective perception of the defined approach is quite positive. 92% of the respondents agreed that by means of the developed PA approach the relevant parameters (product, physical and process parameters) can be represented in a better way and 73% of the designers mentioned that by means of the PA approach it is easier to identify the relevant associative relationships from the part structure of the CAD models. By means of the method the product and process associative relationships can be stored in the defined places and therefore in case of reusability the designers mentioned that they are able to catch the information faster than without a method. From the structuring aspect of the developed PA approach it was possible to observe that 92% of the respondents think that the PA approach has advantages to structure the relevant parameters and associative relationships. Designers mentioned that by means of standard structure templates for CAD assemblies and components it is easier to order the relevant parameters and associative relationships in different information containers. For example if designers have parameter information which is related to the down-stream processes by means of the standard templates of the CAD models it is possible to store this information inside the template. In case of reusing the created CAD components the information can be attached from the CAD structure. Before the introduction of the developed approach the respondents had difficulties to identify and determine the relevant parameters and associative relationships. Figure 2 shows the overall result of the qualitative evaluation of the developed PA approach (Red line demonstrates the results before the method application and the blue line demonstrates the results after the application of PARAMASS).

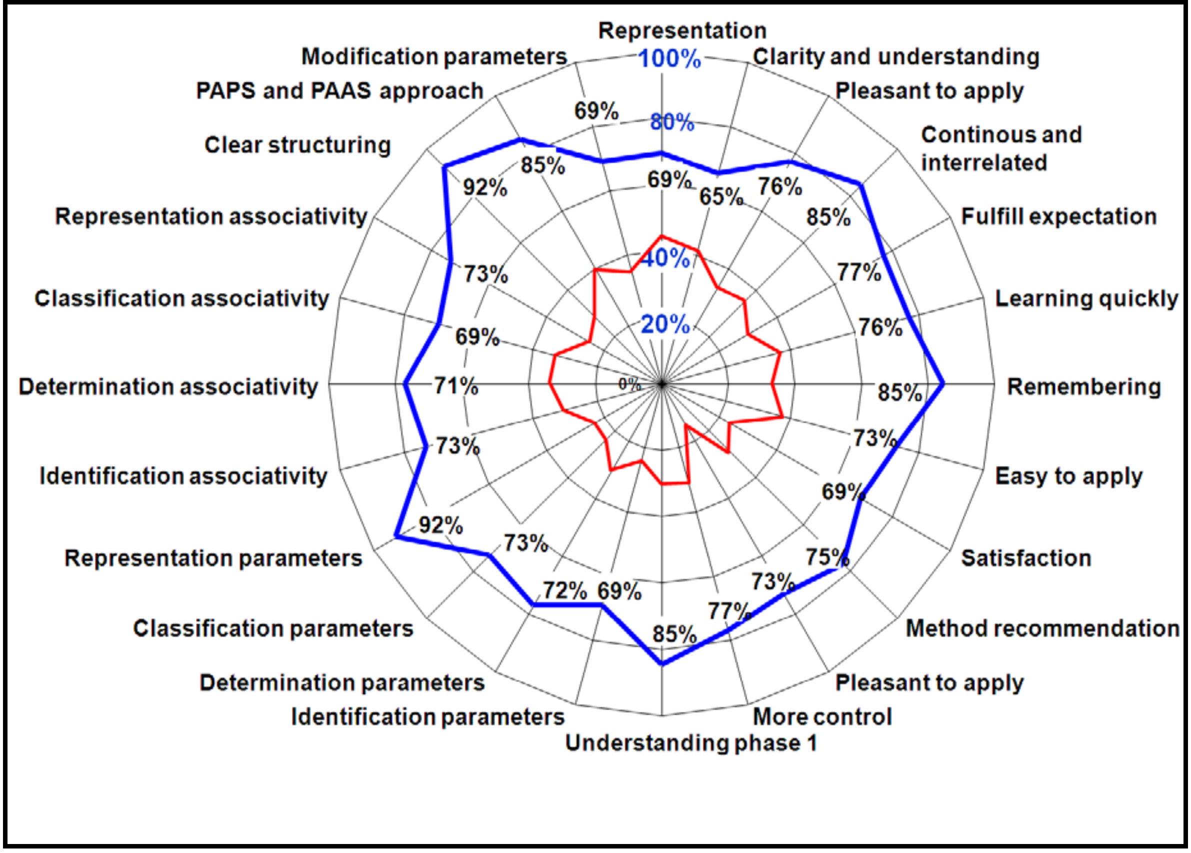


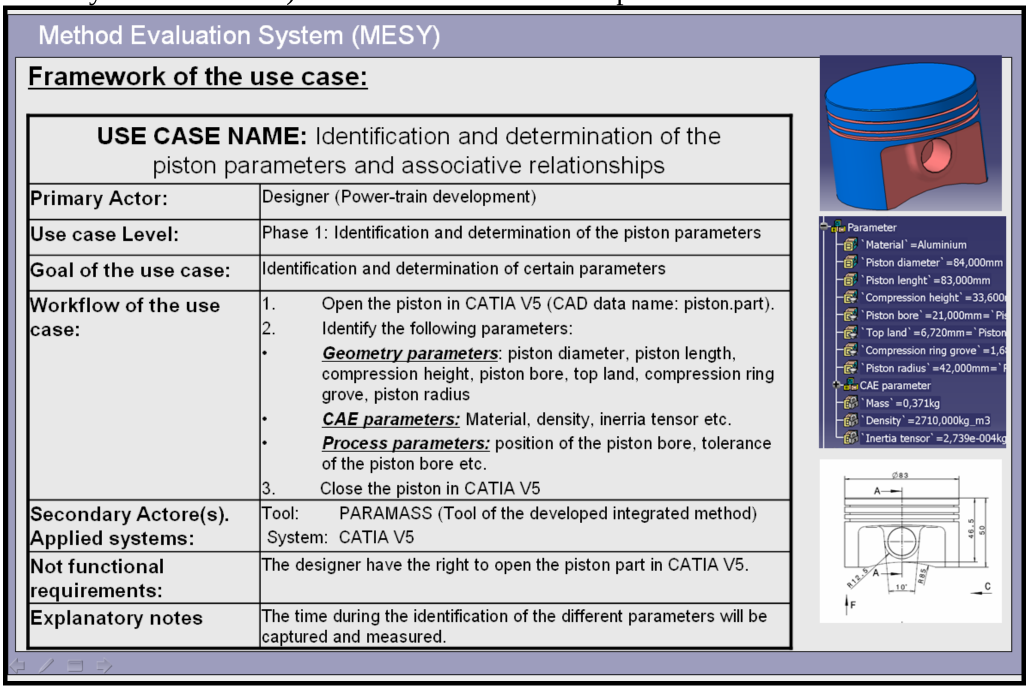
Figure 2: Results of the qualitative evaluation of the developed PA approach

4.3 Quantitative evaluation of the developed PA approach

As previously noted, quantitative measurements are characteristics of a product development process that can be measured, for example, by determining the time needed for performing a certain process step. A number of measurements that could potentially be used for evaluating the impact of a method implementation were collected from literature and from the experience gained in the case study [13], [14]. However, this was solely aimed at clarifying what kind of measurements can be used for comparing different states of the PDPs. The implementation of measurements in real-industrial processes is a challenging task that demands an in-depth knowledge of all aspects of these processes. The results should be reviewed for their validity and significance. Related to the quantitative evaluation of the PARAMASS approach it was important to identify factors which could be measured during the evaluation process. Therefore one of the necessary prerequisites for measuring the approach characteristics was the decomposition of the approach steps into smaller units. That means that it was quite difficult to quantify the 'whole' approach, and the quantitative evaluation thus considered the approach by defining different tasks for measurement of the performance. By decomposing the approach in smaller measurement units it was possible to evaluate the approach more accurately. The decomposition of the procedure during the evaluation process was based on the PA CAD approach steps themselves. During the quantitative measurement triangulation, i.e. use of a variety of sources, was performed in order to validate the collected data. In the evaluation, different tasks related to identification, determination and representation of the relevant parameters (geometrical, process and product parameters) and associative relationships was developed and formulated. The measurements were made by recording the time taken to accomplish tasks with and without the PA approach. The selected approach was based on Use Cases adopted from software and business process evaluation, in order to be able to define a procedure which allowed a very exact planning of the evaluation process.

4.4 Definition of Use Cases

A most important question in the evaluation was "how will it be possible to evaluate and quantify the changes through the developed method?" According to Jacobson "A Use Case is a narrative document that describes the sequence of events of an actor (an external agent) using a system to complete a process [23]." It comprises a collection of scenarios describing: (i) alternative ways of achieving a goal, (ii) unwanted endings and (iii) the reaction to potential exceptions that could arise at different times during otherwise normal scenarios [22]. Each Use Case captures: a) the actor (who is using the application?) b) the interaction (what does the user want to do?) and c) the goal (what is the user's goal?). Figure 3 shows an example of a Use Case for the PARAMASS approach. In this example, a designer from the power train department is involved in the evaluation process. The goal here is to investigate the first specification phase to explore if it helps for a better identification of certain parameters and associative relationships (in the PARAMASS approach the method is divided into three phases – specification, creation and modification). The table describes the workflow steps which are necessary to accomplish the Use Case. In addition there is also information about further actors (can be also a system or method) involved in the evaluation process.


Method Evaluation System (MESY)

Framework of the use case:

USE CASE NAME: Identification and determination of the piston parameters and associative relationships	
Primary Actor:	Designer (Power-train development)
Use case Level:	Phase 1: Identification and determination of the piston parameters
Goal of the use case:	Identification and determination of certain parameters
Workflow of the use case:	1. Open the piston in CATIA V5 (CAD data name: piston.part). 2. Identify the following parameters: • ***Geometry parameters***: piston diameter, piston length, compression height, piston bore, top land, compression ring grove, piston radius • ***CAE parameters:*** Material, density, inerria tensor etc. • ***Process parameters:*** position of the piston bore, tolerance of the piston bore etc. 3. Close the piston in CATIA V5
Secondary Actore(s). Applied systems:	Tool: PARAMASS (Tool of the developed integrated method) System: CATIA V5
Not functional requirements:	The designer have the right to open the piston part in CATIA V5.
Explanatory notes	The time during the identification of the different parameters will be captured and measured.

Figure 3: Framework of the developed Use Cases

The general benefits of using Use Cases are [23]:

- They encourage designers to consider the characteristics of tasks and their environment.
- Usability issues can be explored at a very early stage in the design process of the method.
- Scenarios can help to identify and compare quantitative targets and likely task completion times.
- Scenarios can also be used to generate contexts for evaluation studies.
- Only minimal resources are required to generate scenarios.
- The technique can be used by developers with little or no human factors expertise.

Furthermore, by means of the structure of Use Cases it was possible to describe in the PARAMASS evaluation what and in which way the designers had to act. In this way it could be ensured that during the tests all of the participants exactly know what they have to do and how they should act [23]. Related to the evaluation of the developed approach it was very important to create the Use Cases in a way which allows the evaluation of the different phases of the approach. Furthermore the definition of the possible scenarios was implemented in the regular team meetings of the test participants. In this way all the process participants had the same understanding about the content of the Use Cases and the progress. At the end of the quantitative evaluation 120 Use Cases were defined, with use cases created for each PA method phase. Therefore the identification of possible scenarios was discussed and developed in cooperation with the CAD designers. In this way it was ensured that realistic scenarios were generated. Otherwise the parameters and associative relationships which have been selected for the evaluation can be 'wrong' and the evaluation made on false considerations. Therefore the recommendation was:

- The determination of the PA CAD parts for test purposes should be done with the CAD designers, to ensure that relevant CAD examples are selected.
- The selection of possible parameters and associative relationships should be done with the CAD designers. Only the designers have a full understanding of the different kinds of parameters and associative relationships which are relevant for the design process.
- The created Use Cases should be discussed with the CAD designers, to ensure that the created Use Cases and scenarios are more realistic and industrial based.

4.5 Results of the quantitative evaluation

This section will present the results of the quantitative evaluation of the different aspects of the developed PA approach. The purpose of the evaluation was to demonstrate if there were any changes and improvements through the application of the PA CAD method. After the documentation of the measured time values it was possible to compare the performance of the different groups. There are a lot of aspects which have an impact on the total evaluation process. The results of the quantitative evaluation showed that by using the approach designers were able to identify and determine the required parameters and associative relationships faster than without any specific method. First, the total time during the creation of the PA CAD components (connection rod, piston, piston pin, cylinder head, cylinder block, oil pan etc.) was measured. In case of the piston it was possible to measure that working with the PA approach required longer time for the creation of the model, whether the designers were CAD-experienced or not. However, once the models were created identification and modification of model parameters was much faster when the new PA CAD method was used, as shown in Figure 4.

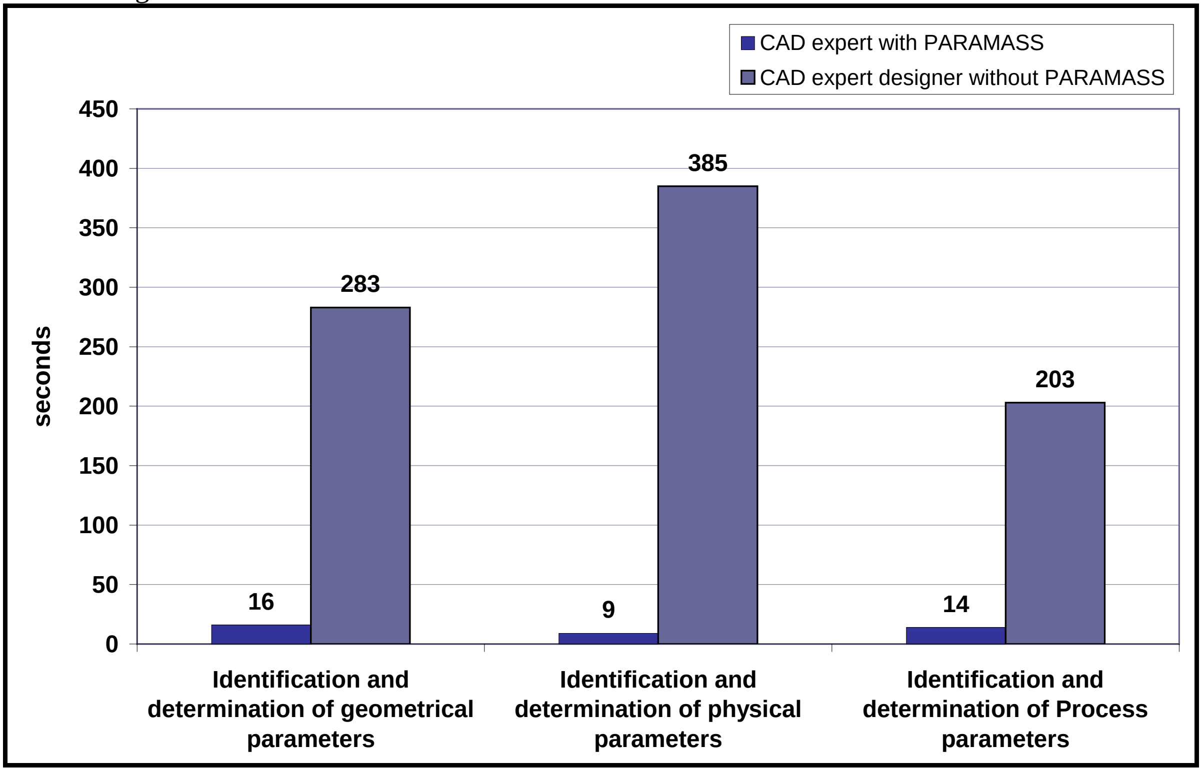


Figure 4: Total time measured during the identification and determination of parameters

In Figure 4 it was encouraging to see how fast the designers were able to identify and determine the required parameters once they were working using a systematic method. The reason is that, depending on the complexity of the created CAD parts most designers have enormous problems to identify and determine the required information created by other CAD designers and colleagues. Furthermore, related to the reusability of the created PA CAD components the designers needed a lot of time to be able to understand the design content of the PA CAD parts created without a systematic approach. Figure 5 shows a PA CAD part designed with and without the PARAMASS approach, which demonstrates the significant difference between working and not working in a methodical way. The relevant parameters which have been determined by means of the PARAMASS approach can be identified in a very easy way, and the relevant parameters are presented in a very structured way. This aspect helps ensure that the relevant parameters are immediately editable and CAD designers do not need a long time to search for the important and required parameters. During the observation of the designers it was also possible to observe that people who are not the creators of the PA CAD components can modify the parameters without knowing the whole structure of the created features and parameters.

This is a very important aspect related to the reusability of the created CAD parts and assemblies. In the past it was possible to observe how difficult it was for designers to select and find relevant parameters. But by means of the PARAMASS approach this information can be identified more quickly. This is also the point where the designers realize the real benefit of methodical working with PA CAD systems. Especially in power train development most of the CAD components are developed with external partners. Therefore such methodical information should be available for the development partners so they are also able to have a certain ‘guideline’ to design their PA CAD components. The right side of Figure 5 demonstrates an example of a PA CAD piston which is not created in a methodological way. It can be see that the history tree of the CAD component contains the features and the parameters of the created piston. It is not possible to see quickly the relevant parameters and associative relationships, which makes the search of the required parameters difficult. The designers have to investigate the whole history tree to find the right parameters and the relationships between them. By means of methodical working the CAD designers were able to define the parameters (geometrical, process and physical parameters) which are required in the design process.

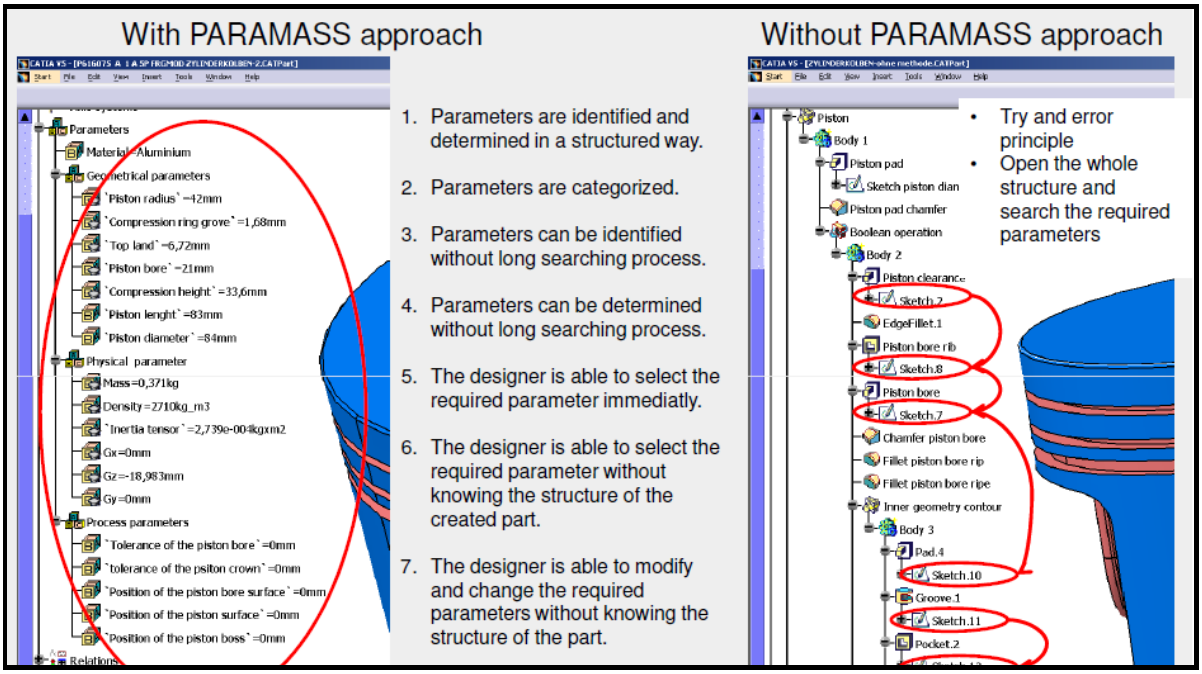


Figure 5: Comparison of the designed piston with and without PARAMASS

The next aspect of the quantitative evaluation was the measurement of the time taken for the identification of PA design information inputs and outputs. Figure 6 shows the times which were measured during the identification of relevant design information inputs and outputs (i.e times for computer-aided engineering (CAE) and computer-aided manufacturing (CAM) designers to be able to identify the right parameters from inside of the model structure). The category ‘design information outputs’ is divided into CAE and CAM information and by means of strong interaction with the CAD designers the relevant parameters can be offered in a systematic and structured way. Further advantages are that downstream process information can be organised in an automatic way. That means that other systems (CAM or CAE systems) can be connected with the predefined structure. In this way the CAE and CAM systems can be adapted to the area where the relevant information is available. By means of adopting PARAMASS, CAE and CAM engineers are able to update their latest information automatically. Examples of the relevant information in the case of the piston are the rough part from which the finished part is machined, finite element and machining models.

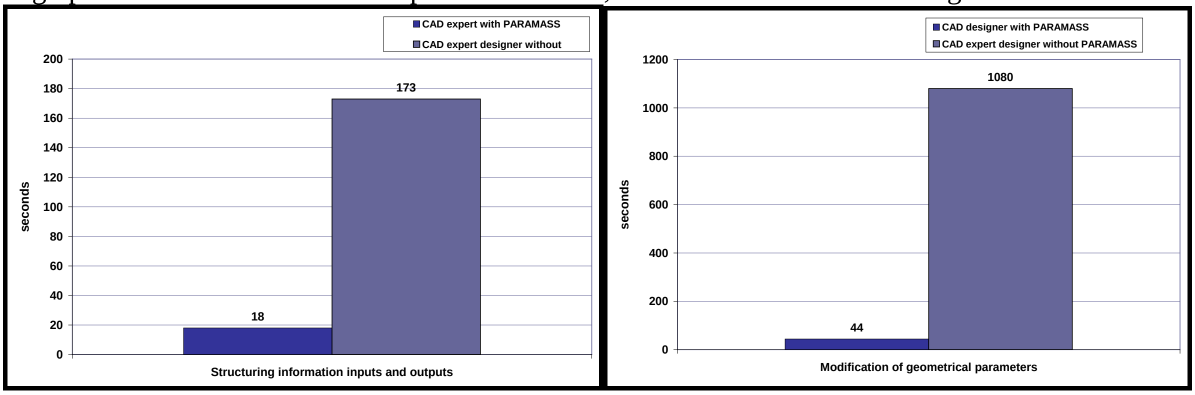


Figure 6: Measured time of the structuring and modification of the PA approach

It was also possible to observe advantages in the application of the final, modification phase of PARAMASS, as shown in Figure 6. Here it is important to say that time required for modification of parameters is also closely related to the time required for identification of the parameters to be modified. That means if the designers are not able to identify the relevant parameters they will also have problems to modify these parameters. Therefore in case of not being able to identify the parameters, which depends on the complexity of the CAD parts, there was a certain time limit applied in the investigation.

5 CONCLUSION

This paper has presented a study of the evaluation phase of a design research project that was investigating the development and application of a new method for PA CAD in an industrial context. It has shown that, by means of a qualitative and quantitative analysis, it was possible to evaluate the method from different aspects. Furthermore it was possible to make visible the changes and improvements obtained in the application of the new method. But the main task of the qualitative and quantitative evaluation process was not only to define an approach for the demonstration of the positive aspects of the developed approach. It was also to have an approach which allows the measurement of subjective Usability and ‘hard’ quantitative measurable criteria. In case of PARAMASS the main tasks were to evaluate the learnability, satisfaction and usefulness of the approach. The questions explored helped to get direct information about the implementation of the different phases of the approach, and by exploring Usability aspects for the different phases it was possible to identify potential improvements. But it should also be noted that the qualitative evaluation process is very time consuming and needed careful planning. The evaluation process took 6 months to plan and carry out and the selection of the questions and relevant use cases needed to be done with the participants (designers) who were involved in the evaluation process. In so doing it could be ensured that the defined Use Cases were more realistic and could reflect “real” design cases.

REFERENCES

[1] Pahl/Beitz ;Engineering Design. A Systematic Approach. Springer Verlag, London, 1. Aufl. 1984.

[2] Griffin A.: Evaluating QFD’s Use in US Firms as a Process for Developing Products. Journal of ProductInnovation Management, Vol. 9, No. 3, 1992, pp. 171-187.

[3] Norell M.: The Use of DFA, FMEA and QFD as Tools for Concurrent Engineering in Product Development Processes. In: Roozenburg, N., F., M. (Ed.): Proceedings of the 9th International

Conference on Engineering Design. Zürich: Edition Heurista 1993, pp. 867-874.
[4] Griffin, A.: PDM A Research on New Product Development Practices: Updating Trends and Benchmarking, Best Practices. Journal of Product Innovation Management, Vol. 14, No. 6, 1998, pp. 429-458.
[5] Norell, M.: Competitive Industrial Product Development Needs Multi-Disciplinary Knowledge Acquisition. In: Duffy, A. (Ed.): The Design Productivity Debate. London: Springer 1998.
[6] Reetz, U.: Performance Measurements - a Key Method for a Guided Implementation of Concurrent Engineering, Principles into Product Development Processes. In: Walker, R.; Weber, F. (Eds.): PACE'97 - A Practical Approach to Concurrent Engineering. Proceedings of The European Workshop held at Marinha Grande, Portugal, pp. 39-52.
[7] Salehi V., McMahon C.: Development of a generic integrated approach for parametric associative CAD systems. In International Conference on Engineering Design, ICED’09, Stanford, August 2009.*Not included to maintain author anonymity*
[8] Dale, R.; Evaluation Frameworks for Development Programmes and Projects, Sage: New Delhi, 1998.
[9] Reichwald R.; Höfer C.; Weichselbaumer J.: Erfolg von Reorganisationsprozessen. Leitfaden zur strategie orientierten Bewertung. Stuttgart: Schäffer-Poeschel, 1996.
[10] Cook, T., Reichardt C.; Qualitative and Quantitative Methods in Evaluation Research, Sage: Beverly Hills, 1979.
[11] Carvalho W.; Implementing Projects for the Poor: What has been learned? World Bank: Washington, 1996.
[12] Wigand R.; Information, Organization and Management. Expanding Markets and Corporate Boundaries. Chichester: John Wiley & Sons, 1997.
[13] Usher J.; Implementing Concurrent Engineering in Small Manufacturing Enterprises. Engineering Management Journal, Vol. 8, No. 1, March 1996, page 33-43, 1996.
[14] Stetter, R.; Method Implementation in Integrated Product Development, PhD Thesis, Technischen Universität München, 2000.
[15] Mittelmann A.; Organisationales Lernen und Geschäftsprozessmanagement. Institutsbericht. Linz: Institut für Wirtschaftsinformatik, 1998.
[16] Reichwald R.; Höfer C.; Weichselbaumer J.: Erfolg von Reorganisationsprozessen. Leitfaden zur strategie orientierten Bewertung. Stuttgart: Schäffer-Poeschel, 1996.
[17] Duffy A.; Enhancing the Evolution of Design Science. Proceedings of ICED’95, Prague, August 22-24, 1995.
[18] Basili V. and Weiss D. A Methodology for Collecting Valid Software Engineering Data, IEEETransactions On Software Engineering, 1984, pp 728-738.
[19] Van Latum F.; Oivo M.; Van Solinge R.; Hoist B.; Rombach D.; Ruhe G.: Shifting to Goal-Oriented Measurement in Industrial Environments. Experiences of Schlumberger. Fraunhofer Institute for Experimental Software Engineering (IESE)-Report 035.97/E, October 1997.
[20] Fugetta A.; Lavazza L.; Morasca S.; Cinti S.: Oldano G.; Orazi E.: Applying GQM in an Industrial Software Factory. ACM Transactions on Software Engineering and Methodology (TOSEM), Volume 7, Number 4, October 1998, p. 411-448.
[21] Lingaard G.; Usability Testing and System Evaluation, Chapman & Hall, London p. 91, 1991.
[22] Grudin, J.; Utility and usability: research issues and development contexts. Interacting with Computers, 4(2):209–217, 1992
[23] Jacobson I., Christerson M., Jonsson P., and Övergaard G.: Object-Oriented Software Engineering: A Use Case Driven Approach, Addison-Wesley, Wokingham, England, 1992.