21ST INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

USABILITY OF PROCESSES IN ENGINEERING DESIGN

Becerril, Lucia; Stahlmann, Jan-Timo; Beck, Jesco; Lindemann, Udo
Technical University of Munich, Germany

Abstract

Processes in Engineering Design are generally optimized towards efficiency, quality, costs, risks, etc., however an analysis that includes requirements from the process users' view is missing. Within the last years, the concept of usability has being introduced to examine business processes. This is a promising approach for Engineering Design, by involving process "users" (designers, engineers, software developers, project managers, etc.) in the process planning phase, several issues such as consistency flaws or counter-intuitive information flow can be identified beforehand. This paper aims to explore the transferability of usability concepts and evaluation methods to processes in the field of Engineering Design. The goal of this paper is to set a basis for further studies with regard on how to plan and design processes that interact efficiently, effectively and satisfactorily with the people involved. For this purpose ten process usability attributes are consolidated from the overlap between usability attributes (of products and systems) and process system properties. Moreover, five usability evaluation methods are examined on their applicability for evaluating design processes.

Keywords: Design management, Design process, User centred design

Contact:
Lucia Becerril
Technical University of Munich
Chair of Product Development
Germany
becerril@pe.mw.tum.de

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 2: Design Processes | Design Organisation and Management, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION

Implementing new Engineering Design processes involves a lot of effort, time, and costs – including trainings, software, and pilot projects. However, the results are not always satisfactory. Many issues can be traced back to factors that are subjective, and context dependent for example: high perceived complexity, non-intuitive information flow, and missing feedback from downstream activities (c.f. Booker, 2012, Filson and Lewis, 2000, Kim et al., 2005, Stetter, 2000). Moreover, due to more interdisciplinary and global projects, the diversity within engineering design teams has increased - adding even more perspectives to the complex process landscape.

The concept of "process usability" has being introduced in recent research to examine business processes in regard of these subjective and context dependent factors (Lemos O. Mendonça, 2006, Aalst, 2014, Thaler, 2014, Heinrich and Paech, 2010). In Engineering Design, consequences of "bad process usability" may include long process-related training for new employees, missing process compliance, or a large number of non-value activities, such as looking for information. To illustrate the potential, a study of the Nielsen Norman group revealed through that improving the usability of their intranet systems a company with 10 000 employees could save around 4 million dollars per year (Nielsen, 2012).

So far, Engineering Design Processes are generally optimized towards efficiency, quality, costs, risks, etc. However, an analysis that includes requirements from the process users' view is missing. Using impulses from user centered disciplines (Usability, User Experience), we aim to improve acceptance and implementation of Engineering Design Processes by enabling the process users (designers, engineers, software developers, project managers, etc.) to play a part in the design of complex and dynamic development processes. Thus, trough involving process users in the process planning phase, several of these issues can be identified beforehand.

Knowledge intensive processes[1] transform inputs into outputs by using information, knowledge, and resources (Lindemann, 2009). The process design specifies what is to be done by whom, when, and where (Hammer, 2001). Product development or engineering design processes are processes involving the activities necessary to create a physical product from a given idea (Bender and Gericke, 2016). Due to the rather abstract nature of knowledge intensive processes and the dynamics of processes in Engineering Design, methods for evaluating process usability cannot be identical to evaluation methods designed for physical products or software. For example, there is a lack of prototypes so that models are used as communication basis.

This paper aims to explore the transferability of usability concepts and evaluation methods to processes in the field of Engineering Design given the challenges above. In summary, the goal of this paper is to set a theoretical foundation for analysing the impact of subjective and context dependent process attributes on the process implementation, performance, and on the satisfaction of the people involved.

2 STATE OF THE ART

This section briefly introduces the main concepts of the proposed topic and gives an overview of current state of research. First, the state of the art on product development processes is briefly presented, then the next section gives an introduction of the concept of usability in the fields of product and software design. The last section presents current research and concepts with regard on the usability of (business) processes.

2.1 Engineering Design Processes as the subject of analysis

As stated before, knowledge intensive processes transform inputs into outputs by using information, knowledge, and resources (Lindemann, 2009). Processes comprise an organizing framework and a process design, which specifies what is to be done by whom, when and where. (Hammer, 2001).

According to Ehrlenspiel and Meerkamm (2013), product development (or engineering design) processes comprise every activity from the definition of a product up to its delivery to the customer. Bender and Gericke (2016) argue that product development processes are business processes involving the activities necessary to create a physical product from a given idea. Since product development processes seek to do something new once, they have a number of characteristics that differentiate them

[1] Here focus on knowledge intensive processes to exclude other types of processes, such as chemical processes.

significantly from other business processes (Browning et al., 2006) For the purpose of this paper, more significant is the common understanding of engineering design processes as complex systems.
According to Kreimeyer (2009), within engineering design processes tasks, documents, and IT systems, as well process stakeholders, i.e., engineers and management, are interlinked, forming a network of multiple layers. Moreover, Browning (2009) argues that a process system, which comprises processes, activities, events, interactions, and flows, is at least as complex as the product or system it seeks to produce.
Managers and engineers use process models to cope with complexity and coordinate work (Browning, 2009). Similarly to all models, process models are simplified depictions of reality. Nowadays, a large number of different modelling techniques can be used to represent engineering design processes (Lindemann, 2009), for example flowcharts or Gantt charts. However, as processes become more complex, addressing issues such as collaboration and information flow by looking at a large process model is "almost impossible" (Kreimeyer, 2009).

2.2 Usability

According to the guideline DIN EN ISO 9241-10, usability is the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use".
Within the context of this paper, several approaches on usability were analysed. Usability is commonly described through a series of attributes such as learnability, consistency, ease of use, flexibility, etc. An extensive literature research provided a collection of 60 attributes, which were mapped to the different literature sources from the field of usability. A selection of these attributes is shown in Figure 1. Moreover, many of the surveyed papers include models on how these attributes are interrelated (c.f. Nielsen 2010).

	Bevan und Macleod (1994)	Brooke (1996)	DIN prEN ISO 9241-11 (2016)	DIN EN ISO 9241-110 (2008)	Eason (1984)	Gucegliogiu und Demirors (2005)	Heinrich und Paech (2010)	Heravizadeh et al. (2009)	Hix und Hartson (1993)	ISO/IEC 9126-1 (2001)	ISO/IEC 25010 (2011)	Nielsen (1995)	…
Efficiency	●		●				●		●	●	●	●	
Handling of errors			●	●			●	●		●	●	●	
Flexibility	●	●	●		●		●			●	●	●	
Motivation / Attractiveness					●	●	●		●	●	●	●	
Ease of Use		●			●	●	●			●	●		
Compliance				●	●	●	●	●		●	●	●	
Understandability				●		●	●	●		●			
Compatibility		●					●			●	●		
Consistency		●										●	
…							●	●		●			

Figure 1: Matrix of usability attributes (extract)

Usability Evaluation is described by Conyer (1995) as "the analysis of the design of a product or system in order to evaluate the match between users and a product or system within a particular context. Usability evaluation is a dynamic process throughout the life cycle of a product or system".
In the context of this work, five usability evaluation methods (UEM) were identified: usability test (UT), survey, heuristic evaluation (HE), cognitive walkthrough (CW), and pluralistic usability walkthrough (PUW). Table 1 gives a brief overview of each selected evaluation method.

Table 1: Five usability evaluation methods

Name	Description	Source(s)
UT	Evaluators observe users while they perform tasks with a system. The test sessions are typically recorded either by video and/or an automated testing tool.	Usability Professionals Association (2010)
Surveys	"Compilations of questions […] that either have quantitative or qualitative scales, or are open-ended, and that target at extracting a variety of information from a representative sample of the target population".	Ozok (2012)
HE	Usability specialists judge whether each dialogue element follows established usability principles (the "heuristics").	DIN prEN ISO 9241-11, Nielsen (2010)
CW	One or more evaluators work through a series of tasks and ask a set of questions. The focus is on understanding the system's learnability for new or infrequent users.	Usability Professionals Association (2010)
PUW	"Are meetings where users, developers, and human factors experts step through a scenario, discussing each dialogue element."	Nielsen (1994)

These UEMs are scientifically or practically relevant and do not focus on domain specific details. Usability evaluation methods can be divided in empirical methods and analytical methods (c.f. Harvey and Stanton 2013, Sarodnick and Brau 2011, Fernandez et al. 2011). Empirical methods involve actual users and are applied generally in the late phases of the development process, while analytical methods are based on expert analysis and can be applied in any phase (Harvey and Stanton 2013, Sarodnick and Brau 2011).

3 METHODOLOGY

As stated in the introduction, the goal of this paper is to set a foundation for analysing the impact of "Process Usability" on process implementation, performance, and on the satisfaction of the people involved in future research. For this purpose, the following research questions are raised:

- What is "process usability" in the context of engineering design processes?
- How could the usability of engineering design processes be evaluated or measured?

To define and characterize process usability, a literature survey was conducted. For this purpose, usability attributes from the fields of software and product usability were collected, as shown in Figure 1. Then, the 60 collected attributes were examined with regard of their applicability to non-physical or non-software systems; for example, "ease of operation" was removed. The result of this step was a list of 13 usability attributes that could describe abstract systems, such as processes.

Afterwards, the question whether these attributes were used in the past to describe processes was addressed. Thus, the selected attributes were surveyed in Google scholar and in previously selected main journals[2]. Here, we counted papers from the process and project management disciplines where the usability attribute (e.g. flexibility) and the keyword "process" appeared together. This provides a notion on which usability attributes are currently used to describe processes as well. Figure 2 shows the number of hits for each attribute together with the word "process".

The attributes on the left side of the dotted line in Figure 2 (flexibility, reliability, accessibility, consistency, maturity, compliance, transparency, compatibility, and robustness) were selected for further study and are described in detail in section 4, since we assume, based on the number of results, that they are broadly used to describe processes in process and project management literature. The concept of "understandability" was selected as well due to its relevance in conjunction with process models. These 10 attributes describe the overlap between usability attributes of systems (in general) and process properties (illities) and are referred to in this paper as process' usability attributes.

[2] These journals are: Business Process Management Journal, International Journal of Business Process Integration and Management, International Journal of Process Management and Benchmarking, International Journal of Management Science and Engineering Management (IJMSEM), Project Management Journal

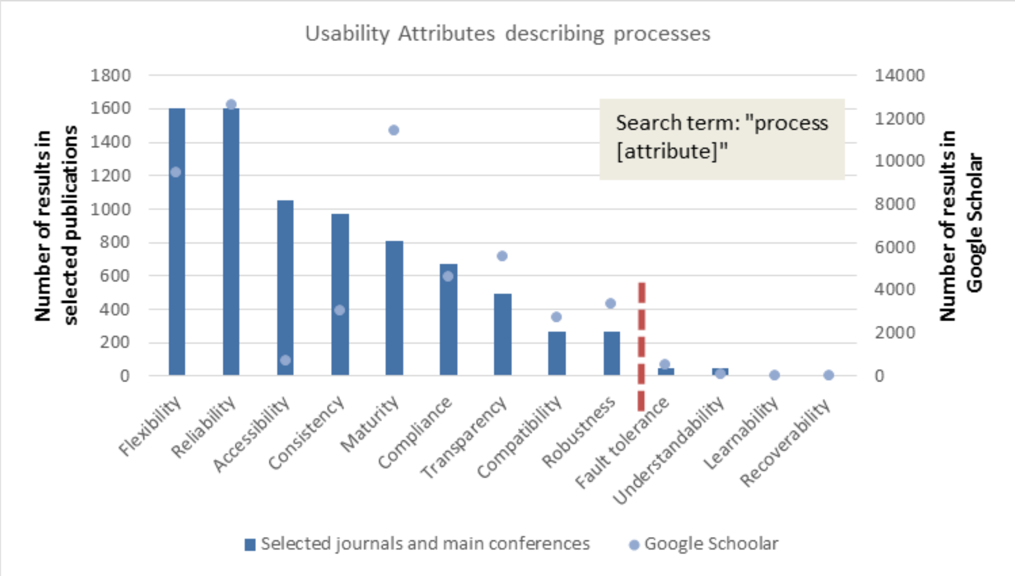

Figure 2: Frequency of appearance of usability attributes in the context of processes

Furthermore, in order to answer the second research question (How could the usability of engineering design processes be evaluated or measured?), usability evaluation methods was collected. Section 5 examines these methods in regard to their applicability for evaluating knowledge intensive processes.

4 ATTRIBUTES OF PROCESS USABILITY

The following process usability attributes were consolidated from the overlap between usability attributes (of products and systems) and process properties, as described in section 3.

Accessibility
In general, accessibility describes "a product, service, environment or facility that is usable by people with the widest range of capabilities." (DIN prEN ISO 9241-11, 2016). However, within the context of this paper, "accessibility" rather aims to achieve highest possible levels of effectiveness, efficiency, and satisfaction during usage (DIN prEN ISO 9241-11 2016; ISO/IEC 25010, 2011).
Here, accessibility refers to the degree to which information is easily accessible (Heravizadeh, 2009). Lemos O. Mendonça (2006) emphasizes that limiting the sources of information and finding concise terms for the information can enhance easy identification and quick access to it. Furthermore, access to relevant data and process steps has to be granted.

Consistency
Consistency is a general principle in the interaction between humans and systems. Consequently, there should be a systematic striving for consistency when it comes to wording, formatting, and establishing procedures (Dumas and Redish, 1999). Within the context of processes, consistency is realized by a coherent representation of all relevant information in a formal structure, which avoids different words, situations or actions with the same meaning (Browning et al., 2006, Lemos O. Mendonça, 2006, Nielsen 1995). Good design should consider both internal consistency – within the system itself – and external consistency – among a specific amount of systems. Thus, an established structure and unified terminology of all process elements is crucial in terms of process usability.

Compliance
Compliance is "ensuring that business processes, operations and practice are in accordance with a prescribed and/or agreed set of norms" (Sadiq et al., 2007). In the ISO/IEC standard 9126-1 (2001) quality dimensions are corroborated with compliance sub characteristics. These ensure that the considered system is capable to adhere to standards, conventions, regulations, or similar prescriptions. In the replacing standard ISO/IEC 25010 (2011) and in related publications, these sub-characteristics

have been removed, with the argument that compliance has to be considered as part of overall system requirements instead of only being a part of quality (Heinrich and Paech, 2010). In the context of processes, the role of regulations and standards is becoming increasingly important (Sadiq et al., 2007).

Compatibility / Interoperability
Compatibility describes a broader view, being the extent to which a system can exchange information with other systems to perform its required functions whilst being used in the same environment (ISO/IEC 25010, 2011). Interoperability ensures that the exchange of information is possible and that this information can be used at all (ISO/IEC 25010, 2011). This implicates a time-bound component meaning as well. Thus interoperability assumes that the interaction allows activities to be executed before or after other specified and scheduled activities (Heinrich and Paech, 2010). Each junction to other systems has the potential to loose information due to incompatibilities (Vajna et al., 2007). Thus, for processes, the mentioned attributes describe how integration with further existing processes and systems is possible, as well as how they contribute and support other process steps and elements.

Flexibility
Flexibility is often mentioned in publications concerned with process properties, software and product usability. Flexibility describes the extent to which a system can be usable in contexts that exceed those the system was initially specified for. Thus, flexibility allows different circumstances, opportunities, contexts of use, or individual preferences that had not been anticipated before and represent unintended contexts (ISO/IEC 25010, 2011). Therefore, the standard ISO/IEC 25010 (2011) suggests two ways of understanding flexibility: firstly, as the degree to which additional users, goals, and types of contexts can be addressed. Secondly, how capable a system is to adapt, suit, and individualize to new types of users, tasks, and environments. Unexpected changes on tasks or unanticipated patterns require flexibility of the running system, e.g. its processes (Leventahl and Barnes, 2008).
Moreover, Engineering Design processes demand for flexible process structures to react adequately and with relation to the situation (Beneke, 2003, Bichlmaier, 2000, Browning et al., 2006). They have to be capable to react to unforeseen circumstances, which can be caused by the process itself or by external influences (Beneke, 2003).

Reliability / Maturity
Reliability can be defined as a system's capability to maintain a predefined level of functional performance being exposed to a specified environment and being used under specified conditions for a specified period of time (ISO/IEC 9126-1, 2001, ISO/IEC 25010, 2011). ISO/IEC 25010 (2011) emphasizes that there are several dependent characteristics including for example availability, security, recoverability or maintainability. In addition, maturity can be seen as sub-characteristic of reliability (Guceglioglu and Demirors, 2005). In this context, it can be described as the property to avoid failure caused by system native faults (ISO/IEC 9126-1, 2001, ISO/IEC 25010, 2011).

Robustness
In system design, activities and functions are considered robust if they can even be executed if invalid, incomplete or conflicting inputs are present (Heravizadeh, 2009). Closely related are the concepts of stability – the system is capable to function and avoid unexpected effects under modified conditions – and reusability – the system can be used in different settings (ISO/IEC 9126-1, 2001, ISO/IEC 25010, 2011). In regard of process usability, robustness means that a process can deliver successful results even when for example human errors or incomplete information are present.

Transparency
Transparency is a "process's capability of being monitored, controlled, and managed by decision makers" (taskmanagementguide.com). Due to increasing complexity of all business processes, the risk of increasing non-transparency is substantial. Hence, the lack of transparency can lead to missing information when it comes to decision-making. Transparency of development processes can be achieved by revealing all processed steps and tasks as well as the planned and scheduled ones (Bichlmaier, 2000). Hereby, the development team is continuously supported with an overview of all relevant process properties as well as of the past and the current status.

Understandability
Usability is highly determined by whether the user experiences an interaction with the relevant system as understandable. This includes that the system has to enable the user to understand whether itself and its components are suitable, which functions it delivers and how all this can be executed in a specified context of use (ISO/IEC 9126-1, 2001, Heinrich and Paech, 2010). To ensure that sense-making, i.e. understandability, can be achieved, many aspects have to be taken into account when designing the process such as user expertise, visualization, and notation or the structural implementation of the above mentioned attributes (Melcher et al., 2009).

5 EVALUATING USABILITY OF ENGINEERING DESIGN PROCESSES

UEMs are mainly designed to evaluate physical or software based products. The differences between these products and engineering design processes must be addressed to adapt UEMs for the purpose of this project. The main difference regarding the evaluation is the precision of the system's representation. Precise product prototypes can be very similar to the real product while real processes cannot be modelled in such a high precision. Thus, processes can be considered in two ways. Either, a process is regarded as conducted in reality or as planned throughout a model. Models can be evaluated with the aim to improve the process that is represented by the model or to improve the quality of the representation itself without considering its process character. Hence, three engineering design process evaluation objects can be distinguished: conducted process, modelled process, and depicted process.
According to this distinction, different requirements for the adapted UEMs can be derived. The evaluation of the conducted process and the modelled process require an evaluator with insight in various scenarios for using the engineering design process (modelled). Both evaluations must include the process contents. Thus, it is not enough to analyse only one state of the process without considering the previous or following process steps. Because of the sensitivity of conducted processes to external influences, its evaluation should cause as few external influences as possible. The evaluation of the modelled process and the depicted process require knowledge about the modelling language. Without this knowledge, the model could be misunderstood and misleading usability problems might be detected. The evaluation of the depicted process can analyse single parts of the model but it does not take the process perspective of the model into account.
The following part gives an overview of the proposed adaptions of the five UEMs presented in section 2: UT, survey, HE, CW, and PUW. To avoid disassociations of the UEMs throughout the adaption, some limitations of the adaption must be introduced: As a prerequisite, all details of the UEMs must either fit in the context of processes or be removable from the UEM. Furthermore, the applied adjustments to the UEM must not cause fundamental changes to the definition, the process, or the results of the UEMs. As a consequence of these limitations, some UEMs are not adaptable to certain kinds of process evaluation objects. Table 2 shows an overview of the potential application of each UEMs to the three evaluation objects: Conducted process, modelled process, and pictured process.

Table 2: Potential of UEMs to evaluate conducted processes, modelled processes, and pictured processes.

	Conducted process	**Modelled process**	**Pictured process**
UT	Yes	No	No
Survey	Yes	Yes	Yes
HE	Yes	Yes	Yes
CW	No	Yes	No
PUW	No	Yes	No

Usability tests
The UT is based on conducting real tasks. Thus, the UEM is only adaptable to conducted processes. Because of the multitude of different UTs, the adaption focuses on suggesting possible variations of UTs. The adapted UT is based on product developers conducting real tasks of a process. In the case of complex processes, single tasks of the process can be evaluated instead of the whole. A moderation of the UT is helpful to support the test subjects during the process. However, the moderator has to reduce his or her influence as much as possible to avoid falsifications of the evaluation results. There are various

methods of collecting data like think aloud, co-discovery, video recording or video feedback that are applicable. Methods like active intervention have a strong influence on the subject, so these methods should not be used.

Surveys

In general, surveys can be adapted to all three kinds of evaluation objects. The questions can have quantitative or qualitative scales. They can also be open-ended. Questionnaires are the main way to conduct surveys in the context of usability evaluations. In order to adapt the technique of questionnaires to the evaluation of processes, new questions can be composed for a questionnaire or existing standardized questionnaires can be used. However, standardized questionnaires can hardly be changed. Consequently, generally formulated questionnaires like AttrakDiff-3 (Hassenzahl, 2003) can be used, while software specific questionnaires like ISONORM 9241/110 and IsoMetrics are not adaptable.

Heuristics

HEs can also be used to evaluate all three kinds of evaluation objects. No adaptions are needed to apply HEs in evaluations of modelled or pictured processes. However, it will be difficult for evaluators to find a proper evaluation and documentation approach throughout the HE of conducted processes. The heuristics that are applied within the evaluations can be adopted and adapted from the evaluation of products, such as "Match between system and the real world" or "Error prevention" (c.f. Nielsen 1994).

Cognitive walkthroughs

CWs cannot be adapted for use in evaluations of conducted processes. Because evaluators are supposed to imagine possible user mistakes within the WE, real test subjects cannot be integrated into this UEM. Thus, no conducted process can be evaluated throughout a CW. Furthermore, CWs cannot be used to evaluate pictured processes because pictured processes do not contain the process character of models. In order to use the CW in evaluations of modelled processes, the originally evaluated action sequence must be replaced by a sequence of modelled process steps of the process. The four central questions of the CW have been established in software evaluations. To avoid a disassociation of the CW, the questions should not be changed. Thus, they must be newly interpreted to adapt the CW to modelled processes.

Pluralistic Walkthrough

The PUW is not adaptable to conducted processes because the method is only usable for the evaluation of printed models. The adaption of the PUW to pictured processes is also not possible because the PUW is based on the evaluation of a logical sequence of process steps. In order to adapt the PUW to the modelled process, two changes must be done. At first, the participating groups of test persons must be changed to product developers, process managers, and usability experts. Secondly, the screenshots (in case of software) or the prototypes (hardware) must be replaced by model parts of the engineering design process. During the evaluation, comments must be noted that suggest how to proceed in the next step of the model.

6 DISCUSSION

This paper aim to provide a basis for research on usability of processes in engineering design. The research results are divided in two parts: the attributes of process usability derived from the overlap of usability attributes and process properties, and the explorative research on the applicability of Usability Evaluation Methods on processes.

In order to answer the first research question "What is process usability in the context of engineering design processes?" attributes that define process usability were identified. From over usability 60 attributes, 13 attributes were found to characterize processes in process management, project management, and engineering design literature. The attributes that were further studied give a more tangible definition to the abstract concept of "process usability".

Moreover, in regard to the second research question "How could the usability of engineering design processes be evaluated or measured?" five common usability evaluation methods were examined. Similar methods to the usability test are already deployed to identify usability problems of a process. Surveys are also known to be usable in process evaluations. However, standardised questionnaires –

developed by the usability research – can additionally support these surveys. The cognitive and pluralistic walkthroughs present an interest opportunity for evaluating processes. Herrmann (2009) proposes a walkthrough for sociotechnical systems, however, the applicability for non-repeatable processes such as product development processes is not addressed. Within the authors' research, a case study tests the applicability of an adapted PUW in an evaluation of a product development process model. In this explorative case study, usability issues of the process model could be identified, for example abstract formulated activities and omitted steps. However, the different characteristics of the five UEMs regarding the type of the evaluation object, the necessity of users, the expenditure of time and material, as well as the qualification of the evaluator can determine a range of UEMs that are suitable in certain circumstances.

7 CONCLUSION AND OUTLOOK

The goal of the research presented here was on the one hand to explore the concept of usability of processes, thus highlighting the role of the "process users" in engineering design. Moreover, this paper should set a basis for further studies with regard on how to plan and design processes that interact efficiently, effectively, and satisfactorily with the people involved. This was achieved by characterizing process usability by a set of attributes. Further steps involve empirical research to examine which of these characteristics have more impact on the implementation and performance of processes in engineering design, as well as on employee satisfaction. Additionally, the above-mentioned attributes are characterized by a high degree of interdependencies between each other. Further research should address these interdependencies.

On the other hand, possibilities to evaluate processes and process models based on existing methods were developed. Here, three different objects for study were identified: conducted process, modelled process, and depicted process. Although an in-depth study is needed to adapt these methods to be applied on processes, the case study conducted provides a proof of concept on how to discover usability issues within process models.

REFERENCES

Aalst, Wil M. P. (2014), “How People Really (Like To) Work”. In Sauer,S., Bogdan,C., Forbrig, P., Bernhaupt, R., Winckler, M. (Eds.): *Human-Centered Software Engineering: Proceedings of the 5th IFIP WG 13.2 International Conference*, HCSE 2014, Paderborn, Germany, September 16-18, 2014, Springer Berlin Heidelberg, pp. 317–321.

Bender, B. and Gericke, K. (2016), “Entwicklungsprozesse”. In U. Lindemann (Hrsg.), *Handbuch Produktentwicklung* Carl Hanser Verlag, München, pp. 401-424

Beneke, F. (2003), *Konzeptionelle Ansätze einer prozessorientierten Produktentwicklung*. (Dissertation). Universität Essen, Shaker, Aachen

Bichlmaier, C. (2000), *Methoden zur flexiblen Gestaltung von integrierten Entwicklungsprozessen*. (Dissertation), Technische Universität München, Utz, München

Booker, Julian (2012), “A survey-based methodology for prioritising the industrial implementation qualities of design tools”, *Journal of Engineering Design* 23 (7), pp. 507–525. DOI: 10.1080/09544828.2011.624986.

Browning, Tyson R. (2009), “The many views of a process: Toward a process architecture framework for product development processes”, *Systems Engineering* 12 (1), pp. 69–90.

Browning, Tyson R.; Fricke, Ernst; Negele, Herbert (2006), “Key concepts in modeling product development processes”. In *Syst. Engin*. 9 (2), pp. 104–128. DOI: 10.1002/sys.20047.

Conyer, M. (1995), “User and usability testing - how it should be undertaken?”, *Australian journal of educational technology*, 11(2), 38-51.

DIN prEN ISO 9241-11 (2016), *Ergonomics of human-system interaction - Part 11: Usability: Definitions and concepts*, Beuth Verlag, Berlin

Dumas, J. S. and Redish, J. C. (1999), *A practical guide to usability testing*, Intellect Books, Oregon

Ehrlenspiel, K. and Meerkamm, H. (2013), *Integrierte Produktentwicklung. Denkabläufe, Methodeneinsatz, Zusammenarbeit*, Carl Hanser Verlag, München

Fernandez, A., Insfran, E., and Abrahão, S. (2011), “Usability evaluation methods for the web: A systematic mapping study”, *Information and Software Technology*, 53(8), 789-817.

Filson, A. and Lewis, A, (2000), “Cultural issues in implementing changes to new product development process in a small to medium sized enterprise (SME)”, *Journal of Engineering Design* 11 (2), pp. 149–157. DOI: 10.1080/09544820050034240.

Guceglioglu, A.S. and Demirors, O., (2005), “Using software quality characteristics to measure business process quality”. In *International Conference on Business Process Management* (pp. 374-379). Springer Berlin Heidelberg.

Hammer, Michael (2001), “The process enterprise: An Executive perspective”. *Hammer and Company* 1 (0).

Harvey, C. and Stanton, N.A., (2013), *Usability evaluation for in-vehicle systems*, Crc Press, Boca Raton

Heinrich, R. and Paech, B. (2010), “Defining the Quality of Business Processes”. *Modellierung* 161, pp. 133-148

Heravizadeh, M., (2009), *Quality-aware business process management* (Doctoral dissertation), Queensland University of Technology.

Herrmann, T., 2009“. Systems design with the socio-technical walkthrough”. *Handbook of research on socio-technical design and social networking systems*, pp.336-351.

ISO/IEC 25010 (2011), ISO/IEC 25010: *Systems and software engineering - Systems and software Quality* Requirements and Evaluation (SQuaRE) - System and software quality models.

ISO/IEC 9126-1 (2001), ISO/IEC 9126-1: *Software engineering - Product quality - Part 1: Quality model*.

Kim, Y., Lee, Z. and Gosain, S., (2005), “Impediments to successful ERP implementation process”, *Business process management journal*, 11(2), pp.158-170.

Kreimeyer, M. (2009) *A Structural Measurement System for Engineering Design Processes*. Doctoral Dissertation, Technischen Universität München.

Lemos O. Mendonça, R. (2006) *Usabilidade de Processos. Workshop Um Olhar Sociotécnico sobre a Engenharia de Softwar*e (WOSES).

Leventhal, L. M. and Barnes, J. A. (2008), *Usability engineering. Process, products, and examples*. Prentice Hall, Upper Saddle River, NJ

Lindemann, U. (2009), *Methodische Entwicklung technischer Produkte*, 3ed., Springer, Berlin, Heidelberg

Melcher, J., Mendling, J., Reijers, H. A. and Seese, D. (2009), “On Measuring the Understandability of Process Models”, *International Conference on Business Process Management*, pp. 465-476. Springer Berlin Heidelberg

Nielsen, J., (1994), “Usability inspection methods”, *Conference companion on Human factors in computing systems* (pp. 413-414), ACM.

Nielsen, J. (1995), *10 Usability Heuristics for User Interface Design.* [Online]. Available at: https://www.nngroup.com/articles/ten-usability-heuristics/ (5th October 2016)

Nielsen, Jakob (2010), *Usability engineering*. 18. [print.]. Morgan Kaufmann, Amsterdam

Nielsen, Jakob (2012), *Intranet Users Stuck at Low Productivity*. Available online at https://www.nngroup.com/articles/intranet-users-stuck-low-productivity/. (12th December 2016)

Ozok, A. (2012), “Survey Design and Implementation in HCI”. In J. A. Jacko (Ed.), *Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications*, CRC Press, Boca Raton,

Sadiq, S., Governatori, G. and Namiri, K., (2007), Modeling control objectives for business process compliance. In *International conference on business process management* (pp. 149-164). Springer Berlin Heidelberg.

Sarodnick, F. and Brau, H. (2016), *Methoden der Usability Evaluation. Wissenschaftliche Grundlagen und praktische Anwendung*, Hogrefe, Bern

Stetter, Ralf (2000), *Method Implementation in Integrated Product Development*. Doctoral Dissertation. Technische Universität München.

taskmanagementguide.com, *WHAT IS PROCESS TRANSPARENCY*? [Online] Available at: http://www.taskmanagementguide.com/glossary/what-is-process-transparency-.php. (1st December 2016)

Thaler, T., 2014. “Towards Usability Mining”. In *GI-Jahrestagung* (pp. 2269-2280).

Usability Professionals Association (2010), *Usability body of knowledge* [online] Available at; http://www.usabilitybok.org/ (10th October 2016)

Vajna, S., Ovtcharova, J. and Weber, C. (2007), “Integration”. In F.-L. Krause, H.-J. Franke & J. Gausemeier (Hrsg.), *Innovationspotenziale in der Produktentwicklung*, Carl Hanser Verlag, München

Hassenzahl (2003), AttrakDiff [online], Available at: http://www.attrakdiff.de/index-en.html (18th April 2017)

Roelofsen, J., and Lindemann, U. (2010), “A framework for situation specific planning of product development processes”, *11th International Design Conference*, Dubrovnik, Croatia.