Usability Evaluation of Cooperation Visualisation in Enterprises: Framework Development and Validation Based on Empirical Results

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USABILITY EVALUATION OF COOPERATION VISUALISATION IN ENTERPRISES: FRAMEWORK DEVELOPMENT AND VALIDATION BASED ON EMPIRICAL RESULTS

Research paper

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Abstract

Cooperation visualisation is used for planning, coordinating, and controlling enterprise cooperation within cross-organisational knowledge management. Visualisation is created using different modelling languages like BPMN 2.0. In this research paper we focus on the usability evaluation of cooperation visualisation in enterprises. We developed a usability evaluation framework and derived a model of hypotheses from it. This model is also linked to usability theory and verified with empirical results. Quantitative data from 432 managers with experience in using visualisation for enterprise cooperation has been collected and the causal model has been tested using the structure equation modelling method partial least squares. The empirical study reveals a critical path for usability evaluation of cooperation visualisation in enterprises. For theory, the impact of organisation properties and usage attributes on the usability of cooperation visualisation in enterprises is demonstrated. For practice, especially the user properties, further usage conditions, usage requirements, and usage variants are supporting the critical usability evaluation path and aid to improve management decisions, model interpretation and usability of cooperation visualisation in enterprises.

Keywords: Cooperation Visualisation, Usability Evaluation, Critical Path, Usage Conditions.

1 Introduction

In corporate practice, cooperation visualisation is important for planning, coordinating, and controlling enterprise cooperation within cross-organisational knowledge management. Such visualisation as a knowledge base provides structure and guidance for enterprise cooperation. Management, central, and support processes, cooperation activities and choreographies can be visualised. Cooperation visualisation is a result of an interactive enterprise modelling process, e.g. with partners during projects. Aspects of comprehensibility, communication, and actor-specific functionality have to be considered in cooperation visualisation in enterprises. Cooperation data is represented in images that are presented on visual displays. Actors perceive, interact with, and interpret the shown visualisation and fulfil tasks on their basis during the enterprise cooperation (Becker et al., 2014, Esther et al., 2011, Koers et al., 2014). Cooperation is visualised by applying different modelling languages, e.g. BPMN 2.0 (Business Process Model and Notation), Choreography- or Collaboration-diagrams (OMG, 2011) as well as the Unified Modelling Language (UML) (OMG, 2015). These languages provide modelling conventions for e.g. activities, gateways, events, and data. For cooperation visualisation BPMN 2.0 contains e.g. a swim lane for each actor within the enterprise cooperation where its activities are visualised. Cooperation can also be visualised on different levels of detail for better model interpretation. In enterprises, cooperation visualisation is created by model developers. After their task
accomplishment, model interpreters or users, like employees and managers, have access to completed cooperation visualisation. Visualisation must be easy to create for model developers and easy to understand for model interpreters.

Figure 1 shows a cooperation visualisation example, modelled with the Cooperation Experience-Approach also applied by Koers et al. (2014). In this model, five partners are represented, that cooperate in a business process named complete renovation. Each partner is involved in one process step and responsible for a specific result, like the Electro Company that has to install the electronic and to inform the next involved partner. Then, the Sanitary-Technic Company can start to assemble the heating system and inform the next partner and so on. Our cooperation visualisation example is based on an easy process flow between the partners, which should be easy to understand for model interpreters or users of cooperation visualisation. Therefore, it was used in our study as an example to aid participants to grasp the term cooperation visualisation based on represented actors and cooperate process steps.

In our view, the differentiation between model development and model interpretation is essential for precise usability evaluation of cooperation visualisation. Model developers are familiar with the visualised cooperation and know how to understand the elements and syntax of a visualisation correctly to reach the goal of a final visualisation. Model interpreters are often not trained in using cooperation visualisation, but must be able to understand the meaning of the resulting cooperation models. The knowledge of model interpreters refers to an intuitive understanding of the model shapes, structure and syntax rather than knowing every detail of the cooperation visualisation (Siau and Wang, 2007; Schalles et al., 2011). For both model developers and model interpreters, usability is important. However, we assume that it is especially crucial for model interpreters, given their generally more limited experience and expertise concerning cooperation visualisation. In this research paper we therefore focus on model interpreters in enterprises considered as users of cooperation visualisation.

Thus, for our study we defined the term cooperation visualisation as a model-based representation of enterprise cooperation. Cooperation visualisation can have a temporary project-specific purpose for planning enterprise cooperation and/or be used continuously for coordination and controlling purposes. For those purposes well-developed model-based cooperation visualisation is important, which is easy to interpret by users. For enterprise modelling practice, a usability evaluation framework can be essential to ensure that cooperation visualisation is well-user-centric-modelled in enterprises. Prior research in information systems (IS) addresses the empirical evaluation and usability of modelling languages, model development and model interpretation (e.g. Gemino and Wand, 2004; Schalles et al., 2010, 2011, 2012, 2014; Schalles, 2013). Results are conceptual or validated empirically and cover selected application fields like software engineering or enterprise modelling. Developed frameworks are covering usability concepts and are used for usability evaluation. To our knowledge, no evaluation framework for the special field of cooperation visualisation is available so far. Existing frameworks are difficult to transfer, because they are developed for special application fields. Also, generic frameworks are not field-specific enough to draw out relevant information, e.g. to
improve cooperation visualisation. Hence, there is a need for theory guided frameworks for usability evaluation, which are particularly focused on the field of cooperation visualisation (see section 2). This leads us to our central research question: How can a developed and based on a causal model empirical validated framework applied to evaluate the usability in terms of model interpretation of cooperation visualisation for enterprise modelling?

2 Related Work

The related work to our research paper consists of IS literature considering usability definitions and frameworks used for usability measurement. A specific usability measurement framework for cooperation visualisation in enterprises is identified as an open research gap. We explain the meaning of usability in the context of cooperation visualisation in enterprises.

2.1 Usability Definitions

The various usability definitions in IS literature make it difficult to select a suitable concept for usability evaluation of cooperation visualisation in enterprises. Therefore, diverse usability definitions are compared to identify a suitable usability concept for cooperation visualisation (see table 1). The most prevalent attributes for usability definition detected in IS literature are learnability (12), efficiency (10), effectiveness (9), memorability (8), ease of use (7), errors (7), satisfaction (7), perceptibility (5), productivity (4), users (4), flexibility (4), attitude (3), and tasks (2).

For our usability concept, we exclude the less frequent criteria attitude (3) and tasks (2). Models of cooperation visualised should enable a high degree of learnability, memorability, and flexibility. High satisfaction and productivity can also be reached if they contain no errors. We concentrate on the perceptibility of users or model interpreters. These are working in enterprise cooperation. The ease of use, effectiveness, and efficiency of cooperation visualisation are supportive to fulfil enterprise cooperation. Ease of use for model interpretation is high, if cooperation visualisation can be easily understood by users. Their perceptibility towards enterprise modelling is indicated as an important factor to generate learnability, memorability, flexibility, satisfaction, productivity, effectiveness, and efficiency.

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2.2 Usability Measurement

The variety of usability definitions is reflected in various frameworks or models for usability measurement. These are developed from theory and/or empirically validated and describe diverse attributes, metrics and variables for usability evaluation.

Many of the usability measurement frameworks or models have their origin in the field of software engineering, human-computer systems interaction, or related fields. For example, Shackel (1991) suggested a framework to describe the relations between the user working with IS on a task to be finished with the aid of a computer assisted tool in a special context or environment (Shackel, 1991). Seffah et al. (2006) proposed a consolidated model for integrated measurement of quality in use. This model differentiates factors, criteria and metrics for usability measurement. The factors are efficiency, effectiveness, productivity, satisfaction, learnability, safety, trustfulness, accessibility, universality, and usefulness. Criteria for usability measurement are linked to these factors like time behaviour, resource utilisation, and loading time with productivity. Metrics are stated as a set of mathematic formulas or functions for calculating usability factors (Seffah et al., 2006). A usability evaluation framework for software engineering methodologies (SEM) suggested by Masood et al. (2014) covers comprehensibility, learnability, applicability, effectiveness/usefulness, and user satisfaction as usability factors for SEM. Measurement criteria are defined to measure these factors like clarity, consistency, conciseness, unambiguous, well-structured, self-descriptiveness, and familiarity/universality for comprehensibility (Masood et al., 2014).

For our research paper, we take only usability measurement frameworks or models into consideration, which are useful for enterprise modelling. In this field there are less usability measurement frameworks or models existing. They aid to evaluate modelling languages, process modelling tools or process models. For example, Gemino and Wand (2004) propose a framework for conceptual modelling languages applied in requirements engineering. It contains measures for effectiveness and efficiency both linked with model development and model interpretation. For model development the product is described as a physical model and the process as a process of creating a model. For model interpretation the product is described as a cognitive model from the perspective of the viewer and the process as a process of understanding a model (Gemino and Wand, 2004). Another framework is suggested for usability evaluation of conceptual modelling languages by Schalles et al. (2010). Modelling language usability attributes, variables, and usability metrics such as using a questionnaire or knowledge test are included in this framework. Language properties are investigated from the side of model development and the side of model interpretation. On both sides, these language properties are characterised by different types (object, relationship, property), shapes and colours. For both sides, the relevant usability factors are user satisfaction, efficiency, effectiveness, memorability and learnability. According to Schalles et al. (2010), perceptibility is irrelevant for model development (Schalles et al., 2010).

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Table 1. Comparison of selected usability definitions within IS literature.
Later Schalles et al. (2011) evaluated the model interpretation side of their usability evaluation framework for modelling languages using their own usability definition. For model interpretation the authors validate a set of relations between perceptibility, user satisfaction, efficiency, effectiveness, memorability, and learnability. To these usability factors, meta-model properties like visual properties and language complexity are added. Furthermore, user experience and model complexity are included in their validated causal hypothesis model (Schalles et al., 2011). Another model of hypotheses is tested by Schalles et al. (2012) for modelling language comparison. This model covers the language usability including effectiveness, efficiency, learnability, memorability, user satisfaction, and visual perceptibility and the language attributes. The impact of different language attributes on the language usability are tested and compared. High usability is confirmed for process modelling languages, behavioural languages, simple structured languages, and visual differentiation (Schalles et al., 2012).

For model development and model interpretation Effinger et al. (2011) designed an integrated usability method for process modelling and modelling tools. Here, the usability of single features is tested with a questionnaire to gain recommendations for the business process modelling tool development process (Effinger et al., 2011). For process modelling tools another usability measurement framework has been developed by Becker et al. (2013). It covers the usability attributes effectiveness, efficiency, learnability, memorability, and user satisfaction. The environment is linked with these usability attributes, where only user satisfaction is related to tool acceptance. The context of use (user, task, modelling methodology) and tool (user assistance, user interface, functionality, collaboration support) are forming the environment (Becker et al., 2013). We think the perceptibility towards model development is missing in this framework because it is especially important for modelling tools.

In the research agenda of Rolón et al. (2015) a usability evaluation framework to be developed for business process models should focus on seven usability principles: task suitability, self-descriptiveness, user expectations conformity, learning suitability, controllability, error tolerance, and individualisation suitability (Rolón et al., 2015).

Based on the analysis of related work, to the best of our knowledge no usability measurement framework or model exists for cooperation visualisation in enterprises. Usability measurement frameworks or models in the field of enterprise modelling are too unspecific and have been developed for different application fields like process modelling. We assume that for the usability evaluation of cooperation visualisation in enterprises, specific aspects, like usage conditions of cooperation visualisation in enterprises, must be reflected and included in a specific usability measurement framework or model to measure usability with fitting attributes, metrics and variables.

3 Usability Theory Development

The usability concept underlying this research paper is focused on cooperation visualisation in enterprises, its users (model interpreters), usage conditions, and usability.

3.1 Usability Framework Development

Applying the usability concept and measurement model development we suggest our framework shown in figure 2. The framework includes four main components defined in subsection 3.2, the properties of the users, properties of the enterprises, usage conditions of cooperation visualisation in enterprises consisting of usage effects, usage barriers, usage requirements and usage variants, and attributes of the usability of cooperation visualisation in enterprises. We expect a causal relation between each dimension, which is explored in our quantitative empirical study. We assume the user properties and enterprise properties to have an impact on the usage conditions of cooperation visualisation in enterprises. These are expected to influence the usability of cooperation visualisation in enterprises.
The criteria-based usability concept grounding in our framework is reflected by the properties of the users based on their own enterprise modelling perceptibility central for learnability, memorability, and flexibility etc. as well as the properties of the enterprises in cooperation, in which the partners such as users or model interpreters work together. They are confronted with multiple usage conditions of cooperation visualisation in enterprises influencing several usability attributes like ease of use, satisfaction and productivity etc. The attributes of usability are therefore theoretically grounded in criteria like collaborative work between enterprises as an essential requirement for cooperation visualisation usage.

**Figure 2.** Framework for the usability evaluation of cooperation visualisation.

### 3.2 Measurement Model Development

We developed a measurement model including measurement scales for each variable to empirically validate the developed framework shown in figure 2. We use latent variables in our causal model with selected indicators (see figure 3). All variables are operationalised with coding and reflective survey items based on different scales (see figure 5 in the appendix). For our quantitative empirical study these survey items have been validated by practitioners like project managers (see subsection 4.1).

**Properties of the users.** Cooperation visualisation is used by different types of users (model interpreters) with dissimilar properties like age, gender, and work experience. The user properties are measured as follows: Age (years), gender (1 = men; 2 = woman), and work experience (years).

**Properties of the enterprises.** Cooperation visualisation is not useful for every enterprise in which users (model interpreters) are working. It depends on the properties of the enterprise like number of employees, turnover, and enterprise size. The enterprise properties are quantified as follows: Number of employees (1 = 1 up to 9 employees; 2 = 10 up to 499 employees; 3 = 500 and more employees), turnover (1 = less than 1 million; 2 = 1 million up to less than 50 million; 3 = 50 million and more), enterprise size (generated based on number of employees and turnover; 1 = small enterprises, if number of employees and turnover < 3; 2 = medium enterprises, if number of employees and turnover > 2 and < 6; large enterprises, if number of employees and turnover = 6).

**Usage conditions of cooperation visualisation in enterprises.** In enterprise modelling practice, there are different usage requirements of cooperation visualisation. Model developers should visualise business processes of the own enterprise and of the cooperation partners with all relevant information. Therefore, information objects (e.g. documents containing information) should be included. Their creation should be quick and easy. Results must be easy to use and understand with no long training periods for model interpretation. Cooperation visualisation can be used in different
collaboration situations like training sessions, projects, meetings, and presentations, but also in different IS like planning games and software. Here, collaboration situations and IS are summarised under the term usage variants. Using cooperation visualisation in enterprises has different usage effects, which can be interpreted as benefits or possibilities like cost and effort reduction, better planning, coordinating, and controlling of cooperation, but also an increase of work productivity and work quality. Using cooperation visualisation in enterprises is confronted by different usage barriers, which can be interpreted as problems or difficulties like high financial effort, lack of human resources, and lack of know-how necessary for cooperation visualisation. Some model interpreters might think it distracts from actual work tasks or the business processes are too complex to visualise, therefore it is not worthwhile to use cooperation visualisation. There are further usage conditions like more usage requirements, usage variants, usage effects, and usage barriers, which are important for cooperation visualisation in enterprises. Therefore, we decided to measure the usage conditions of cooperation visualisation in enterprises with a 7-point-Likert-scale for the measurement of confirmation (1 = I do not agree at all; 7 = I totally agree) and for the measurement of frequency (1 = never; 7 = very often). Values between 1 and 7 are used to allow participants to differentiate their individual estimations. The indicators for the variables usage requirements (UR1-UR7), usage effects (UE1-UE7), and usage barriers (UB1-UB7) of cooperation visualisation are measured by confirmation. The indicators for the variable usage variants of cooperation visualisation (UV1-UV7) are measured by frequency. Each seventh indicator (UR7, UE7, UB7, and UV7) represents further usage conditions of cooperation visualisation in enterprises.

Attributes of the usability. Cooperation visualisation is only useable in enterprises, if users or model interpreters are collaboratively working in enterprise cooperation and using cooperation visualisation in the enterprise. The usability is operationalised as follows: Work in an enterprise cooperation (1 = yes, currently; 2 = yes, in the past; 3 = no, never), usage of cooperation visualisation in enterprises (1 = yes, actual; 2 = yes, in the past; 3 = no, never).

3.3 Structural Model Development

The developed framework (see figure 2) is the basis for the development of a causal model for the usability evaluation of cooperation visualisation in enterprises (see figure 3). Causal relations are added as explorative hypotheses based on the framework. This causal model contains organisation properties and usage attributes. A control variable, so called further usage conditions, is implemented because for usability evaluation it is suitable to build one separate variable covering further enterprise conditions for using cooperation visualisation. We expect the user properties to be positively connected with the usage requirements and usage variants. Users should have requirements and apply matching variants.

Hypothesis 1(+). The user properties are positively influencing the usage requirements.

Hypothesis 2(+). The user properties are positively influencing the usage variants.

We assume enterprise properties to cause usage requirements and usage variants directly. Based on enterprise properties like number of employees, turnover, and enterprise size viewed as positive drivers of usage requirements and usage variants they might be important for both usage conditions.

Hypothesis 3(+). The enterprise properties are positively influencing the usage requirements.

Hypothesis 4(+). The enterprise properties are positively influencing the usage variants.

We argue that usage requirements could positively determine the usage effects, usage variants, and usage barriers directly. Individual usage requirement specification in enterprises may aid to raise usage effects, fix usage variants, and reduce usage barriers of cooperation visualisation.

Hypothesis 5(+). The usage requirements have a positive influence on the usage effects.

Hypothesis 6(+). The usage requirements have a positive influence on the usage variants.

Hypothesis 7(+). The usage requirements are positively influencing the usage barriers.
We estimate that usage effects, usage barriers, and usability might be influenced by usage variants.
Ease of interpretation based on model quality presented in usage variants, like in a planning game,
software or presentation, should increase usage effects, reduce usage barriers, and enhance usability.
Hypothesis 8(+). *The usage variants are positively influencing the usage effects.*
Hypothesis 9(+). *The usage variants are positively influencing the usage barriers.*
Hypothesis 10(+). *The usage variants are positively influencing the usability.*
We assume that cooperation visualisation usability should be also positively influenced by usage
effects like a productivity increase and negatively influenced by usage barriers such as financial effort.
Hypothesis 11(+). *The usage effects have a positive influence on the usability.*
Hypothesis 12(-). *The usage barriers are negatively influencing the usability.*
We expect that more usage requirements, usage variants, usage effects, and usage barriers are relevant.
In enterprise practice, there should exist further usage conditions. They should be linked positively.
Hypothesis 13(+). *The further usage conditions are positively influencing the usage requirements.*
Hypothesis 14(+). *The further usage conditions are positively influencing the usage variants.*
Hypothesis 15(+). *The further usage conditions are positively influencing the usage effects.*
Hypothesis 16(+). *The further usage conditions are positively influencing the usage barriers.*

4 Research Method

4.1 Data Collection

Our sample in total consist of 1,210 managers, which participated in the quantitative empirical study.
Employees with no management function are excluded from this study, because cooperation visualisation
usage of the low (111), middle (235), and top management (86) was in focus. 432
managers, who currently work in cooperation or used to work in cooperation in the past, using and
interpreting cooperation visualisation, are included in this sample. All 432 users have completely filled
in the questionnaire. The questions and items have been formulated and tested iteratively through two
qualitative pre-tests of the paper-based questionnaire with four project managers in a first step, one
project manager in a second step and one quantitative pre-test of the online questionnaire with 30
managers with similar occupational status like in our quantitative empirical study. After the pre-tests,
those survey items are kept, which are easy to understand for practitioners in enterprises (see figure 5
in the appendix).
The sample is a representative mixture of enterprise headquarters and sizes, which were located in key
industries nationwide in Germany 2015, and managers, which were involved in cooperation and have
visualised cooperation. Quantitative data collection was conducted with a panel online survey with all
managers in December 2015. The participants are selected over online panel vendors by defining the
target group with attributes and quotas. These were age (18 until 65 years), region (nationwide),
professionals with higher occupational status (low, middle, and top management) from all federal
states in Germany cooperating and visualising in enterprises in selected industries descending sorted
by participants (health care and social domain, trade, information and communication, manufacturing
domain, finance and insurance services, machinery and plant engineering, operation and construction
of buildings, energy supply, real estate domain, and maintenance and repair of motor vehicles).

4.2 Data Analysis

The partial least squares (PLS) results are obtained with SmartPLS 2.0.M3 (Ringle et al., 2005) by
conducting a PLS algorithm, bootstrapping, and blindfolding procedure (Chin, 1998) out of the 432
complete user data sets relevant for cooperation visualisation usability, to test the significance of the
constructed explorative hypotheses (see figure 3). The PLS algorithm is applied with 300 iterations. For evaluation of the causal model the bootstrapping method is conducted with 432 cases and 5,000 samples to calculate reliable t-values needed for hypothesis test. Blindfolding is realised with a distance value of 7 to calculate the variable cross-validated redundancy ($Q^2$), which is necessary to identify whether or not the causal model has a predictive character.

For data analysis, all questionnaire items are treated as reflective indicators for each variable of the causal model. Hence, each single variable change can be caused by each single indicator. We proved several models based on an explorative factor analysis signifying the indicators with best loadings on the build variables to get reliable results out of the measurement and structural model test (see figure 5 in the appendix). For these tests we had separated and used eight factors. The size of the sample is compliant to the needed cases specified and accepted in IS literature. A minimum of 114 cases is needed based on the formula ($N > 50 + 8m$) of Tabachnick and Fidell (2001), for example, also applied by Bandara et al. (2006). Our data set had 432 valid cases in total.

5 Usability Theory Validation

The usability concept stated by the model interpreters or users of cooperation visualisation, cooperation visualisation, usage conditions of cooperation visualisation, and usability of cooperation visualisation in enterprises is evaluated. The best causal model resulting from data analysis is presented.

5.1 Measurement Model Validation

For measurement model evaluation quality metrics are calculated and interpreted for the measurement model and structural model (see table 2). All alpha values (Cronbach, 1951) as well as composite reliability values are indicating good measurement of variables. All reflective questionnaire items of the variables with loadings smaller than 0.500 are dropped (see figure 5 in the appendix). All values for the average variance extracted (AVE) can be accepted, also for the further usage conditions with a value near the threshold. The user properties as well as the enterprise properties summarised as organisation properties did not clarify the usage requirements at all, because the $R^2$-threshold is smaller than 0.190 (Chin, 1998). We learned that usability is not explained in sum by the (further) usage conditions of cooperation visualisation in enterprises. The usage variants and usage barriers are weak and the usage effects are average explained by other linked factors like usage requirements and further usage conditions. We also calculated the variable cross-validated redundancy ($Q^2$). Here, all values are greater than 0.000, which is indicating that the validated causal model has a predictive characteristic.

<table>
<thead>
<tr>
<th>Quality Metrics of the Measurement Model</th>
<th>Quality Metrics of the Structural Model</th>
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<tr>
<td>Threshold</td>
<td>Type</td>
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<td>User properties</td>
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<td>Usage requirements</td>
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<td>Usage variants</td>
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</table>

Notes. R: reflective; n=432 for all variables; N.A.: not available: because $R^2$ and $Q^2$ are only relevant for
evaluating endogenous variables in the inner model (Chin, 1998).

Table 2. Reliability and validity of the measurement model and structural model (for value comparison this representation is based on Schalles et al., 2011).

5.2 Structural Model Validation

The results of structural model evaluation including all path coefficients and significances of path coefficients are presented in figure 3. The developed causal model for the usability evaluation of cooperation visualisation is validated to demonstrate how different organisation properties and usage attributes are influencing each other and how they are supporting the cooperation visualisation in enterprises. In general, path coefficients can reach values between -1 and 1 in a structural equitation model. A latent exogenous variable with a negative or positive path coefficient can have a negative or positive influence on the latent endogenous variable. A negative or positive path coefficient to be reflected for a structured discussion in section 6 should have a value smaller than -0.200 or greater than 0.200 (Chin, 1998). A positive path coefficient to be considered should therefore have a value of at least 0.100 (Lohmöller, 1989). In addition, we accepted path coefficients between latent exogenous variables and latent endogenous variables with values smaller than -0.100.

Significances of path coefficients are stated with p-values beginning with p-values smaller than 0.001, smaller than 0.01, and ending with p-values smaller than 0.05. All other path coefficients are not significantly measured. For enabling a deeper causal model evaluation for a well-structured discussion in section 6 we also calculated the effect size $f^2$. This size can have a weak effect ($\geq 0.02$), a medium effect ($\geq 0.15$), or a strong effect ($\geq 0.35$). Effect sizes with values smaller than 0.02 are indicating that a latent exogenous variable has no significant effect (influence) on a latent endogenous variable (Cohen, 1988; Chin, 1998). Only significant measured path coefficients between latent exogenous variables and latent endogenous variables with validated effects will be discussed in section 6 – particularly strong effects. The effect sizes are highlighted with bold lines with arrowheads at their end in figure 3.

Figure 3. Validated causal model for the usability evaluation of cooperation visualisation.

Hypothesis 1(+) is verified. The user properties have a very significant positive but weak influence on the usage requirements (path coefficient=0.226, $p<0.001$, $f^2=0.054$).

Hypothesis 2(+) is not verified. The user properties have no significant positive influence without an effect on the usage variants (path coefficient=-0.010, $p>0.05$, $f^2=0.000$).

Hypothesis 3(+) is not verified. The enterprise properties do not have a significant positive influence without any effect on the usage requirements (path coefficient=0.031, $p>0.05$, $f^2=0.001$).
Hypothesis 4(+) is not verified. The enterprise properties have no significant positive influence without any effect on the usage variants (path coefficient=-0.030, p>0.05, $f^2=0.001$).

Hypothesis 5(+) is verified. The usage requirements are very significantly positively influencing with a strong effect the usage effects (path coefficient=0.496, p<0.001, $f^2=0.353$).

Hypothesis 6(+) is verified. The usage requirements have a very significant positive influence with a weak effect on the usage variants (path coefficient=0.241, p<0.001, $f^2=0.059$).

Hypothesis 7(+) is not verified. The usage requirements do not have a significant positive influence without an effect on the usage barriers (path coefficient=-0.034, p>0.05, $f^2=0.002$).

Hypothesis 8(+) is verified. The usage variants have a very significant weak positive influence on the usage effects when using cooperation visualisation (path coefficient=0.132, p<0.01, $f^2=0.025$).

Hypothesis 9(+) is verified but with a negative relation. Surprisingly usage variants have a very significant weak negative influence on the usage barriers (path coefficient=-0.153, p<0.01, $f^2=0.021$).

Hypothesis 10(+) is verified but with a negative relation. Surprisingly usage variants have a very significant weak negative influence on the usability (path coefficient=-0.320, p<0.001, $f^2=0.094$).

Hypothesis 11(+) is not verified. Usage effects have no significant positive influence and no effect on the cooperation visualisation usability (path coefficient=0.053, p>0.05, $f^2=0.002$).

Hypothesis 12(-) is not verified. Usage barriers have no significant negative influence without any effect on the cooperation visualisation usability (path coefficient=-0.076, p<0.05, $f^2=0.007$). T-values indicated a significant path between these latent variables but path coefficients are larger than -0.100.

Hypotheses 13(+) until 16(+) are verified. Further usage conditions of cooperation visualisation in enterprises have a very significant positive influence on the different usage conditions like weak on usage requirements (path coefficient=0.238, p<0.001, $f^2=0.061$), weak on usage variants (path coefficient=0.351, p<0.001, $f^2=0.129$), weak on usage effects (path coefficient=0.190, p<0.001, $f^2=0.052$), and medium on usage barriers (path coefficient=0.482, p<0.001, $f^2=0.237$).

5.3 Usability Framework Validation

The developed framework for the usability evaluation of cooperation visualisation (see figure 2) is adapted based on the causal model validated with quantitative empirical study results (see figure 3). This comparison of developed and verified hypothesis resulted in the empirical validated framework presented in figure 4. The critical path for usability evaluation of cooperation visualisation is illustrated by the grey arrows. It starts with user properties influencing the usage requirements. The further usage conditions are influencing the usage requirements and usage variants. A strong effect is statistically significant between the usage requirements and usage variants, which is the only usage condition linked with the usability of cooperation visualisation in enterprises directly. As figure 4 shows, three relations are not relevant for the critical usability evaluation path. Within the usage conditions of cooperation visualisation in enterprises the usage requirements are influencing the usage effects, whereas the usage variants and further usage conditions are causing the usage effects and the usage barriers.
### Discussion

In this research paper we propose an in enterprises empirical validated framework for usability evaluation of cooperation visualisation (see figure 4). It contains a critical path for cooperation visualisation usability evaluation, which can be used for usability theory improvements and usability practice solutions in the special field of cooperation visualisation in enterprises. Finally, we explain our limitations and give an outlook.

#### 6.1 Implications for Usability Theory

For usability theory, the quantitative empirical study results provide special insights for understanding usability evaluation of cooperation visualisation in enterprises. A critical usability evaluation path is detected for cooperation visualisation in enterprises. On this theory guided basis new usability concepts for cooperation visualisation in enterprises can be developed. They should include at a minimum user properties, (further) usage requirements, (further) usage variants, and usability attributes.

We find indication that usage variants can negatively influence the cooperation visualisation usability in enterprises. Therefore, managers should decide for suitable usage variants depending on their (planned) enterprise cooperation. They can decide for less or more complex usage variants based on their usage experience. We suggest common shared usage variants like a collaboratively used documentation such as a presentation used in common meetings, projects and/or training sessions. This will also aid to manage the different usage requirements based on the user properties. If the users or model interpreters have e.g. extensive work experience, they might need shorter training periods or less relevant information. In such case more complex usage variants like a planning game or software could be the right choice. For users with less experience a presentation or using it in a training session might be a good choice. We now know that planning games or software for cooperation visualisation are existing in enterprise modelling practice. Therefore, serious games and gamification approaches for cooperation visualisation can be framework-based developed and tested in enterprises for

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**Figure 4.** Validated framework for the usability evaluation of cooperation visualisation.
experienced users. The validated framework and critical path aids to include cooperation visualisation usability aspects into these serious games or gamification approaches. The validated framework should be a well-grounded basis for the cooperation simulation in planning games or software to be developed and tested. Therefore, more detailed concepts and prototypes of cooperation visualisation tools are necessary.

6.2 Implications for Usability Practice

For usability practice, the usage requirements and usage variants based on the critical usability evaluation path for cooperation visualisation are most important. Managers in enterprise cooperation are now aware of the usage effects and usage barriers influenced by the usage requirements and usage variants. Managers can use the validated framework as an analytical grid for taking decisions on cooperation visualisation. Now, they are able to know how the organisation properties and usage attributes are working together and how they can positively influence them in their enterprise to raise the cooperation visualisation usability. Model-based representations of enterprise cooperation can be evaluated in a user-centric way based on our validated framework for checking usability or ease of model interpretation. When using our framework as an analytical grid the management should first start with the usage requirements. They should analyse the business processes of the cooperation partners to gain all relevant information for cooperation visualisation. If documents, procedures, or instructions are linked with the analysed business processes, they should be integrated in cooperation visualisation as information objects. Creation should be quick and easy when selecting a planning game or software as a relevant usage variant. For using them in trainings, they should require short times for learning them.

6.3 Limitations and Outlook

The empirical study results are limited to the users of cooperation visualisation in enterprises. These are model interpreters who are working or have been working with visualisation in their enterprise cooperation. Our focus on model interpreters in enterprises aimed to develop and empirically validate a special framework relevant for usability evaluation of cooperation visualisation. This framework is especially valid for small, medium, and large enterprises in selected industries located with their headquarters in Germany. Enterprises of other industries and/or located in other countries can also benefit from this framework, if they compare their organisation properties and usage attributes with the validated framework elements like the critical path for usability evaluation of cooperation visualisation.

The data set collected might have influenced our empirical framework validation because potential newcomers not working in cooperation and not using visualisation are not in focus. Between the actual and potential new model interpreters in enterprises important differences may exist which open up new perspectives on the usability evaluation of cooperation visualisation. Thus, we plan to expand our study to potential model interpreters to gain new usability insights based on a framework comparison.
Appendix

| User Properties. |
| UP1 (0.972). How many years of work experience do you have? |
| UP2 (-0.500). Your gender? (dropped) |
| UP3 (0.977). How old are you? |

| Enterprise Properties. |
| EP1 (0.767). Approximately how many employees does the enterprise in which you are working have? |
| EP2 (0.948). Approximately how much turnover in euros per year does the enterprise in which you work make? |
| EP3 (0.963). Approximately how large is the enterprise you work in? |

| Usage Requirements. |
| UR1 (<0.500). Cooperation visualisation should be limited to business processes of the own enterprise. (dropped) |
| UR2 (0.768). Cooperation visualisation should include the business processes of cooperation partners. |
| UR3 (0.875). Cooperation visualisation should contain all relevant information (e.g. on business processes, tasks, and responsibilities). |
| UR4 (0.829). Cooperation visualisation should be quick and easy to create. |
| UR5 (0.810). Cooperation visualisation should not require long training periods. |
| UR6 (0.802). Cooperation visualisation should refer to information objects (e.g. important documents). |

| Usage Variants. |
| UV1 (0.689). In a training session. |
| UV2 (0.686). In a planning game. |
| UV3 (0.698). In a project. |
| UV4 (0.758). In a meeting. |
| UV5 (0.722). In a software. |
| UV6 (0.790). In a presentation. |

| Usage Effects. |
| UE1 (0.818). ... a significant cost and effort reduction in cooperation with (another) enterprise. |
| UE2 (0.875). ... a better planning of enterprise cooperation with regard to business processes, tasks, and partners. |
| UE3 (0.890). ... a better coordination of enterprise cooperation with regard to business processes, tasks, and partners. |
| UE4 (0.905). ... a better control of enterprise cooperation with regard to business processes, tasks, and partners. |
| UE5 (0.821). ... an increase in the work productivity of enterprise cooperation partners. |
| UE6 (0.855). ... an increase in the work quality of enterprise cooperation partners. |

| Usage Barriers. |
| UB1 (0.799). The financial effort for the usage of cooperation visualisation is too high. |
| UB2 (0.790). There are not enough human resources for the usage of cooperation visualisation. |
| UB3 (0.806). The necessary know-how for the usage of cooperation visualisation in the enterprise is missing. |
| UB4 (0.819). There is a risk that the usage of cooperation visualisation will distract too much from the actual work tasks. |
| UB5 (0.803). The business processes in our enterprise are too complex to visualise them understandable. |
| UB6 (0.824). Working in enterprise cooperation is so rare that it is not worthwhile to use cooperation visualisation. |

| Further Usage Conditions. |
| UE7 (0.791). ... further effects of the usage of cooperation visualisation, which are not listed above. |
| UE8 (0.666). There are further barriers of the usage of cooperation visualisation, which are not listed above. |
| UR7 (0.775). There are further requirements, that cooperation visualisation should fulfil, which are not listed above. |
| UV7 (0.613). Cooperation visualisation is used in further variants, which are not listed above. |

| Usability. |
| US1 (0.787). Have you already worked or do you work in an enterprise cooperation? |
| US2 (0.931). Have you used or do you use cooperation visualisation in your enterprise cooperation? |

Figure 5. Survey items.

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