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How Conceptual Modeling Is Used

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Abstract:

Conceptual models play an increasingly important role for business process engineering, information systems development, and customizing of Enterprise Resource Planning (ERP) systems. Despite the widespread interest in conceptual modeling, relatively little is known to date on the level and nature of conceptual modeling use in practice. Therefore our study investigates how practitioners use conceptual modeling. In particular, we address the following three key questions: To what extent do practitioners use conceptual modeling techniques and tools? How relevant is conceptual modeling for certain purposes? Are there barriers and success factors in using conceptual modeling? This paper informs information systems professionals about recent trends in the area of conceptual modeling. The results of our study should be considered when developing syllabuses for modeling courses as well as when judging the relevance of various research streams in the area of conceptual modeling.

Keywords: modeling, modeling technique, modeling language, tool, method, empirical, survey

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I. INTRODUCTION

Conceptual modeling aims at building a formal representation of a modeling domain [Wand and Weber 2002]. It is a key activity in modern computing. Conceptual models, which are often graphically represented, are used by Information Systems professionals to denote both static and dynamic aspects of a particular domain. They play an increasingly important role during all phases of the information systems lifecycle. Typical examples include the analysis, design, and implementation of software systems; business process engineering; and customizing of Enterprise Resource Planning (ERP) systems.

Despite the widespread interest in conceptual modeling, relatively little is known to date on the level and nature of conceptual modeling use in practice [Batra and Marakas 1995; Davies et al. 2006; Dobing and Parsons 2005; Fettke and Loos 2007; Gorla et al. 1995]. This is why our study investigates how practitioners use conceptual modeling. In particular, we address the following three key questions:

- To what extent do practitioners use conceptual modeling techniques and tools?
- How relevant is conceptual modeling for certain purposes?
- Are there barriers and success factors in using conceptual modeling?

The research began with a review of the literature and some preparatory interviews with practitioners. Based on previous work [Davies et al. 2006], we developed a web survey targeted at German practitioners who are familiar with conceptual modeling. The call for participation in this study was sent to all members of the Gesellschaft für Informatik e. V. (German Computer Society). Besides an executive summary of the obtained results, no further participation incentive was offered.

The design of this study is similar to the research published by Davies et al. [2006] that tackles on the usage of conceptual modeling in Australia. Due to this regional and cultural focus, their results are difficult to generalize for and transfer to the German modeling community. A priori, some important facts must be taken into account in order to judge the usage of conceptual modeling techniques in Germany:

- Conceptual modeling techniques have constituted an integral part of the German Information Systems curriculum since 1990 [Wissenschaftliche Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft e. V. 1990] (German Scientific Information Systems Commission). This is a significant difference to international Information Systems curricula. Hence, it can be concluded that practitioners in Germany are very familiar with the usage of conceptual modeling techniques.
- Petri nets and Event-driven Process Chains are two important conceptual modeling techniques developed in Germany.
- SAP AG and IDS Scheer AG are two German *world-leading* companies that have intensively propagated the adoption of conceptual modeling for the analysis and implementation of information systems since the early 1990s. For example, the standard software package SAP R/3 is fully documented in conceptual models.

It can be argued that those factors have a strong influence on the usage of conceptual modeling techniques in Germany. Hence, it is particularly necessary to study the usage of modeling techniques in Germany.

The remainder of the paper is structured as follows: After introducing the topic of the paper in Section I, Section II overviews the obtained empirical sample. The extent of modeling techniques use is described in Section III. Thereafter, Section IV reports on the purpose of conceptual modeling. The extent of modeling tool use is described in Section V. Section VI discusses barriers and success factors in using conceptual modeling. The results of this study are compared with prior results in Section VII. Section VIII draws some implications for further research. The paper concludes in Section IX.

II. OVERVIEW OF THE RESULTS

The web survey received 304 valid responses from people using conceptual modeling in practice. Respondents reported having experiences in conceptual modeling for the average period of 8.5 years. Ten percent even have gained experiences for more than twenty years. Sixty-nine percent have developed their modeling competencies in academia; 17 percent indicated that they participated in in-house professional trainings. The remaining 14 percent of respondents did not receive any formal training or did not respond to this question.

The participants work for organizations of different sizes: 27 percent of the participants stated that they work for organizations of less than 100 employees. Twenty-three percent work for firms with a headcount of 100 to 1,000 people. Forty-one percent of the participants are employed by organizations having more than 1,000 employees. The remaining 9 percent of the participants did not provide the size of their organization.

III. EXTENT OF MODELING TECHNIQUES USE

A modeling language provides a set of constructs and rules that specify to combine the constructs to model real-world domains [Wand and Weber 2002]. A modeling method proposes procedures by which a modeling language can be used. We use the term *modeling technique* to denote modeling languages as well as modeling methods. In the field of conceptual modeling it is common practice to introduce new modeling techniques or new variants of existing techniques. Therefore, it is interesting to investigate the actual extent of modeling technique use and diffusion in practice. Figure 1 depicts the extent of use of the most frequently used modeling techniques.

The Entity-Relationship model (ERM) and the Unified Modeling Languages (UML) are used frequently by more than 50 percent of the participants. Frequent use means that the technique is used five or more times a week. About 30 percent of the respondents use workflow modeling, Event-driven Process Chains (EPC), and Statechart diagrams frequently. The remaining modeling techniques, not shown in Figure 1, are not frequently used by more than 3 percent of all respondents. The interpretation of these results reveals the following: first, just a dozen modeling techniques are of relevance in practice. Second, the “classical” ERM approach is still of overwhelming importance for practice, closely followed by the UML. Third, dedicated process modeling techniques, such as EPC and workflow modeling, are significantly used today.

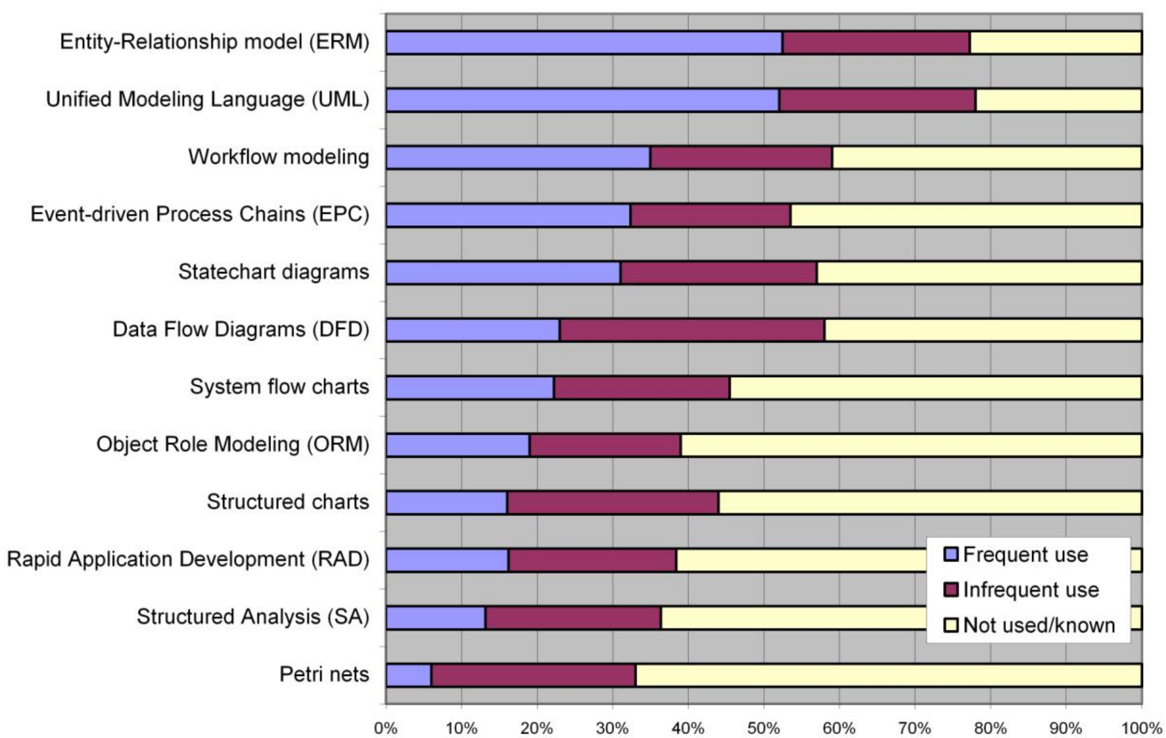

Figure 1. Modeling Techniques Most Frequently Used

We analyzed how the extent of modeling technique use evolves over time. Figure 2 depicts the trend of usage of different modeling techniques. The x-axis (y-axis) represents the difference between the usage frequencies in the past (today) and today (in the future) in percent. For example, the usage frequency of the UML increased by 32 percent in the past and will decline by 1 percent in the future. The following usage patterns can be identified:

- The usage of some modeling techniques has increased over the course of the last years, which applies, for instance, to the use of UML (plus 32 percent), workflow modeling (plus 21 percent), and EPC (plus 16 percent).

- The usage frequencies of another group of modeling techniques (e.g. Petri nets, Statechart diagrams, and ERM) did not alter during the past years. Nevertheless, ERM is still used very frequently. It is not clear how rapidly the usage frequency of this group of modeling techniques will decline.
- The usage frequencies of Data Flow Diagrams (DFD), Structured Analysis (SA), and Structured Charts have declined significantly in the past. Hence, these techniques will not play a major role in the future of conceptual modeling.
- There is no evidence that the use of modeling techniques will increase significantly in the future.

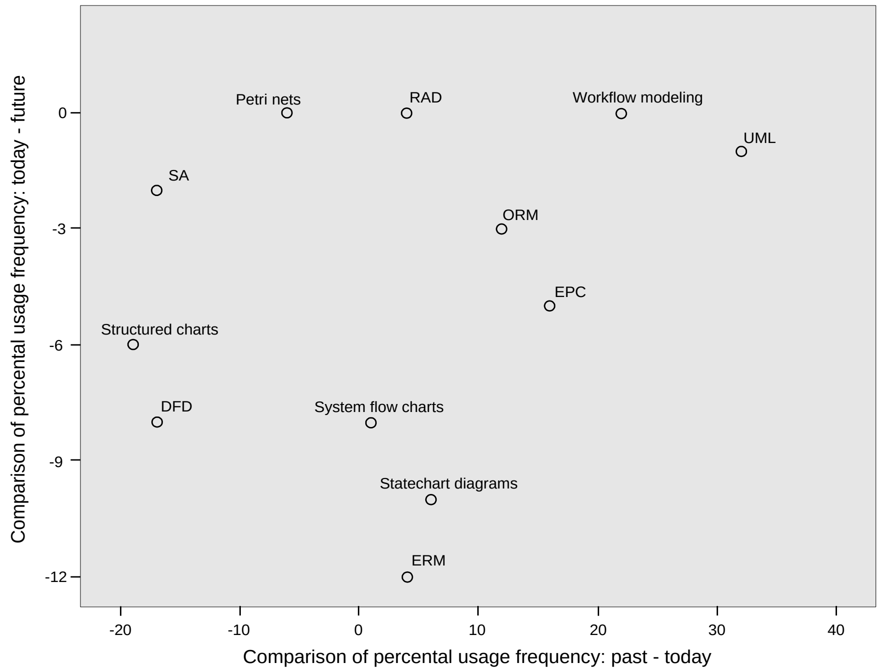

Figure 2. Effect of Time on the Usage of Modeling Techniques

The obtained results show in general an increase in conceptual modeling techniques usage in the past. However, it is somewhat surprising that the usage of no conceptual modeling technique will significantly increase in the future. One possible explanation for this phenomenon may be that conceptual modeling techniques matured in the past. Thus, the market for modeling techniques is saturated. Note for example, that the *International Conference on Conceptual Modeling* is thirty years old in 2009.

Additional analyses were conducted to identify the influence of modeling experience and firm size on the extent of modeling technique use. We identified some trends, for instance the use of ERM increases as years of modeling experience increase. In general, however, data obtained does not support a significant impact of modeling experience and firm size on the modeling technique in use.

Furthermore, we studied which modeling techniques complement each other. For example, according to the Architecture of Information Systems (ARIS) developed by [Scheer 1998a; Scheer 1998b], EPC and ERM can be well used in combination. This is possible because ERM and EPC represent different aspects of a modeling domain: structural aspect of a domain are represented by ERM; behavioral aspects are represented by EPC. We used a correlation analysis to investigate this issue. The analysis reveals several salient aspects: Out of 66 possible correlations, there are 48 significantly positively related. This means that almost all modeling techniques complement each other. In other words, a modeler typically does not use one, but several, modeling techniques in combination. However, there are two important exceptions:

- The UML is only positively related with ERM, ORM, RAD and Statechart diagrams. One possible explanation for this phenomenon might be that the UML consists of thirteen different modeling diagrams. Hence, if a modeler uses the UML there is no need to use other modeling techniques. Furthermore, it must be taken into account that Statechart diagrams are supported by UML. Thus, a strong correlation between UML and Statechart diagrams is not surprising.
- The EPC is only positively related with ERM, Petri nets, and workflow modeling. One may explain this result by pointing out to the fact that the EPC is typically used for process modeling which is an important application purpose of conceptual modeling (compare the next section). Petri nets and workflow modeling are two modeling

techniques which can be used to implement process-oriented application systems. Additionally, structural aspects of the modeling domain, which cannot be represented by EPC, Petri nets, and workflow modeling, are captured by ERM.

IV. PURPOSE OF CONCEPTUAL MODELING

Conceptual modeling is not an end in itself; in fact, it should be performed for some purpose. Accordingly, we investigated the relevance of several application areas for which conceptual modeling is deemed to be used. Figure 3 shows the average score for purpose of use reported by the participants. The score for purpose was measured by a 5-point Likert scale where 5 indicates a very relevant purpose.

According to the responses, database design and management, improvement of internal business processes, and software development are, with an average score of 4.3, the highest prioritized purposes of use for conceptual modeling. The purposes “business process documentation,” “workflow management,” “improvement of collaborative business processes,” and “design of enterprise architecture” rank almost just as relevant, with an average score of 4.0 or better. Conceptual modeling is, on average, not reported as relevant for auditing, human resource management, end-user training, and software selection. These results are consistent with common knowledge [Bajaj et al. 2004]. However, the minor value of conceptual modeling for software selection is surprising because this application purpose is particularly stressed by some authors [Soffer et al. 2003].

The high ranking of database design and management is consistent with the earlier result of ERM being the most frequently used modeling technique. Additionally, the highly frequent use of conceptual modeling techniques such as UML and Statechart diagrams support the fact that software development as a modeling purpose is also ranked very high. Moreover, the relatively highly ranked purposes of improvement of business processes, workflow management, and business process documentation confirms the strong use of modeling techniques such as EPC and workflow modeling mentioned earlier. One possible explanation for the (relatively) low ranking of the other purposes of conceptual modeling (namely, the design of enterprise architectures, software selection, auditing, etc.) might be that no modeling techniques specialized on these application purposes are well-known. Instead, typically general-purpose conceptual modeling techniques are used for these application scenarios. This may be one explanation for the fact that conceptual modeling is not very relevant in these areas today.

We analyzed the influence of modeling experience and firm size on the average score for modeling purpose. However, no statistically significant interrelationships between these factors were found.

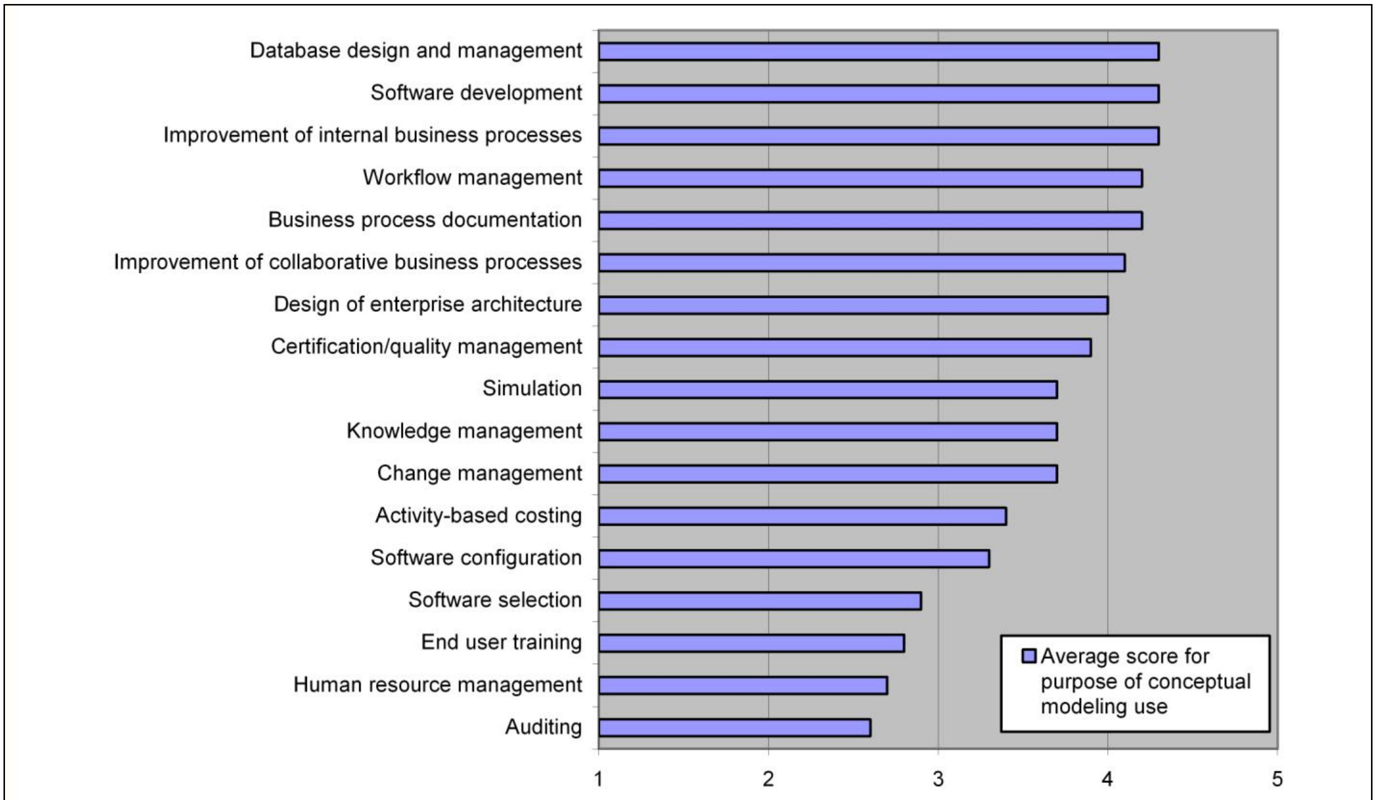

Figure 3. Average Score for Purpose of Conceptual Modeling Use

V. EXTENT OF MODELING TOOL USE

To fully achieve the benefits of conceptual modeling, an adequate tool support through the complete model lifecycle is required. Such tools are widely available on the market. Accordingly, we gathered information on the actual extent of modeling tool use and diffusion in practice. Obtained results regarding this aspect of our survey are shown in Figure 4.

Although there are multiple modeling tools available, our results demonstrate that some products dominate the market for modeling tools: Visio is used by nearly 50 percent of the participants frequently. Again, a frequent use means that a tool is used five or more times a week. About 20 percent of the respondents use Rational Rose and ARIS Toolset frequently. According to our data, Flow Charter, Innovater, ERWin, Together, and Oracle Developer Suite are frequently used by 4 to 13 percent. All other modeling tools not shown in Figure 4 are not frequently used by more than 1 percent of the respondents.

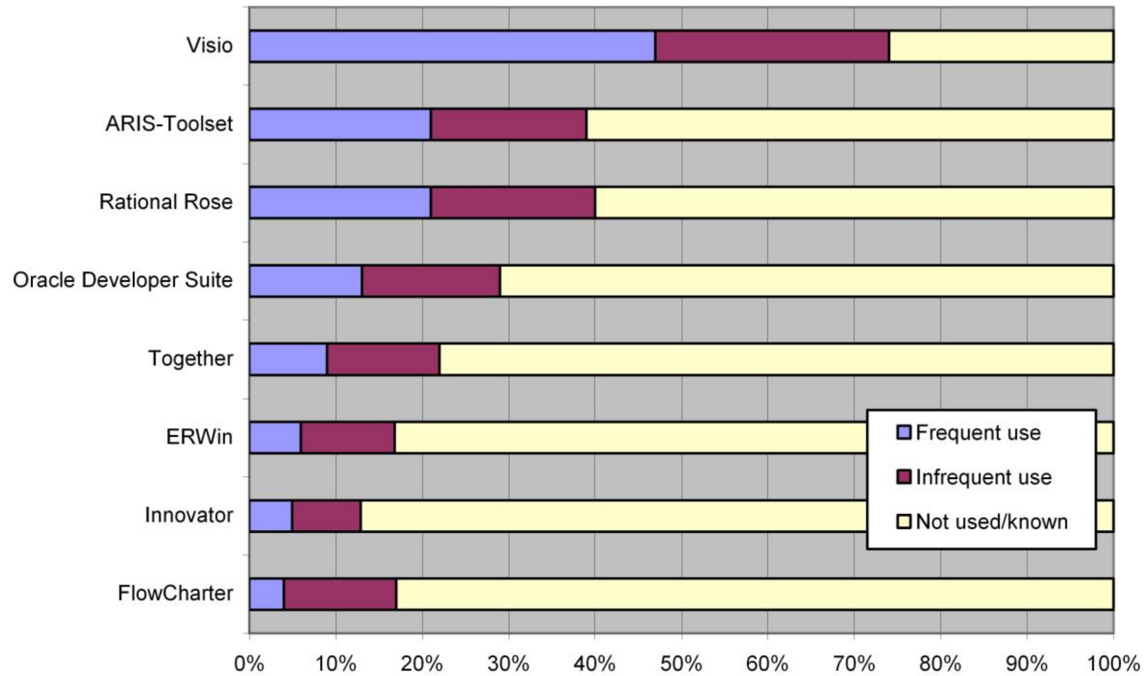

Figure 4. Modeling Tools Most Frequently Used

We analyzed how the extent of modeling tools usage evolves over time. Figure 5 depicts the trend of usage of different modeling tools. The x-axis (y-axis) represents the difference between the usage frequencies in the past (today) and today (in the future) in percent. For example, the usage frequency of the UML increased by 32 percent in the past and will decline by 1 percent in the future. The following usage patterns can be identified:

- This analysis shows that the use of Visio and the ARIS Toolset has increased over the last years significantly, whereas the adoption of all other modeling tools has decreased at the same time.
- There is no evidence that the use of some modeling tools will increase significantly in the future.

The obtained results show in several cases an increase in conceptual modeling tool usage in the past. However, it is somewhat surprising that the usage of no conceptual modeling tools will significantly increase in the future. Again, one possible explanation for this phenomenon may be that conceptual modeling tools matured in the past. Thus, the market for modeling tools is saturated.

Additional analyses were conducted to identify the influence of modeling experience and firm size on the extent of modeling tool use. We found out that in some cases the use of modeling tools increases as years of modeling experience increase. However, the obtained results are not consistent among all modeling tools. Therefore, we have to conclude that our data does not support a significant influence of modeling experience and firm size on the used modeling tools.

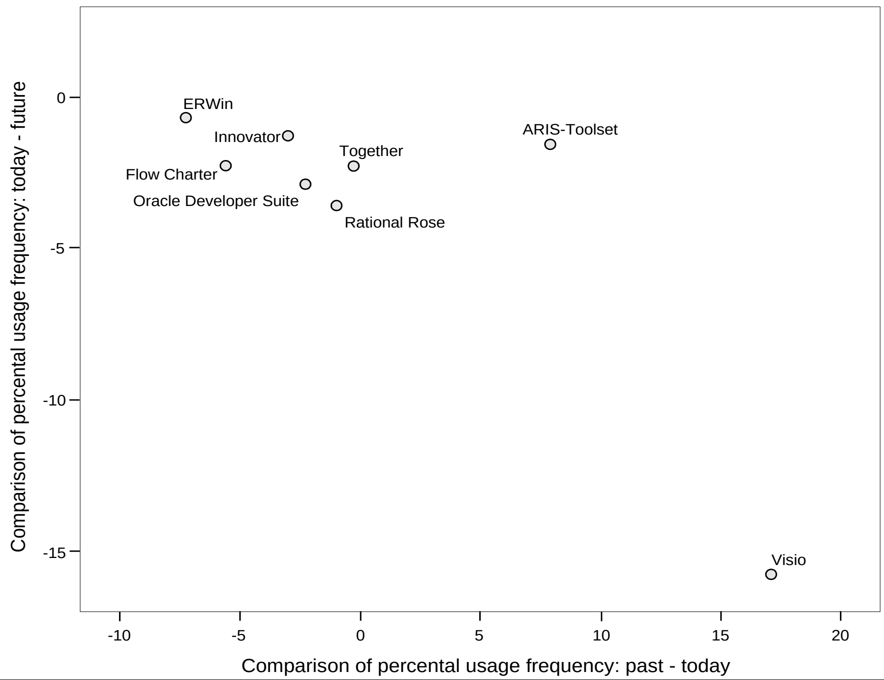

Figure 5. Effect of Time on the Usage of Modeling Tools

VI. BARRIERS AND SUCCESS FACTORS IN USING CONCEPTUAL MODELING

Finally, the survey identified and analyzed barriers and success factors in using conceptual modeling. Therefore, we asked the participants open questions. One question addresses factors which impede the success in using conceptual modeling from the point of view of the participants (barrier). Another question asks for factors which facilitate the success in using conceptual modeling (success factor). In total, the respondents provide more than 900 different barriers and success factors. The given answers mostly consist of a textual phrase which was sometimes complemented with a longer explanation. The mentioned aspects were analyzed and grouped into the categories modeling language, modeling method, model, tool, and miscellaneous [Wand and Weber 2002]. Our analysis only considers factors which are of importance for conceptual modeling in general and not just for particular purposes.

The following method was applied to analyze the received responses to the open questions: (1) The author of this article classified the textual comments describing the barriers and success factors in conceptual modeling according to the categories modeling language, modeling method, model, tool, and miscellaneous. (2) In a second step similar factors where grouped together. (3) Independently, steps 1 and 2 were repeated by another researcher familiar with research in conceptual modeling. The two researchers then met to ensure their points of agreement in the coding and to reconcile coding differences of particular barriers and success factors. After conducting the three prior steps, both researchers agreed on the specific coding of the obtained textual comments representing the barriers and success factors in conceptual modeling as documented in the obtained data.

Table 1 summarizes the factors which were obtained by the prior described procedure. We just considered factors which were reported by at least five respondents to ensure the relevance of the obtained factors. The following section describes and explains the barriers and success factors in a more detailed way. The sections thereafter provide a critical discussion of these results.

Table 1. Identified Barriers and Success Factors

	#	Factor	Type	Explanation
Language	1	Expressiveness	Success factor	The degree to which a modeling language can describe all relevant aspects of a modeling domain
	2	Multi-perspective modeling	Success factor	The ability of a modeling language to represent a modeling domain from different views
	3	Consistency	Success factor	The degree to which a modeling language is free of contradictions
	4	Comprehensibility	Success factor	The degree to which a modeling language is easy to understand
	5	Learnability	Success factor	The amount of effort for a user to be become capable of applying the language correctly
Method	6	Appropriateness of method	Success factor	The degree to which a method is fitted to solve a particular modeling problem
	7	Standard method application	Success factor	The degree to which a modeling method is applied uniformly
	8	Link between application and software models	Success factor	The ability of a method to support the transition between application and software models and vice versa
	9	Information gathering	Success factor	The degree to which a modeling method provides support for gaining information about a modeling domain
	10	Plethora of modeling methods	Barrier	The amount of available modeling methods
Model	11	Model quality	Success factor	The degree to which a model confirms to described requirements
	12	Model evaluation	Success factor	The degree to which the model quality is systematical assessed
	13	Standard models	Success factor	The degree to which modeling patterns, blueprints or reference models are used
	14	Timeliness of model	Success factor	The degree to which a model of a domain is current and not out-dated
	15	Model abstraction	Success factor	The degree to which a model provides adequate and different levels of detail
	16	Unambiguous modeling layers	Success factor	The degree to which the objectives of different modeling layers are rigorously defined
	17	Understandability by nontechnical people	Success factor	The degree to which nontechnical people can comprehend a given model
Tool	18	Price	Barrier	The costs to purchase software licenses for a tool
	19	Investment risk	Barrier	The uncertainty about the market power of a tool vendor
	20	Tool usage	Success factor	The degree to which a tool is actually utilized
	21	Complexity	Barrier	The degree to which a tool is perceived as difficult to understand and use
	22	Support for modeling tasks	Success factor	The degree to which modeling actions are tool-supported
Miscellaneous	23	Acceptance	Success factor	The degree to which the idea of conceptual modeling is adopted by an organization
	24	Project management	Success factor	The management of a modeling project including defining the project scope, aims, milestones, and plans
	25	Top management support	Success factor	The level of commitment by top management to the application of conceptual modeling
	26	Training	Success factor	Training includes professional instructions, workshops and similar activities
	27	Competencies	Success factor	The amount of knowledge users have about using conceptual modeling

Explanation of Identified Factors

According to our investigation, the following aspects of a modeling language influence conceptual modeling success (see Table 1):

1. *Expressiveness*: Modeling languages do not often provide enough or adequate constructs to represent the modeling domain in question. For example, respondents reported that using conceptual modeling in the area of business process management results into new modeling languages such as the EPC [Weske 2007]. Another recent example is the use of conceptual modeling techniques for service-oriented modeling [Bell 2008] which demonstrates the desire for modeling service orchestration and service choreography.

2. *Multi-perspective modeling*: A further problem arises because most languages do not provide enough support for multi-perspective modeling. A typical concern reported is the coexistent use of a modeling language for organizational as well as technical purposes, e.g., business process analysis and workflow implementation. Both application purposes have different requirements, however to be successful, the integration of different perspectives is necessary. A language featuring multi-perspective modeling can foster such integration.

3. *Comprehensibility*: If a user cannot comprehend the constructs of a modeling language, the success of a modeling project is vulnerable. Participants reported that some modeling languages are problematic under these conditions. For example, UML, according to our results a frequently-used modeling language, is criticized by participants for its semantic inconsistency, construct ambiguity, notation inadequacy, and cognitive misdirection.

4. *Consistency*: A consistent language is an important success factor in conceptual modeling. One way reported by the participants to precisely define the syntax and semantics of a modeling language is to develop a meta-model for this language [Hofstede and Weide 1993]. A meta-model describes the basic elements and relationships between model elements and their semantics [Rosemann and Green 2002, p. 78]. The availability of such a meta-model facilitates the application of the modeling language. The use of ontologies, e.g., the Bunge-Wand-Weber ontology [Wand and Weber 1995], provides another way to precisely define a modeling language which was mentioned by the participants.

5. *Learnability*: Modeling languages are often too difficult to understand. Hence, users do not learn the constructs of a language adequately. However, a sufficient understanding of a modeling language is a prerequisite for a successful application of the language. Participants reported that the understandability of a modeling language can be improved by using different modeling views, annotations with natural language, graphical representation of modeling constructs, and domain-specific adoptions of modeling constructs.

Next, we discuss aspects of a modeling method which influence the success of conceptual modeling:

6. *Appropriateness of method:* Every modeling method supports the solution of a particular class of modeling problems. Hence, it is not possible that every modeling method can be used for solving every modeling problem. Instead, it is necessary to select an appropriate method for each particular type of problem. A clear definition of the modeling objective is a prerequisite for gaining an adequate understanding of a modeling problem. Otherwise, a particular modeling method may be selected which is not appropriate for the particular modeling project.

7. *Standard method application*: The application of a modeling method should be standardized and comprehensibly documented. Hence, before starting a modeling projects it is advisable to agree on a set of standards for the particular modeling project [Davis 2008, p. 18]. Such modeling guidelines should be developed as early steps in each project and can often be adapted from guidelines developed by prior modeling projects. Otherwise, there is a huge risk that every modeler uses available degrees of freedom in applying the modeling method which result in many incompatible modeling artifacts.

8. *Link between application and software models*: The transition between application-oriented and software-oriented methods is not easy. Methods often support only one particular step without providing sufficient support for the solution of the overall problem. For example, participants reported that known modeling methods do not provide sufficient guidelines on how to transform a business-oriented process model into an implementation-oriented workflow model and service specification model.

9. *Information gathering*: Participants expound the problem of gathering information about the modeling domain. It often happens that the information needed to develop models cannot be gathered without difficulties. There

is no general method which is successful under all circumstances. Typical reported issues are that the staff of operating departments are not available, provide distorted information, or have no interest to collaborate with the modeling project staff. Note, these issues are not a fault of a method per se. However, modeling methods, for instance use cases, can provide means to reduce the efforts needed for information gathering.

10. *Plethora of modeling method*: In the field of conceptual modeling it seems common practice for modelers to develop their own method. In the last years this has resulted in a tremendous number of modeling methods. It is estimated that about several hundreds or even thousands of different modeling methods exist [Hofstede and Weide 1993]. Participants hold the view that the plethora of modeling techniques is a major barrier in conceptual modeling.

The following factors related to conceptual models are relevant for the success of conceptual modeling:

11. *Model quality*: The participants reported the quality of a model as another success factor. The given answers show that the quality of a model is not fully understood today and there are many different approaches and techniques to measure and enhance model quality. In other words, model quality must be understood as a complex, multidimensional phenomenon.

12. *Model evaluation*: A thorough evaluation of models is another important success factor in conceptual modeling. Reviews and audits, two well-known Software Engineering techniques [Sommerville 1996], are reported to be used for model approval. Many participants hold the view that model evaluation should not be done at the end of the development of a conceptual model but throughout the complete modeling process.

13. *Standard model*: Participants reported as a further difficulty that there are only a few widely accepted standards for developing models. For example, it is often unclear how to name entity types in ERM or process activities in EPC consistently. A possible solution to this problem that was reported by participants are so-called reference models which provide standard models during the modeling process [Fettke and Loos 2007].

14. *Model abstraction*: Models must provide proper abstractions of the problem domain but often fail to reach this objective because they contain too many details, do not use an adequate modeling granularity, or provide inappropriate abstraction layers. Hence, participants argue to explicitly define the intention of the model before the modeling activity starts.

15. *Timeliness of model*: Participants often discovered problems during the application of conceptual models because the developed models do not reflect changes in a timely manner. Therefore, the participants hold the view that a model must be updated if the modeling purpose changes, new aspects about the modeling domain emerge, the modeling domain evolves, etc. If these changes are not taken into account, developed models will be out-of-date. Keeping all models up-to-date is vital.

16. *Unambiguous modeling layers*: Participants reported that typically different conceptual models are used in one modeling project each representing different aspects of a modeling domain. Using different conceptual modeling languages reduces the complexity of conceptual modeling. If several conceptual models are used, it is important to adequately define modeling layers. The relevant level of modeling abstraction and relevant modeling levels should be precisely defined for every model. Powerful models define unambiguous modeling layers.

17. *Understandability by nontechnical people*: Participants indicate that models should be comprehensive for nontechnicians. If models are understood only by technicians, a major success factor of conceptual modeling is ignored. But models should be usable as a communication vehicle between business-oriented and implementation-oriented people.

Several factors related to modeling tools are relevant for the success of conceptual modeling:

18. *Price*: The price for professional modeling tools is high. Participants experienced that often not enough budget to purchase tool licenses is approved which makes it impossible to buy needed licenses.

19. *Investment risks*: Participants complain that the investment risk in modeling tools is high because the tool market is not matured and providers of modeling tools are often small enterprises. Using modeling tools whose further development is not assured jeopardizes the success of conceptual modeling in the long term.

20. *Tool usage*: Participants found out that instead of using dedicated modeling tools, modelers often apply simple drawing tools which do not sufficiently support the development and application of conceptual models. Although simple models can be managed by paper and pencil or with general-purpose tools, complex modeling activities with several users cannot be managed efficiently without tool support. Participants concluded that tool usage is necessary to gain advantages from conceptual modeling.

21. *Complexity*: Participants observed that available tools are often very complex and not easy to handle. Hence, the complexity of known modeling tools is often a major barrier for the success of conceptual modeling.

22. *Support for modeling tasks*: Participants claimed that not only tools must be used but that used tools should support the complete modeling lifecycle, e.g., tool support for model development, adaptation, maintenance, and distribution. The following functions were reported as necessary for success in conceptual modeling: model navigation, visualization and layout, management of large models, open interfaces for model interchange, model versioning, multi-user support, and support for multi-perspective and distributed modeling. The complete modeling functionality should be integrated in one modeling suite because otherwise the exchange of models prevents success in conceptual modeling. However, participants reported that state-of-the-art tools often support only a subset of functions and complained about missing functionalities. Hence, participants advice to develop an integration concept for the usage of several tools.

Finally, some miscellaneous factors were identified which respectively impede and advance the success in conceptual modeling:

23. *Acceptance*: Weak acceptance of conceptual modeling is a barrier of success in conceptual modeling. Participants experienced that important stakeholders are often not aware of the usefulness of conceptual modeling for conducting business and thus did not adopt conceptual modeling.

24. *Project management*: Participants regard an efficient project management as essential for the success. However, they experienced that the management of conceptual modeling projects is often weak. Problems in conceptual modeling have to be addressed by an efficient project management which should take the desires of all stakeholders into account.

25. *Competencies*: An experienced project staff is key factor for successful conceptual modeling projects. Participants reported that modelers and end users often do not have sufficient competencies in conceptual modeling. An insufficient command of conceptual modeling techniques is often-perceived as a barrier in conceptual modeling.

26. *Top management support*: Top management should support a modeling project by providing budget and other necessary resources. However, participants reported a lack of support by the top management.

27. *Training*: The project staff should be provided with enough training on the use of conceptual modeling techniques. Typical training activities include professional classroom instructions, workshops, and individual practice.

Hypothesizing Dependencies Between Factors

As the described barriers and success factors are identified by asking open questions, these factors should be interpreted as *perceived* barriers and success factors in different organizational settings. Hence, it is wise *not* to assume that the identified factors are (a) totally independent and (b) each factor influences success under all conditions. Therefore, it is necessary to analyze dependencies between the obtained factors and discuss possible influences. We use so-called causal loop diagrams [Sterman 2000, p. 13] as an instrument to investigate and to illustrate dependencies between different factors.

Although the following discussion presents some arguments that the hypothesized dependencies may be true, it is obvious that these influences are not “laws” but justified guesses. We do not claim that the identified dependencies are true under all conditions. In fact, we understand this investigation as an early step in theory building in the area of conceptual modeling. Hence, our discussion is primarily rooted in the context of discovery and not in the context of justification of a theory [Reichenbach 1951, p. 260]. However, contrary to other philosophies of science (e.g., the Popper’s philosophy of science), we understand a discussion of early theory building as a valuable contribution to scientific progress.

Our analysis proceeds as follows: We first analyze dependencies between factors of one category (A). Thereafter we analyze dependencies between factors of different categories (B).

A: Analysis of dependencies between factors of one category

Figure 6 depicts the hypothesized dependencies with respect to factors relating to a modeling language:

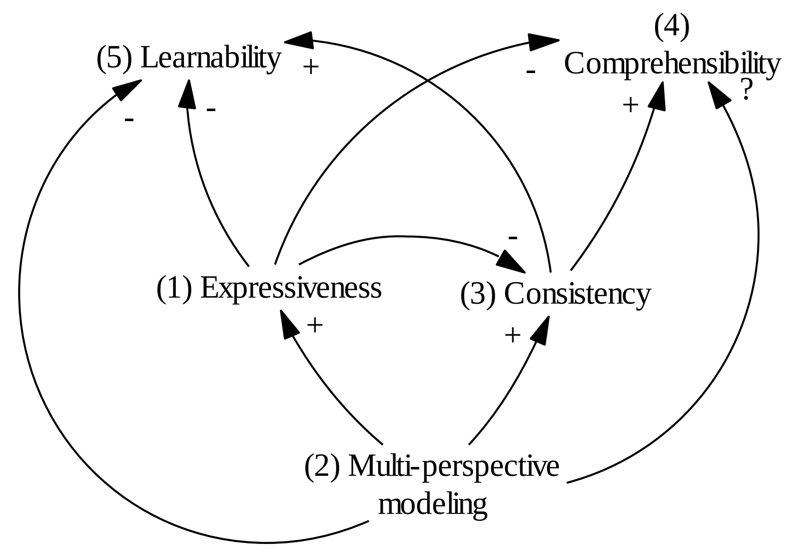

Figure 6. Dependencies Between Factors Related to a Modeling Language

1. *Expressiveness*: Although there is not a commonly accepted approach to measure the expressiveness of a modeling language [Patig 2004; Wand and Weber 1993], it is clear that a new application area of conceptual modeling often requires new modeling constructs. Typically, you have to introduce new modeling constructs to improve the expressiveness of a particular modeling language [Patig 2004]. More modeling constructs result in a more complex modeling language which will be more difficult to comprehend and to learn. Furthermore, an increasing expressiveness jeopardizes the consistency of the modeling language because more modeling constructs are offered.

2. *Multi-perspective modeling*: The use of a modeling language supporting multi-perspective modeling can typically enhance the expressiveness and consistency of this language. For example, the UML provide different diagram types which allow the representation of different aspects of a modeling domain. Each diagram just consists of a few constructs which are typical for these aspects. Hence, it is assumable that these constructs are more consistent for a model user. However, the support of multi-perspective modeling makes a modeling language more complex. This can contradict the success factor that the modeling language should be easy to understand and to learn. Hence it can be argued that multi-perspective modeling also has a negative influence on the learnability of a language.

3. *Consistency*: It can be argued that a consistent language is easier to comprehend and to learn. For example, if a language definition has inconsistencies or is not transparent, it is not easy to understand the constructs of a language. Additionally, users unfamiliar with this language have to invest much effort to become used to this language.

4. *Comprehensibility*: This factor does not influence other factors of this category.

5. *Learnability*: This factor does not influence other factors of this category.

6. *Appropriate method for problem type*: The development of a customized method which kindly fits the particular problem type to be addressed results in a new method variant. A new method variant contradicts the idea of a standardized method and a standard application of the method. To fulfill the specific requirements of different modeling problems, one has to customize a known modeling method accordingly or develop a new modeling method. Thus, the amount of modeling methods increases.

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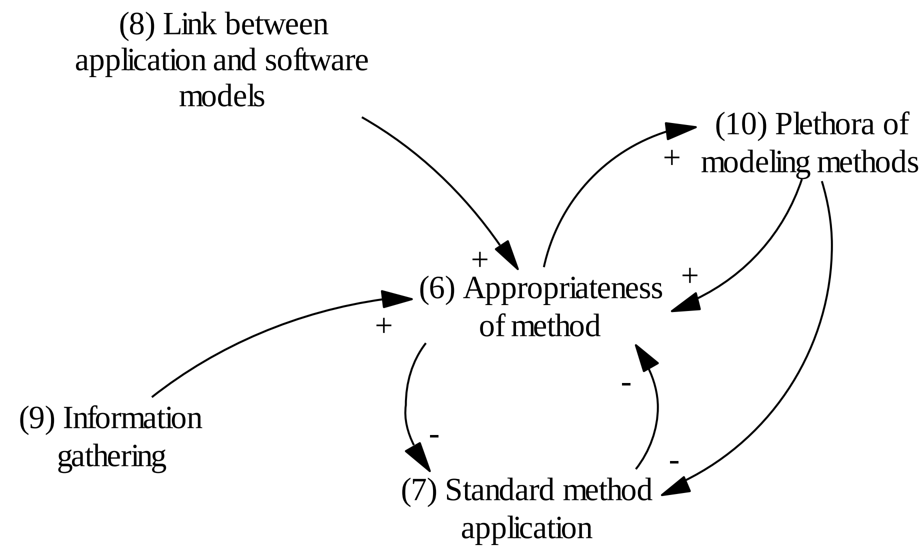

Figure 7. Dependencies Between Factors Related to a Modeling Method

Figure 7 depicts the hypothesized dependencies with respect to factors relating to a modeling method:

7. *Standard method application*: The unified application of the modeling method can result in inadequate considerations of the requirements of a particular modeling problem. Therefore, a standard method application can reduce the appropriateness of a method.

8. *Link between application and software modeling*: If conceptual modeling is just used for organizational purposes such as business process documentation, quality or knowledge management (compare Section IV) then it does not make sense to use methods which support a link between application and software models. Hence, in these circumstances it is not necessary to use such methods. However, under many other circumstances, a seamless transition between application and software models is a prerequisite for success.

9. *Information gathering*: This factor can enhance the appropriateness of a method. A good support for analyzing and gaining information about a domain will increase the likelihood that the method can operate on adequate information about the particular domain. Thus, it will be better fitted for solving a particular modeling problem.

10. *Plethora of modeling methods:* The plethora of modeling methods has a positive effect on the appropriateness because, in this case, it is possible to choose between different modeling methods which fulfill different requirements. However, the plethora of modeling methods conflicts with the standardization of methods.

With regard to factors related to a model, we first state the following remark: The given explanation of model quality is open to different aspects of model quality. Hence, it can be argued that several factors are typically positively related with model quality, namely, timeliness of model, unambiguous definition of modeling layers, etc. Someone might argue that one particular factor does not belong to a set of requirements of a model he believes to be relevant. However, it is extremely unlikely that someone evaluates, for instance, an inadequate model abstraction as a characteristic of a high-quality model. Similarly, it is not likely to argue that a model should be understandable by nontechnical people as an indicator of model quality. However, someone might argue that some particular requirements are not relevant for his conception of model quality. If this is true, then these particular requirements do not influence the model quality by definition. However, we do not believe that this is a typical perception.

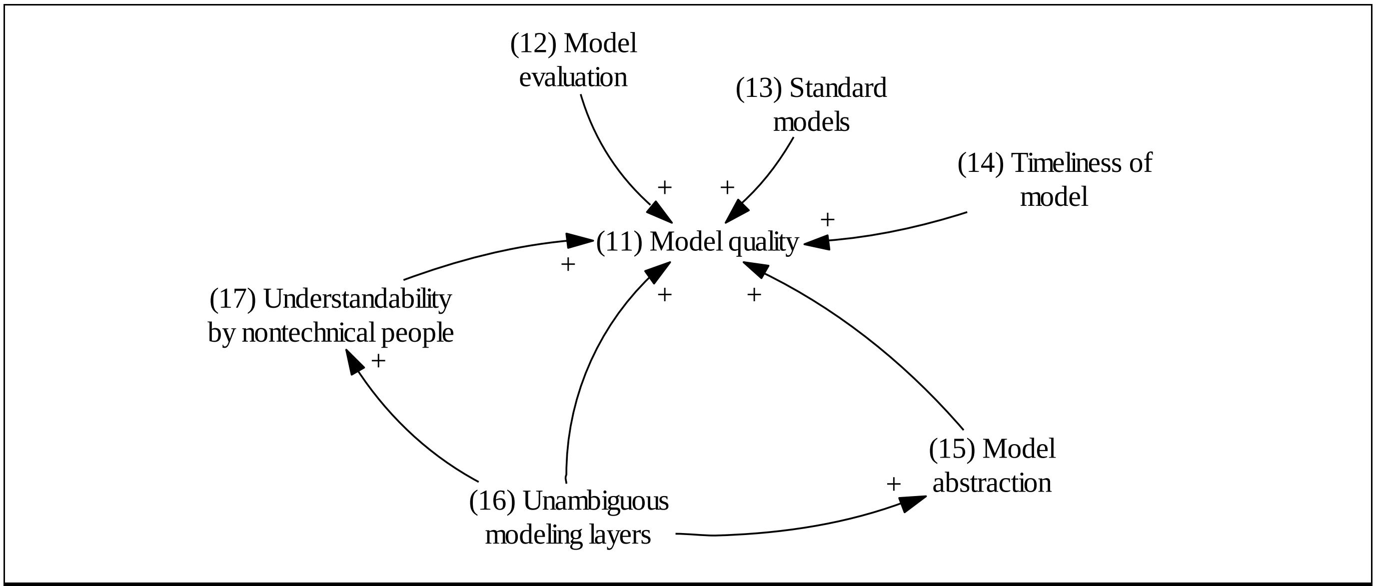

Figure 8. Dependencies Between Factors Related to a Model

Figure 8 depicts the hypothesized dependencies with respect to factors relating to a model:

11. *Model quality*: This factor does not influence other factors of this category.

12–15. *Model evaluation, standard models, timelineness of model, model abstraction:* These factors influence model quality (see remark above).

16. *Unambiguous modeling layers*: This factor influence model quality (see remark above). Furthermore, we hypothesize the following dependencies: If a modeling project uses different modeling layers which are rigorously defined, then it is more likely that a model provides an adequate level of abstraction. In particular, it is possible to provide different levels of abstraction which can support different abstraction needs. Additionally, if a model provides different, rigorously defined modeling levels, then it is easier to define modeling layers which address the needs of end users. Hence, the use of different modeling layers improves the understandability of a model.

17*. Understandable by nontechnical people*: This factor influence model quality (see remark above).

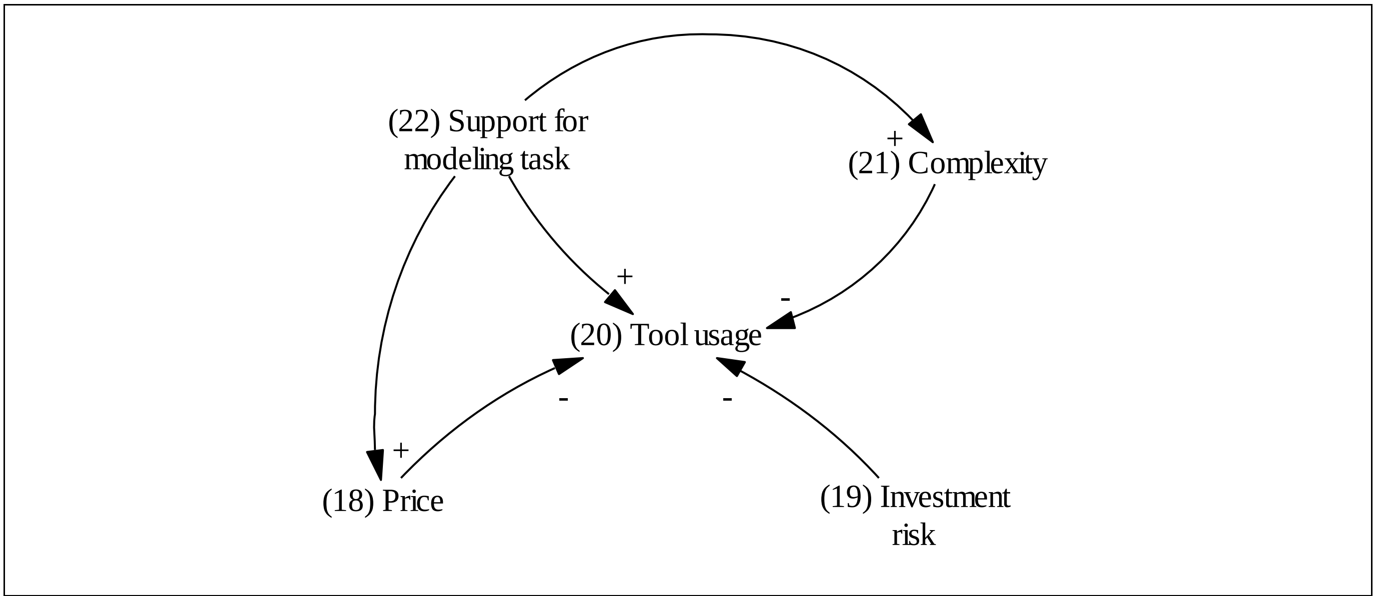

Figure 9. Dependencies Between Factors Related to a Modeling Tool

Figure 9 depicts the hypothesized dependencies concerning factors relating to a modeling tool:

18. *Price*: According to a well-known economic interrelationship, the demand for a good and its price are negatively correlated. Hence, a higher price of a modeling tool results in lower tool usage.

19. *Investment risk*: Because of the uncertainty of the future market development, a potential tool user may delay his/her investment in a particular modeling tool. Hence, tool usage will decrease in such a situation.

20. *Tool usage*: This factor does not influence other factors of this category.

21. *Complexity*: A high complexity of a modeling tool jeopardizes the tool usage because it is very likely that potential users become discouraged by the sheer degree of functionality of a tool.

22. *Support for modeling tasks*: It is obvious that a tool can only be applied for a particular modeling task if the tool supports these tasks. A tool which provides more support for modeling tasks is typically more expensive than a tool which offers only some particular functions. If a single tool does not provide sufficient support for modeling tasks, different modeling tools can be used simultaneously. Note that the use of different tools increases the complexity because the usage of different tools must be integrated.

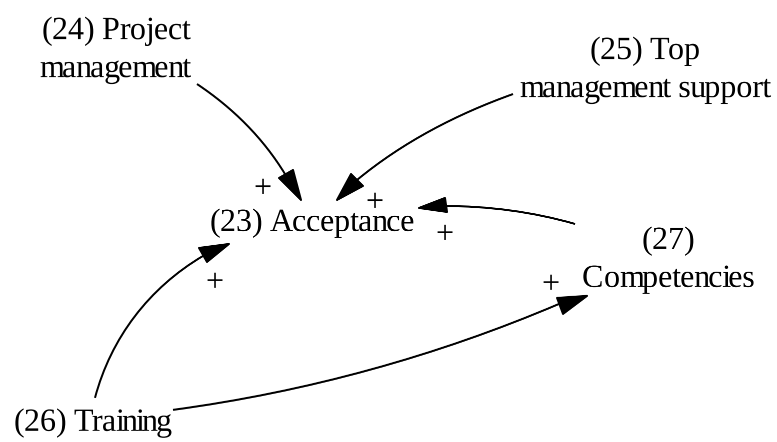

Figure 10. Dependencies Between Factors Related to Miscellaneous Aspects

With regard to factors related to miscellaneous aspects, our first remark is the following: It can be argued that in the long run (a) all success factors have a positive influence on the acceptance of conceptual modeling and (b) all barriers have a negative influence on conceptual modeling. The previous statement is not very informative. However, it is not known how strong the dependencies between these factors are without further empirical or theoretical knowledge. It might be argued that it is not wise to use the factor “acceptance” for further theory building because its definition is very general. We do not share this view because the respondents of our empirical study mentioned acceptance as an important success factor in conceptual modeling. Hence, we argue that it is necessary to gain more knowledge about this factor.

Figure 10 depicts the hypothesized dependencies with respect to miscellaneous factors of conceptual modeling:

23. *Acceptance:* This factor does not influence other factors of this category.

24, 25. *Project management, top management:* These factors influence acceptance (see remark above).

26. *Training*: This factors influences acceptance (see remark above). Additionally, it can be argued that good training in conceptual modeling will avoid the problem of missing competencies in conceptual modeling.

27. *Competencies*: This factor influences acceptance (see remark above).

B. Analysis of dependencies between factors of different categories

After discussion dependencies between factors of one category, in the following we analyze dependencies between factors of different categories. Table 2 shows the hypothesized dependencies between all factors. The first column and first row of the table represent the identified factors. The symbol “+” (“–”) in one cell of the table denotes that the correspondent factor in the first column have a positive (negative) influence on the correspondent factor in the first row. The symbol “?” denotes that the direction of an effect between two factors is unknown. No symbol means that we do not argue for a dependency between the correspondent factors.

Please note that the remark above also holds for other factors and is not explicitly mentioned in the below discussion.

			Factor (Effect)																										
			Language					Method					Model							Tool					Miscellaneous				
			1	2	3	4	5	6	7	8	9	10	12	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
			Expressiveness	Multi-perspective modeling	Consistency	Comprehensibility	Learnability	Appropriateness of method	Standard method application	Link between application and software mod	Information gathering	Plethora of modeling methods	Model quality	Model evaluation	Standard models	Timeliness of model	Model abstraction	Unambiguous modeling layers	Understandability by non-technical people	Price	Investment risk	Tool usage	Complexity	Support for modeling tasks	Acceptance	Project management	Top management support	Training	Competencies
Factor (Cause)	Language	1 Expressiveness			-	-	-	+		+			+									+	+		+				
		2 Multi-perspective modeling	+		+	?	-	+		+			+					+	+			+	+		+				
		3 Consistency				+	+	+					+									+			+				
		4 Comprehensibility						+			+		+									+			+				+
		5 Learnability						+			+		+									+			+				+
	Method	6 Appropriateness of method							-			+	+									+			+				
		7 Standard method application						-																	+				+
		8 Link between application and software models						+																	+				
		9 Information gathering						+					+												+				
		10 Plethora of modeling methods						+	-						-				-		+		+	-	-		-		-
	Model	11 Model quality																				+			+				
		12 Model evaluation											+												+				
		13 Standard models											+												+				
		14 Timeliness of model											+												+				
		15 Model abstraction											+												+				
		16 Unambiguous modeling layers											+				+		+						+				
		17 Understandability by non-technical people											+												+				
	Tool	18 Price																				-			-				
		19 Investment risk																				-			-				
		20 Tool usage					+		+				+												+				
		21 Complexity																				-			-				
		22 Support for modeling tasks																		+		+	+		+				
	Miscellaneous	23 Acceptance																				+							
		24 Project management							+					+	+	+						+			+				
		25 Top management support																				+			+				
		26 Training																				+			+				+
		27 Competencies							+				+									+			+				

Table 2. Dependencies Between All Factors

We argue for the following dependencies:

1. *Expressiveness:* The expressiveness of a language influences several factors positively, namely: appropriateness of method, link between application and software model, model quality, tool usage, and acceptance. It can be argued that a more expressiveness model language is a better prerequisite for achieving the particular success factor. However, expressiveness has also a negative influence because a more expressive language increases the complexity of modeling tools supporting this language.

2. *Multi-perspective modeling*: The possibility of multi-perspective modeling influences several factors positively. It can be argued that the usage of different modeling perspectives offers means reaching the particular success

factor. For example, the usage of different modeling perspectives enhances the definition of unambiguous modeling layers. This argument is also valid for several other factors, namely, appropriateness of method, link between application and standard software models, model quality, understandability by nontechnical people, tool usage, and acceptance. However, multi-perspective modeling is also positively related with complexity because modeling tools which support multi-perspective languages are more difficult to configure and use.

3. *Consistency*: A consistent modeling language can be viewed as one prerequisite to achieve appropriateness of a method, model quality, tool usage, and tool acceptance. It can be argued that these factors cannot be achieved if the language is not consistent enough.

4. *Comprehensibility*: The comprehensibility of a language is another prerequisite for achieving other success factors, namely appropriateness of method, information gathering, model quality, tool usage, acceptance, and competencies. If a modeling language is not comprehensible, it is more difficult to achieve the aforementioned factors. Comprehensibility is particular important for information gathering because a comprehensible modeling language is easier to use, particular by nontechnical people.

5. *Learnability*: This factor has similar dependencies as the factor "comprehensibility." Again, if a modeling language is not easy to learn, it is difficult to achieve the appropriateness of method, information gathering, model quality, tool usage, acceptance, and competencies.

6. *Appropriateness of method*: It can be argued that the appropriateness of a method positively influences the tool usage and acceptance of a conceptual modeling. If the applied modeling method does not fit the modeling problem, a modeling tool will not be used and conceptual modeling will not be accepted.

7. *Standard method application*: The standardization of the application of modeling methods influences the competencies positively because the modeling methods are uniformly applied. Hence, it is very easy to become acquainted with a new modeling project.

8. *Link between application and software models*: We do not hypothesize that this factor has further influences.

9. *Information gathering*: We do not hypothesize that this factor has further influences.

10. *Plethora of modeling methods*: The plethora of modeling methods increases the complexity of modeling tools because more modeling methods have to be supported. Furthermore, it is more likely that modeling tools specialized to particular methods do not find enough demand on the market and will disappear from the market. Hence, the investment risks will rise further. Additionally, a clear set of *some* modeling methods, and not hundreds, would enhance the acceptance of conceptual modeling, the support by top management, and competencies in using conceptual modeling.

11. *Model quality*: If developed models are of low quality, the chance of accepting conceptual modeling is very low.

12–19. *Model evaluation, standard models, timelineness of models, model abstraction, unambiguous modeling layers, understandability by nontechnical people, price, investment risk:* We do not hypothesize that these factors have further influences.

20. *Tool usage*: If tools are used, the learnability of a modeling language is easier because tools make it easier to learn a new modeling language and its constructs. For instance, tools can provide means to help to understand the modeling language and provide rules for model checking, e.g., the syntax of a modeling language. Because of similar reasons, tool usage fosters a standard method application and enhances model quality.

21. *Complexity*: The complexity of tools influences acceptance of modeling language negatively because people are not willing to get familiarized with complex functionalities.

22. *Support for modeling tasks*: We do not hypothesize that this factor has further influences.

23. *Acceptance*: If conceptual modeling is accepted by people, than the tool usage is rather likely.

24. *Project management*: This factor can influence all factors in the long term. Thus, it can be argued that project management has an influence on all factors. However, we believe that project management has a sustainable influence on some factors because a project manager can relatively easily take action to achieve them. For example, project management can plan to implement some activities or prescribe some guidelines which have

to be obeyed. Thus we argue that project management has a particular influence on standard method application, model evaluation, standard models, timeliness of models, and tool usage.

25. *Top management support*: This factor can, similarly to the factor “project management,” influence all factors in the long term. However, it has a particular influence on tool usage because top management has a major influence on necessary budget for tool acquisition.

26. *Training*: This factor influences tool usage positively because people trained in one particular tool will use this tool more often.

27. *Competencies*: Model quality and standard method application is influenced by competencies. Without sufficient competencies, it will be difficult to develop models of high quality and to apply conceptual modeling methods uniformly.

Analysis of Potential Conflicts Between Two Factors

The previous discussion reveals that some identified factors influence each other. From an action-based perspective, such dependencies are welcomed if one success factor has a positive influence on another success factor. For instance, the success factor “expressiveness” has a positive influence on the success factor “model quality” or the success factor “training” has a positive influence on the success factor “competencies.” The developed model consists of many such welcomed dependencies. However, there are also dependencies which are unwelcomed because there might be a potential conflict between factors.

Table 3 shows dependencies between two factors in our model which are potentially conflicting, e.g., the two factors are not positively related or one factor has a negative influence on the other. In these situations, more knowledge must be acquired to better understand the dependency. In the following, we provide some guidelines which set a framework for deeper analysis of one particular dependency (an extended analysis of the presented model can be requested by the author upon request):

Table 3. Potential Conflicts Between Two Factors

	Factor (cause)	Factor (effect)
1	Expressiveness	Consistency
2		Comprehensibility
3		Complexity
4	Multi-perspective modeling	Learnability
5	Appropriateness of method	Standard method application
6	Standard method application	Appropriateness of method
7	Support for modeling tasks	Price
8		Complexity

- Dependencies #1, #2 and #3: Expressiveness has a negative influence on consistency and comprehensibility of a language and is positively related with complexity. It is important to clearly define and introduce new modeling constructs. Otherwise, the understanding of the modeling language is jeopardized and an easy training is not possible. A clear definition also supports the control of complexity. The introduction of new constructs should clearly be motivated by the need to express particular aspects of the modeling domain. From an action-oriented point of view, it must be taken into account that choosing a more expressive language results in less comprehensibility and learnability. If these two latter factors are of major importance in one particular situation, e.g., model users are not familiar with a language, it may be advisable to use a less expressive language.

- Dependency #4: Multi-perspective modeling has, in addition to its positive effects, negative effects on the learnability of a language. Different perspectives have to be distinguished if the overall effect of multi-perspective modeling is judged. Hence, the perspective of the language developer and the perspective of the user of a language have to be differentiated. There is no doubt that a multi-perspective modeling language is more complex for the developer of this language. The main idea is that the usage of the language is easier and the language can be learned more easily. The usage of a multi-perspective language is easier because each user can concentrate on the perspectives which are really relevant for him/her. For example, the development of organizational aspects can abstract from workflow details. The workflow details are added later on from a workflow specialist.

  However, two assumptions have to be made. First of all, an adequate tool must be available which supports the usage of multi-perspective modeling. Second, it is necessary to have a method expert at hand who is responsible for the configuration and usage of the method. If both requirements are fulfilled, less experienced users normally do not have difficulties in using a multi-perspective modeling language.

- Dependencies #5 and #6: The factors “appropriateness of method” and “standard method-application” negatively influence each other. This interrelationship does not allow both factors to be reached simultaneously. In fact, reaching one factor directly results in neglecting the other, and vice versa. This situation we define as the *dilemma of conceptual modeling*: On the one hand, conceptual modeling strongly tends to standardize the use of modeling methods. On the other hand, conceptual modeling needs appropriate modeling methods. This fundamental conflict is a conflict between standardization and individual differentiation and cannot be easily solved.

  Maybe, one strategy to overcome this dilemma is the idea of method engineering [Brinkkemper 1996]. The idea of method engineering provides a standard way to adopt a modeling method for a particular purpose in a modeling project. Method engineering allows the use of individualized and differentiated modeling approaches at the same time by providing means to uniformly adapt a modeling method.

  Although the idea of method engineering is of overwhelming attractiveness, there is also one major drawback. If this approach is successful and will become widely known as successful, it will be adapted by different stakeholders and thus cannot be a root for differentiation and competitive advantage anymore [March and Sutton 1997, p. 699]. Hence, some market actors will try to differentiate their methods or will invent a fully new approach to conceptual modeling which will be more appropriate and compensate the advantages of a standard method application.

- Dependencies #7 and #8: More support for modeling tasks results in a higher price and higher complexity. The discussion of the overall effect should differentiate between the perspectives of (a) a tool user and (b) a tool developer.

  (a) From the perspective of a tool user, the support for modeling tasks is given with the used tool. The decision to buy and use a tool typically has to be regarded as an investment decision with a perennial planning horizon. If the investment in a particular tool is profitable, then the examined tool should be acquired. Hence, the price determines tool usage. However, this situation changes after the investment is done. After the investment in a modeling tool, its price is not relevant anymore from an economic point of view because its acquisition costs are sunk costs. In other words, the precise interrelationship between the factors “support for modeling tasks” and “price” is influenced by the concrete investment appraisal.

  (b) From the perspective of a tool vendor, decisions about the functionality offered by a modeling tool is a product management decision. Such a decision often has strategic implications for the organization of the tool vendor. According to Porter, product differentiation and low costs are two main competencies of a company [Porter 2008]. Modeling functions supported by a tool provide a means for product differentiation. However, it is obvious that the development and maintenance of more tool functions also causes more costs. Hence, there is a conflict between product differentiation and costs. From a strategic point of view, this conflict is not a problem if the company follows a segmentation strategy which focuses on a particular market segment by definition. However, a company might not be able to define a market segment for which a segmentation strategy can be profitably implemented. If market segmentation is not possible, the company does not compete in a *narrow niche* of the modeling tool market but in the *broad* market of all modeling tools. From the strategic point of view, the conflict between product differentiation and costs does significantly matter in a broad market. According to Porter, a company can use a differentiation or a cost leadership strategy if the broad market is addressed. If a company follows a differentiation strategy, then the implementation of particular tool functionalities may be one mean for product differentiation. If the company follows a cost leadership strategy, the company might resist implementing new modeling functions because their implementation and maintenance is too cost-intensive. Hence, the tool vendor has to decide whether its competencies are product differentiation or low costs, respectively he/she wants to implement a differentiation or a low cost strategy.

  One possible solution to overcome this conflict may be a strategy that we call *hybrid.* A hybrid strategy is based on a generic tool platform for implementing different modeling tools which can be complemented with several more specialized modeling modules. The complete functionality is decomposed in different functional modules which kindly fit particular needs. The generic modeling platform addresses the needs of the broad market. Needs of particular market segments can be addressed by different modules offering functionality for particular modeling purposes. A hybrid strategy offers a cost-efficient mean to harmonize the conflict between support for modeling tasks and price as well as tool complexity.

The IDS Scheer AG is one exemplary tool vendor who follows a hybrid strategy. They offer the ARIS Platform which can be enhanced with different modules such as “ARIS Strategy,” “ARIS Design,” “ARIS Implementation,” and “ARIS Controlling” (see www.ids-scheer.com). Each module is based on the ARIS platform, addresses particular market needs, and is sold separately.

VII. COMPARISON WITH PRIOR RESULTS

In this section, we compare our results with prior results obtained by [Davies et al. 2006]:

- Modelers in Germany rate conceptual modeling significantly more relevant than modelers in Australia (except for end user training). In most cases, the response rates average 0.5 to 1.0 scale points higher. The higher use of conceptual modeling in Germany is not surprising if the particularities of the German modeling community are taken into account (compare Section I). Additionally, it becomes apparent that the relative ranking of the different modeling purposes are very similar. For example, the four most important purposes of conceptual modeling in Germany and Australia (namely, database design and management, software development, improvement of internal business processes, and workflow management) are identical. Hence, our results generalize the prior findings by Davies et al.

- The ERM is the most frequently used modeling technique both in Germany and Australia. Furthermore, the top-six modeling techniques in Australia are ranked in the top-ten in our study. In other words, usage frequencies of modeling techniques in Australia and Germany are very similar. However, there are two important exceptions. First, approximately 50 percent of the German modelers use the UML frequently, but only roughly 30 percent of the Australian modelers use the UML frequently. Second, EPC are frequently used by more than 30 percent of the German responses, but less than 16 percent of the respondents use this process modeling technique in Australia frequently. A possible explanation for this phenomenon might be that the EPC has been invented in Germany and, therefore, is very heavily used there.

- Davies et al. reported several interrelationships between the use of modeling techniques/tools and organization size and modeling experience, respectively. For example, they found a significant increase in the use of modeling techniques, moving from medium to larger organizations. Although our analysis found such interrelationships for some modeling techniques, our data does not support these interrelationships for all relevant modeling techniques. One possible explanation for these differences might be that Davies et al. studied these effects on an abstract level aggregating the usage of different modeling techniques and tools. Thus, the use of different modeling techniques might interfere with each other.

- Modelers in Germany use modeling tools more frequently than modelers in Australia. The relative usage frequencies of different modeling tools in Australia and Germany are very similar. However, there is one important difference. The ARIS Toolset is used by more than 20 percent of modelers in Germany, but less than 2 percent of the modelers in Australia. Again, a possible explanation of this phenomenon might be that the ARIS Toolset has been developed in Germany and, therefore, adoption is higher here.

VIII. IMPLICATIONS FOR FURTHER RESEARCH

As explained before, the former discussion is primarily rooted in the context of discovery of theories. Further investigations should provide more arguments for the justification of the identified interrelationships. The presented model of barriers and success factors in conceptual modeling should not be understood as a complete, fully acceptable theory. In fact, an accepted theory does not exist at the moment. The presented model can be interpreted as a starting point for further investigations and theory building.

The presented discussion is one step in this direction. Further research should analyze particular dependencies and provide more arguments for the justification of the interrelationships from a theoretical point of view. Theoretical approaches should be complemented with further empirical studies which can test particular hypotheses. Such a discussion from the context of justification of theory is out of the scope of this paper. However, the above discussion can be understood as one step toward further theory building.

The previous discussion of different barriers and success factors in using conceptual modeling should not be mistaken as clear advice. Instead, the identified factors and dependencies may serve as a heuristic instrument to structure the overall problem space in conceptual modeling projects: Modelers should be aware that there are several intervening factors which are perceived as important for gaining success.

Success in conceptual modeling is a complex phenomenon which is influenced by several factors. In fact, it may be argued that the success of conceptual modeling may in turn influence some of the identified success factors. For instance, it is likely that the support for conceptual modeling by top management is in turn affected by the success of conceptual modeling. Because of these interdependencies, it might be interesting to study the use of conceptual modeling techniques and tools from the perspective of network theory. From such a theoretical perspective, direct and indirect network effects of using conceptual modeling techniques and tools might be researched.

To summarize, future research must develop a deeper understanding of the identified factors and barriers in conceptual modeling.

IX. CONCLUSIONS

Conceptual modeling has gained tremendous attention and is widely used in practice. The results of this study on conceptual modeling practices can be summarized as follows:

- There are many different types of conceptual modeling techniques. However, only ERM, UML, workflow modeling, EPC, and Statechart diagrams are at least frequently used by 30 percent of the participants. Other techniques are either used less frequently or are not used at all. In the past, UML gained a significant increase in use. However, our data indicates that no modeling techniques will gain more relevance in the future.
- Conceptual modeling is highly relevant for the improvement and documentation of business processes, software development, and database design.
- The market for modeling tools is heterogeneous but dominated by Microsoft Visio. Although this tool mainly provides drawing functionalities, it is frequently used for conceptual modeling by about 40 percent of the participants. Dedicated modeling tools, such as ARIS Toolset and Rational Rose, are used frequently by about 20 percent of the participants.
- There is no support for the hypotheses that firm size and modeling experience have a statistically significant influence on modeling technique and tool use respectively.
- The success of conceptual modeling is a complex phenomenon which is influenced by several interweaved factors. Several barriers often limit success in conceptual modeling. However, there are also strong indicators that some arrangements guarantee the success of conceptual modeling.

Although the field of conceptual modeling is sometimes called a methodology jungle [Hofstede and Weide 1993], our results reveal that only a couple of techniques and tools are frequently used in practice. Hence, we cannot conclude that the actual use of conceptual modeling resembles a jungle. These results should be considered when developing syllabuses for modeling courses as well as when judging the relevance of various research streams in the area of conceptual modeling.

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