Assessing the Value of Conceptual Modeling: 
A Cost-Benefit Study

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Abstract. Conceptual modeling has become the de facto standard for requirements analysis and database design in organizations. There are many claims for its positive effects on database system development. However, to the best of our knowledge, there is no reported empirical evaluation of the costs and benefits of using conceptual modeling in a large, industrial setting. Thus it is sometime difficult for organizations to justify the adoption of conceptual modeling due to lack of such analysis. The objective of this study is to perform a comprehensive assessment of the value of conceptual modeling using both quantitative and qualitative research approaches. We will attempt to understand the importance of conceptual modeling by analyzing a Bill of Material (BOM) database development case in a large automobile manufacturing organization. As part of this study we will investigate the conditions under which conceptual modeling is effectively utilized. By better understanding the external conditions and the economic value of conceptual modeling in a real world setting, we will be able to develop a multi-perspective framework for evaluating the utility of conceptual modeling.

1 Background and Objective

One of the major challenges in information systems (IS) development is implementing the right system that meets users’ requirements and business needs. The key to achieving this goal lies in the early stages of IS development since the quality of IT systems is highly dependent on decisions made in this phase. Conceptual modeling is the process of defining and representing the real world for the purpose of facilitating communication among various stakeholders, from a data perspective. In this study, we will use the Entity-Relationship (ER) modeling since it is one of the most popular conceptual modeling techniques widely used in practice to define user requirements and to facilitate database design and implementation [2]. An ER model is then transformed into a logical model which is compatible with a database technology.

It is also known that the impact of conceptual modeling on the final system is greater than that of any other development phase [5] [9]. However, there are few
reported empirical studies for evaluating the costs and benefits of using conceptual modeling in large, industrial settings. Despite the widespread adoption of conceptual modeling, many still perceive it to be an ineffective and wasteful activity, in particular, under tight resources and time pressure. Thus it is important to investigate whether the use of conceptual modeling can make a practically significant difference that would justify the costs.

The objective of this study is to perform a comprehensive assessment of the value of conceptual modeling using both quantitative and qualitative research approaches. We will attempt to understand the importance of conceptual modeling by analyzing a Bill of Material (BOM) database development case in a large automobile manufacturing organization. As part of this study we will investigate the conditions under which conceptual modeling is effectively utilized. By better understanding the external conditions and the economic value of conceptual modeling in a real world setting, we will be able to develop a multi-perspective framework for evaluating the utility of conceptual modeling.

1.1 Research Questions

This research extends and integrates prior research and explores the following research questions:

i. Does conceptual modeling reduce the effort required in database implementation? In other words, does conceptual modeling improve productivity of database system development?

ii. Does conceptual modeling improve the functional correctness of logical models and database implementation?

iii. If conceptual modeling results in improving productivity and functional correctness, how does it achieve such efficiency and effectiveness in the database system development process?

iv. What are the plausible and necessary conditions for conceptual modeling to be effective within an organization?

These questions form the basis for our research methodology to: (a) define value of conceptual modeling; (b) design an experiment in an industrial setting; and (c) propose a comprehensive framework for practical evaluation of the utility of conceptual modeling. The motivation for the last question arises from the fact that most organizations adopt and modify conceptual modeling technique for their own use. Thus it is important to investigate what and how external factors affect the effective use of conceptual modeling.

1.2 Related Work

The extant research on the evaluation of the utility of conceptual modeling includes:

d. Frameworks for empirical evaluation of conceptual modeling that are based on their underlying grammars [1] [3] [4] [9] [11]. Many previous studies focused on the comprehension of the proposed constructs in conceptual models [4].
ii. Requirement engineering and database design modeling processes [2] [5] [9] [12]. Past work has revealed high failure rates in systems projects, and such project failures were attributed to inadequate or incorrect requirements specification [5]. Conceptual modeling has the potential to improve the requirement analysis process by formalizing domain understanding [9].

iii. Diverse quality metrics for conceptual models and logical models and database quality factors [6] [7] [10] [12]. A number of quality metrics have been proposed in literature most of which provide quality definitions and criteria for conceptual model [8]. Lindland et al. [10] define a framework, based on semiotics theory, which defines syntactic, semantic, and pragmatic quality of conceptual models. By examining the proposed quality factors, we will be able to derive a practical quality model for evaluating conceptual models and logical model, which will be used in our case study.

The research described above has helped us gain an insight into the current approaches about the cost-benefit assessment of conceptual modeling. However, to the best of our knowledge, none of the prior research provides a mechanism for empirically assessing the quantitative benefits of conceptual modeling in a large, industrial project setting. Additionally, there are few studies investigating what aspects of conceptual modeling facilitate the system development process and how they impact the quality of the logical design and actual implementation.

2 Research Methodology

The overall research method applied here is a case study combining both quantitative and qualitative research approaches. Case studies can be explanatory, exploratory, and/or descriptive [8] [15]. This case study can be best characterized as explanatory and exploratory since it triangulates both broad numeric trends from quantitative research and qualitative research.

The purpose of this two-phase, sequential mixed methods study is to obtain quantitative results from a database system development case and then follow up with participants to explore these results in more depth. The quantitative results will enable us to evaluate the quantitative efficacy of conceptual modeling practices in a real world setting. Qualitative interviews and surveys will be used to explore what aspects of conceptual modeling improve the BOM development process and what conditions are necessary for it to be effective.

2.1 Experimental Setting

We have identified a large automobile manufacturing organization that has agreed to participate in this study. This organization is in the process of implementing a database system to unify their Bill of Materials. The goal of the project is to facilitate better production planning and engineering change control. The development is taking place at one site in North America.
2.2 Experimental Design and Data Collection

Quantitative Analysis
To assess the quantitative efficacy of conceptual modeling, employees involved in the project will be randomly assigned to the control and treatment groups. Participants in the treatment group will use conceptual modeling in their development process, while participants in the control group will design logical models and implement the BOM system without the help of conceptual modeling.

In the first phase, we want to assess whether conceptual modeling helps to reduce the effort required to develop the logical design and actual implementation. In other words, we are interested in determining whether the conceptual model can help reduce the costs of database logical design and implementation. To perform such a cost analysis, we will measure the time required to complete the system implementation. It is also important to assess the functional correctness of the delivered system, because conceptual modeling may impact the number of defects in the implemented system. On the other hand, without the use of a conceptual model, the database system may be implemented correctly, but it may be poorly designed. Thus we also assess the quality of the logical design and the implemented system with and without the use of a conceptual model.

Qualitative Analysis
Qualitative methods in a case study are most suitable for investigating research questions of the types what, how, and why. In this second phase, we investigate how the development process is improved by adopting conceptual modeling, what specific problems are encountered with the use of conceptual modeling, and why these problems occur. Qualitative interviews or surveys will be used to probe quantitative cost-benefit results by exploring aspects of the actual practices of conceptual modeling and other external factors affecting the design and implementation.

One of the limitations of this study is that the study findings will be based on a single-case study. However, the single-case study design is appropriate when the selected case is the typical case [15]. The results obtained from two comparative cases will be informative to other system development teams or organizations. In order to increase external validity, the researchers will select study cases based on predefined criteria, and will provide rich contextual data describing the cases. The focus of our research is restricted to the assessment of the value of Entity-Relationship modeling, which is regarded as the most widely used conceptual modeling technique in practice [2].

3 Expected Results
The results are expected to show that, even though the development of BOM conceptual models is costly in terms of time, conceptual modeling helps improve both the functional correctness and the design quality in the logical models and implemented system.
Expected Contributions

This work will make the following contributions to the field of requirements engineering and conceptual modeling:

1. It will conduct a study to evaluate the costs and benefits of using ER modeling in a real world setting. This work will provide empirical evidence of the utility of ER modeling, and will provide economic justification for conceptual modeling.
2. Our study will result in a useful methodology for evaluating other conceptual modeling techniques such as UML.
3. This study will provide a mechanism to operationalize measures for assessing the quality of conceptual models in practice.

References