

Evolutionary Method Engineering – A Case Study in Meta Modeling

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Abstract: Meta modeling is a widely established means for developing conceptual modeling methods (CMM). Here, we show how a CMM for the structured conceptual design of management information systems has been developed in an evolutionary process based on meta modeling. The aim of management information systems is to satisfy the information need managers have to successfully accomplish their tasks. The quality of management decisions is highly dependent on the information they are based on. A structured conceptual design of management information systems is a crucial task that has to precede their implementation and monitoring. Several conceptual modeling methods have been developed in order to support the specification of data warehouse structures and management information systems. However, none of them was found to be appropriate to bridge the communication gap in the process of requirements analysis. Thus, in an ongoing research effort, a CMM has been designed to adequately support the conceptual design of management information systems. Several case studies were conducted and in an iterative process the findings were incorporated to improve the initial CMM. The result of this process is a CMM quite different to the original one. The aim of this paper is to elaborate on the evolutionary development of a CMM using meta modeling and to show how it has successfully been applied in multiple case studies.

1 Introduction

The aim of management information systems is to satisfy the information need managers have to successfully accomplish their tasks. The quality of management decisions is highly dependent on the information they are based on. Thus, a structured conceptual design of management information systems including a comprehensive information requirements analysis is a crucial task that has to precede their implementation and monitoring [JKD01]. Information requirements analysis has to support the conceptual specification of information needs [WS04]. To facilitate information requirements analysis there is demand for a conceptual modeling method (CMM) that is understandable to both IT developers and system users. By this, management support and user participation in the development process can be increased dramatically [BDR03; WW01]. Furthermore, the CMM should hold a degree of formality that allows for the derivation of data warehouse and OLAP structures and thus fosters the implementation of the resulting information system [Ho02].

The aim of this paper is to present an ongoing research effort in which a CMM for adequately supporting the conceptual design of a management information system has been designed. We particularly focus on how the method was developed by means of meta modeling. The work we describe here spans across a period of altogether nine years. During this time five case studies and multiple iterations through the research process were performed. Due to word limitations, in this paper we present only two cases. However, the selected cases document all significant changes in the CMM. We show how the CMM has been applied to conceptually design management information systems. In an iterative process the findings of the case studies were incorporated to improve the initial CMM.

We distinguish between *evolutionary method improvements* and *method customizations*. Evolutionary method improvements arise in projects with particular companies but may be used within other companies or projects as well. Method customizations address requirements of a certain company or project and are not expected to be used in further projects with different companies. In this paper, we focus on evolutionary aspects of method engineering and thus on evolutionary method improvements.

The structure of the paper is as follows: First, we elaborate on the foundation of our research endeavor by explaining the research methodology that guided us through the evolutionary process of method engineering. Second, we provide an overview of related work and provide a starting point for the design of the original CMM. Third, we present two case studies followed by a cross case analysis to describe the changes that were made in the research process. We particularly regard to the according meta models and show how the changes were incorporated. We conclude summarizing our results and provide an outlook to future research activities.

2 Research Methodology and Case Studies

The research methodology of this paper is illustrated in Figure 1. This research belongs to the design science paradigm [He04; MS95]. It strives for developing a practically relevant IT artifact in form of a domain independent, purpose-specific CMM.

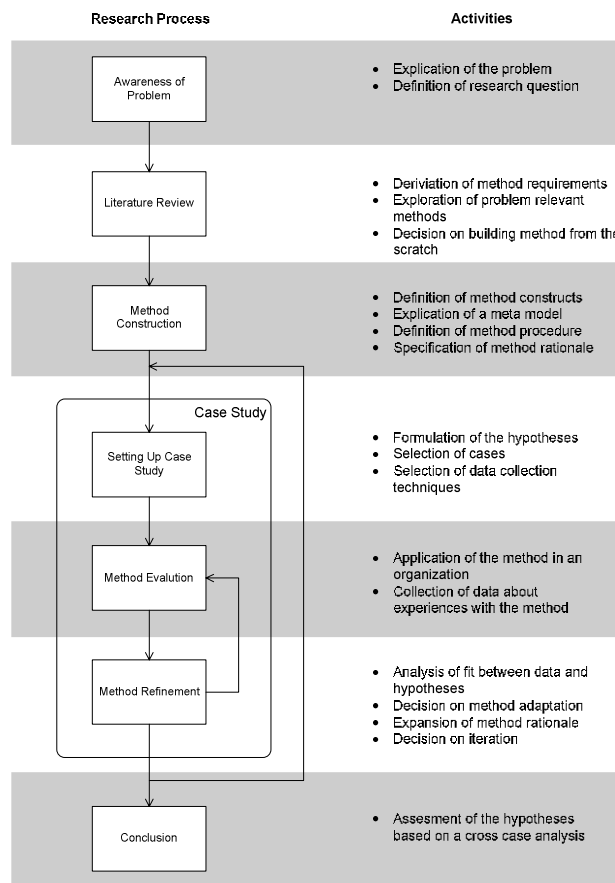


Figure 1: Research Method

The research process started with the awareness of a practical problem [Ta90]. The practical problem the researchers were concerned with and still are can be formulated by the following research question: How to specify a management information system on a conceptual level? The aim of the research process is to provide a CMM guiding the development of a management information system. Our comprehension of an architecture of a CMM is described in Figure 2. In this paper we focus on the language based aspects of the CMM. The practical need for such a CMM became apparent in discussions with IT managers about their experiences with management information systems (inductive reasoning) and from theoretical considerations about cost accounting theory (deductive reasoning) [Ho99]. From the inquiry it turned out that to solve the identified practical problem such a CMM must:

- (R1) *Foster the company wide communication in order to identify relevant information needs and eliminate weaknesses in the current management information systems.* The effective implementation of a management information system must be preceded by an in-depth information requirements analysis including an evaluation of the current management information system. This necessitates a sound communication between IT developers and system users. Hence, a CMM must support this process by providing a conceptual language that can be understood by both parties.
- (R2) *Prepare and assist the technical implementation of the management information system.* From a technical perspective a management information system consists of a data warehouse, a corresponding online analytical processing (OLAP) tool as well as standard reporting tools. As the Entity Relationship approach [Ch76] prepares the implementation of a database structure, the CMM should provide the conceptual basis for an implementation of a data warehouse structure. Furthermore, the models of the CMM should serve as a template for the specification of the reports in OLAP and standard reporting tools.

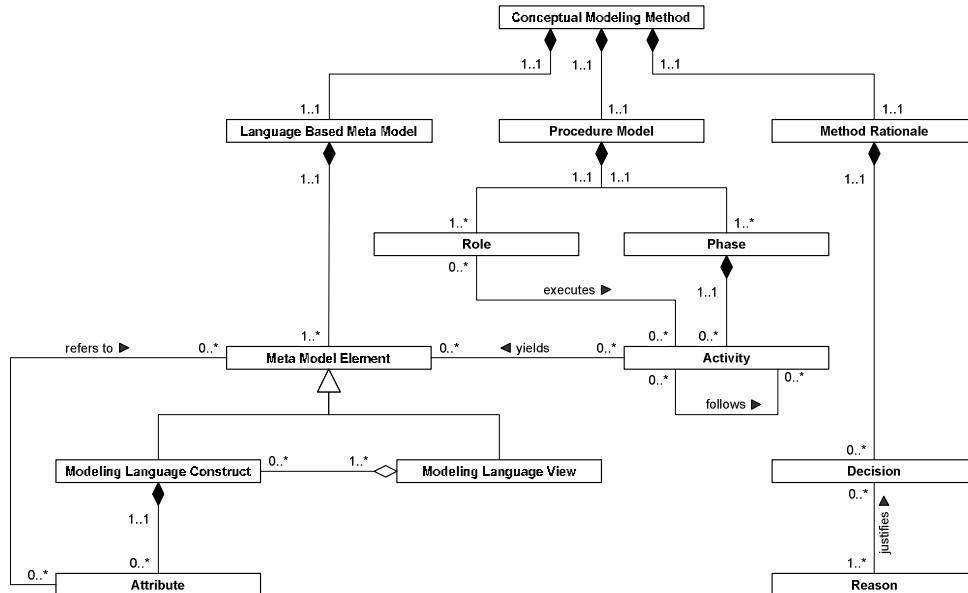


Figure 2: Architecture of a Conceptual Modeling Method

In the next step of the research process, a literature review has been performed in order to consider previous work on management information systems (cf. section 3 on related work). Based on (R1) and (R2) the study of literature resulted in a set of requirements which must be met by a CMM in order to be able to specify a management information system. Three major approaches could be identified which already aimed at the specification of management information systems. However, a detailed analysis of these approaches based on the comparison process of Song & Osterweil [SO94] showed that they do not meet all relevant requirements. Therefore, the decision was made to develop a CMM for the specification of management information systems from scratch.

The construction process of the CMM [Ho01; Ho99] is comparable to the procedures proposed by Greiffenberg [Gr04, p. 166 ff.] and Gupta & Prakash [GP01, p. 143]. First, all relevant *Modeling Language Concepts* were identified. Afterwards, the resulting concepts were supplemented with *Attributes* and, thus, relations between the concepts were established [GP01, p. 143]. In the next step, the *Modeling Language Constructs* have been assigned to one or more *Modeling Language Views* in order to reduce the complexity of the resulting conceptual models. All elements of the conceptual modeling language as part of the CMM have then been consolidated in form of a *Language Based Meta Model*. To make all those design choices traceable all *Decisions* including their *Reasons* have been documented in form of a *Method Rationale* [Ro00, p. 6 ff.].

As mentioned above, all elements of the conceptual modeling language as part of the CMM have been consolidated in form of a *Language Based Meta Model*. Whereas a model is an abstract representation of a real world object, a meta model is a model of a language for modeling that real world object [St96; N96]. If the abstraction takes place on a language based level the meta model is called a language based meta model [St96]. Holten shows the cohesion between model and language on the following levels: meta level, type level, and instance level [Ho00] (cf. Figure 3). Model M1 of a part of the real or perceived world is constructed in a language L1. Model M2 is a model of the language L1. Thus, it is a language based meta model of the object that is part of the real or perceived world. The model M2 is constructed in a meta modeling language L2.

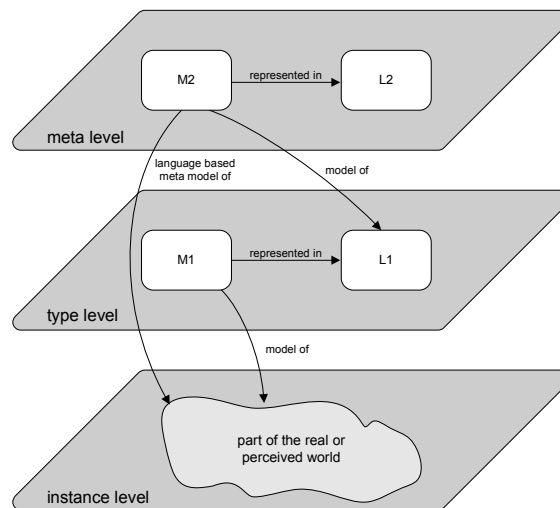


Figure 3: Meta Modeling – Language Abstraction Levels [Ho00]

The evaluation of the CMM has been performed in multiple case studies [Y03, p. 43 ff.]. While setting up these case studies the following four hypotheses were generated based on (R1) and (R2) as well as on considerations from evolutionary method engineering:

- (H1) An application of the CMM improves company wide communication and supports the identification as well as the elimination of weaknesses in the current management information system.
- (H2) An application of the CMM is useful for the technical implementation of a management information system.
- (H3) Method engineering is a continuous, evolutionary process which does not converge to a universal method which meets all technical and organizational contingencies [Ro04, p. 358].
- (H4) Meta Modeling is an appropriate means to support continuous, evolutionary method engineering.

Using theoretical sampling [Ei89, p. 537; GS67, p. 45 ff.] in each of the two iterations an organization was identified which faced the problem of inaccuracies and inconsistencies in its management information system. Since the problem of these organizations and the scope of the CMM corresponded, these companies were selected for an application of the CMM. As data collection techniques, interviews and document analyses have been used. The names of the companies, facts on performed interviews, and the examined documents are listed in Table 1. The interview partners in the organizations were chosen according to the corresponding roles of the procedure model of the CMM. As relevant roles persons in charge of the reporting, report recipients, and system administrators were identified. Moreover, relevant documents were selected according to the procedure model of the CMM. Strategy documents, reports, specifications of the IT infrastructure, documents on the organizational structure, and process models were considered.

Guided by the procedure model of the CMM, in a series of semi-structured open-ended questions the participants were asked to explicate their information needs and to specify the data they can provide to satisfy the information requirements of the company. The interviewer documented the responses of the interview partners by applying the modeling language of the CMM. As second data collection technique the documents of the organizations were analyzed according to the information needs and the available information stock. The resulting data was described by using the same modeling language of the CMM. During the application of the CMM the interviewer noted the reactions of the interview partners on the procedure of the CMM. The interviewer (method expert) also recorded statements from interview partners as well as described facts extracted from documents, which were relevant from his perspective for the specification of the management information system, but not describable by means of the CMM.

Organization	Number of Interviews	Interview Partners	Examined Documents
Swiss Re	7	Financial Service Manager, Risk Manager, IT Project Manager	Paper based reports, contracts
Christ Juweliere und Uhrmacher seit 1863 GmbH	21	CIO, Controlling, Top Management, Managers Purchasing, Managers Sales, Managers Logistics, IT Department	Standard reports (daily, monthly), purchasing data warehouse

Table 1: Facts on the case studies

The experiences from the interviews and the document analyses were then compared to the hypotheses. New requirements on the CMM were derived, deficiencies in the CMM were identified, and suggestions for improvement were specified. Depending on the number and the importance of the proposed changes, the CMM has then been adapted via meta modeling. *Modeling Language Constructs* were introduced, were omitted or were modified. All *Decisions* about adaptations of the CMM including their *Reasons* were documented in form of a *Method Rationale*. After the adaptation of the CMM the interviews and the document analysis continued with the new version of the CMM. This cycle of interviews, document analyses, and method adaptations has been continued until the management information system of the organization has been specified completely. Then it has been decided whether a new case study should be started.

The evolutionary development of the CMM followed guiding principles that have been derived from the Guidelines of Modelling (GoM). These are *correctness*, *relevance*, *economic efficiency*, *clarity*, *comparability*, and *systematic design*. These guidelines aim to “increase the quality of models beyond the fulfillment of syntactic rules”[BRU00]. For a detailed description cf. [BRS95; BRU00]. In analogy, we used the same guidelines to evaluate our CMM by questioning if models constructed using the CMM meet the guidelines. Consequently, the guidelines were applied after every change that was made to the CMM. All changes we describe here were found to meet the guidelines.

After two iterations the findings of the case studies were evaluated in a cross case analysis. This resulted in a further adaptation of the CMM.

3 Related Work

In order to exchange thoughts, opinions and beliefs about the development process of management information systems and its objectives, representation forms of the object system have to be created. Conceptual modeling is considered to be a suitable tool for creating such representation forms respectively conceptual models [Fr99]. As mentioned above, three modeling approaches were identified that are of major importance to the design of management information systems: the Multidimensional Entity Relationship Model (ME/RM) [Sa98], the Application Design for Analytical Processing Technologies (ADAPT) [Bu96; Bu98], and the Dimensional Fact Model (DFM) [GMR98]. Generic approaches to system design, such as UML/OO, Structured Analysis and Design Technique (SADT) or System Dynamics, were not taken into account. They do not contain explicit model constructs for the design of management information systems (see below). This, however, is the goal of this CMM.

ME/RM: Since the Entity Relationship (ER) Model of Chen [Ch76] does not provide sufficient support in the design of multidimensional structures the *Multidimensional Entity Relationship Model* is proposed. The aim is to only slightly enhance the ER language to ensure the flexibility and the simplicity of the ER notation but to allow the definition of hierarchies with qualifying and quantifying data and the hierarchical structure of the qualifying data. New constructs are a fact relationship set, a dimension level set, and a roll-up relationship set. The former connects atomic dimension levels

(i. e. the dimension hierarchy) while the latter connects different dimension levels. Attributes that are assigned to the fact relationship set are regarded to as ratios. An obvious drawback of ME/RM is that alternative hierarchies are complicated to model.

ADAPT: The *Application Design for Analytical Processing Technologies* approach is independent of any prior existing modeling language. The core elements of the language are hypercubes and dimensions. Each cube can have multiple dimensions. Each dimension consists of one or more hierarchies which in turn consist of levels. Each dimension can be associated with members, scopes, and attributes. Members are singular objects of the dimension, scopes are collections of members, and attributes are descriptive information about members of a dimension. Furthermore, models and contexts can be added. Models in this case are algebraic calculation of derived data and a context is a section of a hypercube. Ratios are associated with a cube via a ratio dimension. ADAPT covers most of the required modeling language constructs specified below. However, a comparable construct to dimension scope combinations (cf. Table 2 and section 5.1) is not available. Furthermore, ADAPT does not support modeling on instance level (i. e. “Audi, BMW” instead of “Car”) what we consider to be relevant for information requirements engineering.

Modeling Language Construct	ME/RM	ADAPT	DFM
Dimension Object	-	Member	-
Dimension	-	Hierarchy	-
Hierarchy Level	Dimension Level Set	Level	Dimension, Dimension Attribute
Dimension Scope	-	Scope	-
Dimension Grouping	-	Dimension	Hierarchy
Dimension Scope Combination	-	-	-
Ratio	Attribute	Member	Fact Attribute (Measure)
Ratio System	-	Measure Dimension	-
Information Object	Fact Relationship Set	Hypercube/ Cube	Fact

Table 2: Comparison of Modeling Constructs

DFM: The *Dimensional Fact Model* provides so-called dimensional schemes which consist of a set of fact schemes whose basic elements are facts, dimensions, and hierarchies. The DFM, too, was developed to fill the conceptual gap between the end-user's requirements and the logical or physical design of the data warehouse. The center of any DFM is the fact. It is usually provided with fact attributes, i. e. ratios that measure the fact. Hierarchies are ordered around the fact and provide aggregation paths of dimensions and their attributes that are situated along the path. Dimensions are the finest level of information. Apart from dimension attributes there may be non-dimensional attributes which cannot be used for aggregation. A drawback hindering the use of DF models to foster communication with non-IT staff is that DFM abstracts from the actual object instances and only shows hierarchy levels.

In a comprehensive analysis, required modeling language constructs for the specification of management information systems were defined [Ho99; Ho01]. For an explanation of these constructs cf. section 5.1 of this paper. Table 2 shows the required modeling language constructs and how they are supported by existing CMMs [Kn04]. The table lists semantically similar constructs. If a modeling language construct is not available in a CMM this is denoted by “-“. This analysis led to the conclusion to develop a CMM from scratch that contains all necessary constructs and fosters modeling on instance level.

Since 1999 when the final decision was made to design the new CMM, other approaches have been proposed to model data warehouse structures. Apart from the Common Warehouse Metamodel [OMG01] several efforts to create other modeling methods for data warehousing semantics include but are not limited to the extension of the UML as proposed by Totok [T00] as well as another ER based approach, starER [TBC99], and the Multidimensional Aggregation Cube (MAC) [TKS01]. For other comparison efforts besides this cf. [TKS01; ASS00; GG98; HPN03].

5 Method Construction and Evaluation

5.1 Method Construction: MetaMIS

As mentioned above, the MetaMIS approach has been developed to conceptually specify information needs. It comprises a conceptual language that facilitates the communication between management and IT analysts. Besides, MetaMIS models can be used to derive data structures for the development of data warehouses and management information systems [Ho02]. The conceptual language is used within a procedure model that comprises both as-is-analysis and to-be-modelling [Ho99]. For a more comprehensive introduction of MetaMIS than we can give here cf. Holten [Ho02].

Figure 4 shows an extract of the initial meta model. For the complete meta model cf. [Ho03]. In the following we introduce the key language elements and give examples for their usage.

Basic constructs of MetaMIS are *Dimensions* and *Ratios*. Dimensions serve to organize information spaces. Dimensions consist of *Dimension Objects* such as certain products that can be ordered hierarchically by different aggregation levels such as product groups. To specify the information need respectively a report for certain management tasks it is necessary to specify extracts from Dimensions. These extracts are called *Dimension Scopes* and are sub trees of a Dimension. Figure 5 depicts an exemplary Dimension and a Dimension Scope derived from that Dimension.

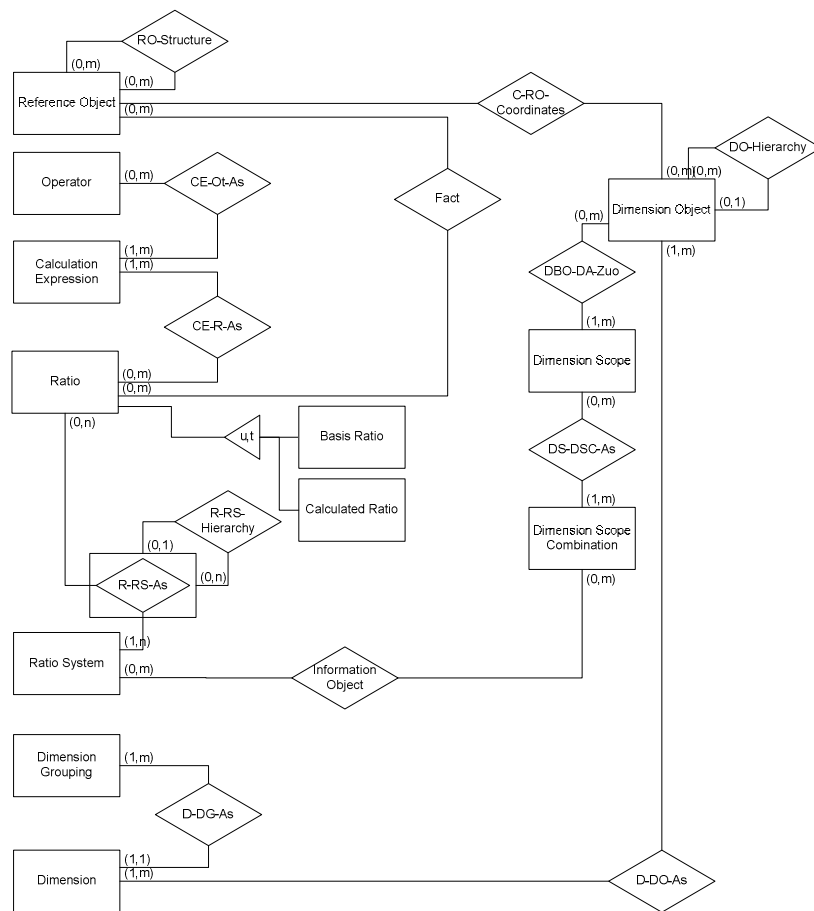


Figure 4: Extract from the Initial Meta Model

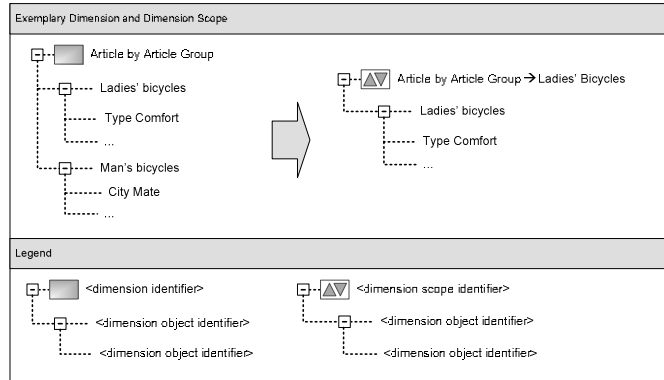


Figure 5: Exemplary Dimension and Dimension Scope

Dimension Scopes always refer to exactly one Dimension. However, management views are multidimensional in most cases. Thus, Dimension Scopes can be combined to *Dimension Scope Combinations*. Dimension Scope Combinations represent multidimensional sub spaces of the overall information space relevant to a certain management task.

Ratios or Measures have been introduced to value Dimensions. Ratios are combined to *Ratio Systems*, which order Ratios hierarchically and enable the top down analysis of reference objects and, thus, of business situations. Ratio Systems and Dimension Scope Combinations are assembled to *Information Objects*. An Information Object is a set of *Facts*. A Fact results from the combination of a Ratio with a (combined) reference object, which consists of one or more Dimension Objects. Information Objects represent the information need related to a certain management task. Figure 6 depicts an exemplary Information Object containing the constructs mentioned above.

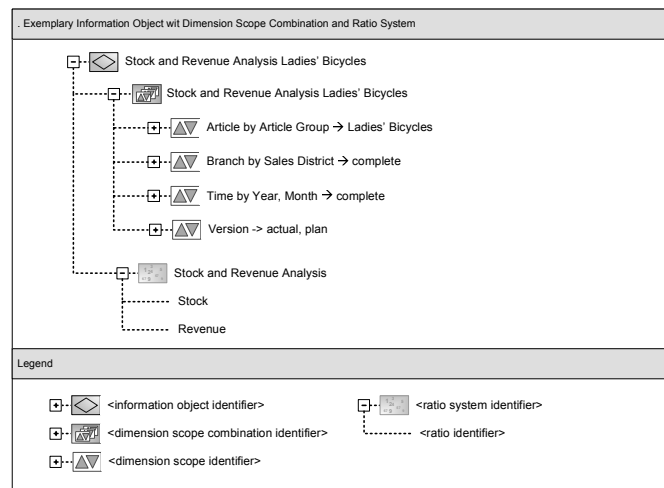


Figure 6: Exemplary Information Object with Dimension Scope Combination and Ratio System

In the following we elaborate on the two mentioned case studies as well as on the cross case analysis and show how the language was altered by incorporating changes into the meta model.

5.3 Case Study: Swiss Re

The Swiss Reinsurance Company (Swiss Re) was founded in 1863. When the case study was conducted in 2002 the company had over 70 offices worldwide and employed more than 9,000 people. The company offers a wide range of products to manage capital and risk. In this case study the MetaMIS approach was used to optimize the communication between business and IT since the specification of management reports was based on documents handed over from business to IT [HDS02]. Thus, there was no tool support or language that could be used for communication between IT and business. At the outset, dimensions were constructed. These were mandatory dimensions such as time and valuation as well as company specific dimensions like *type of business*, *type of agreement*, and *type of transaction* [HDS02]. Second, Dimension Scope Combinations were defined based on the identified Dimensions. In a next step, Ratio Systems were identified and modeled. Here, both *Basic Ratios* and *Calculated Ratios* were accounted for. In a last step the required Information Objects were created to depict certain reports.

Method Evaluation and Refinement

It was found that to depict reports in Swiss Re, different Facts (e. g. the combination of Ratios with combined reference objects, i. e. certain Facts) had to be used within calculations. This led to the introduction of a new construct called *Fact Calculation* [HD02]. Another finding was that there is need for the possibility of parameterization of Dimension Scopes (e. g. with a certain year for a Dimension Scope based on the dimension time) and Dimension Scope Combinations. Furthermore, it became clear that it is useful to strictly distinguish between overall master data and report master data. Overall master data are Dimensions and Ratios, e. g. report master data are Dimension Scopes, Dimension Scope Combinations, Fact Calculation and Ratio Systems. Overall master data are necessary to overcome misunderstandings related to homonymous and synonymous usage of terms, for example. Hence, their identification focuses on the communication gap mentioned above. Furthermore, they build the foundation for the creation of report master data and, thus, for specifying certain information needs.

Table 3 shows a scope of the changes made within this case study.

Modeling Language Construct	Decision	Reason
Fact Calculation/ Fact Calculation Expression	Introduction of a modeling language construct	There was no construct that allowed for the combination of Ratios related to different combined reference objects.

Table 3: Method Rationale for Case Study Swiss Re

Figure 7 shows the parts of the meta model that have been changed within the method refinement of this case study. In *Calculation Expressions* there are now two types of operands: Facts and Ratios. Consequently, the relationship type Fact had to be re-interpreted. The finding that there is need for a strict distinction between overall master data and report master data was not incorporated into the meta model nor were the parameterization of Dimension Scopes. The distinction between overall master data and report master data is relevant in the context of the method's procedure model. The possibility of parameterization of Dimension Scopes had to be incorporated into the grammar that describes how Dimension Scopes have to be named. This is not subject to this paper.

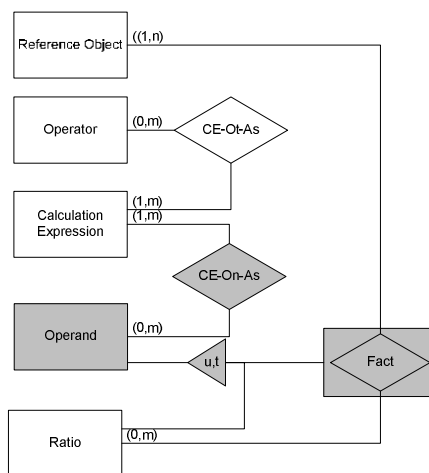


Figure 7: Parts of the Meta Model that have been changed to introduce Fact Calculations

Figure 8 shows an exemplary Fact Calculation from Swiss Re. It can be seen, how parameterized Dimension Scopes are to be used. A Fact Calculation consists of the relevant Dimension Scope Combination (Dimension Scopes respectively), Ratio System, and a Fact Calculation Expression. If Ratio Systems are omitted, the Fact Calculation can be applied to the Ratio System that is part of the Information Object the Fact Calculation belongs to. These relationships are expressed via the relationships between the meta model elements Ratio, Operand, and Calculation Expression: An operand can be a Fact that consists of a (combined) reference object that is part of a Dimension Scope Combination. An operand can be a Ratio (that is part or a Ratio System), too. The linkage is established through the meta model element Calculation Expression, where the elements are combined in an algebraic expression. How these expressions look like is subject to a grammar that is not subject to this paper.

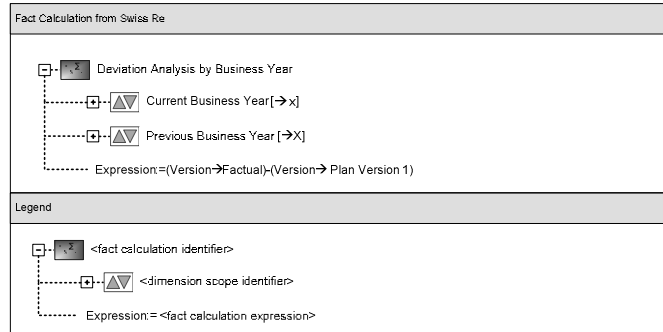


Figure 8: Fact Calculation from Swiss Re

5.4 Case Study: Christ Juweliere und Uhrmacher seit 1863 GmbH

Christ Juweliere und Uhrmacher seit 1863 GmbH is a German retail company in the fields of jewelry and watches. The company has more than 200 branches in Germany. In the course of the introduction of a new enterprise resource planning system a new management information system was introduced as well.

In this case study both, an as-is analysis and a to-be modelling, were accomplished. Within the as-is analysis eight interviews with the top management and with report receivers from different departments (sales, logistics, purchasing) were conducted (i. e. including controlling a total of 21 interviews). These aimed at identifying the actual information need. As-is models served as a communication basis between the groups mentioned and IT analysts. Besides, there was a continuous communication with the company's controlling and IT department. We had access to all report definitions and outputs. More than 150 reports were identified and analyzed. Based on the analysis of the as-is models, redundancies and deficiencies (such as synonymous terms for ratios) of the current system could be identified and suggestions for improvement were made. To-be models were derived from the as-is models and served as templates for the implementation of the future system. Moreover, these models are used for a continuous maintenance of a report repository.

Method Analysis and Refinement

It turned out that the specification of information objects was not precise enough to actually depict the company's management information system. Hence, the linking of *Dimension Scope Combinations* with *Ratio Systems* was insufficient to describe reports and a more detailed description was demanded. It was found necessary to precisely define certain Ratios in a report. Therefore, it was decided that Dimension Scopes should be linked directly to the corresponding Ratios.

The intermediate results of this project led to an adaptation of the original language which entailed the possibility of completely omitting Dimension Scope Combinations. Dimension Scope Combinations act solely as containers and provide the specification of a multidimensional analysis view. On a report level they do not provide any enhancements in contrast to the immediate association of Dimension Scopes to Ratios especially when only single Dimension Scopes are assigned to Ratios. As a result, the CMM was found to be more clearly laid out and easy to use.

Table 4 shows a scope of the changes made within this case study.

Modeling Language Construct	Decision	Reason
Dimension Scope Combination	Modification: Model element can be omitted. Thus, direct relationships between Information Objects and Dimension Scopes are allowed.	For report modeling Dimension Scope combinations do not provide enhancements in contrast to immediate association of Dimension Scopes to Ratios.
Ratio	Modification: Relationships between Ratios and Dimension Scopes are allowed.	Demand for a more detailed description of reports.

Table 4: Method Rationale for Case Study Christ

Figure 9 shows the parts of the meta model that have been changed within the method refinement of this case study.

There has been added a direct linkage between the meta model elements Ratio and Dimension Scope. The fact that Dimension Scope Combinations can be left out has been incorporated into the meta model through a generalization of the meta model elements Dimension Scope and Dimension Scope Combination to the meta model element Dimension Space.

Figure 10 shows an exemplary report specification from the as-is analysis. It can be seen that the Ratio *Sales* occurs twice: Once related to the current year, once related to the last year.

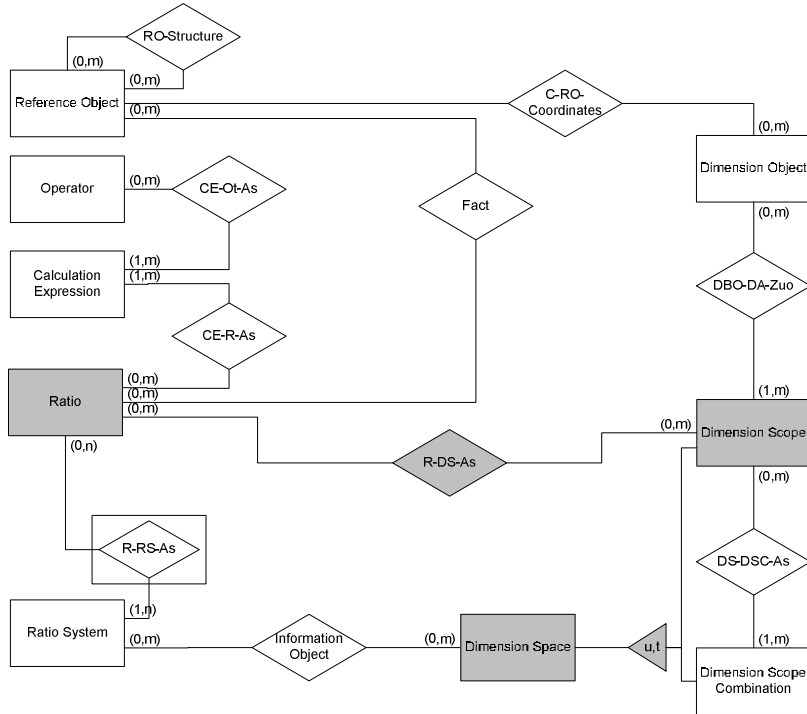


Figure 9: Parts of the Meta Model that have been changed within the Christ Case Study

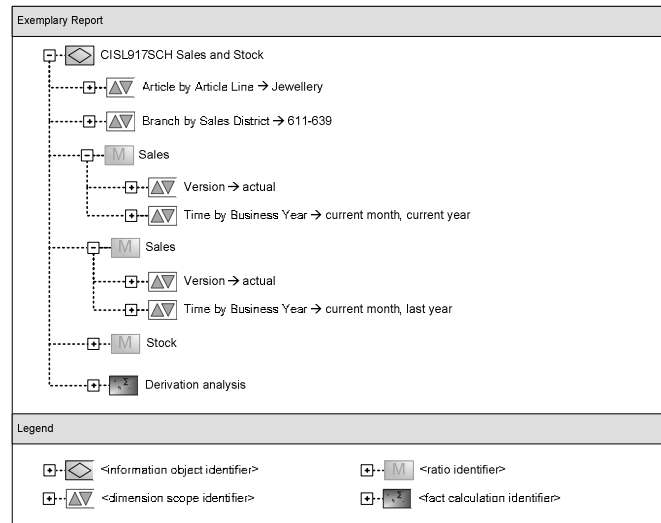


Figure 10: Exemplary Report

Altogether, it was found that the used CMM led to a precise and comprehensive understanding of the existing management information system. During the as-is analysis deficiencies and redundancies could be identified. Furthermore, it could be ensured that no information that was already accounted for in the existing system and that would be demanded in the future system would be omitted unintentionally. As-is models served as a starting point for the to-be modelling. Within the implementation phase the models were found to be useful templates that facilitated the construction of a more user adequate and redundancy free system.

5.5 Cross Case Analysis

Based on the performed case studies a cross case analysis was conducted. Particularly, it was found that there is need for a more detailed specification of reports. Consequently, the conceptual language and, thus, the CMM have been altered another time. A new modeling language construct was introduced and called *report*. Report specifications can be seen as starting points for the navigation within information objects. This language construct allows for a better communication with report receivers and serves as a detailed template for implementation.

Table 5 shows a scope of the changes made within this iteration step.

Modeling Language Construct	Decision	Reason
Report	Introduction of a modeling language construct	Need for representing reports for a report inventory as well as for technical implementation.
Filter	Introduction of a modeling language construct	Filters are a part of reports.
Report Row	Introduction of a modeling language construct	Report rows are a part of reports.
Report Column	Introduction of a modeling language construct	Report columns are a part of reports.

Table 5: Scope of the Method Rationale for the Cross Case Analysis

The changes mentioned above were substantial to the meta model. Figure 11 shows the new meta model. This time those elements are highlighted that show the connection to the meta model of the former CMM.

A report is a two-dimensional projection of a multi-dimensional navigation space (and thus of an information object). This is common practice of reporting tools.

Here, we can only give a short introduction into the meta model. A *Report* can be a *Basis Report* or a *Compound Report*. A *Compound Report* is a structure that consists of at least two *Basis Reports*. A *Basis Report* consists of a *Report Row Definition* and a *Report Line Definition*. *Report Rows* and *Report Lines* consist of *Report Elements*. A *Report Element* can be a *Dimension*, a *Dimension Scope*, a *Dimension Object*, a *Ratio System*, or a *Ratio*. The actual content of a report can be derived through the combination of *Report Elements* that are *Row Content* and *Report Elements* that are *Line Content*. The according results are facts as described above. The language construct *Position* has been introduced to allow for structural breaks in reports: A *Report Element* can be a *Position* that itself can contain other *Report Elements* such as *Dimensions*, *Ratios* etc.

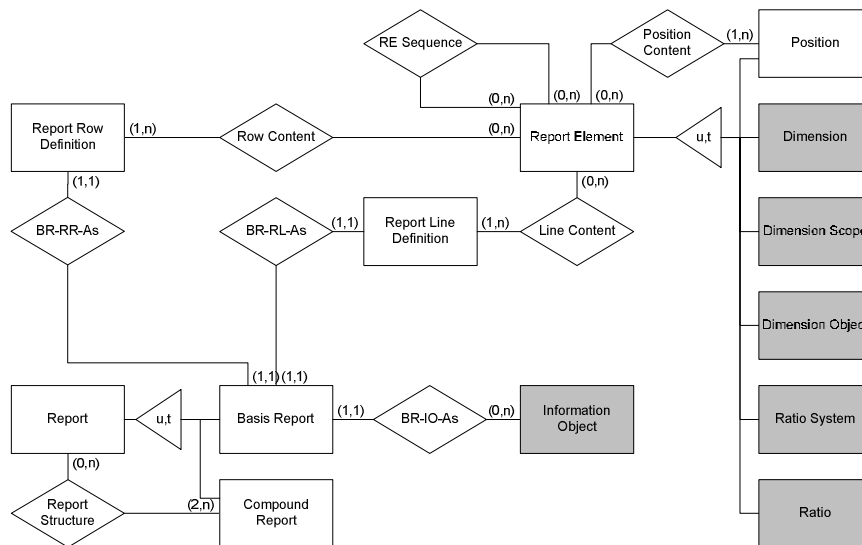


Figure 11: Meta Model Cross Case Analysis

Figure 12 shows an exemplary report specification. The columns are headlined with two Ratios: stock and revenue. In the lines articles are listed by article groups. The filter allows limiting the scope on certain article groups respectively articles.

Besides the before mentioned changes in the CMM, there were others which did not affect the meta model. For example, a grammar for fact calculation expressions and naming conventions was introduced. This is due to the fact that it turned out that only a strict set of guidelines on how to create models leads to a good mutual understanding between IT analysts and system users.

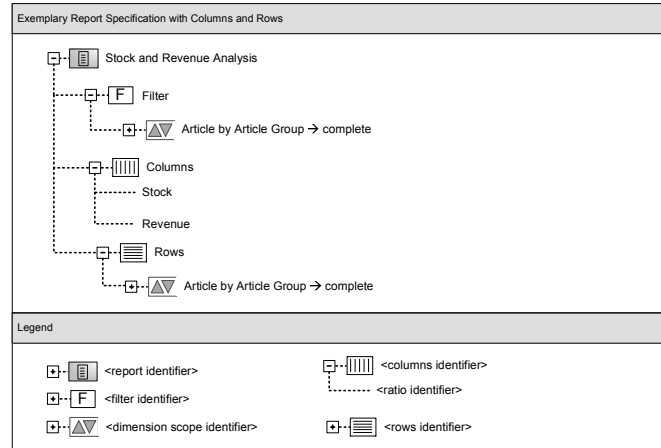


Figure 12: Exemplary Report Specification with Columns and Rows

6 Summary and Outlook

The basic assumption of this research was that there is a practical need for the conceptual specification of management information systems. This goal-oriented research process was accompanied by different case studies in which the CMM was evaluated. Findings of the case studies were incorporated and the CMM has continually been altered via altering its meta model. Thus, the process of method construction was iterative. This allowed for reacting to certain demands that were project or even company specific and led to a CMM quite different to the original one.

The resulting CMM exhibits the following properties:

1. *The CMM comprises a conceptual language which can serve as a communication basis between IT developers and the management respectively the report receivers.* In the case studies it was found that the modeling language of the CMM is easy to understand and to apply by management and IT department as well. It has been observed that the models of the CMM could provide a common communication basis and hence allow for the identification and elimination of weaknesses in the management information system (H1).
2. *The models of the CMM can serve as templates to derive actual data warehouse and OLAP structures.* Since, the language of the CMM shows significant similarities with the logical languages of data warehouse and OLAP systems it is straight forward to apply the models of the CMM as an implementation template. From the case studies it could be concluded that the CMM can therefore assist the technical implementation of a management information system (H2).

Furthermore, we could show that meta modeling is an appropriate means for the construction of a CMM in a continuous, evolutionary process (H4). Within the case studies the CMM has been evaluated and proposals for method refinement have been made. These refinements were incorporated into the CMM via meta modeling. Thus, meta modeling offered the required flexibility to adapt the CMM to certain project and company specific needs.

Regarding to the research method introduced in this paper, the process of method construction does not end here. The experiences made in the case studies rather support the hypotheses that method engineering is an evolutionary process that continually leads to new method versions (H3). This is not only due to the fact that the CMM has not reached a state of maturity yet where changes in the CMM are only caused by variation in the environment but also due to project and company specific differences which are too singular to include them in the CMM. Therefore, we believe that the further development of the CMM will not converge to a permanently stable version of the CMM. In this paper we focused on those changes that we expect to be valid beyond the boundaries of one company or project. These changes we called *evolutionary method improvements*.

Besides the already mentioned practical benefits of supporting the communication between different parties involved in the reporting process and deriving data warehouse respectively OLAP structures the CMM provides an important contribution to the IS knowledge base. The CMM is an empirically proven artifact that can guide further research on management information systems. Based on the CMM and its models, theories on the efficiency and complexity of management information systems can be developed. Likewise, relations between the structure of the management information system and the success of management decisions can be identified. Hence, the conceptual representation of the management information systems of an organization enables its qualitative analysis.

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