MULTIDIMENSIONAL REFERENCE MODELS FOR DATA WAREHOUSE DEVELOPMENT

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Abstract: In the area of Data Warehousing the importance of conceptual modelling increases as it gains the status of a critical success factor. Nevertheless the application of conceptual modelling in practice often remains undone, due to time and cost restrictions. Reference models seem to be a suitable solution for this problem as they provide generic models which can be easily adapted to specific problems and thus decrease the modelling outlay. This paper identifies the requirements for multidimensional modelling techniques whose fulfillment are a prerequisite for the construction of reference models. Referring to the ME/RM, the concrete implementation of these requirements will be illustrated.

1 INTRODUCTION

To develop data warehouse systems it is necessary to identify what kind of data has to be provided to whom (decision maker) for what kind of management decision (Holten 2003). Despite the fact that an appropriate specification of data warehouse systems is notably necessary at the beginning of a project (e. g. for long-term maintenance reasons), the construction of conceptual models, is often neglected (Vassiliadis, Bouzeghoub, Quix 2000) as data warehouse engineers often attempt a fast realisation (Vassiliadis 2000). This seems to be critical because several studies reveal the importance of determining information requirements in data warehouse development (e. g. Watson et al. 2004; Wixom, Watson 2001).

Reference models can increase the efficiency and effectiveness of conceptual modelling because they can be used as a starting point for the construction of project and enterprise specific models. Thus, reference models provide best (or common) practice solutions for information modelling projects. They are blueprints representing a class of domains and can therefore be seen as reusable requirements. In order to capture the subjectivity of users' needs it is necessary to adapt these blueprints according to their requirements. The process of adaptation should provide mechanisms and modelling constructs that explicitly represent variability in conceptual models.

In the following article reference models will be discussed in the context of data warehousing. After presenting related work the most important requirements concerning reference models in data warehousing will be developed. A concrete approach for reference modelling in data warehousing concludes this paper.

2 RELATED WORK

From a methodical perspective, the debate about design issues of data warehouse systems is dominated by manifold modelling approaches. For the multidimensional specification of data warehouse requirements, a broad variety of modelling techniques exists (Abello et al. 2000; Trujillo et al. 2001). Some of them are closely related to Entity-Relationship Models (ERM) (Chen 1976) or provide

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data warehouse specific ERM extensions (Sapia et al. 1998). Others are derived from modelling approaches for scientific and statistical data bases (Chan, Shoshani 1981; Rafanelli, Bezenchek, Tininini 1996; Rafanelli, Shoshani 1990), are related to object-oriented modelling approaches (Harren, Herden 1999; Trujillo et al. 2001), or present a multidimensional modelling approach which is not based on an already existing modelling technique (Bulos 1996; Thomsen 1997; Golfarelli, Maio, Rizzi 1998a; Holten 2003).

The state-of-the-art of reference model application in the requirements specification phase of data warehouse projects mostly refers to an ad-hoc modification of existing information models (Adamson, Venerable 1998). As the analysis of various multidimensional modelling methods shows, the proposed modelling methods do not provide constructs for supporting model adaptation. Libraries comprising reusable elements of data warehouse reference models are mostly specialised on particular model element types (Spitta 1997).

Collections and definitions of ratios and ratio systems are widespread in business literature (Copeland, Koller, Murrin 1990; Eccles 1991; Lapsley, Mitchel 1996; Kaplan, Norton 1996). However, these collections neglect important aspects (mainly dimensions that have to be analysed for management tasks) of the data warehouse requirements specification (Holten 2003).

In contrast to the area of data warehousing the usage of reference models for the specification of business processes is widely accepted. The adaptation of business models based on configuration patterns is widely discussed (Nordstrom et al. 1998; Nuseibeh 1994; Nissen et al. 1996; Hofstede, Verhoef 1996; Kotonya, Sommerville 1995; Becker et al. 2004). From a practical perspective, corresponding approaches are particularly established in the context of customising Enterprise Resource Planning (ERP)-systems (Rosemann, Shanks 2001; Rosemann 2003). However, ERP-configuration parameters for report definitions are mainly restricted to a selection of predefined reports and organisational roles. But the documentation of underlying configuration rules is often inadequate since the configuration is conducted on a rather technical level. Thus, end users are only able to comprehend effects of the configuration in the form of eliminated reports or eliminated report parts.

The transformation of data warehouse specification models into design schemes and implementations is addressed in a broad variety of approaches being based upon the tool support of data warehousing (Hahn et al. 2000; Golfarelli et al. 1998b; Blaschka 2000; Burmester, Goeken 2006). These approaches aim at a (semi-) automatic transformation of data warehouse requirement specifications into initial data warehouse implementations. Thus, for further developments on data warehouse reference modelling it seems reasonable to address the requirement specification layer.

3 REQUIREMENTS FOR REFERENCE MODELS FOR DATA WAREHOUSE DEVELOPMENT

Data warehouses aim at the satisfaction of users' information needs. These needs are determined by several factors and thus imply different requirements in the design of reference models. To fit these requirements a two-step procedure is proposed (cf. figure 1).

Step 1 (situational positioning and role orientation): An important factor impacting the information needs is the so called "situational positioning". The situational positioning of an enterprise is determined by branch, company type, current life cycle phase and other enterprise attribute values. (Mertens, Griese 2002). Different types of companies imply company specific decisions which have to be supported by the data warehouse system. Only a specific company type requires specific decisions; the information need related to this decision is relevant.

Furthermore the information need is affected by the role of the decision-maker. A role describes the decision rights and accountability of the decision-maker. To enable a so called "role orientation", information needs have to be adapted to the role of the decision maker (Mertens, Griese 2002).

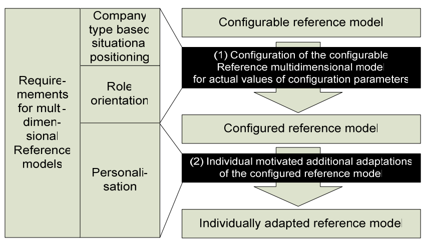

Figure 1: Process of application of multidimensional reference models.

Our approach addresses situational positioning and role orientation by adding a rule basis to multidimensional models. Depending on enterprise attribute values and roles, the rule basis assigns relevance to the elements of information needs. This kind of rule based adaption of reference models in literature is discussed explicitly as "c*onfigurative reference modelling*" (Becker et al. 2004; Knackstedt, Klose 2005; Delfmann et al. 2006). In the following we will apply this approach to a specific multidimensional modelling technique.

Step 2 (Personalisation):

Analysis of data warehouse projects identify unsatisfactory or missing user orientation as a critical success factor of data warehouse development (Poon, Wagner 2001; Mukherjee, D'Souza 2003; Wixom, Watson 2001). User oriented information delivery cannot be realised independently from single users, and the possibilities for standardisation are limited, since the view of reality or the universe of discourse is highly subjective. Hence, the users with their individual preferences should play a significant role in the adaptation process of the reference models. This factor is discussed as *personalisation* (Mertens, Griese 2002).

In our approach the personalisation is taken into account by the fact that in specific models, constructed on the basis of the reference models, the individual and subjective needs of the future users are taken into consideration. This process of adaptation requires a high level of user participation. Therefore, a data warehouse reference model should enable variants and possibilities for individual adaptation.

It has to be noticed, that different variants to analyse facts and measures must not exclude themselves and besides can be implemented often in parallel at the same time. For this the reference models must offer modelling constructs that mark the relationship between variants explicitly i.e. represent clearly whether variants can exclude themselves or can be implemented in parallel. Therefore, we suggest extensions to multidimensional modelling languages for the representation of variants.

Altogether, by serving as a starting point, reference models support requirements elicitation. Requirements Elicitation is the process through which the users and developers discover, review, articulate, and finally define the requirements the to-be system has to fulfil. It is supported, because users and developers do not start "from scratch". Instead, the reference model can be used as a blueprint which is adapted to subjective and individual information needs.

4 MULTIDIMENSIONAL REFERENCE MODELLING TECHNIQUES

4.1 Basic Modelling Technique

In the following, our extension concept will be applied to a concrete modelling technique. Therefore a notation related to multidimensional ERM (ME/RM) by Sapia et al. is used (Sapia et al. 1998). The ME/RM extends the traditional ERM by an entity type, the 'dimension level' and two specific relationship types, the 'fact relationship' and the 'rolls-up-relationship'. The core of ME/RM is represented by a fact relation, visualised by a three dimensional square. It represents a set of facts, i. e. an economically relevant area of interest, substantiated by ratios as quantitative units of measurement. Like in ME/RM the ratios are annotated as attributes of fact relations. The fact relation connects several dimension levels of different dimensions. Dimensions characterise the facts and represent qualified aspects, from which facts and ratios can be analysed. The dimension levels within a dimension are related in a hierarchical order and are connected by a directed acyclic graph, the rolls-up-relationships. It is for the reason that the ME/RM does not provide an explicit qualification of dimensions that – following the DFM by Golfarelli et al. (Golfarelli et al. 1998) – the dimension is visualised by an oval. Facts and ratios (as quantitative values) as well as dimensions and dimension levels (as qualitative values) are the main components of multidimensional modelling. Further components of multidimensional modelling– like dimensional attributes, different types of dimensions and relationships or heterarchies – are neglected in following.

4.2 Extensions for Rule Based Configuration

In order to use configurative reference modelling concepts in practise, the extension of modelling methods for data warehouse specification is necessary (Knackstedt 2006, Knackstedt, Klose 2006). Constructs are required to label model components which are exclusively relevant in a given application context. Model element types of the modelling method that are designated for configuration are connected to configuration parameters.

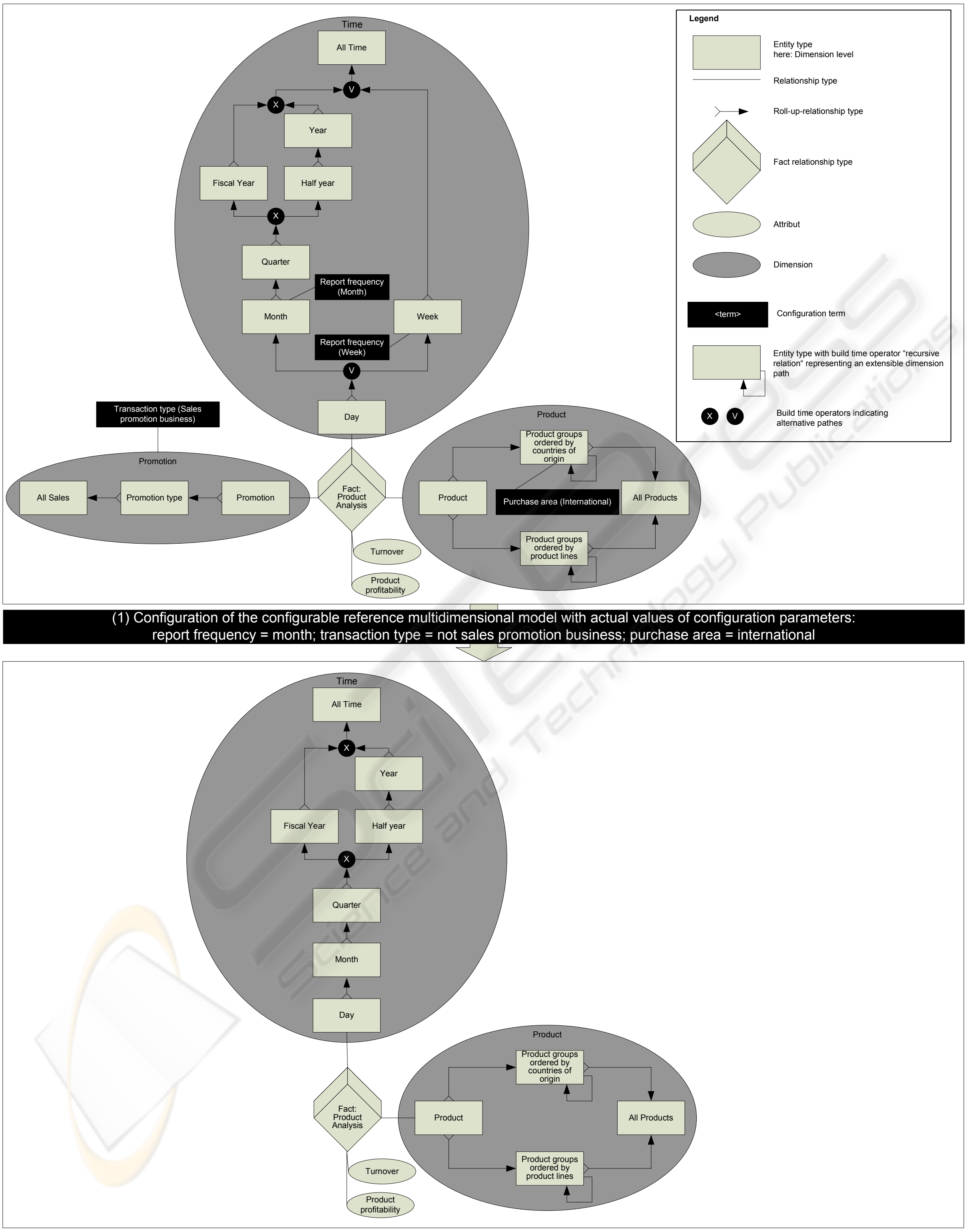

Figure 2: Reference model application (part I).

Concerning our case dimensions, dimension level attributes, attributes and fact relationship types are affected. We propose enterprise attribute values and roles as specialisations of configuration parameters. Enterprise attribute values are used as configuration parameters to cover aspects of situational positioning. Roles are used to cover requirements on role orientation. Figure 2 illustrates the application of the reference model configuration. Here, the specification of a fact for product group analysis is provided. Within our example, configuration parameters are enterprise attributes ‘transaction type’, ‘purchase area’ and ‘report frequency’. An analysis of product turnovers and product profitability according to sales promotion types seems to be reasonable only if the retailer makes use of a ‘sales promotion business’ instead of a permanent ‘low price strategy’. Moreover, a consideration of products according to countries of origin only makes sense in case of an ‘international’ purchase area. The report frequency affects selection possibilities of analysis hierarchies with respect to the reference object ‘time’.

conditions			actions			
trans-action type	report frequency	purchase area	Product groups ordered by countries of origin	week	month	pro-motion
sales promotion business	weekly	national		x		x
		inter-national	x	x		x
	monthly	national			x	x
		inter-national	x		x	x
low prise strategy	weekly	national		x		
		inter-national	x	x		
	monthly	national			x	
		inter-national	x		x	

Figure 3: Decision table.

The underlying rule basis can be presented in alternative representation forms. The decision table depicted in Figure 3 assigns the stated conditions as combinations of enterprise attribute values with specific actions. Actions consist of removing or adding model elements. The crosses used in Figure 3 illustrate which model element is a component of the derived enterprise-specific model. By means of analogous extensions we are able to create models that include perspectives and configurable ratio systems as well.

An alternative representation form is the use of parameterisations that can be added to certain model elements. Depending on configuration parameter values parameterisations determine which model elements are parts of the derived project-specific model. Figure 2 illustrates the application of parameterisations. Here, the configuration term ‘purchase area (international)’ is annotated to the entity type ‘product group ordered by countries of origin’. This rule defines that the entity type ‘product group order by countries of origin’ is to be dropped out in case of an enterprise exclusively purchasing nationally. The syntax of parameterisations can be defined in the form of a context-free grammar formulated in the Extended-Backus-Naur-Form (EBNF) (Hopcroft, Motwani, Ullman 2000) (cf. figure 4).

```
<term>                            ::=  <expression> {<operator> <expression>}
<expression>                      ::=  <prefix> "role" <role value list>
<expression>                      ::=  <Prefix> <enterprise attribute>
                                       <enterprise attribute list>
<role value list>                 ::=  "(" <prefix> <role value list>
                                       { <operator> <prefix> <role value list> } ")"
<role value list>                 ::=  <role>
<enterprise attribute value list> ::=  "(" <prefix> <enterprise attribute value list>
                                       { <operator> <prefix>
                                       <enterprise attribute value list> } ")"
<enterprise attribute value list> ::=  <enterprise value>
<role>                            ::=  "executive purchaser"   "executive producer" etc.
<enterprise attribute>            ::=  "purchase area"   "transaction type" etc.
<enterprise attribute value>      ::=  "national"   "international" etc.
<operator>                        ::=  " "   "+"
<prefix>                          ::=  "NOT" | <leer>
```

Figure 4: Grammar for parameterisations.

4.2 Extensions for Individual Adaptation

For the support of individual adaptation generic extensions of the conceptual language are used. The extensions refer to so called build time operators which represent points where variability takes place. Using these build time operators one can illustrate the various variants a reference model contains and communicate them to users (Goeken 2004; Halmans, Pohl 2004). By means of these build time operators the reference dimensions will be adapted to the subjective user needs. The adaptation refers to the number of dimension levels and paths, their hierarchical arrangement as well as their naming.

Figure 2 shows a build time operator indicating that the number of dimension levels has to be adapted according to the specific conditions of the enterprise. The “recursive relation” represents the adaptation point. During the development process this adaptation point has to be solved and bound to a specific variant. In Figure 5 a concrete model is presented which was deduced from the blueprint, represented by Figure 2. It contains two concrete paths within the product dimension.

In addition, the reference model can give more concrete dimension levels, dimension hierarchies and/or dimension paths. Hence, we suggest – in addition to

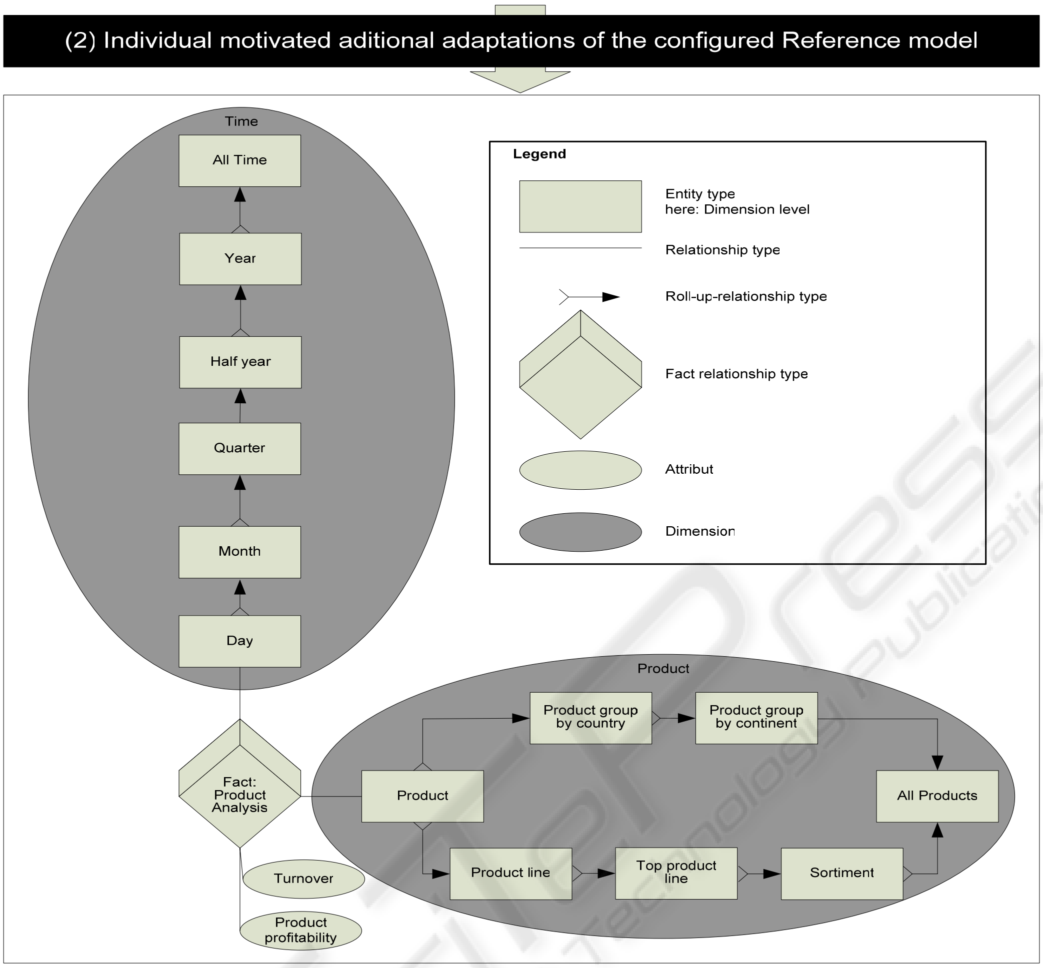

Figure 5: Reference model application (part II)

the recursive relations – another extension of the multidimensional modelling language which helps to illustrate the relationship between variants.

The possible relationship types can be subdivided into the inclusive OR (∨) and the exclusive OR (×). The former means that concerning a business ratio two dimensions with their dimension hierarchies can be implemented in parallel whereas the exclusive OR is mutually exclusive (also according to a selected ratio). In the adaptation process it is required to accept, rename or drop the levels and the names which the reference model suggests.

The meaning of the exclusive OR can be illustrated with the help of a generic time dimension (again fig 2). It shows, that according to the concrete context, some dimension levels and dimension paths can be dropped completely, because they contradict each other or have no relevance. For example, if the fiscal year starts in January, calendar year and fiscal year are equivalent. Than there is no need to report the relevant ratios for the time span October – September. Therefore, we can drop "fiscal year" in this case (cf. figure 2 and figure 5).

5 CONCLUSION AND FUTURE WORK

In this paper we presented extensions for multidimensional modelling techniques to support the usage of reference models when developing data warehouse systems. To apply these reference models a two-step procedure is proposed. The first step comprises a rule based configuration of the models whereas on the basis of the evaluation of this rule base the individual adaptation of the reference model takes place in the second step. This procedure consequently fits both on enterprise and role specific impact factors for information needs and further allows the integration of preferences of data warehouse users in the specification process.

The presented solution generally can be transferred to many different types of multidimensional modelling techniques. Examinations concerning the transferability have been successfully performed.

Methodical parts of the approach were tested in several projects in practise. It is our aim to develop extensive reference models for different domains, e. g. retail information systems, university administration, and banks which are using our methodical extensions (Knackstedt, Janiesch, Rieke 2006). These reference models perform a significant contribution to the explication of knowledge for the construction of data warehouse systems and can stimulate future research in this field. In practise these models can support a faster and more sophisticated development of data warehouse systems by providing suitable initial solutions. The analysis of the benefits of these models in reality will be an important aspect of further research.

Another aspect of future research can be seen in the development of software based modelling tools which support model-building and their application (Delfmann et al. 2006). This could lead to a basic stimulation for the implementation of extensions in modelling tools because the tools available on the market lack these functions.

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