# Using Reference Models for Business Process Improvement: A Fuzzy Paradigm Approach

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**Abstract**

In business practice the enterprise-specific adaptation of reference models for process improvement is characterized by the fact that decision-making premises do not exist in the form of mathematic models or numeric values. Decisions are characterized by consideration and creativity and are usually derived from fuzzy conditions. Although these conditions are not precise, additional and important information for the understanding of concrete business situations is connected with them. Thus, verbal information, as well as vaguely formulated statements, premises, objectives and restrictions are very important for reference model adaptation. The systematic consideration of fuzzy data in reference model adaptation can only succeed, when the models to be adapted themselves allow the consideration of fuzzy data. The fuzzy set theory-based extension of information modeling therefore provides the foundation for the development of a methodology, as well as the prototypical realization of a tool for reference model adaptation with regard to fuzzy data in this article.

## 1. Vagueness in Reference Model Adaptation

Information models are defined as purpose-relevant representations of an information system designed by way of a construction process [vom Brocke 2003, p. 16; Thomas 2005a, p. 25]. They are simply referred to as models. A reference model—to be precise: reference information model—is an information model used for the construction of other models. This article is therefore based upon a use-oriented reference model term which focuses on the use of reference models for the construction of enterprise-specific models [vom Brocke 2003, p. 34; Thomas 2005b, p. 24]. The reference model terms often found in information systems literature, based upon attributes which characterize these reference models—in particular the attributes "universality" and “recommendation character” [vom Brocke 2003, p. 31 ff.]—will not be followed here. Every model resp. partial model which can be used to support the construction of another model can be seen in this sense as a reference model. The reutilization of reference models connected with this can be seen as a fundamental idea resulting from paperless, tool-supported data-processing consulting at the start of the 1990ies.

The user‘s primary task in reference model-based construction, which can be supported by IT-tools, is the adaptation of reference models. The derivation of specific models from a reference model characterized by this term corresponds with the creation of variants of reference models [Schütte 1998, pp. 207–209]. Thus, for example, the enterprise-specific models *information model product-oriented manufacturing enterprise* $E_1$ or *information model process-oriented manufacturing enterprise* $E_2$ could be derived as variants of the reference model *manufacturing*. The adaptation of a reference model consists of two phases in accordance with the understanding of the term in this article [Schütte 1998, p. 316]. In a first step, the reference model is approximated to the requirements of the enterprise being considered. In a second step, modifications are made to the model. While the first phase focuses on a semi-automatic adjustment process, the second phase represents a process which must be carried out manually by the model-user. The result of the adaptation process is an enterprise-specific to-be-model, which can be put into practice, i. e. implemented in the company.

Although a wide variety of guidelines, procedure models, modeling languages and tools for the development of to-be-models for business processes exist, reusable “know-how”, which considers process flow and data processing support in an integrated sense, is not sufficiently available. In many areas the need for the repeated use of work-pieces (for example: modular systems in industrial product design) exists, not least due to economic reasons, whereas process design usually represents industrial single-part production. Research activities which attempt to remedy this problem exist among other things for model supported business process construction with process particles [Remme 1995], for context-specific individualization of process models [Rupprecht et al. 2001], for the design and distribution of construction processes in reference modeling [vom Brocke 2003] or for the management of reference process models [Thomas, Adam, Seel 2004]. Many of these approaches focus on the user-friendly and intuitive usability of methods by approximating these with human ways of thinking. However, necessary decisions require the exact quantification and formalization of decision rules.

Often though, only uncertain, imprecise and vague information is available concerning the frequently technically indeterminable procedures for business processes [Rehfeldt 1998; Forte 2002; Hüsselmann 2003]. By the same token, the target system which is the basis for the adaptation of reference models is generally characterized by imprecise formulations and implicit interdependences. This is for example, illustrated by the statement “the processing time for commissions with a priority of ‘very high‘ should be reduced by proportionately reducing processing intensity, while retaining a ‘high‘ processing quality”. In this example, neither the concrete specification of both goals concerning processing time and quality, nor the measures derived can be quantified without the loss of information and in doing so, made directly processable. Today, information models, especially reference models, as well as methods for their enterprise-specific adaptation still do not consider these forms of fuzziness adequately.

In the following, the perception of the term "fuzziness", as well as the consideration of fuzzy data with the help of the fuzzy set theory, which has established itself in research and practice as an adequate approach, will be accounted for (section 2). Then, the existing approaches for the integration of fuzziness in information modeling will be set forth (section 3). On the basis of this, a recommendation for reference model adaptation under consideration of fuzziness, based on the modeling language Event-driven Process Chain (EPC) will be outlined (section 4). The article ends with a conclusion (section 5).

## 2. From Crisp to Fuzzy Sets

In this article, fuzziness is understood as the uncertainty in regard to data and its interdependences. The trigger for fuzziness can be reality itself, language as a builder of models for reality or the use of language. The fuzzy set theory attempts to overcome the separation of a technologically necessary precision on the one side, as well as the empirically desirable consideration of qualitative information on the other and to tolerate a certain lack of precision, as well as vagueness and uncertainty in modeling processes.

The fuzzy set theory was developed in the middle of the 1960ies [Zadeh 1965]. The crucial point in the fuzzy theory is not only to evaluate conditions (of objects) with "true" or "false", but also rather to allow intermediate stages. Subsequent to ZADEH's original idea, the classic theory of crisp sets is extended by the description and combination of fuzzy sets: The degree of membership for each element $\omega$ of a predetermined (crisp) basic set $\Omega$ to a subset $A \subseteq \Omega$ is expressed by a value $\mu_A(\omega)$ of a mapping $\mu_A : \Omega \to [0;1]$. One selects these degrees of membership from the interval [0;1] and gives the following interpretation: the higher the degree of membership of an element with regard to a (fuzzy) set, the more it belongs to this set. $\mu_A$ is called the membership function of the fuzzy set $\{(\omega; \mu_A(\omega)) \mid \omega \in \Omega\}$.

With fuzzy sets, linguistic variables [Zadeh 1973] can be formulated, which adopt expressions in natural language—so-called linguistic terms—as values. Figure 1 shows the linguistic variable "Order Value". It features the terms "low", "middle" and "high".

The memberships of an object value to these fuzzy sets are expressed by the membership functions $\mu_{low}$, $\mu_{middle}$ and $\mu_{high}$. The object value 70,000 € belongs for example, to 0.5 to the fuzzy set "middle" as well as to the fuzzy set "high". This representation of crisp values on fuzzy sets is called fuzzification. In a crisp context it would only be possible for example, to characterize an object value up from 70,000 € as a "high" order value, while 69,999 € would already be considered as "middle".

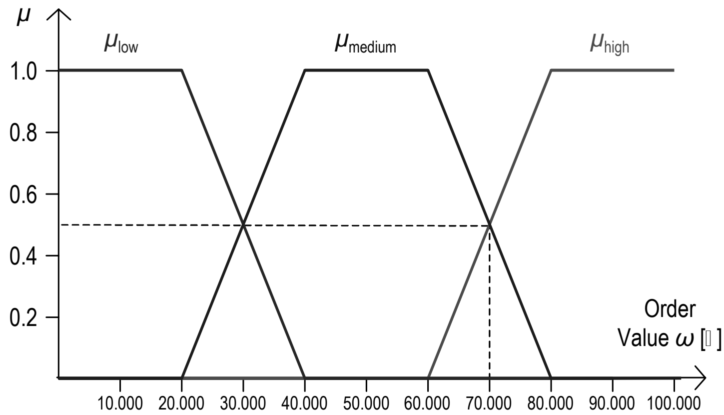


**Figure 1.** Linguistic Variable "Order Value".

A fuzzy system consists of input and output variables, whose respective attributes are connected by rules, consisting of a premises and a conclusion, for example in the form "IF Customer appraisal = middle AND Size of order = very high THEN Customer order evaluation = high". The input and output variables are assigned to one another by way of an inference procedure. For an executable action, for example: "set priority", a crisp value from the output variable is required. A defuzzification step provides this crisp value. Fuzzy systems are used successfully in the fields of automatic control engineering, sensor technology and data analysis resp. decision support. Fuzzy software tools support users in the planning, modeling, analysis, simulation and implementation of fuzzy systems. They provide editors for naming of linguistic variables and for the graphic design of membership functions, rule assistants and consistency tests for designing rule sets with several input and output variables [Parallel and Distributed Processing Laboratory 2000].

# 3. Related Work - Existing Approaches for Fuzzy Modeling

There are only a few approaches which integrate fuzziness-aspects in information modeling with the help of the fuzzy set theory. The fuzzy-extension of the Entity Relationship Model (ERM) [Chen 1976] was described by ZVIELI, CHEN. Here, types of entities, relationship types and sets of attributes can take on fuzzy values [Zvieli, Chen 1986].

Fuzzy theory-based extensions of object-oriented modeling methods for business processes can be found in [Benedicenti et al. 1998; Cox 2002].

An object-oriented approach based on the fuzzy set theory for the simulation of business processes is presented by VÖLKNER and WERNERS [Völkner, Werners 2002].

In order to represent the system behavior with fuzzy process conditions or incomplete, vague information Petri Nets [Petri 1962] were extended with fuzzy-concepts. The Fuzzy Petri Net results from the projection of several crisp Petri Nets, in which the structure information is represented as fuzzy sets [Lipp 1982].

REHFELDT and TUROWSKI [Rehfeldt, Turowski 1996; Rehfeldt 1998] point out the consideration of fuzzy data in business process modeling with Event-driven Process Chains [Keller, Nüttgens, Scheer 1992] using the example of industrial order processing. Vague sales information is seen as important, fuzzy exogenous input data, which is then transformed into tentative customer orders.

THOMAS, ADAM and HÜSSELMANN examine how fuzzy data can be used for the design of knowledge-intensive and weakly structured business processes and its implementation in application systems [Thomas, Hüsselmann, Adam 2002; Thomas, Adam, Seel 2005; Adam, Thomas 2005]. They identify business process modeling in the form of Fuzzy Event-driven Process Chain—in short: Fuzzy-EPC as a possibility. This method is exemplified in Section 4.

In summary, it must be criticized, that only rudimentary approaches which go into the aspects and requirements of a universal integration of fuzziness in business process modeling exist. The possibilities for the integration of fuzziness in information modeling are in fact limited by the existing approaches which demand completeness and precision. The few approaches mentioned limit themselves to the graphic representation or textual notation of "fuzzy" modeling. A scientific discussion about the "extension" of reference models using fuzzy aspects, as well as the enterprise-specific adaptation of reference models for purposes of process improvement has not yet been held. A corresponding tool support also does not exist. In the following, this shortcoming will be made allowance for by an approach to reference model adaptation under consideration of fuzzy data.

# 4. Reference Model Adaptation with Regard to Fuzziness

The fundamental idea followed here states that the systematic consideration of fuzzy data in the adaptation of reference models can only be successful when the models to be adapted themselves allow the consideration of fuzzy data. The fuzzy theory-based extension of information modeling is therefore the foundation for the development of a methodology, as well as for the prototypical realization of a tool for reference model adaptation under consideration of fuzzy data. The fuzzy theory makes the representation of the decision-logic based on the experience of those responsible for the business processes possible. By taking fuzzy conditions and vaguely formulated objectives into consideration, the user with technical process knowledge should himself be able to carry out the enterprise-specific adaptation of reference models using intuitive and simple linguistic evaluations. The adaptation-tool should—like us humans—make decisions on the basis of fuzzy terms. The following section justifies the consideration of fuzzy data in reference modeling and points out its application potential using a simple example process for customer order processing.

Figure 2 represents a part of a reference process for customer order processing in the form of an Event-driven Process Chain (EPC) [Keller, Nüttgens, Scheer 1992]. The model describes the course of events for the definition and execution of the checking functions for a customer order. The decision regarding the acceptance or the refusal of the customer order is made by the parallel execution of various sub-functions. The customer order is checked for technical feasibility and in addition, the customer creditworthiness and the availability of the product are determined. Negative results, such as for example, "Order is not technically feasible" or "Poor credit rating", lead to the rejection of the customer order by way of the function "Reject customer order".

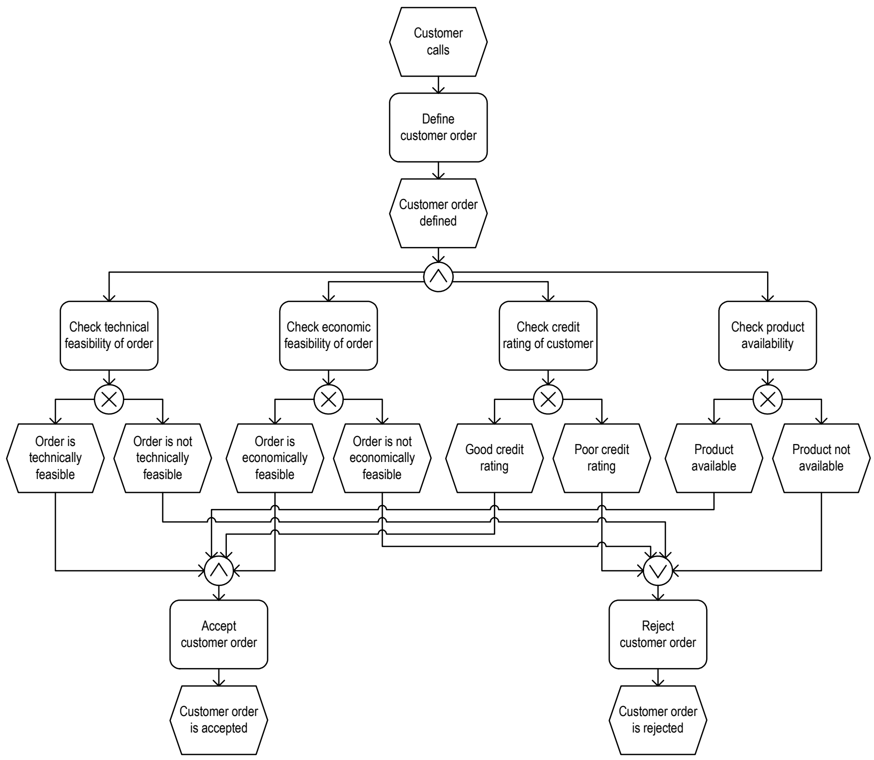


**Figure 2.** Reference Process Model for Customer Order Processing.

A weak point in the modeled process immediately becomes obvious: each of the negative results leads to the immediate rejection of the customer order—independent of the inspection results of the other functions. This is contradictory to business practice where such absolute elimination criteria are only rarely complied. In fact, through man as the decision-maker implicit compensation mechanisms are used, which counter-balance an exceedance of limiting values in one area with better values in another area. The rules for the interdependent impact are not documented here, but rather based upon the decision-makers know-how. Furthermore, it is usually a case of simple rules, which establish only scale-related combinations and which orient themselves on target systems with vague interdependences. In the present case, the decision as to whether a product is available could be answered not only with a crisp "Yes" or "No", but rather also be characterized by the additional effort resulting from weighing things up, so that the product for example, could be requested from another warehouse, if all other inspections turned out to be positive. A corresponding decision orients itself on the trade-off between the goal to avoid additional costs and the focus on customer needs. This results in the challenge to represent fuzziness in reference and procedure models for their adaptation, in addition to the problem of the development of implicit knowledge.

Beyond the contextual difficulty, problems also arise in the use of the present reference model given that two modeling intentions are being followed. In addition to the generally accepted procedure for customer order processing, the criteria used to support the decision for the inspection of the customer order are also represented. The steps for the definition and inspection of the customer order with its final acceptance or rejection can be transferred to various application contexts and must rarely be modified in the enterprise-specific adaptation. These elements of the reference model serve as a generic procedure model for the processing of customer orders. In fact, the concrete decision made during the inspection of the customer order represents a decision rule, which was modeled in the EPC. The individual questions pertaining to this are often decided upon in companies. This pertains to the object values to be checked, as well as to their reciprocal dependencies. The fuzzy set theory provides compensatory operators for the carrying out of inference for the integration of these interdependences.

Now that the diversity of the problem has been presented, one can say that possible answers, i.e. the target set, differ heavily due to those assigned to specific tasks. Thus, the testing criteria can generate differently structured linguistic terms. As represented, the terms fuzziness, vagueness and impreciseness can be found in the sphere of the adaptation of reference models which analogue to the traditional application areas of the fuzzy set theory should not be neglected, but rather used for the improvement of processes and decision support.

Figure 3 shows the fuzzy extension of the reference process for customer order processing—embedded in a graphical user interface from a fuzzy modeling tool. The process is represented in the main window in the form of a Fuzzy-EPC

[Thomas, Hüsselmann, Adam 2002]. The fuzzy constructs of the EPC are characterized by grey shading.

After the definition of the customer order, its acceptance is checked. The checking of the individual functions in the "crisp" processes is however extended by way of inspections pertaining to the size of the order and customer appraisal. The functions are thereby not modeled as "subordinate" activities of the customer order verification, but rather as fuzzy object attribute of the function "Check customer order" in the form of linguistic variables (cp. window "Attributes" in Figure 3). The object attribute "order size" is for example, activated in the Attribute Explorer. In the example, it features the terms "very low", "low", "middle", "high" and "very high" as linguistic variables (cp. Figure 3).

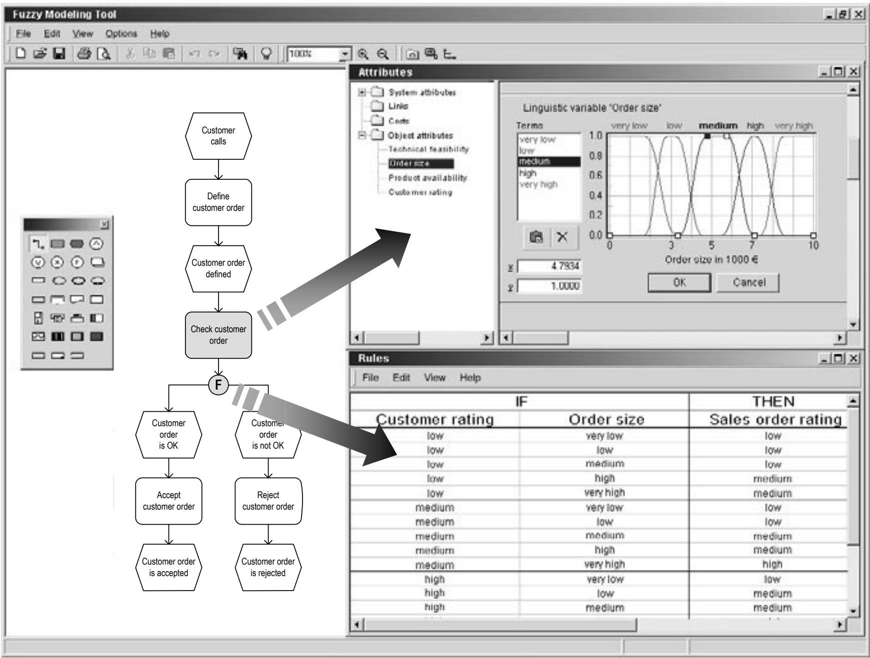


**Figure 3.** User Interface of a Fuzzy Modeling Tool.

In the right part of the attribute window the user can change the membership functions of the linguistic terms using the Variable Editor, for example by "pulling" the "vertices" of the functions which are represented by small squares. A Variable Assistant supports the user by way of an automated variable definition. A Rule Editor (cp. window with the same name in Figure 3) displays the rules deposited in the fuzzy Operator "F"—similar to a spreadsheet. In the example, a section of a rule set with the input variables "Customer rating" and "Order size", as well as the output variable "Sales order rating" is represented.

The user generates the rule sets in the table by manual selection or for example, by the automated adoption of complete sets of rules from a Rule Assistant equipped with consistency checks (cp. Section 2 on fuzzy systems).

The extension of the reference process consists of two levels. The modeling level (cp. **Figure 3**, on the left) still shows the process model, in this case a fuzzified Event-driven Process Chain. On this level, the semi-formal modeling is limited to the content required by the user for the comprehension of business process logic. In a further level (cp Figure 3, on the right), the decision-supporting rules which result in the acceptance or refusal of the customer order are deposited. This level falls back on ideas from the fuzzy set theory, in order to represent the attribute of deliberative conditional nodes. The enterprise-specific adaptation of such a process is now limited to the technical knowledge deposited in the decision rules and the flow logic of the process remains unaffected. Through the consideration of fuzzy conditions and vaguely formulated objectives using approaches from the fuzzy set theory, a user with command of technical knowledge can carry out the enterprise-specific adaptation of the reference process himself by way of intuitive and simple linguistic evaluations. This also implicates that a process already adapted can principally be understood as a reference process—the flow logic of the process at its adaptation remains unchanged and the decision making must be adjusted anyway. And this, although the process already adapted does not represent a "common practice solution". In fact, it is—like the process just being designed for which it is used as a model—an individual development—in a way it is the "best local practice solution".

# 5. Conclusion

The manageability of the adaptation of reference models finds itself in the tug-of-war between theoretical foundation and pragmatic simplicity and displays a high degree of complexity in practice. To reduce this complexity a modeling approach, allowing the consideration of fuzzy data and its possible usage has been outlined in this article. The concept is based on the "level extension" of Event-driven Process Chains: business process models are limited to the content required by the end-user for the comprehension of the logic of business processes, while the technical knowledge necessary for the decision support of individual model-elements is deposited elsewhere.

The fundamental idea followed states that the systematic consideration of fuzzy data in the adaptation of reference models can only be successful when the models to be adapted themselves allow the consideration of fuzzy data. The fuzzy theory-based extension of information modeling in the form of Fuzzy Event-driven Process Chains therefore builds the foundation for the development of a methodology for the adaptation of reference models under consideration of fuzzy data. The fuzzy set theory makes the representation of the decision-logic based on the experience of those responsible for the business processes possible.

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