Evaluating Modeling Sessions Using the Analytic Hierarchy Process

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Abstract. In this paper, which is methodological in nature, we propose to use an established method from the field of Operations Research, the Analytic Hierarchy Process (AHP), in the integrated, stakeholder-oriented evaluation of enterprise modeling sessions: their language, process, tool (medium), and products. We introduce the AHP and briefly explain its mechanics. We describe the factors we take into consideration, and demonstrate the approach at the hand of a case example we devised based on a semi-realistic collaborative modeling session. The method proposed is to be a key part of a larger setup: a "laboratory" for the study of operational (i.e. real) modeling sessions and related study and development of methods and tools deployed in them.

Keywords: Enterprise Modeling, Collaborative Modeling, Modeling Process Quality, Analytic Hierarchy Process.

1 Introduction

This paper was written in the context of the longer term goals of doing solid evidence-based study and development of operational modeling methods. This calls for an adequate way of evaluating and comparing the quality of modeling methods in their broadest sense, i.e. including modeling languages, the modeling process, the outcome of the process (the model, but also common understanding of and agreement on it), and the media used in the process (for example, some modeling tool). Also, these aspects should be viewed in terms of how good they are with respect to the actual, *operational* process. Hence we focus on specific modelling sessions, with their own specific goals and context. More general judgements concerning pros and cons of particular methods should, in our approach, be based on generalizations over data gathered from a number of individual instances of modeling sessions.

In this paper, we focus on the application of a known method from the field of Operation Research, the analytic hierarchy process (AHP) [1], for the comparative evaluation of a number of factors concerning the quality of a modeling

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session. This is to be a core component of what should eventually become a "modelling lab" in which methods, tools, and techniques for enterprise modelling are to be studied, evaluated, and developed within the Design Science tradition [2]. We aim to include in our eventual lab the results of sound judgements concerning the effectiveness and efficiency of particular methods, increasing (insight in) the "Return on Modelling Effort" in view of the utilitarian goals that are set for a particular session. Although our current focus is on collaborative modeling, it is our contention that if we can deal with collaboration factors, the evaluation can also cover non-collaborative (i.e. solo) sessions. While a number of approaches have been developed for the evaluation of (collaborative) modeling processes [3,4,5,6], these are limited in scope, and they do not integrate the weighting of stakeholders' (modellers', project managers', clients') priorities and preferences in view of the modelling process and its direct outcomes. We propose the AHP method as a superior tool for such goal-oriented multi-factor evaluation.

AHP is one of the most popular and widely used techniques in decision making. Its popularity stems from its ability to combine the subjective aspects and intangibles associated with human analysis of complex problems. AHP's wide use in decision making further stems from its ability to integrate the subjective and objective opinions, its ability to integrate the individual and group priorities (and/or preferences) as well as its ability to combine the deterministic and the stochastic in order to capture the interdependencies of the model [7]. Subjectivity and inconsistency are two phenomena associated with evaluation of modeling artifacts by individuals due to personal priorities and preferences. To reach consensus and reconcile their preferences, stakeholders in a collaborative modeling session undertake a negotiation and decision making process. AHP is one of the tools to control their subjectivity by bringing it within tolerable levels of inconsistency. This is achieved by aggregating individual preferences or priorities into group preferences and/or priorities, see for example [8]. To determine the most appropriate method that captures the modelers' quality goals, modelers have to weigh the attributes of the modeling artifacts by comparing them, pairwise, a-priori. It is because of this, and the desire to control modelers' subjectivity in the comparative evaluation, that we use AHP.

This paper is organized as follows. In Section 2 we present our evaluation framework in which identified quality dimensions for the artifacts are described. In Section 3 we describe a case study and the setup of the modeling session carried out. Our evaluation method as applied to the case study, using the quality dimensions, is described in Section 4. A review of some related work is given in Section 5. Finally, Section 6 closes with a brief summary of our main conclusions and future directions.

2 Modeling Process Evaluation Framework

Our evaluation framework follows and extends the approach suggested by Pleiffer and Niehaves [9] to evaluate the different artifacts used in, and produced during, the modeling process. Their approach follows a design science approach [2] to

Table 1. Modeling Language and Modeling Procedure Quality Attributes (a) and (b)

(a) Modeling Language Quality Attributes

	Quality Criterion	Explanation
Modeling Language	Understandability	Understandability refers to how adequate the model represents concepts you recognize in view of your or someone else's domain knowledge.
	Clarity	Clarity of the modeling language refers to how easily you learn and remember the concepts and notations of the modeling language through the signs, symbols, textual expressions of the modeling language.
	Syntax correctness	The syntax is the common agreed communication language for agents in a collaborative modeling process and establishes a set of signs which can be exchanged and rules (syntactical rules) governing how the signs can be combined. The syntax is related to the formal relations of signs to one another.
	Conceptual minimalism	Conceptual minimalism refers to the existence of primitive (basic) signs and symbols for representing data concepts of the domain as separate objects and assembling the objects to form composite abstractions. Conceptual minimalism relates to the simplicity of the modeling language.

(b) Modeling Procedure Quality Attributes

	Quality Criterion	Explanation
Modeling Procedure	Efficiency	Efficiency of the modeling procedure refers to the resources, e.g., time, required for reaching the solution and attaining the modeling goals and objectives; the time needed to negotiate, reach agreement and consensus.
	Effectiveness	Modeling procedure effectiveness refers to how the modeling procedure enables the modelers in using communication and negotiation to get the expected outcome and thus attain their set goals. It also includes the facilitation and the way the modeling process is carried out and/or conducted, and the decision-making process.
	Satisfaction	Satisfaction of the modeling procedure refers to the modelers' positive feeling about the achievement of the intended result using the modeling procedure. Intended results may include intermediary or end-results. Satisfaction can concern the way modelers communicated, negotiated, reached agreement and how they made modeling decisions.
	Commitment & Shared Understanding	Commitment and shared understanding refer to the modeler's stake and promise to support the goals and objectives of the modeling process, the responsibility to abide by the modeling rules and group decisions and his/her readiness to contribute to the group's shared understanding .

identifying the different IS research artifacts evaluating them. Because their framework employs the philosophical notions of structuralism, it still focuses mainly on the inner structure of the models and the evaluation of their quality. Our approach extends their framework by evaluating a wider range of modeling artifacts involved in the modeling process. The quality attributes we study for each of the modeling artifacts in the framework are given and explained in Tables 1 – 2; they are based on [4,5,6,9,10,11,12,13].

3 Research Setup: Case Study Scenario

This section of the paper describes a realistic modeling case study we carried out in one of the modeling sessions. The proposed AHP evaluation methodology is applied to this case together with the quality dimensions from Section 2.

Table 2. Products and Medium-Support System Quality Attributes (a) and (b)

(a) Modeling Products Quality Attributes

	Quality Criterion	Explanation
Modeling Products	Product Quality	Product quality refers to the accuracy of the model in depicting all the identified aspects, adequate representation of the domain concepts in the products, abstractedness, clarity and correctness.
	Understandability	Understandability of the products refers to the degree to which the modelers comprehend the language concepts represented in the products, e.g., its syntax, semantics, etc., the relationship between the different concepts which are depicted by the products, and the ease with which the modelers can explain the concepts in the products even to those who never participated in the modeling process.
	Modifiability and Maintainability	Modifiability and maintainability of the products refer to ease of changing the products to accommodate new changes and the degree to which the products can be kept up-to-date, and how easily they can be re-used in the re-engineering and re-structuring of the enterprise processes.
	Satisfaction	Product satisfaction of the modelers refers to a positive feeling about the product's quality. This could include satisfaction with respect to the product's correctness, completeness, accuracy, consistency, clarity, understandability and/or its complexity.

(b) Medium - Support System Quality Attributes

	Quality Criterion	Explanation
Medium – Support System (Tool)	Functionality	Tool functionality refers to the different functions that a tool has which support activities of the modeling process. It also refers to how the support tool executes the modeling activities and how reliable it is in executing those activities.
	Usability	Usability of a tool support refers to its effectiveness and efficiency to achieve specified goals in particular environments. It is a set of attributes which bear on the effort needed for use and on the individual assessment of such use by a stated or implied set of users. Where efficiency relates to the level of effectiveness achieved to the expenditure of resources whereas effectiveness refers to the goals or sub-goals of using the support tool to the accuracy and completeness with which these goals can be achieved.
	Satisfaction & Enjoyment	Satisfaction refers to perceived usability of the support tool by its users and the acceptability of the support tool to the people who use it and to other people affected by its use. It also refers to the degree of fun and enjoyment by the modelers in using the tool. Measures of satisfaction may relate to specific aspects of the system or may be measures of satisfaction with the overall support system.
	Collaboration & Communication Facilitation	Collaboration and communication facilitation refers to the degree to which the support system helps modelers to collaboratively achieve the set goals and objectives. It also refers to the ability of the support system to aid the communication process and decision making process to reach agreement and consensus.

Research Design and Subjects. We carried out a modeling session and applied AHP to it. Apart from the modeling process as such, we also had participants negotiate about factors for measuring the quality of the modeling process. Participants in the modeling process were drawn from an undergraduate Information Systems course. All students have skills in conceptual modeling as well as basic computer skills.

Problem Description. The assignment given to the students concerned an airline company facing a re-engineering problem. The current information systems had not kept up with information and data needs and there was therefore a need to upgrade them. To achieve this, the company wanted to come up with an information model of the system. The modeling case identified the main processes, e.g., making a booking, associated activities and tasks (e.g., air-craft inspection), business rules, (e.g., no pilot is allowed to fly a plane without undergoing a general fitness check and test), and the actors involved, (e.g., pilot, passenger, air-hostess), etc. The data model included reservations, scheduled flights, inspection, etc.

Evaluation Criteria Identification. To measure and evaluate the quality of the modeling process, especially with regard to the quality goals and satisfaction, a number of quality criteria were identified. These criteria are given in Tables 1 – 2. The modeling session experiment was aimed at evaluating the quality of modeling process.

Collaborative Modeling Session Phase. The modeling session took 1 hour 50 minutes. During this phase modelers engaged in different types of communication and negotiations to reach a shared and common understanding about the domain concepts to be modeled. The modeling process was carried out using a simple UML editor. Figure 1 is a screenshot of the model produced collaboratively using the COMA tool.

Collaborative Modeling Process Evaluation Phase. In the second part of the modeling session, which took 35 minutes, modelers were given an instrument to evaluate the modeling process. An evaluation instrument (see, Fig. 3) based

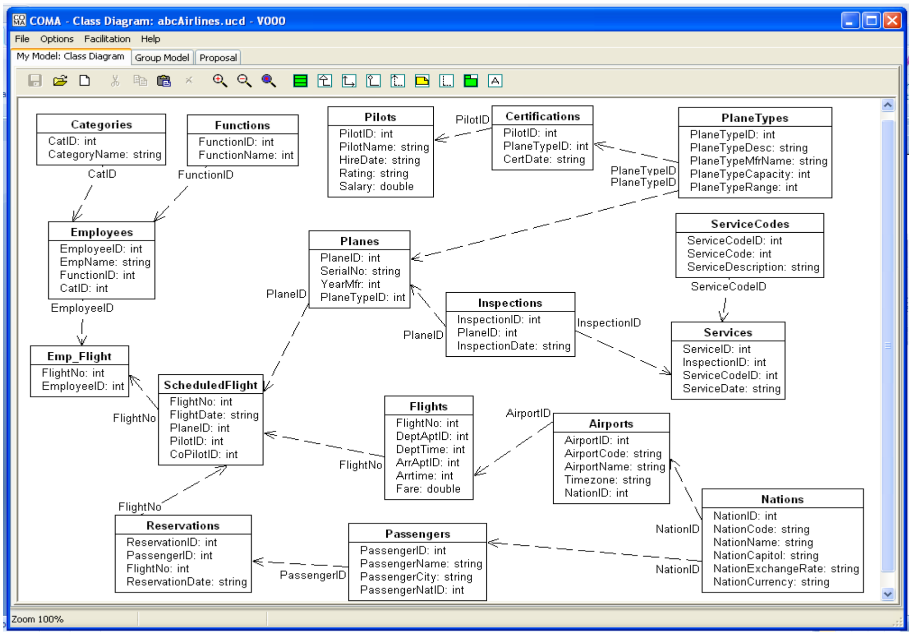

Fig. 1. Screenshot of model from the collaborative modeling session

on the analytic hierarchy process (AHP) fundamental scale was used. The same group was used to exclude their personal characteristics [14] and to track and control the degree of subjectivity in the evaluation.

4 Proposed Evaluation Method: AHP Method

In this paper we apply principles and concepts from the analytic hierarchy process (AHP) to measure and evaluate the modeling process artifacts. AHP is, essentially, a method for making complex decisions on the basis of subjective opinions by multiple stakeholders. In our case the process renders the score for an individual modeling session which can then be compared with a similarly calculated score for another session. Given that variables between the sessions are sufficiently controlled, this enables well-founded judgement about which method works best. The advantages of our evaluation framework and AHP approach lie in advanced management of subjectivity, aggregation of individual priorities, and preferences of the stakeholders about the quality of the modeling artifacts into group priorities and preferences. Also, the AHP helps the stakeholders reach consensus about their preferences and priorities.

4.1 Analytic Hierarchy Process Methodology

AHP consists of mainly three main steps: *structural decomposition, comparative judgement, and synthesizing*, broken into a number of steps, see for example [10].

4.2 Structural Decomposition Step

The decomposition step has basically two sub-steps explained below.

Problem Identification. This step involves identifying the unstructured problem to solve. It could be an evaluation, selection, or a location/allocation problem. Problem identification means also identifying the characteristics or features of the problem which can be used in decision making. These could be criteria, sub-criteria, attributes and alternatives. We decompose the modeling process evaluation problem as shown in Fig. 2 for the case scenario. This is the structural decomposition of the identified problem - *Modeling Process Evaluation (MPE)* of collaborative modeling approaches (CMAs). The different quality attributes, sub-criteria and criteria for each artifact and the overall goal are identified. By weighting these, modelers are able to assign and determine their priorities and preferences.

Hierarchy Construction. This step involves decomposing the problem into a hierarchical structural with distinctive levels. The structure can be obtained using *"decision-tree like diagrams"*. The topmost level, in the hierarchy, is the goal level followed by the criteria level, which is followed by the sub-criteria (if any) up to the lowest level which consists of alternatives.

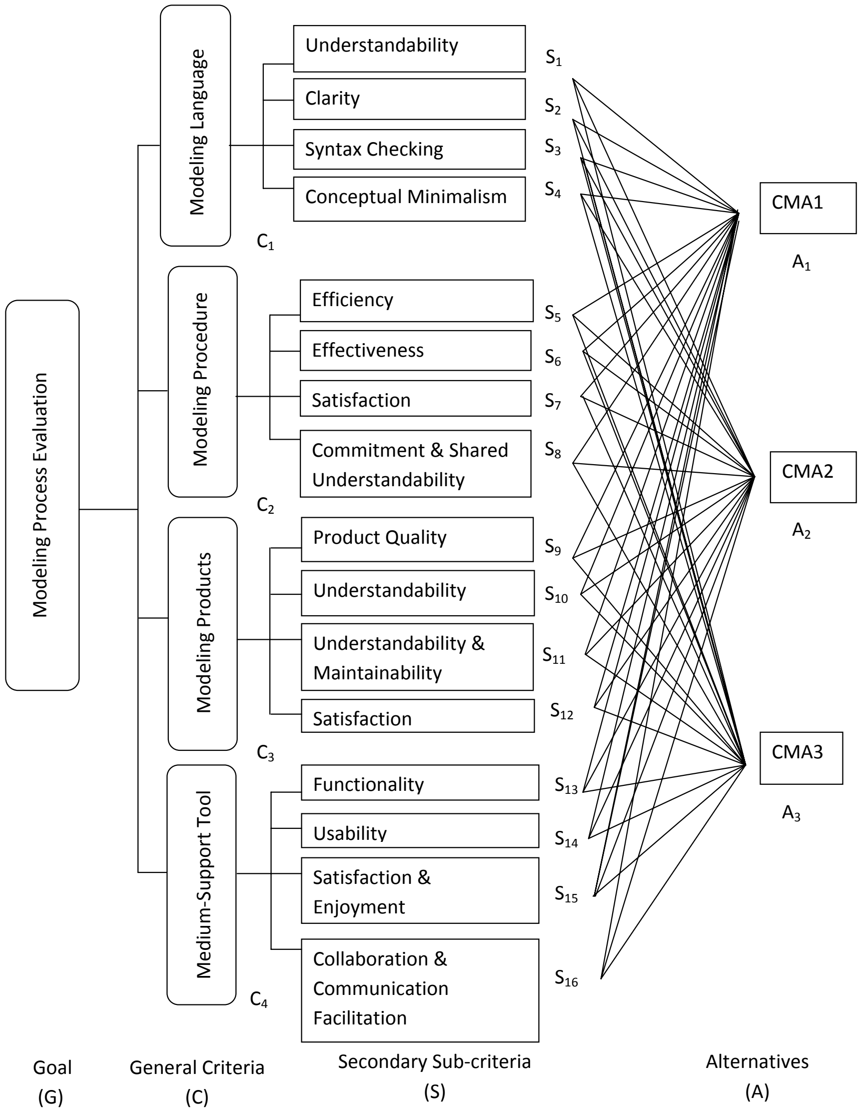

Fig. 2. AHP hierarchy for modeling process evaluation

4.3 Pairwise Comparison - Comparison Scale

The comparative step consists of pairwise comparison, formation of a comparative matrix and priority vector, and checking consistency. The comparative judgment step is aimed at establishing (local) priorities at each level by comparing, pair-wise, each criterion, sub criterion, etc., in the low hierarchy levels to determine the priority of each. Therefore, if we have n evaluation criteria

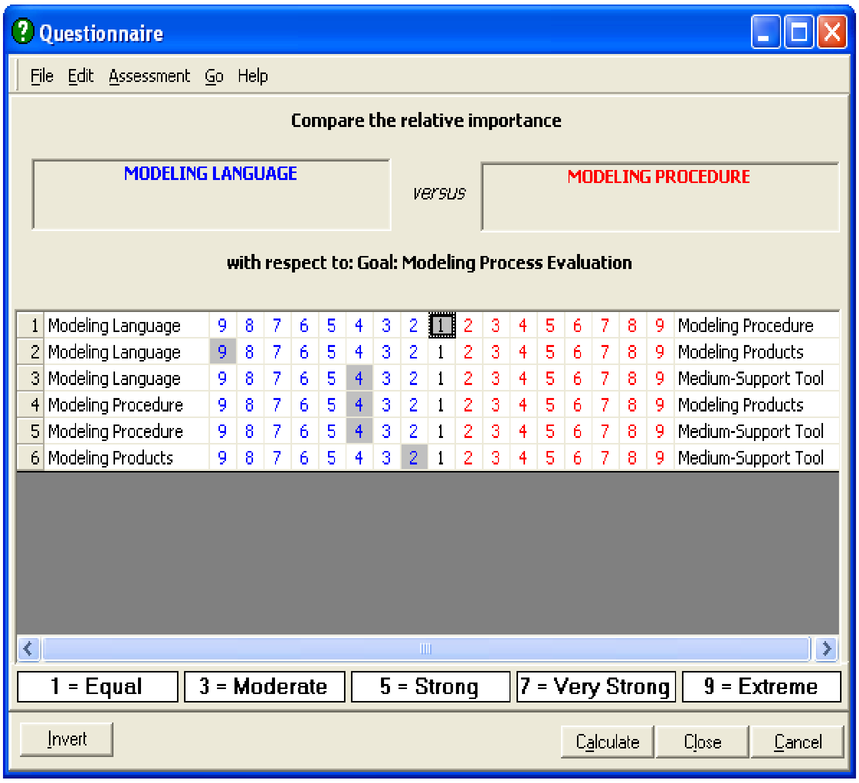

Fig. 3. Expert Choice questionnaire form

(sub criteria or attributes) we will have to carry out a total of $n(n-1)/2$ pairwise comparisons. In the comparison step, each of the elements is assigned and ranked using a nine (1 - 9) point scale in a questionnaire-like instrument in order to determine their relative importance to each other.

To answer the question: *"Of the two elements, which one is more important with respect to a higher level criterion and what is the strength of its dominance?"*, we ask judges (collaborative modelers) to compare, pairwise, the elements at each level in the AHP hierarchy given in Fig. 2. This is aided by using, for example, ExpertChoice [15], a software tool for multi-criteria decision analysis. Figure 3 shows how the relative importance of elements is determined by comparing them, pairwise, with respect to their parent element. In this case, two criteria: *modeling language* and *modeling procedure* are pairwise compared with respect to their parent criterion: *Modeling Process Evaluation*. A judgement (relative scale), e.g., 9, is given in the left half of the questionnaire meaning that *"modeling language is relatively strongly more important than modeling procedure"* in measuring or assessing modeling process quality. A reciprocal, (1/9), means that *" modeling procedure is strongly more important than modeling language"*.

4.4 Pairwise Comparison - Forming a Comparative Matrix

The outcome of the comparative judgment step is a comparative matrix the entries of which are the comparison values between the i^{th} row and the j^{th} column indicating the relative importance (from scale 1-9) of one criterion over another. This comparison value gives the importance of the row's criterion relative to the column's criterion. Let $\mathbf{A} = (a_{ij})$ be an $n \times n$ comparative (judgement) matrix and let a_{ij} be its entries. Then $\mathbf{A} = (a_{ij}) = 1/a_{ji} = 1, i = j$. This means that the elements, a_{ii}, for all i, on the principal diagonal are all equal to 1. The purpose of the pair-wise comparison is to determine the (priority) vector, w, with weights $w_1, w_2, ..., w_n$ which represent the expert's relative opinion/judgement for the criteria, sub-criteria or attributes, i.e.,

$$w = (w_1, w_2, ..., w_n)^T, \quad where \quad w_i > 0, \quad \sum_{i=1}^{n} w_i = 1 . \tag{1}$$

The relation of the weights w_i to the entries of the matrix A is:

$$a_{ij} = w_i / w_j, \qquad 1 \leqslant i, j \leqslant n . \tag{2}$$

The matrix $\mathbf{A} = (a_{ij})$, where $a_{ij} = w_i / w_j$, for $i, j \in \{1, ..., n\}$, has all its entries positive and is called a *reciprocal matrix* since it satisfies the property:

$$a_{ji} = 1/a_{ij} . \tag{3}$$

Matrix $\mathbf{A}$ is said to be *consistent* if the following condition holds:

$$a_{jk} = a_{ik}/a_{ij}, \quad i, j, k \in \{1, ..., n\} . \tag{4}$$

The judgements given by the modelers are put in a comparative (judgement) matrix, using Eq. 2, and the reciprocal condition in Eq. 3. The criteria, sub-criteria, etc., are put along and on top of the matrix. Table 3 is an example of a comparative matrix which, pairwise, compares the relative importance of the general criteria ($C_1 - C_4$): with respect to the goal, G. When an element is compared to itself, we give it a relative scale of 1 (equal importance) and this explains these values on the principal diagonal of the comparative matrix. The reciprocal property in Eq. 3 requires that if an element (criterion comparative

Table 3. Comparative matrix of general criteria $C_1 - C_4$ w.r.t goal G

	Modeling Language	Modeling Procedure	Modeling Products	Medium Support Sys.	Priorities vector
Modeling Language	1	1	9	4	0.469
Modeling Procedure	1	1	4	4	0.093
Modeling Products	1/9	1/4	1	2	0.079
Medium (Support Sys.)	1/4	1/4	1/2	1	0.041

λ_{max} = 4.220 C.I = 0.073 C.R = 0.082

judgement intensity), say, 9 is entered in the first row, third column, i.e., $a_{13} = 9$, its reciprocal is entered in third row, first column, i.e., $a_{31} = 1/9$.

The matrix in Table 3 is a 4×4 positive reciprocal matrix (see Eq. 3), a necessary though not a sufficient condition for consistency. A necessary and sufficient condition for a consistent matrix (see for example, [16]) is that the principal eigenvalue, λ_{max}, in Eq. 7 be equal to the order, n, of the matrix in Eq. 5.

4.5 Relative Weight Estimation - Eigenvector Method

There are a number of methods for computing the (priority) vector of the relative weights and aggregating individual and group judgements or priorities. The most popular aggregation methods are *aggregation of individual judgements (AIJ)* and *aggregation of individual priorities (AIP)* [8]. For prioritization, the *right eigenvector method (EGVM)* and the *row geometric mean method (RGMM)* are the most popular. We prefer to use EGVM to show how the relative weights are computed because of its simplicity and transparency. The relative weights of all the attributes are computed from the eigenvalue problem of the form:

$$\mathbf{A}w = nw \quad or \quad (\mathbf{A} - n\mathbf{I})w = 0 \ . \tag{5}$$

which is a system of homogeneous linear equations and $\mathbf{I}$ is the identity or unit matrix. This system has a non-trivial solution if and only if the determinant of $\mathbf{A}$ vanishes, i.e.,

$$det(n\mathbf{I} - \mathbf{A}) = |n\mathbf{I} - \mathbf{A}| = 0 \ . \tag{6}$$

In this case n is the eigenvalue of $\mathbf{A}$. In order to facilitate the computation, the eigenvalue problem in Eq. 5 can be expanded as:

$$\mathbf{A}'w = \lambda_{max}w \quad or \quad (\lambda_{max}\mathbf{I} - \mathbf{A}')w = 0 \ . \tag{7}$$

where λ_{max} is the largest eigenvalue of $\mathbf{A}$, called the *principal eigenvalue of* $\mathbf{A}'$, which is used as an estimator of n in Eq. 5 and $w = (w_1, w_2, ..., w_n)^T$. The importance of this largest eigenvalue is its use in controlling the inconsistency and subjectivity in the evaluators' judgements. Equation 7 is a system of homogeneous linear equations having a non-trivial solution if and only if the determinant of $\mathbf{A}'$ vanishes, i.e.,

$$det(\lambda_{max}\mathbf{I} - \mathbf{A}') = |\lambda_{max}\mathbf{I} - \mathbf{A}'| = 0 \ . \tag{8}$$

• *Normalization.* Normalization is a process that shows relative importance of the criteria when compared with respect to each other. If R_i is the row-sum for the i^{th} row, i = 1, 2, ..., n, and T_R is the total of all row-sums of matrix $\mathbf{A}$ then we have:

$$R_i = \sum_{j=1}^{n} \frac{w_i}{w_j}, \qquad i \in \{1, ..., n\}. \qquad T_R = \sum_{i=1}^{n} R_i \ . \tag{9}$$

Table 4. Modeling language and procedure comparative matrices (a) and (b)

(a) Comparative matrix of subcriteria $S_1 - S_4$ w.r.t subcriterion C_1

	Understandability	Clarity	Syntax Checking	Conceptual Minimalism	Priorities vector
Understandability	1	1/4	3	1	0.178
Clarity	4	1	5	6	0.607
Syntax Checking	1/3	1/5	1	1	0.096
Conceptual Minimalism	1	1/6	1	1	0.119

λ_{max} = 4.139 C.I = 0.046 C.R = 0.052

(b) Comparative matrix of subcriteria $S_5 - S_8$ w.r.t subcriterion C_2

	Efficiency	Effectiveness	Satisfaction	Communication & Shared Understand	Priorities vector
Efficiency	1	2	6	3	0.464
Effectiveness	½	1	5	6	0.368
Satisfaction	1/6	1/5	1	1	0.077
Communication & Shared Understanding	1/3	1/6	1	1	0.092

λ_{max} = 4.174 C.I = 0.058 C.R = 0.065

Therefore, the normalized entries, w'_i, of the principal eigenvector (local priorities), $w' = (w'_1, w'_2, ..., w'_n)^T$, are given by:

$$w'_i = R_i/T_R, \quad where \quad w'_i > 0, \quad \sum_{i=1}^{n} w'_i = 1 . \tag{10}$$

which is the solution to Eq. 5. The principal eigenvector (vector of priorities), $w = (w_1, w_2, ..., w_n)^T$ is given by Eq. 7. Concepts from this section were applied to the case study and the results are given in Tables 4 and 5. The priorities given in these tables are normalized as can easily be checked by Eq. 10. From Table 4(b), efficiency has the highest priority, followed by effectiveness and communication and shared understanding, whereas satisfaction has the least priority. This means that while determining the quality of the modeling process with respect to the modeling procedure, modelers' priority and preference is on modeling procedure's efficiency and effectiveness. Results in Table 5 are similarly interpreted.

4.6 Consistency Check

To check whether matrix judgments (decisions) are consistent, we need to check the consistency of the comparative matrices at each level of the hierarchy. This is done via the *Consistency Index (C.I)* and the *(Consistency Ratio (C.R)*, calculated, respectively, by:

$$C.I = (\lambda_{max} - n)/(n - 1) \qquad C.R = C.I/R.I . \tag{11}$$

Table 5. Modeling products and medium comparative matrices (a) and (b)

(a) Comparative matrix of subcriteria $S_9 - S_{12}$ w.r.t subcriterion C_3

	Product Quality	Understandability	Modifiability & Maintainability	Satisfaction	Priorities vector
Product Quality	1	1/9	1/5	1	0.064
Understandability	9	1	2	8	0.559
Modifiability & Maintainability	5	1/2	1	6	0.318
Satisfaction	1	1/8	1/6	1	0.061

λ_{max} = 4.014 C.I = 0.047 C.R = 0.053

(b) Comparative matrix of subcriteria $S_{13} - S_{16}$ w.r.t subcriterion C_4

	Functionality	Usability	Satisfaction &Enjoyment	Collaboration & Comm. Facilitation	Priorities vector
Functionality	1	1/2	3	5	0.309
Usability	2	1	6	4	0.505
Satisfaction & Enjoyment	1/3	1/6	1	2	0.109
Collaboration & Comm. Facilitation	1/5	1/4	1/2	1	0.077

λ_{max} = 4.133 C.I = 0.044 C.R = 0.049

where, as noted in [16], R.I is a *Random Index* (the average consistency index) calculated as an average of a randomly generated pair-wise matrix of the same order. It is noted, in [17] that the acceptable upper threshold for C.R is:

$$C.R = \begin{cases} 0.05, & n = 3 \\ 0.08, & n = 4 \\ 0.10, & n > 4\ . \end{cases} \tag{12}$$

Therefore, if C.R is less than or equal to the given upper bound, matrix **A** is of sufficient consistency and the judgment/decision is acceptable. To check for consistency, we use Eq. 8 and Eq. 11 to compute the principal eigenvalue (λ_{max}), consistency index (C.I) and the consistency ratio (C.R). The random index (R.I) for an n = 4 order matrix (the order in our case) is 0.89, [17]. These values are given at the bottom of the comparative matrix tables. The comparative matrices in Tables 4 - 5 are all of order n = 4 (4×4 square matrices). Equation 12 confirms consistency except for 0.082 (in Table 3) which is slightly above the upper-bound indicating some small degree of inconsistency.

4.7 Synthesizing - Overall Rating and Ranking

This step consists of determining overall rating and ranking of alternatives whose priorities may be given as normalized or idealized priorities. It determines the overall priority (preference) rating of the alternatives by aggregating the relative weights of the criteria. Suppose we have got m alternatives. Let w'_{ik} be the local priority for the k^{th} alternative, A_k, for $k \in \{1, 2, ..., m\}$, with respect to the i^{th} criterion, C_i. Let w'_i be the local priority of C_i with respect to the goal, G. Then the global priority, w'_{A_k}, of alternative A_k with respect to all local priorities of the criteria is given by:

$$w'_{A_k} = \sum_{i=1}^{n} w'_{ik} w'_i, \quad w'_{A_k} > 0, \quad \sum_{k=1}^{m} w'_{A_k} = 1 \ . \tag{13}$$

Idealized Priorities. An alternative way of expressing overall (global) priorities for alternatives is to use an idealized form [18]. Priorities for the ideal mode are obtained by dividing each priority by the *largest one*. Let w''_{A_k} be the idealized overall priority for alternative k, $k \in \{1, 2, ..., m\}$. Then

$$w''_{A_k} = w'_{A_k} / \max\{w'_{A_k}\}, \qquad k \in \{1, 2, ..., m\} \ . \tag{14}$$

Note that from this point, CMA1 reflects our case whereas CMA2 and CMA3 are fictional, i.e. would require further cases. To synthesize the priorities of alternatives, we make use of the local priorities of the alternatives with respect to each criterion and compute the composite or the global priorities using Eq. 13. Synthesized results, are shown in Table 6.

Table 6. Synthesized results for alternatives with respect to goal

	Modeling Language (0.469)	*Modeling Procedure (0.359)*	*Products (0.093)*	*Medium (0.079)*	*Priorities (Normalized)*	*(Idealized)*
CMA 1	0.705	0.637	0.573	0.683	0.667	1.000
CMA2	0.181	0.274	0.330	0.205	0.230	0.345
CMA3	0.141	0.089	0.098	0.112	0.116	0.174

Interpretation

The overall priority values indicate that the first collaborative modeling approach: CMA1 has the highest priority followed by CMA2 and CMA3 has the least priority. The normalized priorities in Table 6 can also be given in an idealized form (last column) using Eq. 14, meaning: CMA2 is 35% as good as CMA1 in meeting the evaluation goals and criteria whereas CMA3 is 17% as good.

5 Related Work

The first work to counteract criticisms for lack of methodology for the evaluation process of (process) modeling is [11]. The methodology developed therein provides an initial understanding of process model quality and is used as a generic approach for deriving theoretically grounded measurements and empirically-based strategies for evaluating quality. There are a number of methods and frameworks that have been proposed for the evaluation of the *"quality"* of the models produced from the *"modeling process"*. In [12], for example, a process -oriented framework for quality of modeling (*QoMo*) is proposed based on the SEQUAL [13] framework. QoMo is one of the first process-oriented quality frameworks. The QoMo framework extends the SEQUAL framework by incorporating the *rules* and *goals* of modeling as a way of describing the processes for modeling. There are, however, very few methods for performing a comprehensive evaluation of all the modeling artifacts used in and produced during the modeling process, more particularly in collaborative modeling [19]. Evaluation of the modeling process, including its “return on modeling effort”, through cost-benefit analysis is a key part of the evaluation phase in the design cycle of the collaborative modeling game analysis [20].

6 Conclusion and Future Work

This paper has presented an evaluation approach for modeling processes. Driven by the aim of trying to understand modeling process, the paper has put emphasis on the quality of four artifacts that are used or produced during the modeling process. Analysing the quality of these artifacts by identifying the different attributes and criteria gives us a way to gauge the quality of the modeling process. By using the AHP we can deal with the important phenomenon that modelers and evaluators, in general, may be biased towards evaluation criteria. We do this by using an approach in which every one’s judgement and evaluation is put into consideration and the overall priority is aggregated as a group decision. The developed approach serves as a basis for deriving adequate as well as theoretically sound and quantified quality criteria for the modeling process using the AHP method. Further research activities will be geared towards tracing judgements pertaining to the end state of the process to tangible flaws within the communication and negotiation process as such, i.e. interactions and rules governing the modeling process stemming either from the method and tools (media) used, or from particular actions taken by participants within boundaries set by tool or method. Studying interdependencies (sort of “cause-effect” relationships) between the modeling artifacts forms part of our future work.

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