Towards Selecting Among Business Process Modeling Methodologies[1]

Roland Kaschek[1], Roman Pavlov[2], Vladimir A. Shekhovtsov[2], Sergiy Zlatkin[1]

[1] Department of Information Systems,
Massey University,
New Zealand
{R.H.Kaschek|S.Zlatkin}@massey.ac.nz

[2] Department of Computer-Aided Management Systems,
National Technical University "KPI",
Kharkiv, Ukraine
shekvl@kpi.kharkov.ua

Abstract

The problem of selecting the business process modeling methodology best suited for the business process modeling task at hand is often hampered by the conditions under which the selection is made. In this paper we sketch the foundations of a framework for selecting business process modeling methods. We base this framework on the Analytic Hierarchy Process. We therefore use a hierarchy of characteristics of business process modeling methodologies for our selection approach. To demonstrate how our approach works we discuss its application to two business process modeling tasks. We have developed a software tool that implements our framework. We describe this tool briefly in this paper.

Keywords: business process modeling, methodology, comparison, analytic hierarchy process, multi-criteria decision making

1. Introduction

Enterprise culture has to serve at least two goals. Firstly, it must optimally service the market. Secondly, it must optimally administer the resources. Addressing the first goal leads to a focus on business processes. Life cycle models have been proposed [MH05] for business processes. The overall success

---

[1] The author list is ordered alphabetically and Sergiy Zlatkin is the corresponding author.

of a business process depends largely on the quality and adequacy of the model that the process implements. Providing goods or services is by no means the only purpose of business process modeling. This purpose may be an informational or demonstrative one. It may involve process simulation or automation by means of a workflow management system [WM99], business process management system [Ou05, SF02] or another kind of process-aware information system [Du05]. As is the case for application oriented modeling tasks in general, business process modeling has many stakeholders. These include customers, owners, business analysts, system analysts, programmers, and testers.

Business process modeling therefore has considerable complexities. One of these is the selection of an adequate modeling methodology. The choice of a business process modeling methodology (BPMM) is often hampered by the conditions under which it is made, such as incomplete knowledge, insufficient resources, compatibility requirements, and lack of time. Under such conditions, developers tend to reduce risk and opt for a BPMM with which they are already familiar.

There is a variety of BPMMs from which to choose. Some of them are vendor specific (e.g. WDL [Gr03], etc.), some are de-facto standards created and promoted by different standardization organizations (e.g. UML Activity Diagrams by OMG [OM03], XPDL by Workflow Management Coalition [WM05], etc.), some are well accepted for modeling processes for a particular class of problems (e.g. Petri Nets [Aa98], Event-driven Process Chains [Ke92], etc.). For the more well-known BPMMs there is instruction material available, but recommendations regarding which methodology to use, and when, are both hard to find and hard to assess.

A number of works focusing on methodology selection for different domains have been published during the last decade. Kaschek and Mayr in [KM96] and [KM98] proposed frameworks for comparing object-oriented modeling (OOM) tools and analysis methods, respectively. Using these frameworks, they built two detailed lists of characteristics for selecting both tools and methods. We think that the overall approach to method selection in [KM98] is suitable for selecting BPMMs. We therefore reuse their overall approach for this paper and discuss its pros and cons. Albertyn [AZ04, AK04, Al05] has introduced an ontology for e-Processes (i.e. processes for developing e-commerce information systems). This ontology provides two-level characteristics of e-Processes, scales thereof, and a conceptual framework for quantitative assessment of e-Processes under comparison. Al-Humaidan and Rossiter did similar work [AR01]. They developed a taxonomy for classifying methodologies of workflow-oriented information systems. Mansar et.al. [Ma05] proposed a strategy for selecting process redesign knowledge.

Some works also dealt with comparison of BPMMs. An obvious approach to use is pairwise comparisons of the admissible methodologies (e.g. [Fe01] compares UML and EPC, or [Sh02] compares XPDL, BPML and BPEL4WS). Other approaches focus on one particular criterion. For example, van der Aalst et. al. identify a list of control workflow patterns [Aa03] and analyze several

BPMM regarding the aid they provide for using these patterns [Aa05]. Running a few steps forward, we suggest that our experts refer to workflow patterns when valuing behavioral perspective (see section 3.4). Mendling et. al. have compared how different BPMMs are interchanged between tools and systems [Me04]. We refer experts to that work when valuing exchangeability (see section 3.6).

Apart from those isolated approaches, we are not aware of any general framework for selecting from a set of admissible BPMMs. In this paper we try to build the foundation of such a framework based on a method ranking approach combined with a case based approach (according to [KM98]). We will also justify each criterion introduced in this framework, and describe the supporting software.

The rest of the paper is organized as follows: in the next section, we explain our selection method. In section 3, we introduce the criteria of our framework. In section 4, we apply our approach to two real-life problems. We briefly discuss the tool developed to support the approach in section 5. In section 6, we conclude the paper and discuss our future directions.

2. The Selection Method

We propose a method for selecting from a set of admissible BPMMs those that are best suited for a set of modeling cases. The method quantitatively assesses the admissible BPMM for each modeling case, aggregates the individual assessment outcomes, and then selects the BPMM that scores highest for the total. In this paper, however, we focus on obtaining the assessments of the admissible BPMMs.

We understand "assessing" metaphorically as measuring, with a person obtaining the data by following a heuristic procedure. Assessing therefore requires defining a quality and a respective scale such that each scale instance represents a specific condition of the quality. The scale values can be figures and then each figure stands for a particular multiple of a unit of the quality. The scale becomes then an ordered set, as it inherits the order of numbers. Alternatively, the scale values can be labels of an arbitrary kind. Such a label being the score of a BPMM means that the BPMM meets a condition that is associated with the label. The quality on which we focus in this paper is the suitability of a BPMM for a modeling task.

We consider the quality of a BPMM to be multi-faceted, as is commonly done for other complex entities such as software systems [Gh04] or software processes [So04]. The purpose of a BPMM is to guide a number of individuals in modeling business processes. A BPMM therefore must incorporate knowledge about how to model business processes. We group this knowledge into the following classes:

- the modeling system, i.e. the suggested modeling notions, abstraction concepts, patterns, and anti-patterns;

- the representation system, i.e. the suggested notation for representing business process models;
- the cost for producing the result, including the ability to forecast this cost and the precision and cost of the forecast;
- the domain of application, i.e. the domain regarding which the BPMM claims to be useful;
- the usability, i.e. the ability of BPMM to support multiple views (perspectives) of business processes;
- the compatibility of the BPMM with other methodologies, and
- the maturity, i.e. its stability, theoretical foundation, tool support, documentation, etc.

Please note that in this paper we only consider the selection of a BPMM for a modeling task. Obviously, when focusing on a different task such as (1) implementing a business process with a workflow management system, or (2) using the BPMM until further notice for modeling all business processes, the BPMM suitable for that task might may be different from the one most suitable for the task on which we focus in this paper.

We consider the classes introduced above as characteristics of BPMMs. Scoring a BPMM with respect to these characteristics depends strongly on knowledge of the characteristics. We consider obtaining these scores to be a task requiring business knowledge. It requires case-specific knowledge, which typically is available to business experts but not to method experts. Business experts, on the other the other hand, often would not have a sufficient knowledge of the existing methodologies and their assessment and thus would have difficulties choosing a suitable methodology. Consequently, effective and efficient choice of the BPMM best suited for a set of cases, requires blending the knowledge of business experts and methodology experts. We propose achieving this by using the Analytic Hierarchy Process (AHP) [Sa90].

AHP has grown into an interdisciplinary scientific branch. It has strict mathematical and psychological grounds and numerous areas of application. AHP takes into account different opinions, different criteria, and different possible solutions. It allows ranking of the alternative solutions. The main disadvantage of this method is its high complexity, which makes it nearly impossible for a single person to follow the method correctly. We propose relieving this problem by splitting it into simple ones and attracting experts working independently from each other. This serves as an additional means of security.

AHP assessment follows a four-step procedure. First, the main objective is defined (which is "select the best suited BPMM" in our case), followed by the methodology step, business step, and decision-making step.2

---

[2] We use a terminology that is different from the original one used in [Sa90].

2.1. Methodology step

Before proceeding with the selection, it is necessary to complete the definition of the set of characteristics. Our characteristics form a two-level hierarchy. On the top level, there are the characteristics provided above (modeling system, representation system, cost, etc). On the bottom level, we use characteristics that we obtain by decomposing the top-level characteristics (see section 3 for this). AHP does not limit the number of characteristic decomposition steps. However, we limit ourselves to using only one such step, as we have found that a two-level hierarchy is sufficient for our examples.

We then pick the alternatives, i.e. the admissible BPMMs. Together with the characteristics, they build the complete hierarchy shown in Fig.1.

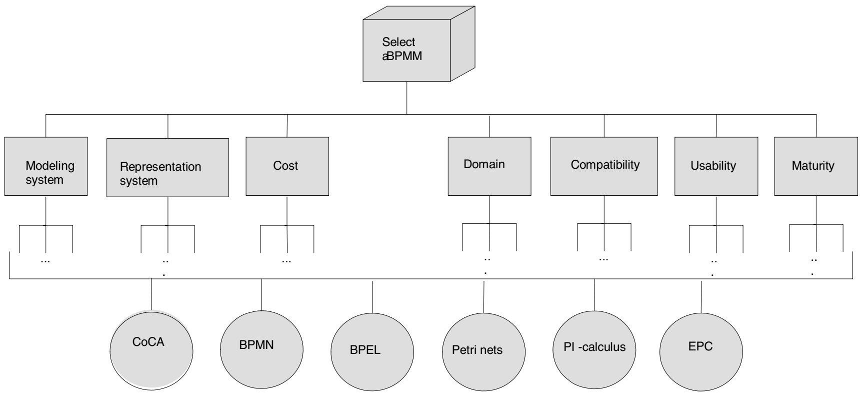

Figure 1. Hierarchy for BPMM assessment.

Finally, the methodology experts assess the admissible BPMMs by pairwise comparison in terms of the second-level criteria. Let x, y be BPMMs. For expressing a number of increasingly strong preferences for x over y we define the predicate n-better(x, y), for $n \in \{1, 3, 5, 7, 9\}$. The predicate 1-better(x , y), 3-better(x , y), 5-better(x , y), 7-better(x , y), 9-better(x , y) means that no preference, light preference, moderate preference, strong preference, and extreme preference respectively is given to x over y. Let C be a set of second level characteristics, E a set of experts, and X a set of admissible BPMMs. The comparison mapping has the signature $a: C \times E \times X \times X \rightarrow \{n, 1/n \mid n \in \{1, 3, 5, 7, 9\}\}$. We define its mapping rule by:

- a(c, e, x, y) = n, if expert e judges n-better(x, y) = TRUE with respect to characteristic c; and
- a(c, e, x, y) = 1/n, if expert e judges n-better(y, x) = TRUE with respect to characteristic c.

Obviously, a(c, e, x, y) = 1/a(c, e, y, x), and in particular a(c, e, x, x) = 1, for all $c \in C$, $e \in E$, $x, y \in X$.

Let $c \in C$ be a characteristic and $e \in E$ an expert. Let $X = \{x_1, \ldots, x_n\}$ and denote the BPMM x_i by i, for all $i \in \{1, \ldots, n\}$. Then the restriction A(c, e) of the comparison mapping a to $X \times X$ has the mapping rule A(c, e)(i, j) = a(c, e, i, j), for all i, j. We represent it as a matrix, which is known as the pairwise comparison matrix [Sa90]. The elements of this matrix correspond to the results of comparisons of every pair of admissible BPMMs.

$$A(c,e) = \begin{pmatrix} a(c,e,1,1) & a(c,e,1,2) & \cdots & a(c,e,1,n) \\ a(c,e,2,1) & a(c,e,2,2) & \cdots & a(c,e,2,n) \\ \ldots & \ldots & \ldots & \ldots \\ a(c,e,n,1) & a(c,e,n,2) & \cdots & a(c,e,n,n) \end{pmatrix}$$

If this matrix is consistent (i.e. $a(c,e,i,k) \cdot a(c,e,k,m) = a(c,e,i,m)$ for any i, k, and m), the maximum eigenvalue $\lambda_{max}(c,e)$ of A(c, e) and the corresponding eigenvector $f(c,e) = (y_1, \ldots, y_n)$ are known.[3] This vector, after normalization, contains the relative weights y_i of admissible BPMMs x_i, for all $i \in \{1, \ldots, n\}$. The relative weight of $x \in X$ following [Sa90] is denoted as $f_{c,e,x}$. It is well-known that if the pairwise comparison matrix is not consistent then using the AHP may be contested and that in certain cases it is not recommended; see, e.g. [No04, p. 1194].

The result of the methodology step is a mapping f that associates to each admissible BPMM $x \in X$ its relative weight. This mapping has the signature $f: C \times E \times X \to [0, 1]$, and the mapping rule $f(c, e, x) = f_{c,e,x}$. In this paper, we use the simplified version of AHP described in [No04]. We refer to this simplified version of AHP as AHPS. AHPS deviates from AHP in two respects. Firstly, the pairwise comparisons are reduced to the minimum needed for determining a consistent pairwise comparison matrix. Secondly, based on the specific procedure for defining the pairwise comparison matrix simple formulae are available for the relative weights of each admissible BPMM. Following [No04] one defines a(c,e,i,j) as a(c, e, 1, j) / a(c, e, 1, i), for all $i, j \in \{1, 2, \ldots, |X|\}$[4], where X is the set of admissible BPMMs. The corresponding relative weights are $w_i = (1 / a(c, e, 1, i)) / (1 / a(c, e, 1, 1) + \ldots + 1 / a(c, e, 1, |X|))$, for all $i \in \{1, 2, \ldots, |X|\}$. The assignation of the n-better predicate to pairs of admissible BPMMs according to AHPS can be managed such that an arbitrary methodology $x \in X$ at first is chosen. Then $y \in X \setminus \{x\}$ is chosen such that the assignation of the appropriate predicate n-better(x, y) can be obtained most easily. Then $z \in X \setminus \{x, y\}$ is chosen such that the appropriate predicate n-better(y, z) can be obtained most easily, and so forth until X is exhausted.

AHP recommends considering aggregating the individual outcomes of expert evaluations in case several methodology experts are employed. According to

---

[3] This is a vector for which holds $A(c, e) (y_1, \ldots, y_n) = \lambda_{max}(c,e) (y_1, \ldots, y_n)$.

[4] The cardinality, i.e. the number of elements, of a finite set S is denoted as | S |.

[AS83], the recommended aggregation is based on the *geometric mean*, i.e. for each characteristic $c \in C$ one defines an aggregated value $a(c,x,y) = \sqrt[|E|]{\prod_{e \in E} a(c,e,x,y)}$, for all $x, y \in X$.

2.2. Business step

At this step, the business experts rank the relative importance of the characteristics for the modeling case at hand. They first rank the top-level characteristics and then the second-level characteristics inside the particular branch of hierarchy. For these rankings, the pairwise comparison technique is used that is described in section 2.1. The top-level characteristic chosen first will be "**modeling system**".

The rankings performed result in mappings of the characteristics to the sets of their relative weights. For the set C^1 of top-level characteristics we have the mapping $w^{**}: C^1 \rightarrow [0, 1]$, with the mapping rule $w^{**}(\gamma) = w^{**}_\gamma$, for all $\gamma \in C^1$. Now let all $\gamma \in C^1$ be J_γ: the set of second-level characteristics into which γ has been decomposed. We consider then the mapping $w^*_\gamma: J_\gamma \rightarrow [0, 1]$, with the mapping rule $w^*_\gamma(j) = w^*_{\gamma, j}$, for all $j \in J_\gamma$. Please note that the mappings listed here have mapping rules that are defined by experts. These mappings are in the sequel used for defining integrated weights for all second-level characteristics.

Let $C^2 = \cup_{\gamma \in C^1}$ be J_γ: the set of all second-level characteristics. Their weights are determined by the mapping $w: C^2 \rightarrow [0, 1]$, with the mapping rule $w(c) = w_{o(c)}$, for all $c \in C^2$, where $o: C^2 \rightarrow \{1, \ldots, |C^2|\}$ is a bijection that is defined in the sequel. For defining o we assume bijections $o_\gamma : J_\gamma \rightarrow \{1, \ldots, |J_\gamma|\}$ be chosen, for all $\gamma \in C^1$, as well as a bijection $\omega : C^1 \rightarrow \{1, \ldots, |C^1|\}$. We define then the number $N(\gamma) = \sum_{m=1}^{\omega(\gamma)-1} |J_{\omega^{-1}(m)}|$, for all $\gamma \in C^1$. This number is then used for completing the mapping rule of w by defining $o(c) = N(\gamma) + o_\gamma(j)$, and $w_{o(c)} = w^{**}_\gamma w^*_{\gamma, j}$, for all $c \in C^2$, with $c = j \in J_\gamma$ and $\gamma \in C^1$.

2.3. Decision making step

During this step, the methodology expert knowledge and the business expert knowledge are blended. To calculate the *final priorities* of the admissible BPMM, the "ideal synthesis" AHP mode [FS01, pp. 151-174] is used. Let X be again the set of admissible BPMMs. For every second-level characteristic $c \in C^2$ let $f^*_c = \max \{f_{c,x} \mid x \in X\}$. For $c \in C^2$ and $x \in X$, let $p_{c,x} = w_c f_{c,x} / f^*_c$, the so-called per-characteristic priority of x.[5] The priorities (p_x) of admissible BPMMs

[5] Obviously $p_{c,x} = w_c$, for all $x \in X$ with $f_{c,x} = f^*_c$.

($x \in X$) are defined as $\frac{\sum_{c \in C} p_{c,x}}{\sum_{x \in X} \sum_{c \in C} p_{c,x}}$. The set of BPMMs best suited for the modeling task at hand is considered to be the set $\{x \in X \mid p_x = \max \{p_y \mid y \in X\}\}$. The priorities of admissible BPMMs can be used for ranking these.

2.4. Suitability of the AHPS

The two main problems with the "classic" AHP (described in [Saa90]) concerning the selection among a set of given alternatives are: (1) ensuring the consistency of the pairwise comparison matrix, and (2) avoiding *rank reversals*. We address both problems in our method. The consistency of the pairwise comparisons matrix is ensured by using the AHPS modification of the AHP algorithm. [No04] contains the proof that the matrix calculated via AHPS is consistent. The rank reversal is the situation when additional to the set X of admissible alternatives a second such set X' is considered with $X \cap X' \neq \emptyset$. The ranking obtained with AHP for the alternatives in $X \cap X'$ depends on whether X or X' is considered as the set of admissible alternatives.

We have addressed the rank reversal by using the "ideal synthesis mode" modification of AHP. As shown in [FS01], using this mode precludes the rank reversal affecting the outcome of the method, because the priorities of alternatives are expressed as fractions of the highest priority for the particular characteristic. In this situation, adding or deleting a set of alternatives does not change the ranking of the priorities of other alternatives because the values $(f_{c,x} / f^*_c) \cdot w_c$, $x \in X$ only depend on the considered alternative x and the alternatives for which the maximum f^*_c is obtained. A rank reversal cannot occur because of adding admissible alternatives due to the formula of the AHPS for the relative weights of admissible alternatives given above. This is especially important as we are solving the problem of selecting one out of the set of admissible alternatives. If rank reversal could not be avoided the AHPS would suggest that the method knowledge cannot converge which would be counter-intuitive. We consider AHP with the discussed modifications as appropriate for selecting the most suitable methodologies out of a set of admissible BPMMs.

3. The BPMM characteristics

As mentioned above, the characteristics for BPMM evaluation are organized into a two-level hierarchy. On the top level, there are general characteristics (BPMM knowledge classes) described in section 2: *modeling system*, *representation system*, *cost, domain, usability, compatibility, and maturity*. In this section, we describe the sub-characteristics of these knowledge classes in detail.

3.1. Modeling system

We subdivide this general characteristic into the following sub-characteristics:

- **Completeness**, i.e. the degree to which the BPMM provides a means of expression, such as modeling notions, abstraction concepts, patterns, and anti-patterns, that enables the business experts to effectively and efficiently solve modeling tasks within the domain of application of the BPMM. The corresponding question is *"does the BPMM provide a means of expression and guidance for efficiently modeling business processes belonging to the BPMM's domain of application?"*
- **Redundancy**, i.e. the ratio of the BPMM provides a means of expression that can be defined by the means of other such entities. The corresponding question is *"what is the relative number of means of expression that can be defined using other such means?"*
- **Concept quality**, i.e. the ratio of ill-defined (ambiguous or unclear) means of expression of the BPMM. The corresponding question is *"what is the relative number of means of expression that are ambiguous or not clearly defined?"*
- **Concept adequacy**, i.e. the suitability of the BPMM-suggested modeling system for modeling tasks within the BPMM's domain of application. The corresponding question is *"how close to the common understanding of domain objects and concepts are the BPMM means of expression?"*
- **Process nesting**, i.e. the degree of support of model and process nesting for the particular methodology. The corresponding question is *"which degree of business process nesting is supported?"* Complex process models can be split onto simpler models that contain more specific routine activities or subprocesses.

3.2. Representation system

We subdivide this general characteristic into the following sub-characteristics.

- **Readability**, i.e. the simplicity and clarity of the particular notation, the level of representation of the widely accepted business-oriented concepts. The corresponding question is *"how readable is the notation of the particular BPMM for people that are familiar with the method's domain?"*
- **Granularity** with the corresponding question *"how much detail in business process descriptions is supported?"* Some problems require very fine-grained descriptions for the business activities; some can be used with more abstract, coarse-grained descriptions. For example, for business process reengineering it would be necessary to specify the exact way of sending the document, e.g. "put the document into an envelope", "put the stamp on the envelope", "send the envelope with the document via priority mail" (later on all of these could be replaced e.g. with "send the document via email"). For other problem areas, it would be sufficient to use a coarser "send the document" description.
- **Learnability,** with the corresponding question *"how steep is the learning curve of this BPMM?"* Sometimes the users have no previous experience

working with any BPMM - in this case the simplicity of learning could have high relative merit for them. On the other hand, experienced users (or users with more time and other resources) could treat other characteristics as more important.

3.3. Cost

As mentioned above we include here:The complete hierarchy of criteria is shown on Figure 1.

- **Ability to forecast** precisely the cost of creating a model using a particular BPMM. This may include such items as hardware and software costs, human resources involved, etc. The corresponding question is *"how precise are the cost forecasts suggested by the BPMM?"*
- **Cost of the forecast,** with the corresponding question *"how expensive is a cost forecast as suggested by this BPMM?"*

3.4. Domain of application

We subdivide this characteristic into the following sub-characteristics:
- **Versatility,** with the corresponding question "how flexible is this BPMM, and what is its ability to cover different problem areas?"
- **Suitability for the particular problem areas,** with the corresponding question "how well is this BPMM suited for a given problem area?". For this paper, we selected three problem areas: real-time process modeling, web services interaction modeling and the process modeling in the communication domain.

3.5. Usability

We subdivide this characteristic into the following sub-characteristics according to [JB96].
- **Functional perspective**, i.e. the estimation of the BPMM's ability to describe and store the general specification of the business process. The corresponding question is "*what is the quality and completeness of the general specification of the business processes implemented in this BPMM?"* The most important part of specification with regard to this criterion is the goal of the process; other valuable components are the process tasks, its general description, etc.
- **Behavioral perspective**, i.e. the estimation of the BPMM's ability to support elements describing the complex behavior of the business process (sequential actions, synchronization, asynchronous execution, loops, exceptions etc.). The most practical way of making this evaluation is to estimate the BPMM capabilities of implementing the common workflow patterns [Aa03] via the following question *"what is the level of implementation of the workflow patterns for this BPMM?"*

- **Resource perspective**, i.e. the estimation of the BPMM's ability to describe and store the resources of the business process: its inputs and outputs, its internal data etc. The corresponding question is *"what is the quality and completeness of the resource descriptions implemented in this BPMM?"*
- **Organizational perspective**, i.e. the estimation of the BPMM's ability to describe the participants of the business process (departments, people, systems etc.) and their roles. The corresponding question is *"what is the quality and completeness of the participant descriptions implemented in this BPMM?"*

3.6. Compatibility

We subdivide this characteristic into the following sub-characteristics.

- **Exchangeability,** with the corresponding question *"how well can instantiations of a given BPMM be exchanged between tools implementing the BPMM?"* The survey paper [Me04] can be useful for the comparison according to the criterion based on this characteristic.
- **Mappability,** with the corresponding question *"how well can instantiations of a given BPMM be mapped onto instantiations of other BPMM?"*

3.7. Maturity

We subdivide this characteristic into the following sub-characteristics.

- **Stability,** with the corresponding question *"how stable (or well accepted) in the BPM community is this BPMM?"* Stability can address the quality of the method, the time of its foundation, the reputation of its authors, etc.
- **Theoretical foundation**, i.e. the level of theoretical support for the particular BPMM, the ability of its basic concepts to be mathematically proved, its analytical capabilities (for example, the ability of its models to be converted into simulation models). The corresponding question is *"how satisfactory is the theoretical foundation of a given BPMM?"*
- **Tool support**, i.e. the presence and quality of the current software implementation of the particular methodology. The corresponding question is *"what is the quality and availability of tools to implement a given BPMM?"*
- **Documentation,** i.e. the availability and quality of the respective documentation for the BPMM, its comprehensiveness and relative simplicity. Hence, the question is *"is the required documentation available and how comprehensive is it?"*

4. Application of Approach

In order to demonstrate how proposed heuristics work we apply them to two sample problems. The objective of both problems is to find the best-suited business process modeling methodology. We therefore firstly describe the problems and then follow the steps of the AHPS explained in section 2.

4.1. The example problems

Problem 1. With respect to Ukrainian universities enrollment is a very complicated process. For each Ukrainian university there exists both a university top-level enrollment commission and faculty enrollment commissions for each faculty. Each faculty and even the departments within a faculty are free to define suitable enrollment procedures. Therefore, the amount of work imposed on each commission is larger than required. In addition, university entrants are often confused with all these rules, so take the wrong pass and choose a specialization that differs from what they wanted initially.

In order to help both the staff and the entrants, the registry of a Ukrainian university decided to create a model of the enrollment process and publish it on the university web site and in brochures, handouts, etc. It is obvious that the model should be as readable and understandable as possible; it should be created with the available hardware and software. The registry currently considers neither automation nor simulation as important. The tables 1, 2 and 3 show the results of the comparisons of the criteria defined in the previous section performed by the methodology and business (university business process analyst) experts.

Problem 2. The top library managers of several universities have agreed to introduce an interlibrary loan system for shared use of library holdings. The responsible business process analyst, prior to implementing this system, wants to use a BPMM for modeling the dynamics of library interaction, in particular the types of messages necessary. In this model, it is important to consider the optimal structure of the process, its simulation, further implementation, etc. End users, i.e. users of the interlibrary loan system, are not supposed to have access to the model.

4.2. Methodology step

As specified in section 2.1 we first have to introduce the criteria for assessment. For that purpose, we use the classification provided in section 3. We then have to select possible solutions. We have decided to assess the following BPMM alternatives for both problems: CoCA [Ka98, ZK05], BPMN [Wh04], BPEL [An03], Petri Nets [Aa98], Pi Calculus [Mi80] and EPC [Ke92]. We selected these alternatives mainly because they are the most widely used and therefore good quality resources and support are available.

We then have to invite methodology experts to compare the alternatives against the criteria defined. In Table 1 we show the values of three experts.

Table 1. Assessment of the admissible BPMMs.

Characteristics	Experts	BPMM comparison results					
		CoCA	BPMN	BPEL	Petri nets	PI-calculus	EPC
Completeness	E_1	1	1/3	1/3	3	5	1/3
	E_2	1	1/3	1	5	5	1/3
	E_3	1	1/3	1/3	5	3	1/3
Redundancy	E_1	1	3	1	1	1	1
	E_2	1	5	1	1	1	3
	E_3	1	3	1	1	1	5
Non-ambiguity	E_1	1	1/3	1	1/3	3	1/3
	E_2	1	1/3	1	1	5	1/3
	E_3	1	1/3	1	1/3	5	1
Concept adequacy	E_1	1	1	1	3	5	1
	E_2	1	1/3	1	5	7	1
	E_3	1	1/3	1	3	3	1/3
Process nesting	E_1	1	3	5	7	7	3
	E_2	1	3	5	7	7	5
	E_3	1	5	3	7	5	7
Readability	E_1	1	1/5	1/3	1/5	3	1/7
	E_2	1	1/7	1/3	1/3	3	1/5
	E_3	1	1/9	1/3	1/5	5	1/5
Granularity	E_1	1	1	3	5	7	3
	E_2	1	1/3	1	7	7	5
	E_3	1	1	3	5	9	3
Learnability	E_1	1	3	5	3	5	3
	E_2	1	1	3	5	7	3
	E_3	1	1	3	3	7	5
Ability to forecast	E_1	1	1/3	1/3	1/3	1	1/3
	E_2	1	1/3	1/3	1/3	1	1/3
	E_3	1	1	1	1	1	1
Cost of the forecast	E_1	1	1/3	1/3	1/3	1	1/3
	E_2	1	1/3	1/3	1/3	1	1/3
	E_3	1	1	1	1	1	1
Versatility	E_1	1	1	3	1	1	1
	E_2	1	1	3	1	3	1
	E_3	1	1	5	1	3	1
Real-time	E_1	1	1/3	1	1/3	1/3	1
	E_2	1	1/3	1/3	1/3	1	1
	E_3	1	1/3	1	1/3	1/3	1
Web services	E_1	1	1/5	1/7	1	1	1
	E_2	1	1/5	1/5	1	1	1
	E_3	1	1/7	1/7	1	1	1

Communications	***E₁***	1	1/5	1/5	1	1	1/3
	E₂	1	1/3	1/5	1	1	1/3
	E₃	1	1/3	1/5	1/3	1	1
Functional	***E₁***	1	7	7	7	7	5
	E₂	1	7	5	7	9	5
	E₃	1	5	5	5	9	7
Behavioral	***E₁***	1	1/5	1/7	1/5	1/3	1/5
	E₂	1	1/3	1/7	1/5	1/3	1/7
	E₃	1	1/7	1/7	1/7	1/3	1/3
Resource	***E₁***	1	1	1	5	5	1
	E₂	1	1	1/3	3	5	3
	E₃	1	1	1/3	7	3	1
Organizational	***E₁***	1	3	3	9	9	3
	E₂	1	5	3	7	9	3
	E₃	1	5	3	9	5	5
Exchangeability	***E₁***	1	1	1/3	1/5	1	1/5
	E₂	1	1	1	1/5	1	1/5
	E₃	1	1	1/3	1/5	1/3	1/5
Mappability	***E₁***	1	1/3	1	1/5	1	1/5
	E₂	1	1/3	3	1/5	1	1/3
	E₃	1	1	3	1/3	1	1/3
Stability	***E₁***	1	1/5	1/5	1/7	1/3	1/7
	E₂	1	1/5	1/7	1/7	1	1/5
	E₃	1	1/7	1/5	1/5	1	1/5
Theoretical foundation	***E₁***	1	1/3	1/3	1/9	1/7	1/5
	E₂	1	1/3	1/3	1/9	1/5	1/7
	E₃	1	1/5	1/5	1/5	1/7	1/7
Tool support	***E₁***	1	1/3	1/5	1/3	1	1/5
	E₂	1	1/3	1/7	1/3	1	1/3
	E₃	1	1/5	1/5	1/3	3	1/3
Documentation	***E₁***	1	1/5	1/5	1/9	1/3	1/7
	E₂	1	1/3	1/5	1/9	1/3	1/7
	E₃	1	1/3	1/5	1/7	1	1/7

4.3. Business step

We now expect the business expert to give his/her assessment of the importance of the criteria for each problem. We combine these values in the following two tables. Tables 2 and 3 contain comparisons of top-level criteria and second-level criteria respectively. We refer to the enrollment problem as P_1 and to the interlibrary loan problem as P_2.

Table 2. Weights of top-level characteristics.

	Modeling system	Representation system	Maturity	Domain	Com-patibility	Usability	Cost
P_1	1	1/7	3	3	5	1/3	1/5
P_2	1	1	1/3	1/5	1/3	1/7	1/5

Table 3. Weights of second-level characteristics.

Modeling system		*Completeness*	*Redundancy*	*Non-ambiguity*	*Concept adequacy*	*Process nesting*
	P_1	1	5	1	1/3	5
	P_2	1	3	1	3	3
Representation system		*Readability*	*Granularity*	*Learnability*		
	P_1	1	3	1		
	P_2	1	3	1		
Cost		*Ability to forecast*	*Cost of the forecast*			
	P_1	1	1			
	P_2	1	1			
Domain		*Versatility*	*Real-time*	*Web services*	*Communications*	
	P_1	1	1	1	1/9	
	P_2	1	3	1/5	1/5	
Usability		*Functional*	*Behavioral*	*Resource*	*Organizational*	
	P_1	1	1/3	1	5	
	P_2	1	1/5	1/5	1/3	
Compatibility		*Exchangeability*	*Mappability*			
	P_1	1	1/3			
	P_2	1	1/3			
Maturity		*Stability*	*Theretical. foundation*	*Tool support*	*Documentation*	
	P_1	1	3	1/3	1/3	
	P_2	1	3	1/3	1/3	

4.4. Decision making step

Having applied the heuristics derived in section 2.4 we achieved the final priorities of the BPM methodologies for the sample problems. We provide those priorities in table 4.

Table 4. Final BPMM priorities for the sample problems.

Problem	Final BPMM priorities					
	CoCA	BPMN	BPEL	Petri nets	PI-calculus	EPC
P_1	0.165	**0.244**	0.183	0.159	0.066	0.182
P_2	0.113	0.205	**0.228**	0.183	0.082	0.190

As a result of these evaluations, the BPMN was selected as the best methodology for Problem 1, and BPEL for Problem 2. These results were expected, but we are not going to carry out analysis as the examples had an illustrative purpose only.

5. Tool

We have developed a tool that supports the heuristics mentioned above. We call this tool BPMM Selector. It is a web-based information system that can be accessed by both methodology experts and business experts using standard means such as web-browsers. The high-level architecture of BPMM Selector is shown in Fig. 2.

All of the methodology experts' values are stored in a database. The system interface allows its users (i.e. business experts) to choose a subset of the methodology experts' values to use in the computation (e.g. users may wish to use values from methodology experts from a particular geographic region, or practitioners rather than theoreticians, etc.)

We have developed the computation part as a separate module, independent from both the database and the presentation layer. The external interface of this module is implemented as a web service. It allows us to provide the computational resource to other systems (business partners) where similar assessment routines are required. We expect the business partners to fall into two categories. One category includes other BP-related or process-aware systems where the selection of BPMM is required. In this case, the web service input consists of the list of alternatives considered by the business experts and their values for the criteria importance. The BPMM Selector provides the criteria and the methodology experts' assessments. The other category includes arbitrary systems where AHP-based decision making is needed. These systems have to provide their own criteria hierarchy, solution alternatives, methodology expert values, and business experts' values. Since the values are organized in a hierarchy, XML appears to be the best choice of format for their transfer.

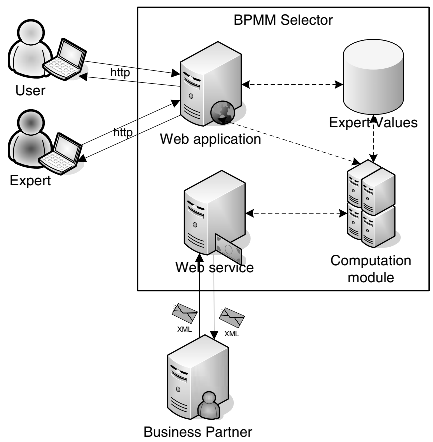

Figure 2. BPMM Selector Architecture.

6. Conclusions and future work

In this paper, we have introduced a taxonomy for business process modeling methodologies. We have identified a list of characteristics, which we group into a number of top-level characteristics. We have decomposed each of these characteristics into bottom-level characteristics. We have then used a specific version of the AHP for demonstrating how we can select the best business process modeling methodology for a given modeling task. We have discussed two major problems of the classical AHP, i.e. the consistency of the pairwise comparison matrix and the rank reversal. We have shown that the version of the AHP that we used does not suffer from these problems. We have furthermore briefly discussed a tool we have implemented that supports this version of the AHP. We have used two examples to illustrate our tool as well as the AHP.

Future work could focus on: (1) attracting methodology experts to populate the Expert Values database, (2) applying the heuristics and the tool in a number of fully realistic case studies, and (3) comparing the BPMM selection method described in this paper with rule-based selection methods as well as case-based selection methods.

7. References

[Aa98] van der Aalst, W.M.P.: The Application of Petri Nets to Workflow Management, Journal of Circuits, Systems and Computers 8(1), pp. 21-66, 1998.

[Aa03] van der Aalst, W.M.P.; ter Hofstede, A.H.M.; Kiepuszewski, B.; Barrios, A.P.: Workflow Patterns. Distributed and Parallel Databases. Vol. 14, No. 1, pp. 5-51, 2003.

[Aa05] van der Aalst, W.M.P.: Standard Evaluation, URL: http://is.tm.tue.nl/research/patterns/standards.htm (last accessed 07/01/06), last edited 2005.

[Al05] Albertyn, F.: Ontology for the Selection of e-Processes, Web Information Systems Engineering - WISE 2005 Workshops, LNCS 3807 Springer, pp. 1-10, 2005.

[An03] Andrews, T. et. al.: Business Process Execution Language for Web Services, Specification, Version 1.1, 5 May, 2003.

[AK04] Albertyn, F.; Kaschek, R.: E-process selection; In Kotsis G., Bressan S., Taniar D., Ibrahim I. K. (Eds.) The Sixth International Conference on Information Management and Web-based Application & Services, Austrian Computer Society, Books@ocg.at Vol. 183, pp. 143 – 152, 2004.

[AR01] Al-Humaidan, F.; B.N. Rossiter, B.N.: A Taxonomy and Evaluation for Systems Analysis Methodologies in a Workflow Context: Structured Systems Analysis Design Method (SSADM), Unified Modelling Language (UML), Unified Process, Soft Systems Methodology (SSM) and Organisation Process Modelling, CS-TR: 751, Department of Computing Science, University of Newcastle, 2001.

[AS83] Aczel, J.; Saaty T.L.: Procedures for Synthesizing Ratio Judgments, Journal of Mathematical Psychology, 27, pp.93-102, 1983.

[AZ04] Albertyn, F.; Zlatkin, S.: The Process of Developing a Business Processes Assembler, in Anatoly E. Doroshenko and Terry A. Halpin and Stephen W.

Liddle and Heinrich C. Mayr (eds.): Proceedings of ISTA 2004 Conference, LNI P-48, pp. 165-176, GI, 2004.

[Du05] Dumas, M.; van der Aalst, W.M.P.; ter Hofstede, A.: Process-Aware Information Systems: Bridging People and Software Through Process Technology, Wiley, 2005.

[Fe01] Ferdian: A Comparison of Event-driven Process Chains and UML Activity Diagram for Denoting Business Processes, Project Work, Technical University Hamburg-Harburg, 2001.

[FS01] Forman, E.H.; Selly, M.A., Decision By Objectives, World Scientific Press, 2001.

[Gr03] Groiss Informatics: System Administration, Dokumentversion 6.1.1, URL: http://www.groiss.com (last accessed 07/01/06), 2003.

[Gh04] Ghezzi, C.; Jazyeri, M.; Mandrioli, D.: Software Qualities and Principles. Chapter 101 of Tucker, A. B.: Computer Science Handbook Chapman & Hall/CRC, 2nd ed. 2004.

[JB06] Jablonski, S.; Bussler, C.: Workflow Management: Modeling Concepts, Architecture and Implementation, International Thompson Computer Press, 1996.

[Ka98] Kaschek, R.; Wiltsche, M.; Rinderer, T.: CoCA - Towards Reuse Support at the Business Process Meta Level, In: Rozman, I. (Ed.): Proceedings of IS'98, International Conference on Development and Reengineering of Information Systems, Ljubljana, Slovenija, pp. 5 – 8, 1998.

[Ke92] Keller, G.; Nüttgens, M.; Scheer, A.-W.: Semantische Prozeβmodellierung auf der Grundlage "Ereignis- gesteuerter Prozeβketten (EPK)", in: Scheer, A.-W. (Hrsg.): Veröffentlichungen des Instituts für Wirtschaftsinformatik, Heft 89, Saarbrücken, in German, 1992.

[KM96] Kaschek, R., Mayr, H.C. A characterization of OOA tools. Proceedings of the Fourth International Symposium on Assessment of Software Tools (SAST '96), pp. 59-67, 1996.

[KM98] Kaschek, R., Mayr, H.C. Characteristics of Object Oriented Modeling Methods. EMISA Forum, Vol. 8, No. 2, pp. 10-39, 1998.

[Ma05] Mansar, S.L.; Reijers, H.A.; Ounnar, F.: BPR Implementation: a Decision–Making Strategy, Proceedings of the Workshop on Business Process Design 2005.

[Me04] Mendling, J.; Neumann, G.; Nüttgens, M.: A Comparison of XML Interchange Formats for Business Process Modelling. In: F. Feltz, A. Oberweis, B. Otjacques, eds.: Proc. of EMISA 2004 "Informationssysteme im E-Business und E-Government", Luxembourg, Luxembourg, LNI, vo. 56, pages 129-140, 2004.

[MH05] zur Muehlen, M.; Ho, D.T.Y.: Risk Management in the BPM Lifecycle, Proceedings of the Workshop on Business Process Design 2005.

[Mi80] Milner, R.: A Calculus of Communication Systems, LNCS, vol. 92, Springer-Verlag, 1980.

[No04] Noghin V. D.: A Simplified Variant of the Analytic Hierarchy Processes Based on a Nonlinear Scalarizing Function. Computational Mathematics and Mathematical Physics, Vol. 44, No. 7, pp. 1194-1202, 2004.

[OM03] Object Management Group, OMG Unified Modeling Language Specification, Version 2.0, URL: http://www.omg.org/technology/documents/formal/uml.htm (last accessed 07/01/06), March 2003.

[Ou05] Ould, M.: Business Process Management: A Rigorous Approach, BCS, Meghan-Kiffer Press, 2005.

[Sa90] Saaty T.L.: Multicriteria Decision Making: The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. Pittsburgh: RWS Publications, 1990.

[Sh02] Shapiro, R.: A Technical Comparison of XPDL, BPML and BPEL4WS, Cape Vision, 2002.

[So04] Sommerville, I.: Software Process Models. Chapter 102 of Tucker, A. B.: Computer Science Handbook Chapman & Hall/CRC, 2nd ed., 2004.

[SF02] Smith, H.; Fingar, P.: Business Process Management: The Third Wave, Meghan-Kiffer Press, 2002.

[Wh04] White, S.A., ed.: Business Process Modeling Notation, Version 1.0, BPMI, URL: http://www.bpmn.org (last accessed 07/01/06), 2004.

[WM99] Workflow Management Coalition Terminology and Glossary, Document Number

WFMC-TC- 1011, URL: http://www.wfmc.org (last accessed 07/01/06), 1999.

[WM05] Workflow Management Coalition: Process Definition Interface - XML Process Definition Language, Document Number WFMC-TC-1025, Version 2.00, URL: http://ww.wfmc.org (last accessed 07/01/06), 2005.

[ZK05] Zlatkin, S.; Kaschek, R.: Towards Amplifying Business Process Reuse, In: ER 2005 Workshops, LNCS volume 3770, Springer, 2005.