Evaluation of the main existing methods and tools for product development process modeling

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Abstract: This article discusses the results of research on the used of different combinations of methods and tools for business processes modeling, with special emphasis on the construction of product development. The article presents fundamental concepts of modeling, a description of the main methods and tools employed in process modeling, and an analysis of the practical application of these methods and tools. In these work was defined one specific product development reference model the experience of modeling a same business process. In addition to a comparative analysis of the methods, several considerations are put forward which may aid professionals and researchers involved in similar projects.

Key words: Modeling, Methods, Tools.

1. Introduction

Enterprise modeling has been widely employed as a form of documenting business processes, integrating the overall enterprise areas. The use of models aims to provide an integrated and concise vision of the company, aiding its management and operational change processes. Furthermore, it allows for the recording of knowledge and the rationalization and visualization of information flows.

Enterprise Models describe the activities, information, organizational responsibilities and resources involved in the business process, thus comprising a wide range of interrelated knowledge. Several modeling methods and tools can be used in order to represent one specific enterprise. The major challenge is to define the best combination of methods and tools that enable one to visualize and understand the process as a whole.

This article therefore focused on an analysis of the main methods and tools for modeling business processes, aiming to pinpoint the advantages and disadvantages of each one, thereby facilitating the choice of methods and tools for modeling product development processes according to the objective of the modeling. Section 2 consists of a bibliographical review concerning the concepts relevant to the development of this work, while section 3 discusses the methodology utilized. Sections 4 and 5 present preliminary evaluations, the former of the modeling methods and the latter of the modeling tools. Section 6 discusses the choice of a development process that served as an example, while section 7 discusses the choice of methods and tools that were evaluated. Section 8 makes a comparative analysis of the models involved here, and lastly, section 9 contains our final remarks.

2. Bibliographic Review

2.1. Enterprise Modeling

The management by process approach, which began with computer-integrated manufacturing and reengineering, is utilized today in various administrative areas, such as quality, information systems implementation and others (CRUZ, 2003; VERNADAT, 1996). The application of this concept in the area of product development is fundamental. This activity should be studied and managed from a business process standpoint, considering the contribution of the company's various areas and of different professionals in the integrated manner required for the creation of a minimally complex product destined for industrial production. The first step to be taken is to outline a representation of this business process, which can be done through a company model.

A model can be defined as "a representation (with a greater or lesser degree of formality) of the abstraction of a reality expressed in a specific kind of formalism" (VERNADAT, 1996, p. 24). A company model is a specific type of model comprising a set of models that seek to represent the company's different visions. According to VERNADAT (1966, p. 71), "a company model is a consistent and complementary set of models describing various aspects of an organization, whose purpose is to aid one or more users in a company to achieve a given purpose".

An interesting aspect to note in this definition is the notion of a "set" of models. The reality that a Enterprise Models has to deal with is extremely complex. Therefore, it is impossible to represent all these elements in a single model. The solution is to construct models that represent specific aspects of the company, each of which is commonly called a "vision" of the company. Thus, with a set of consistent and complementary visions, the most complex reality, i.e., the company, can be represented clearly.

The area of study involving company modeling usually distinguishes a reference model from a specific model, and the latter is also simply called a model or a company model. A company model is called specific when it describes the business process of a specific company, and is applied only in this context. Reference models, on the other hand, are models with broader and more general applications, which are built for use by different companies and/or in different contexts, serving as a reference for the development of specific models (AMARAL, 2002). Some methods for the construction of Enterprise Models are presented below.

2.2. Process modeling methods

Innumerable methods can be used in the process of modeling companies to represent the various visions. This work aims to analyze the representation of the business process and is thus limited to an analysis of the process vision. Two important methods relating to this vision, which were used in this work, are described below:

SADT and IDEF0

To increase the productivity of the aerospace industry through the systematic use of computational resources, the US Air Force, as part of its ICAM (Integrated Computer Aided Manufacturing) project, developed the IDEF0 technique (ICAM 1981) in the early 70s.

This technique, an offshoot of the SADT (Structured Analysis and Development Technique), offers a structured representation of a system's intrinsic functions and describes its interactions. The models obtained aid the analysis and integration of processes by graphically and structurally representing the activities, inputs, outputs, mechanisms and controls inherent to the process in question. However, there is no concern regarding the duration or sequence of activities (VERNADAT, 1996).

As with the SADT, the objects used are blocks (which represent the functions) connected by arrows (representing data or objects of input, output, control or mechanism). Thus, the functions convert inputs (which reach the block from the right) into outputs (which exit the block on the left-hand side). The control arrows are not modified by the function, but affect its occurrence or performance. The mechanism arrows represent the resources that support the function's development (ICAM, 1981).

A model may contain from three to six blocks interconnected by arrows. If necessary, each of these blocks can be detailed in another diagram, and this hierarchic relationship between diagrams is explained through codes. Hence, a diagram should be analyzed from the top downwards (MARCA & McGOWAN, 1998).

The IDEF0 (Integration definition for function modeling) technique does not limit the levels of detailing used in the construction of models, which makes it easy to understand what is being modeled. IDEF0 progresses from a generic to a more detailed level (VERNADAT, 1996; AIR FORCE, 1980).

The static nature of the models built by the IDEF0 method is perhaps its main failure, for it requires considerable manual effort and interpretation to identify the functions that should contain a given input and to check their consistency.

EPC (Event-driven process chain) / eEPC (extended EPC)

The EPC method was developed as part of the ARIS (*Architecture for Integrated Systems*) architecture and is used to represent sequential procedures as in a logical chain of events. This method is composed of events that establish links among functions (SCHEER, 1998).

By event it is understood that an information object is in a situation in which it controls or influences the sequence of the business process. Events are represented graphically by hexagons. Because the events determine what activates the beginning and end of a function, the objects that begin and conclude an EPC diagram are events.

Several functions can be initialized by an event, and a function can result in diverse events. For these representations, connectors are used which, in addition to their graphic function, define the logical relation between linked objects.

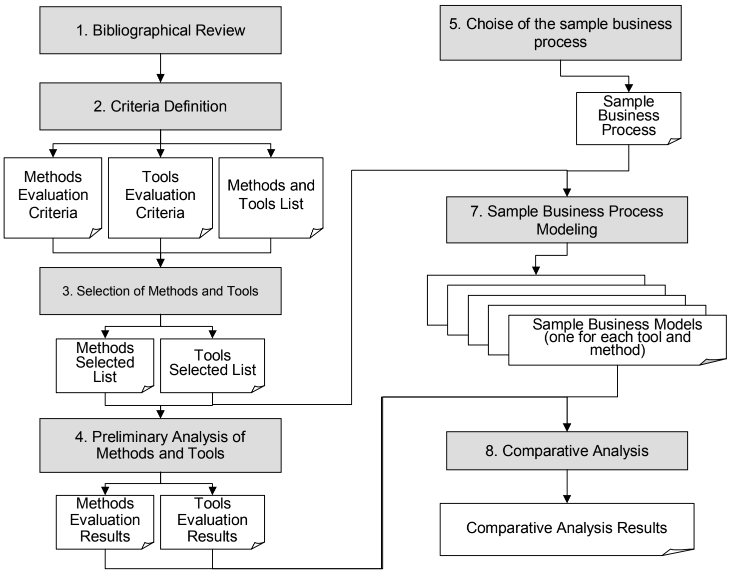

Figure 1: Activities conducted and results obtained through the development of the work

The connectors used are the following:

"AND": the event/function can only begin after the execution/occurrence of all the functions/events or the function/event results in all the events/functions.

"OR": the event/function begins as soon as at least one of the functions/events is executed/occurs or the execution of a function results in the occurrence of at least one of the events.

"either/or (XOR)": the event/function begins as soon as a function/event has occurred or the execution of the function results in the occurrence of a maximum number of events.

In the way in which it was described, the EPC models the business process control flow. However, it can be (and often is) extended through a link with other entities originating from other visions. Thus, the functions can be linked to their input and output information (data vision), to the resources utilized for their execution (resources vision) and to the organizational unit responsible for their execution (organization vision). This form of representation is known as eEPC (extended EPC).

3. Methodology

The project was developed according to a research-action methodology. This style of work proved very suitable because it allies study and analysis to the practical application and validation of concepts.

The main activities developed during the project were:

- A bibliographical review of the basic concepts relating to process modeling, the main methods and tools employed in company modeling;
- Definition of criteria for the preliminary analysis of modeling methods and tools;
- Selection of the methods and tools to be analyzed according to the preestablished criteria;
- Preliminary analysis of the methods and tools selected;
- Choice of the sample business process to be represented according to various methods and tools;
- Selection of the methods and tools to be employed to model the chosen business process;
- Modeling of the sample business process; and
- Comparative analysis of the modeling methods and tools based on the constructed models.

Figure 1 illustrates all these activities carried out during the development of the project, as well as the results obtained through each one.

4. Preliminary analysis of modeling methods

The preliminary analysis involved the process modeling methods found in the literature. To this end, a definition of the criteria is required, which should be established according to the information taken from the bibliographic review.

The defined criteria cover issues relating to syntax, semantics and diffusion of the analyzed method, the difficulties involved in learning, reading and understanding the represented model, and the capacity to represent the different views of the company through the model.

As an example, Table 1 shows the preliminary analysis of the process modeling methods that were subsequently chosen (phase 6 of the work), although it should be kept in mind that this preliminary analysis was not restricted to these methods.

5. Preliminary analysis of modeling tools

As in the analysis of the methods, the preliminary analysis of the modeling tools required the establishment of comparison criteria. These criteria were established based on the bibliographic review and on information concerning the main modeling tools. Advantage was also taken of the research group's experience in the use of business process modeling tools, by having the results of this analysis reviewed by researchers experienced in process modeling projects.

With the purpose of facilitating the comprehension and analysis, the criteria were classified in four groups, i.e., Models construction, Model presentation, Model management, and Analysis, Table 2 lists the criteria according to their classification.

After these criteria were established, a preliminary analysis was made of several tools commonly employed in process modeling, i.e., Visio Professional, ARIS Toolset, Family Flow Chart, SmartDraw and PowerPoint. This evaluation indicated that the process modeling tools can be grouped into three classes:

1. Specific tools for modeling processes: They have more advanced resources for analysis, complex graphic interfaces, high cost, and are more limited in terms of object formatting and creation. (Example: ARIS Toolset)

2. Tools for generic representation: These have many formatting and editing resources that make the representation process faster; they are flexible, allowing representation by different methods, they lack model and object management resources, which makes the representation and maintenance of complex models difficult, and are reasonably priced. (Example: VISIO Professional, Family Flow Chart)

3. Presentation support tools: Lack resources for model and object management, but allow the representation of simple models; they have good formatting resources, are flexible for representation according to several methods, and their cost is low (Example: Powerpoint).

Presented below are the summarized results of the analyses of the tools selected in phase 6 of this work.

VISIO PROFESSIONAL: This modeling tool stands out for its good graphic interface and its easy editing and adjustment of the represented models. It can be integrated with other tools such as ARIS and with older versions of

Table 1 – Preliminary analysis of methods

		Modeling methods		
Criterion	**Description**	**SADT**	**EPC**	**IDEF0**
Well-defined syntax	Evaluates the rules used to relate the objects (clarity, consistency,...)	yes	yes	yes
Well-defined semantics	Evaluates the definition of the objects used in the modeling (quantity, properties, identification,...)	no	no	no
Diffusion	Evaluates how much the method has been applied in modeling processes	yes	no	yes
Difficult to learn	Evaluates the degree of difficulty involved in learning the method	high	low	high
Difficult to read	Evaluates the difficulty involved in interpreting the model	high	low	high
Visions represented	Activity	yes	yes	yes
	Information	yes	no	yes
	Resources	yes	no	yes
	Process	yes	yes	yes
	Organization	no	no	no

VISIO. The tool has a large library of objects and permits the creation of new objects. In addition, it has a resource for grouping the objects used in the model, which greatly facilitates the modeling process, especially when the models are being represented by several people. VISIO allows links to be made between a model and an object; however, the same object cannot be used in different models and therefore, it is impossible to check the consistency of the names of objects, and it does not have resources for listing object relationships. These features make it difficult to manage complex models represented through the VISIO tool. Cost: up to US$ 1000.

ARIS TOOLSET: This is one of the most complete modeling tools currently available. Its model and object management resources are noteworthy for greatly facilitating the representation and management of complex models. Among the tools analyzed here, ARIS is the only one that has a meta-database that allows the same object to be utilized in several models, has object search features, checks name consistency, lists the relationships of an object, and compares models. ARIS has many objects, permitting modeling according to all the methods of the ARIS methodology. However, the construction of a new object can be complex if there is no standard ARIS object with the object relationship characteristics one wants to build. This renders the tool little flexible for representing models according to different methods. Another weak point of this tool is its complexity, which may make the learning process difficult, and its lack of formatting and editing resources. Cost: from US$ 5000 to US$ 15,000, depending on the configuration.

POWERPOINT: This is also an easily accessible drawing tool, since it is part of the Office package. It has a limited number of objects, but allows the creation of different objects, enabling the representation by several methods. It also has good formatting and editing resources. This tool does not allow for navigation through the models on the Internet but allows a model and an object to be linked through *Hyperlink*. It lacks model and object management resources. Cost: irrelevant, since it is part of the MS Office package available at most work stations.

6. Choice of a sample business process

The main purpose of the preliminary analysis was to underpin a more in-depth analysis in which it would be possible to evaluate methods and tools based on their use. To this end, a sample product development process was

Table 2 – Criteria for the preliminary analysis of modeling tools

	Classification of criteria				
	Model construction	**Model presentation**	**Model management**	**Analysis**	**Support Facilities and Non-Functional Criteria**
Criteria	Representation according to several methods	Adjustment of objects to fit the page	Control of versions	Checking consistency	Integration with other software programs
	Personalization (methods)	Browsing through the model via the Internet	Control of access and modification	Search	Cost of acquisition
	Use of the same object in various models	Printed quality of the models		List of relationships	
	Model/object relationship			Simulation	
	Object attributes			Comparison of models	
	Creation of new objects				
	Adjustment of the object to the text				
	Automatic links				
	Checking the consistency of names				
	Graphic interface				
	Editing resources				

selected and modeled using different combinations of modeling methods and tools. The process chosen was the reference model for the development of "consumer goods" type products (refrigerators, washing machines, etc.) developed by the Integrated Engineering Group with support from a leading manufacturer in this segment Brazil (BENEDICTIS et al., 2002).

7. Choice of methods and tools for representation

After the model to be represented was selected, the methods and tools to be employed in the modeling process were defined. The choice fell on two methods and three tools in order to obtain six different combinations representing the same model. This was a way to obtain a set of models with fairly differentiated characteristics, allowing for the development of a consistent comparative analysis.

For the selection of methods, the choice fell on IDEF0 which, as mentioned in the bibliographic review, is a method well-known and widely used in process modeling. The eEPC was also chosen since, though not as well-known, it is used for process representation in the ARIS methodology, which is widely employed, particularly in information technology.

The tools utilized for modeling were ARIS Toolset, VISIO Professional and PowerPoint. These tools were selected for being the most representative in each of the three basic types identified (see section 5 of this article).

The "Evaluate Program" phase of the selected reference model was therefore modeled following the combinations:

1. Method: IDEF0 + Tool: ARIS Toolset (specific tool)
2. Method: IDEF0 + Tool: Visio Professional (generic tool)
3. Method: IDEF0 + Tool: PowerPoint (design tool)
4. Method: eEPC + Tool: ARIS Toolset
5. Method: eEPC + Tool: VISIO Professional
6. Method: eEPC + Tool: PowerPoint

8. Comparative analysis of the model's representations

The chosen model was represented according to the combinations of methods and tools described under section 7.

During the of model representation, records were kept of the problems, advantages and disadvantages of each of the forms of representation developed, based on the various criteria established initially (easy use, fast representation and easy visualization and understanding of the represented model) and on the possible emergence of new aspects.

Listed below are some relevant considerations about the six forms of representation employed.

1. IDEF0 + ARIS: Difficulties were encountered in representing the model in IDEF0 using the ARIS tool, because it lacks specific objects for representation by this method, so objects had to be created and added to the tool. ARIS allows one to insert objects with shapes unlike those contained in the tool, but there is a significant limitation: a new object of any shape can be added to the tool provided one of its standard objects has the attributes of the object one wishes to insert. In other words, the tool only allows for the substitution of a symbol for another, but does not permit alterations of its properties (linking rules, for example). After completing the tool's customizing process, the representation process was quite fast; however, the visual quality of the represented model is inferior to that of the models represented in VISIO or PowerPoint. On the other hand, one should note this tool's major differential, i.e., its model and object management resources, which greatly facilitate modifications of models that are already represented.

2. IDEF0 + Visio Professional: The representation of the model in IDEF0 using Visio was quite simple and fast owing to the functionalities of the tool, which has a set of specific objects and links for representation by this method. In addition, the tool's formatting features are quite satisfactory and the visual quality of printed models is above average, which makes them easy to understand. The only difficulty is the absence of model and object management resources, which means that any modification of an object must be repeated in all the models containing this object.

3. IDEF0 + PowerPoint: The representation process was quite slow due to the tool's limitations, but the visual quality of the models obtained was very good, facilitating their interpretation. Because this combination lacks object and model management features, all modifications have to be done manually. This combination can be very useful for companies with simple business processes, which cannot afford to invest in a more specific tool.

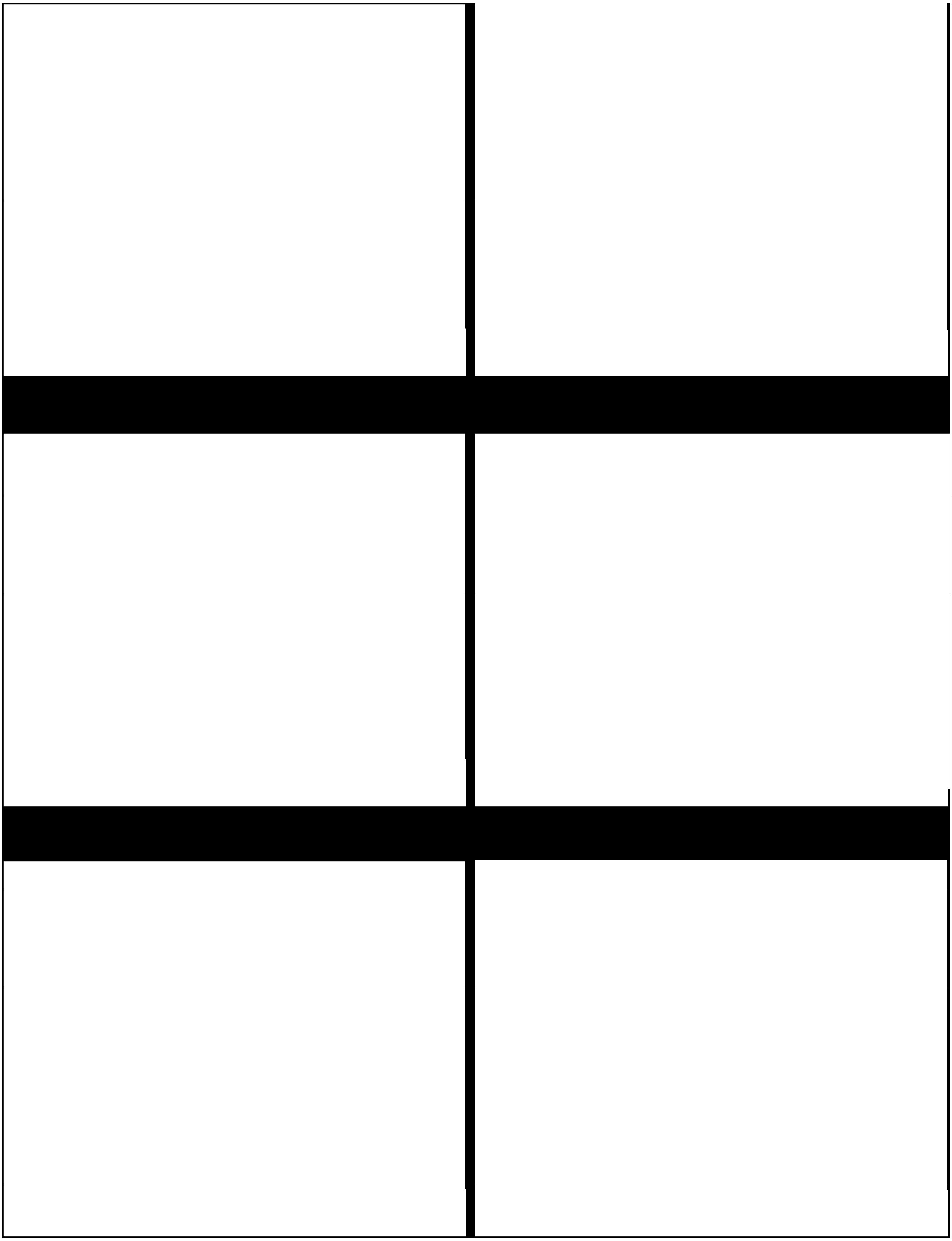

Figure 2: Representations of the model according to the combinations of modeling methods and tools

4. eEPC + ARIS: Extremely simple representation, since this is a standard method of the tool, containing all the objects, links and attributes required for representation. The model and object management features enable modifications to be made very easily. The visualization of a model represented in eEPC is simple for the model represented, but it may be far more complex for models containing many simultaneous activities or with a very intensive flow of information.

5. eEPC + VISIO: The VISIO tool allows for the easy representation of models according to the eEPC method, since it permits the selection of some objects and links for use in the modeling according to a given method. This greatly speeds up and facilitates the modeling process, especially when the models must be represented by more than one person, preventing mistakes when using different objects in the representation of the same entity. The printed model shows adequate visual quality and the tool's graphic interface is friendly enough: the best of them. Again, the major difficulty here involves modifications, due to the absence of model and object management resources, like consistency between object occurrences at different models.

6. eEPC + PowerPoint: The representation of the model using the eEPC method and the PowerPoint tool was quite simple owing to the existence of the necessary objects and links in the tool itself. Moreover, the formatting features are very useful, hastening the representation process and contributing to the good visualization of the represented model. Obviously, the time spent on the representation using PowerPoint was much longer than with the other tools, so it is not recommended for longer and more complex models.

Figure 2, below, illustrates the representations of the sample model according to the various combinations of modeling methods and tools described above.

9. Final remarks

This article presented several analyses and comparisons of modeling methods and tools obtained from a systematic way involving careful surveys of the literature, from commercial information and from practical modeling experience.

Overall, it demonstrates that modeling tools can be grouped into three major classes, according to their functionalities, limitations and cost. The first class comprises specific tools for modeling processes, with many features, greater complexity, and higher costs. The strong point of these tools is the functionalities for managing and evaluating the consistency of the constructed models. The second class is composed of specific tools for graphic design, whose major advantage is their greater flexibility in terms of modeling methods that can represent and their easy use compared with the tools of the first group. Lastly, there is the class comprising tools for generic use, with more limited resources, but very accessible.

In practice, this means that, for the development of more complex product development process models, the most appropriate would be specific modeling tools, or a combination of these tools with graphic tools, so as to ensure the model's consistency. The use of graphic tools or standard tools is recommended for simpler processes.

The comparative analysis also revealed several aspects regarding the difference between methods and the method-tool relation, e.g., the difficulties encountered in the representation of the process by the IDEF0 method using the ARIS Toolset tool, although the latter is one of the best and most up-to-date modeling tools. This analysis also indicated the advantage of using the VISIO Professional tool for the representation by this method.

The list of criteria for evaluating tools is quite comprehensive and can, therefore, be utilized for in-depth evaluations of other tools not included in this work.

Of course, the best choice of the method and tool to be used in modeling a product development process requires an analysis of factors such as the complexity of the model to be represented, the desired form of representation (poster, reports), the size of the process to be modeled, the number of people involved in the modeling process, and the availability of financial resources for the acquisition of a modeling tool. Only a detailed analysis of all these variables would lead to the correct choice of a given modeling method and tool. This work systematizes criteria and comparative information about modeling methods and tools with the purpose of aiding this decision. Once in possession of the specific information of the case, it is easy to define a specific method and tool, based on the analyses presented herein.

Future work in this area may involve a continuation of this line of research, through the evaluation of other methods and tools destined for the construction of the most diverse models.

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