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USING PRODUCT DESIGN METHODS IN DESIGNING AND VALIDATING ENTREPRISE MODELS

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Keywords: Enterprise model, model design, model validation, model function.

1. Introduction

In our research, the enterprise is considered as a system evolving in an environment (the market, the concurrences, suppliers, humanity) with given objectives, generating certain values, that carries out an activity (a set of processes) and sees its internal structure evaluating without losing its unique identity [Bocquet JC 2008]. To handle the complexity, the ever-changing state of this particular system many models are proposed. The profusion of enterprise models makes it confusing to understand and use them. But as enterprises continue their evolution, we will be building new models to fit new enterprise needs. But models design is rarely discussed. Besides, it is already difficult to choose between different existing models. Studying models' validation can give us some criteria to assume that a model is more efficient and though will be better used.

In this paper, we, first, draw a state of the art of enterprise models that will justify our focus on some enterprise models. Second we present a design method to guide the building of selected enterprise models. The proposed design method is made clear by its application to a selected model. Third, we are proposing to validate the model through the functions it is fulfilling for the enterprise. And finally we present the perspective for our research.

2. State of the art of enterprise models

Numerous researches were carried on enterprise modelling through the last decades proposing several modelling techniques and applying different tools. It is important to define accurately some terms like: an enterprise model, a modelling language and a modelling methodology.

Besides, we tried to give an idea about previous researches' results on enterprise models. In fact, our state of the art on this domain does not enumerate previous papers but classifies them according to two major criteria. The first one is the part of the enterprise emphasised: enterprise functions, enterprise data or information and enterprise resources. The second one determines whether the previous papers refer to an enterprise model, to a modelling language or to a modelling methodology. The proposed classification of the state of the art justifies beginning our study by focusing on certain process models we will define later on this paper.

2.1. Sorting through the terminology of enterprise models

Going through the research work on enterprise modelling brought many definitions of a model. Before trying to study the design and the validation of enterprise models, we estimate that it is important to give a clear definition of what we consider as an "enterprise model".

A model is basically “every representation of a real system, whether it is a mental representation or a physical representation, that comes into a verbal form, a graphical form or a mathematical form” [Walliser 1977]. Each model is based on a modelling language. The language contains the main primitives (used to express real system and real systems components) and the rules to assemble these primitives to form the model.

In the enterprise modelling literature, we distinguished between enterprise models which are designed especially for a certain enterprise system and modelling languages which have been used for enterprise system and for other systems as well. We identified also previous research papers that went further than presenting a model for a unique process or viewpoint in the enterprise. They presented different models of the enterprise depending of the approach to adopt. We refer to these research results as modelling methodology as they give literally a methodology to link models of different aspects of an enterprise.

2.2. Classifying previous enterprise models:

F. Vernadat [Vernadat, 1999] identified three important approaches for an enterprise model: the functional approach, the data/ information approach and the Resources approach.

From a functional point of view, the enterprise could be considered as a set of functional activities or processes that contribute to the execution of planned actions. From a Data/ Information point of view, the enterprise is built on an information system that spans through each department and gathers the important information to run the company efficiently. From a Resources point of view, the focus is on the resources (human resources, technical resources, knowledge...) needed to fulfil the enterprise projects. Table 1 gives a classification of some researches on enterprise modelling. We followed a chronological order beginning with the older ones and ending with the most recent ones.

Table1. A classification of enterprise models

Approach	Identification	Known as :
Functional	Modelling Language	SASS (Structured Analysis and System Specification)
Functional	Modelling Language	SADT Structured Analysis and Design Technique
Functional	Modelling Language	IDEF0 (Integrated Computer- Aided Manufacturing Definition)
Functional	Modelling Language	IDEF3
Functional Data/Information	Modelling Language	IDEFx1
Information	Enterprise model	ARIS (Architecture of Integrated Information Systems)
Information	Modelling Language	MERISE
Functional Data/Information Resources	Modelling Methodology	CIMOSA (Computer Integrated Manufacturing Open Systems Architecture)
Functional Data/Information Resources	Modelling Methodology	GRAI (Graphs with Results and Activities Interrelated)
Functional Data/ Information Resources	Modelling Methodology	PERA (Purdue Enterprise Reference Architecture and Methodology)
Functional Data/ Information Resources	Modelling Methodology	GIM (GRAI Integrated Methodology)
Functional(Process) Data/Information Resources	Modelling Methodology	GERAM (Generalised Enterprise Reference Architecture and Methodology)
Functional Data/ Information	Modelling Language	UML (Unified Modelling Language)
Functional Data/ Information	Modelling Methodology	UEML (Unified Enterprise Modelling Language)
Functional	Modelling Language	SysML (System Modelling Language)

At this point of our research, we found it confusing and almost impossible to deal with all enterprise approaches at the same time and all models proposed in each approach.

We decided to consider enterprise process models. This approach is explained in the following section of this article.

2.3. Selected Enterprise models

Process thinking has become widely used due to the growing concern for quality. An enterprise process is a sequence of actions transforming an input into an output using certain resources and adding value through the transformation. A process model ideally has to state the enterprise functions needed to be performed to realise the process (an enterprise functional approach), the data flow or information flow generated by the process (a data/ Information approach) and the resources consumed by the process (a resource approach). Hence, we can address the different approaches of an enterprise by studying its process models.

Our scope is to focus on the three important business processes in an industrial company: The Supply Chain process, the product lifecycle process and the customer relationship process. Supply chain

processes, product lifecycle processes and customer management processes are highly related and considered as “key-success factors” [Srivastava et al, 1999]. The methodology we propose is mainly applied to Supply Chain Management (SCM) models, Product Lifecycle Management (PLM) models and Customer Relationship Management (CRM) models.

Besides, our definition of an enterprise model is, though, more specific than the one presented by Walliser.

Models are mainly used by managers to view the process they are interested in and to enhance the management of this process according to the business plan of the enterprise. A model is a representation of the real process in order to reduce its complexity, understand it and change it for better performances. An enterprise model for our research though doesn't depict only a real system but it allows performing changes on this system in accordance with the modeller's objectives.

3. Designing Enterprise models

It is not common to discuss the design of a model. Our purpose is to investigate this subject to help design new process models and access the existing models. Like a product, the model is composed of a list of components that are assembled according to a precise order. Each enterprise model goes through two different phases of its lifecycle.

3.1. The model Lifecycle

Like a product the model goes through different lifecycle phases that affect its design. The closer we look in these phases the better we will deal with the model in the enterprise. Besides validating the model depends on which phase of its lifecycle we are.

There are two important phases in a model lifecycle:

- The building phase
- The use phase

3.2.1 The building phase of a model

In this phase, we consider the modelling methodology apart from its application. We focus on the methodology it used to go from the real system to a given representation. Only the modeller is involved, the user of the model is not yet involved. Before given a model of an enterprise process, it is important to understand the components that are going to be used and the instructions to follow.

In this phase of the model's lifecycle, we are exactly before the application of a modelling methodology, the modeller holds the modelling knowledge, and he is about to pass it to the users of the model or about to apply it himself. We access the clarity of the model's components, their definitions, the information they could contain and the way they have to be assembled to form the model.

3.2.2 The use phase of a model

The use phase begins when the model's user understands the significances of the model's components and the rules leading to build the model. Then, the real system (to be modelled) is accurately defined. Finally the model's user begins translated the components of the real system using the language of the model. Once the translation process is completed, we obtain the model of the real system; this model is in its use phase as it is strongly related to a give real system. In this phase we access the ability of the model to represent a real system, to reduce its complexity and to operate changes on it.

3.2. Proposing a methodology for designing a model

So first of all, a model is based on a “modelling code”. The easier the modeling code is to understand, the easier the model is to use.

A model is like a language: it is composed of structural words: the structural components that form the model. The syntax of the language dictates the rules of assembling these words in order to be

understood by a reader. Each model has its own syntactic rules that depict the way the model components are to be used in order to understand the whole structure.

But sorting the words according to correct syntactic rules sometimes leads to meaningless sentences. So a model has to be checked systematically by the modeler and the user in order to assert that it corresponds to a real case or to a possible real case.

Already we can say that these steps are rather important when designing a model:

- Determining the basic components of a model
- Stating its syntactic rules
- Avoiding meaningless association by checking the consistency of the whole model according to the objectives of the modeler.

Being able to distinguish the structural components of a model and proving that it has coherent syntactic rules is already an indication that the model is well-structured and will meet the modeller needs.

If we include these three recommendations, the steps to design a process model could be:

1. To understand the basic components of a model and the rules to assemble these components
2. To delimit the real system, we want to model: its components, its functioning and the objectives of this real system
3. To state the objectives of the modelling process that is to say what we are expecting the model to perform on the real system
4. Translate the real system into a model using the model's components
5. To ensure that all the model's rules are respected
6. To verify whether the obtained model is coherent with the reality or not
7. To check whether the objectives of the modelling process are realised

In our researches, the process models we are studying are all checked using these simple steps. As an example we are trying to access the design of a supply chain model: The Value Stream Mapping model.

4. Applying the design methodology to an enterprise process model

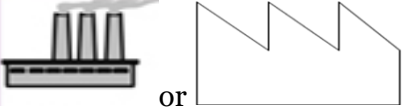
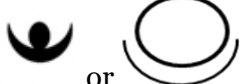


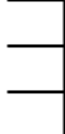
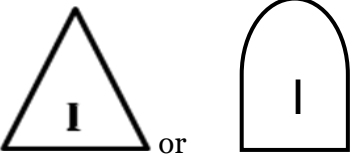
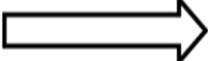



In this example we are trying to apply the design steps introduced in the last section on the case of the supply chain process of a manufacturing company.

4.1. To understand the basic components of a model and the rules to assemble these components: The Value Stream Mapping (VSM) model

The VSM model is part of the “lean manufacturing” toolkit [Womack and Jones 2003]. The model is meant to represent the current state of a broad production supply chain (starting from the raw material suppliers and ending by the final customer). The main objectives of the model are to separate value – adding actions from non-value-adding actions, to determine the cause of wastes in processes and eliminates its roots [Shingo 1989].

There are many components of a VSM model, but the most used ones are introduced in Table 2.

Table2. The structural components of a Value Stream Mapping model

VSM structural component	Meaning of the component				
	A supplier or a customer in the supply chain				
	The presence of an operator executing an activity				
	A production process in the production line				
<table border="1" data-bbox="368 620 580 797"> <tr><td>Productivity:</td></tr> <tr><td>Process time:</td></tr> <tr><td>Three shifts</td></tr> <tr><td> </td></tr> </table>	Productivity:	Process time:	Three shifts		A box holding the important data about a production process
Productivity:					
Process time:					
Three shifts					
	The application of a planned instruction				
	A warehouse or a stocking supermarket				
	An intermediary stock point indicating the stocks level				
	Material flows (semi finished products) between different production process				
	Information transmitted on paper or orally from an operator to the other				
	Information transmitted automatically without the intervention of an operator				
	Transport between the company, its suppliers and its customers (raw materials from the suppliers to the first process of the production process and final finished products to the customer)				

4.2. To delimit the real system, we want to model: its components, its functioning and the objectives of this real system: The supply chain

The Supply Chain is the set of procedures and software using for managing optimally the information flows, material flows and the interfaces between the different actors: suppliers, producers and customers that are related to the manufacturing of a product or the delivery of a service. All the data (from the customer requirement until the distribution scheme, through the conception and production) are gathered and used to build the supply chain [Eymery 2003]. In order to apply the model we took

here the simple case of a manufacturing company, with two suppliers, two customers and a four-step-production process.

4.3. To state the objectives of the modelling process that is to say what we are expecting the model to perform on the real system

The VSM model is expected to depict the supply chain, including the raw materials providers, the manufacturers, the distributors and the final product customer. It is supposed to make visible the different flows exchanged and to allow its evaluation. The main objective of the VSM model is to reduce waste and eliminated waste roots. In our case, the first objective of the model is to evaluate production and delivery times (the upper line below the production boxes in figure1) and to reduce them. The second objective is to evaluate the quantities of raw materials (the bold line below the production boxes in figure1) used and try to reduce it also.

4.4. To translate the real system into a model using the model’s components

The example depicted here is of a company producing simple (two parts) steel tubes that has to be painted before the final assembly.

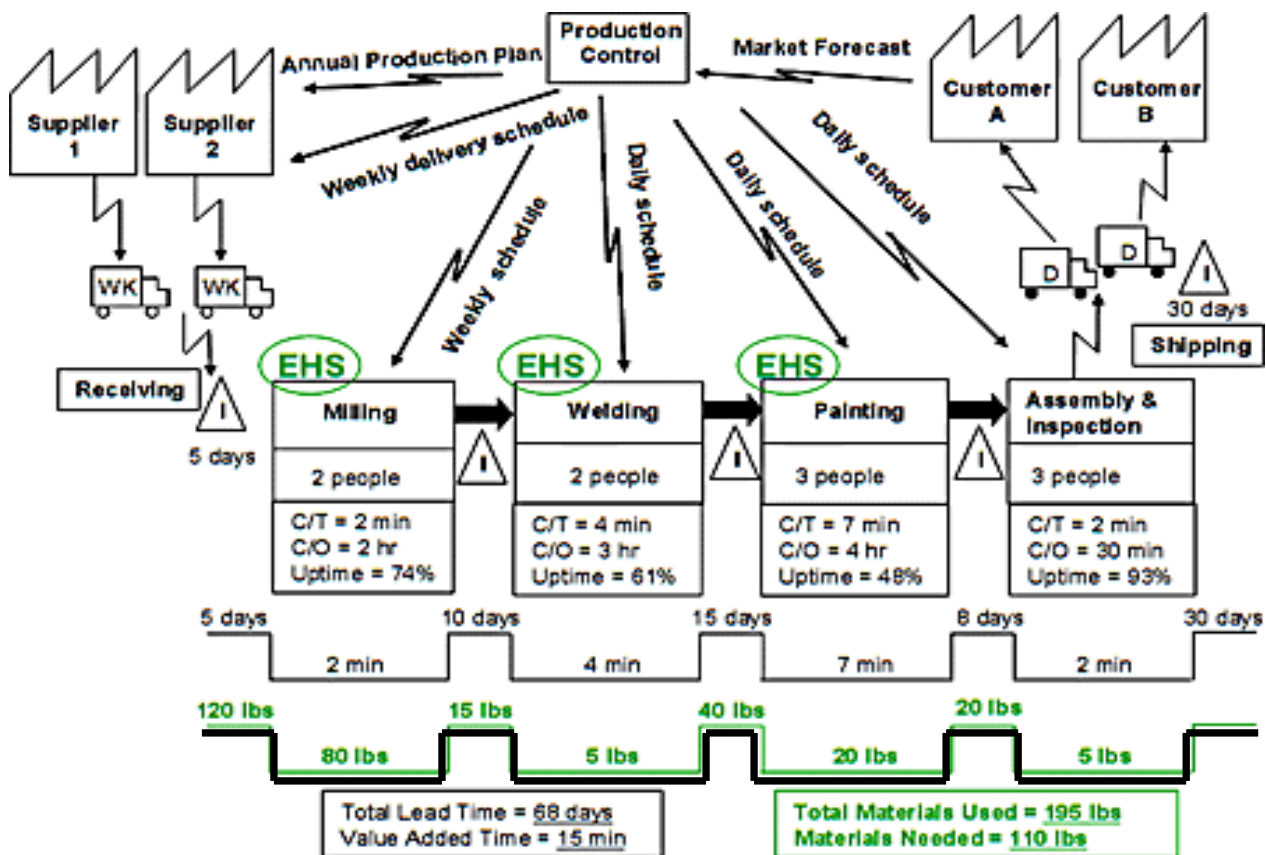


Figure1. An example of a VSM model

4.5. To ensure that all the model’s rules are respected

In the above figure, the VSM model’s rules are respected. The whole supply chain is depicted, performance measures are put on the right places and waste roots are visible. First, the supply chain begins by the suppliers and ends by the customers, the manufacturing steps are detailed in between. Second, all the different flows are depicted: information and material flows. The manufacturing times are estimated according to the corresponding time line (the upper line below the production boxes in figure1). Information flows are mainly exchanged with the production control (market forecast,

production plans...) And finally, performance measures are pointed out: manufacturing times, stock quantities, number of employees needed, time of shipment and quantities of material flows consumed at each step.

4.6. To verify whether the obtained model is coherent with the reality or not

Even if our model is that of a virtual company, we could see that there are no improbable associations. The model is acceptable and could be perfectly fit the case of a real company. But in a real case this step will mainly concentrate on establishing the acuity of the performance measures on the model and whether they are prone to depict the real performance measures on the supply chain.

4.7. To check whether the objectives of the modelling process are realised

The objectives of a VSM model are to depict the supply chain which is naturally met: the principal actors are at their due places, material flows are described and information flows are specified. Then the determination of performance measures allows the managers to evaluate the efficiency of their supply chain and perform enhancements to improve these measures. The main concern in this model will be to reduce stock times and reduce the quantities of materials used.

5. Validating Enterprise models

Most of the work related to model validation dealt with quantitative models that are based on mathematical equations and formulas. Qualitative models are scarcely addressed. We tried to consider a model like many other product for which certain criteria are to be validated, so our work is inspired from the Functional analysis methodology and the Quality Function Deployment methodology. According to our analyses of a model lifecycle, the validation of the model the two introduced phases is different.

5.1 The building phase of a model

In this phase we consider mainly the construction of the model apart from a real system it is meant to depict. It is not common to run a functional analysis on enterprise models, but we found, in the literature, papers that define the important functions of a model and focus on the importance of these functions to validate the model and validate thought the choice of the model.

Besides we are assimilating enterprise models to products so we propose to adapt Functional analysis tools to process models.

5.1.1 The required functions to prove the model validity:

Walliser [Walliser 1977] proved that all models are meant to fulfill a given set of functions. The four important functions are “the descriptive function”, “the cognitive function”, “the decisional function” and the “normative function”.

The descriptive function states that the model makes a clear distinction between the “internal variables of the system” (its internal structure) and the external variables which are to be split into the “in variables” that enter the system and the “out variables” the system produces.

A model with its internal components made clear and designed on strict syntactic rules is more validated if it provides different components to designate the different types of variables (internal, in and out variables) and states in its rules that these components can not be interchanged when designing a model of a real system.

The cognitive function assumes that the model has to be understood by a large number of people as it represents the internal relationship of the studied system (its internal structure). This function is made possible by the descriptive function that presents the “actor” providing the internal relationships within the system.

The decisional function states that the model helps predict and picture the evolution of the variables to exit the system in accordance with the changes of the variables that entered the system. These predictions can orientate the decision in order to meet or to avoid a predicted evolution of the system.

Ideally, Walliser states that the decisional function is stronger if the model runs a procedure to check that a proposition is “true” or “false”.

AFIS, the French Association of System Engineering [AFIS www.afis.org] consolidated some of Walliser’s ideas by proposing a classification of the models according to the functions it delivers, particularly cognitive models and normative models.

5.1.2 The Functional analysis to determine required functions of a model:

In product development field, the functional analysis is the beginning of the Quality Function Deployment (QFD). In fact the QFD is an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (i.e., marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production, sales) [Chan and Wu 2002]. The objective of applying this methodology is to maximise the value of a product. In fact once a product defined, QFD enables the design phase to focus on functions that the customer really seeks for the product. We do not pretend to run a whole QFD action on our system (an enterprise model), but running a functional analysis helps identify the required functions to prove the model’s syntactic validity.

We followed “the external environments method” that considers the studied system at the centre of other systems, parts of its environment. The studied system has a certain number of relations with those surrounding elements expressed in terms of functions.

The models environment, in its building phase, is composed of three important elements:

- The modeler
- The real system to be modeled
- The result of the modeling (the representation we get of the perceived system using the components of the model and its rules)

Figure 1 depicts the model as the system of the study in its environment. In figure 1 CF, bold black arrows stands for Contact Function, it links the model to only one of the elements of its environment. The function detailed then is a service, an action or a modification done by the model to this particular element. TF, blue normal arrows stands for Transfer Function; it links two elements of the environment of the model. The function detailed here is essentially aimed at determining the nature of the links between two elements of the model. The model “transfers” the action of an element A to the element B.

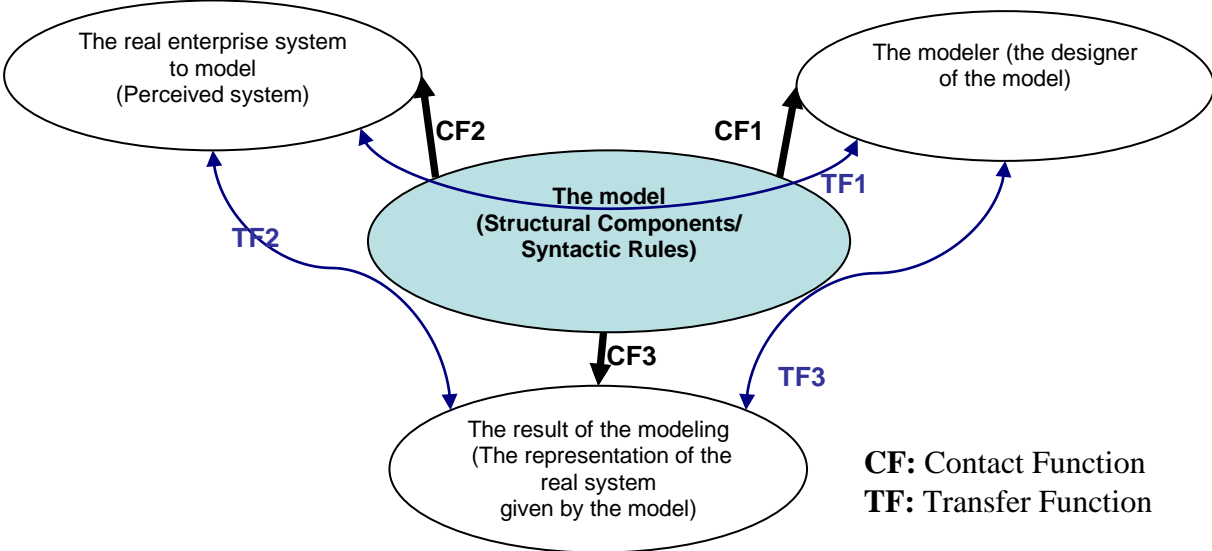


Figure2. The model and the functions linking it to its environment

The Connection functions are:

- CF1: The model must be easy to use for **the modeler**.
- CF2: The model must cover more than a case of **real enterprise systems** (not exclusively designed for a specific enterprise case)
- CF3: The model must provide a **modeling result** using its structural components and following its syntactic rules.

The Transfer Functions are:

- TF1: The model must help **the modeler** to understand **the real system**.
- TF2: The model must make it possible and easy to design a **modeling result** of **the real system** under study (the perceived system)
- TF3: The model must present the necessary internal characteristics to help **the modeler** access and to work on a **modeling result**.

Studying more closely the Transfer functions of a model, we could find the same functions pointed out by Walliser. TF1 is about understanding the system by the modeler: it is mainly the “cognitive function”. TF2 is about giving the possibility to represent a real system: it is mainly the “descriptive function”. TF3 is about working a modeling of a real system. The decisional function will require also working on the modeling method to make choices concerning the real system so those two functions are similar.

To summarize our functional analyses (Table 2 summarizes the set of functions obtained), we find out that the list of functions obtained, when filled in, guarantees a validation of the model. The connection functions guarantee the ease of use of the model, its possible adaptation to different real systems and the fact that we are sure to get a result. The Transfer functions are consolidated by Walliser analyses and guarantee the “cognitive function”, the “representational function” and the decisional function” proved.

Table3. The result of our functional analysis of a model

Contact Function 1	The model must be easy to use for the modeler
Contact Function 2	The model must cover more than one case of real enterprise systems (not exclusively designed for a specific enterprise case)
Contact Function 3	The model must provide a modeling result using its structural components and following its syntactic rules
Transfer Function 1 or “the cognitive function”	The model must help the modeler to understand the real system
Transfer Function 2 or “the descriptive function”	The model must make it possible and easy to design a modeling result of the real system under study (the perceived system)
Transfer Function 3 or “the decisional function”	The model must present the necessary internal characteristics to help the modeler access and work on a modeling result

These established tables are meant to be a list of criteria to help choose the most efficient model to model a certain process. The validation of the model is still to be completed during the use of the model.

5.2 The use phase of a model

As we said before, this phase begins when the model is applied to a real case. We have, thought, in hand a model of an enterprise process: a supply chain process, a lifecycle management process or a customer relationship process. Our aim is to validate the model.

We strongly believe that the model is validated when it met the objectives it is build for. A process model is validated in practice ones, the process enhancement are proved. In fact a manager chooses the model for a given purpose and it is validated for him if this purpose is attained. The work of [Abdulmalek et al, 2007] with a VSM model confirms this idea.

If we were dealing with a product, the next step (following the functional analysis) will be to classify the product's functions according to the measured improvements on the product. This classification will enhance the realisation of the technical solutions that are linked to the functions having the best impact on the product.

We did not address this step in our research but it is among the research most interesting perspectives.

6. An example of a process model validation:

To carry on our VSM model study, after building the model, we propose here to validate it using the tables of the fifth section of this paper.

Table4. The functions of a VSM model

Contact Function 1	The VSM model must be easy to use for the modeler	A VSM model is composed of a set of pictograms that are easy to use and rules that are simple and easy to understand
Contact Function 2	The model must cover more than one case of a supply chain	There are many cases of supply chains and the variety of symbols a VSM model displays should allow the representation of a handful of these cases
Contact Function 3	The model must provide a modeling result using its structural components and following its syntactic rules	The VSM maps and the improvement plan are modeling results. VSM symbols are used to establish the current state map and the future state map and VSM rules are used to constitute the improvements actions.
Transfer Function 1 or "the cognitive function"	The model must help the modeler to understand the real system	A VSM model gives a representation of the Supply chain for the supply chain managers and operators to understand how it works
Transfer Function 2 or "the descriptive function"	The model must make it possible and easy to design a modeling result of the real system under study (the perceived system)	The maps of the Supply Chain are drawn using the VSM modeling techniques applied on the studied supply chain
Transfer Function 3 or "the decisional function"	The model must present the necessary internal characteristics to help the modeler access and work on a modeling result	The improvement plan that draws a future state map is the result of decisions to change the actual state map of the supply chain. Drawing a VSM model applies taking some decisions to perform some changes.

And finally the use phase validation of the model is strongly related to the company it is applied on, it could be to help the company reduce manufacturing times, steel material quantities consumed or the number of employees at each step.

7. Discussions and research perspectives:

In this paper we focused on the design and the validation of enterprise models. It will take more than a PhD-study to consider all enterprise models under all viewpoints. We decided though to limit our focus to the important process models under the process viewpoint of the enterprise.

The design steps that we estimate a model must have are a way of building new process models like PLM models [Fathallah et al 2008] which are required to manage product lifecycle processes in an enterprise.

Other research perspectives will be to apply the validation technique to other enterprise models and come up with a more sophisticated methodology to guide the choice of enterprise models. The scope is to provide more accurate indications of the validation of a model in its use phase. For now we believe that the use of a model is validated by the fact that it meets the objectives of the users. But the proposed validation methodology, based on a functional analysis, is not completed. To carry on a QFD method we have to evaluate the impact of each function on the use of the model.

Finally, we aim at using the enterprise knowledge assets to build and use enterprise models. Knowledge Management is believed to guarantee the competitive advantages that the enterprises are seeking [Boughzala and Ermine 2007], in our case we are seeking to enhance model's management.

8. Conclusion

A process-based approach can be considered as a good way to address the complexity of the enterprise. If we focus on the key- enterprise processes, there is a serious competitive advantage to be expected from this methodology.

However the variety of modeling techniques is confusing. It is difficult to make a choice of the suitable model and method to be used. In this paper, we tried to set up a simple way to understand the design of models by determining the design steps necessary to build up a model. We also tried to define a set of functions that guarantee a model will meet its objectives. Proving the model validity can help managers select the models suited to the needs of their enterprise without asking them to go through all of available models, test them and choose the ones giving the best results.

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