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A STANDARD DESIGN PROCESS FOR THE BUILDING SECTOR

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1 Introduction

The paper is about the proposition of a common and shared model (representing design process) for the collaborative design, based on a systemic approach and formalised using UML language. It evolves on three principal parts; the first part describes the building design and manufacturing context within actor's interoperability (chapter 2). The second one concerns the modelling of the building design process towards interoperability (chapter 3) and the last one consists on the definition of the "building product" evolving in this process (chapter 4). The particularity of this work is to intervene in the building modelling according to a systemic approach regarding the building world as being not a multitude of distinct elements, but as an integral single "system" [1]. The whole of these elements interacting will be henceforth in this paper the "building system" instead of the building world.

2 Context of building design activities

In spite of the several actors concerned with the building design, the building sector remains one of the rare fields excluding tools and methods dedicated to collaborative work. Nevertheless, it is strongly depending on the legal framework specific to each country.

2.1 Legal context

In the current European context of building design, buildings are subject to a particular cutting of the life cycle regulated by the law. This legal framework constitutes a privileged instrument of management of the activities related to the building sector [2]. The MOP law (Maitrise d'Oeuvre Publique) which is specific to France, codifies the missions of each actor intervening in the building design and manufacturing process [3] (similar laws exist in each country).

In this cutting, the project of construction is born from an intention which expresses a need. This need is formalised by a program which expresses the requirements of the customer. Based on this program, a draft including conceptual solutions is then developed by actors of design.

Starting from this stage, a Preparatory Project Summary is created and integrated into an administrative file for a building authorization. The development of the PPS will work out the Preparatory Project Detailed which includes the technical solutions evaluated by the partners of design (office of: structure studies, electric studies, etc.). This work leads to the realization of the Tender Documents to the Companies composed of the Plans of Execution of the Project and the Technical Specifications detailed.

The reception of the project is the last stage in the life cycle cutting; it comes to mark the completion of the project. The building enters then in the phase of exploitation for which it was intended [4].

2.2 Towards a collaborative design

The legal framework presented above constitutes a kind of method which influences the building design. In nowadays other methods of design initially conceived for the industrial sector come to influence the building sector. They are not always adapted to it (Design for manufacturing, systemic production, etc.) and only few of them can integrate it, in particularly: the concurrent engineering [5].

The tendency today is for this new method; which gives a margin of flexibility to the building companies. These companies are directed for their designs towards the co-operation and the exchange of information, around a co-operative process of building design. This co-operation is organized on the basis of information systems. It allows joining different know-how on the same problem, in order to produce a solution. This solution would be only the compromise among the various points of view (of the architect, the engineers, the contractor, and of course of the customer). This method seems to be adapted to the building sector requirements.

Concurrent engineering is the normal evolution to which the building sector should evolve. The continuation of this paper will take for objective to satisfy this need and will deal only with tools related to this method.

2.3 The conceptual modelling as a background of interoperability

A great number of works about conceptual models in France were initiated (BOX, GSD, MOB, JUICE, TECTON, etc.), but also in the international area (ATLAS, COMBINES, MISSED, etc.), with a principal objective concerned on the description and the development of data building product models and building design process models [6].

These works were variously based on research laboratories from the academic world, with the assistance of institutional and industrial partners implied in the manufacture of hardware and the edition of software.

The most important international action for answering the problem of interoperability with a conceptual model in nowadays is the project of the International Alliance for Interoperability "IAI". It consists on the IFC model (Industry Foundation Classes). The IFC model is different from all the precedent models in measurement that it proposes an extremely detailed structure of the building product [7].This level of detail is justified by the fact that the IFC are a whole of resources, thought as a support to the building software publishers.

The IFC propose the modelling of the building life cycle, structured according to four levels:

- Level 1: four general phases are identified: feasibility, design, construction, and exploitation of the building.

- Level 2: each preceding phase breaks up into a whole of secondary phases, organized according to a chronological order (the phase of design for example breaks up into: programming, diagrammatic design, detailed design, documents of execution, tender documents.)

- Level 3: each one of these secondary phases is declined in a series of chained processes, which correspond to the various actions of the designers during the project. They establish continuity in the cycle of design.

- Level 4: finally each process breaks up into a whole of activities. Each one of it is associated to a diagram, in which are described the tasks to carry out, also indicated in the model by "methods of design".

It is to note that these works have relatively close ambitions. It is question of facilitating the communication of information relating to the building product among the actors using a conceptual model. The principal idea in this tool is to model the building product as a whole of objects evolving in a process of production. It is important to know that this vision is very restrictive of the reality. It does not permit to satisfy requirement of actor's interoperability in order that it represents the design process as a linear and sequential activity based on the actual building life cycle.

2.4 Synthesis

Actor's interoperability in the building design activities is a real requirement for the sector. Different projects aim to realise it. The principal idea in these works is to regroup all actors intervening in the design process around a common and shared model. Each actor's proposition is represented according to this model. Nevertheless the actual models in the background are not adapted and constrain actors in their personal methods, by reproducing a sequential representation of the design process.

This paper proposes a new approach of modelling (systemic approach) which will consider the building in real context of interoperability. Systemic approach is called also "cybernetic", it offers a structure of analysis of four axis (structural, transformational, functional, teleological) considered as generic and applicable to any filed or topic.

3 A systemic approach for building design modelling

Going beyond the actual cutting in the building design process (by a conceptual model) means first of all the reconstitution of an informational continuity in the building life cycle. We propose to intervene on this cycle according to a systemic approach regarding the world of the building as being not a multitude of distinct elements (as in the actual models), but as a single "system" integrating a set of components in interaction [1].

3.1 The building system definition

The "building system" is the set of human, material, and immaterial components intervening in the activities related to the building life cycle. The limits of the system are the terminals characterizing the beginning and the end of the life cycle. The system inputs are data characterizing its components and the outputs are the level of the production.

3.2 The building life Cycle: from the stage to the state (structural description)

The majority of models, laws, and existing approaches define the building life cycle as a linear axis which does not support any tasks parallelization (MOP law "Maîtrise d'Ouvrages Publics" specific building design law to France, IFC model "Industry foundation classes" developed by the international alliance of interoperability "IAI", etc) [2]. Even the contents of the axis change from a definition to another; there are always two stages which never change whatever the approach: "the expression of needs" and the "destruction/recycling" of the product (Fig. 1). Two terminals points of the axis which express the birth and the extinction of the life cycle.

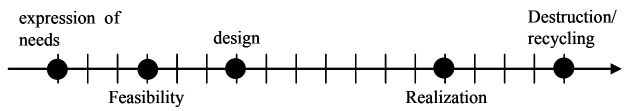

Figure 1. Traditional building life cycle axis

In the multitude of the stages distributed on the life cycle axis, some of them only must be on a linear axis and follow one another in time. It is a question of the design, the organization, piloting and tasks coordination (O.P.C.), the realization, and the exploitation and maintenance.

According to the systemic approach, stages which are obligatorily successive are come out of the life cycle axis and put in a new axis discredited compared to time. The time graduations on this axis are reported so that indicating "states" of the building system (Fig. 2). The building life cycle passes from the stage characterizing an evolution in time, to the state characterizing a system's evolution [8].

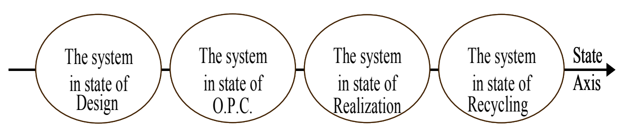

Figure 2. Obligatorily successive states axis

It is clear in the states axis, that what was O.P.C. stage can not be done before the design stage. And that the realization comes obligatorily after these two stages and before the exploitation and maintenance.

By considering the building in a systemic approach, defining it as being a set of components interacting, and evolving in time, the axis drawn above becomes characteristic of the whole system's evolution (with all its components) from a state to another.

This representation can evolve to a more complex representation according to two axes. One compared to time, the other compared to the variable states of the system (Fig. 3). The system evolves from a state to another according to the variables state.

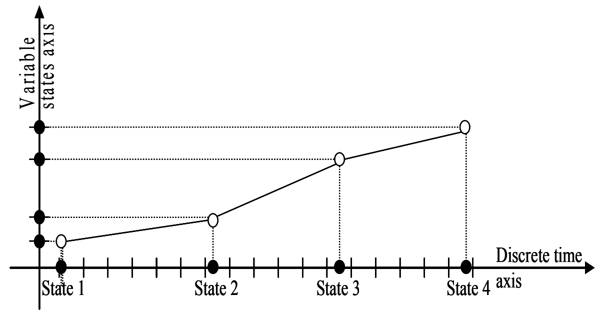

Figure 3. Building system evolution graph

3.3 The building system: a conceptual model (functional description)

To each building system's state corresponds: material, and human "components", organized forward the production of the system's output. These outputs consist an a wallet of plans and other documents for the state 1, information systems and schedules for the state 2, the building it self for the state 3, building services for the state 4 (Fig. 4).

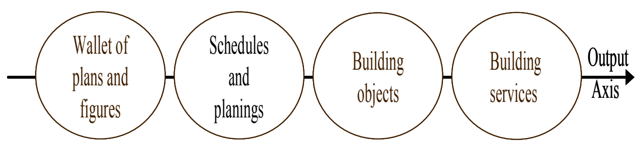

Figure 4. Axis of various formalization of the building system

3.4 The system state's definition

The stages of the building life cycle, which were not bring from the classic axis, are considered able to be overlap and integrate the obligatorily successive states closest to them. The feasibility stages, marketing studies, program development, are not obligatorily successive stages which can be integrated in "the state One" of the system (design state).

From this fact, system states take a general definition, where it passes from fragmented "design stage" and separated from the engineering stages, feasibility, etc., to a "design state". This state is built around an actor's diversity, information, representations, etc., requiring an interworking method. It means that to each building system's state, correspond a specific output, and a particular interoperability requirement. It can be qualified as the "First level of interoperability".

3.5 The system's states Agreement (transformational description)

In order to create an informational continuity and to go beyond the existing fractionation between actors, we will put the axis of states on a not linear axis, but in "V" axis [9]. The choice of this life cycle representation (traditional for the manufactured goods) presents the interest to combine a temporal axis with the possibility of connecting different stages from the life cycle independently from this temporal axis. This will enable to define what can be called the "second level of interoperability" (Fig. 5). This second level defines an interworking between the stages included in the various states (correspondence between the design stages and realization for example). This representation includes the higher main of the model in V: the first stages prepare the last one; the passage can be done between the upstream stages and the swallow one, etc.

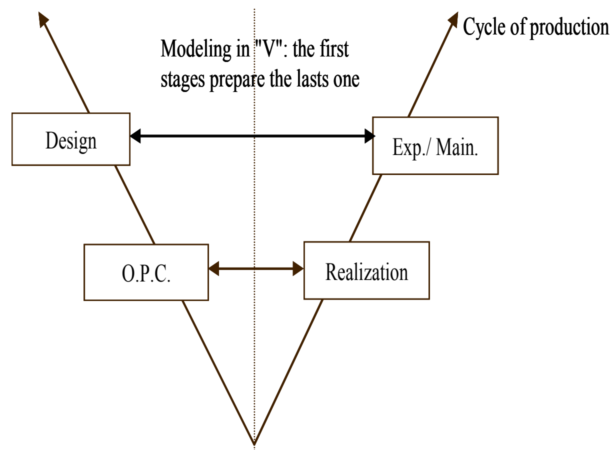

Figure 5. Representation in « V » of the building life cycle

It results according to this approach, a representation founded and structured according to a systemic approach, integrating two levels of interoperability. A level specific to each stage which concerns the "Co-design" to design and build a definite system state [10], and a level shared between the whole stages (parallel and successive) depending from a "simultaneous engineering", to design and build a state considering the whole aspects of the system [11].

The Co-design is the actor's collaboration (intern) being in the same system's state (actors specific to the design, O.P.C., etc,). Simultaneous engineering is the collaboration between actors being in different system's state (design and realization, etc.).

3.6 Towards a building system conceptual model (teleological description)

The elements introduced in the preceding title allow to talk about the cycle of evolution of the building system, because there is a passage from the simple building representation (objects assembly) evolving in its composition according to a time axis (life cycle), to a building system (descriptive variables and interactions rules) evolving dynamically compared to a states axis.

The (Fig. 6) puts in correspondence the various definitions which will define the conceptual model. It integrates the systemic and dynamic aspects (states axis), the practical and trade aspects defined by the production context (production axis) and the "product" aspects defined by the building system formalization levels throughout its life cycle (outputs axis).

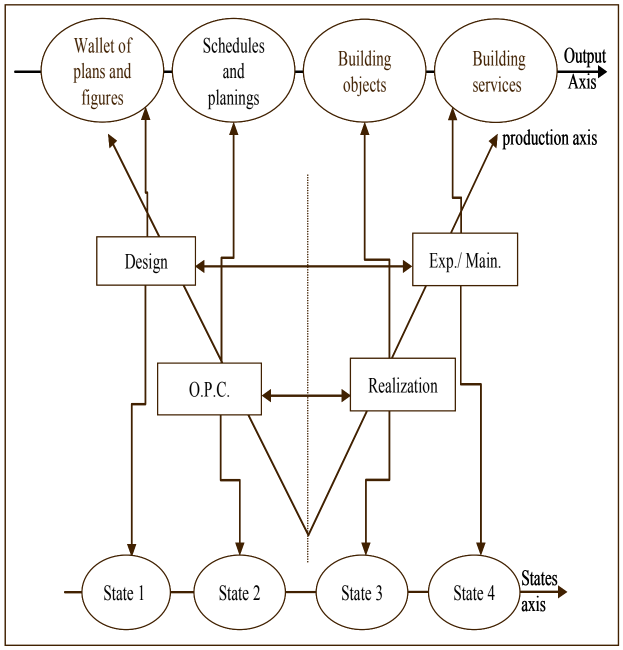

Figure 6. Informal conceptual model of the building system

In this illustrated synthesis the system evolutes as following: the building system passes from a state to another consequently of an activity which proceeds on a "V" production axis. The passage from a present state to a future state is defined by a formalization suitable to the systemic (internal variables causing the change of state) on a system's state axis according to time. This passage goes with the production of the system's output, defining a formalization level, corresponding to a system's state.

3.7 Synthesis

The building system is proposed instead of the classic building life cycle. It permits to create an interoperable structure of work representing the different states, and product of the system. It was describe according to the four axes of analyse of the systemic approach. To complete this structure, it is necessary to introduce the definition of the "building product" evolving in the system. Using the same approach we will define the building project evolving in the design process.

4 From the "building system" to the "building product"

The installation of a systemic framework of building design and manufacturing includes the definition of the building system, but also the definition of the building product produced in this system. Is it a set of different objects? Is it a set of spaces? Is it a service offered in a defined space? These questions show well that there is a basic problem in the building production related to the product definition.

The actual conceptual models introduced in this paper, consider in the major part of the cases, the building as an assembly of objects (problem of limitation of objects), and a whole of rules defining the relations between these objects.

4.1 Relativity of the product building definition

In practice, it is very current to relate several and different definitions to only one building product. It is possible to distinguish two categories of views able to define the building product. A category of actors-product view and another one of stages-product view.

In the first category, the product is related to an actor view. In general the point of view of the economist participant to a project constitutes a compromise among the actors. The building for the economist is seen as a set of objects and batches of objects. The other actors have their own point of view. The architect for example sees the building according to his personal convictions and according to his artistic tendencies. He considers the building as a whole of full and vacuums, a whole of spaces served and spaces given a service. An engineer of structure has a view considering the building as a mechanical model, and so one [12].

In the second category, the product is related to a stage of the life cycle. It is an infrastructure, a superstructure, an envelope, and so on until it becomes a finished construction assigned to a service.

In the continuity of the approach undertaken (system approach), all the points of view of actors contributing to the production, must be taken into account and all the stages of the life cycle. The definition given to the building product is in this case "variable" evolving in a set of actors and stages.

From this fact a first conclusion can be done: the definition of the building product is relative respectively, to the actor's point of view and to the stages of the building life cycle. It cannot be restricted to only one actor point of view or only one stage of production. The product building becomes then definable on a set of views and different stages; it is variable.

4.2 The building product variable in the building system

The building product is the variable component on the set of the stages of the "state of design" (the state of design is the state of the building system including all the stages of: feasibility, programme, APP, APD, etc.). In this state of the building system, the output consists on a wallet of documents (plans, etc.) representing a first form of the building product definition [13].

The design in this state of the system is organised according to a representation of three referential: methodological, conceptual and normative [14]. Defining the building on this base means give a "semantic" definition taking in account the actor's point of view represented in the referential (Fig. 7).

We go then from an ineffective and traditional representation of modelling built around building objects and their processes of realization to an effective and more adapted representation built around referential.

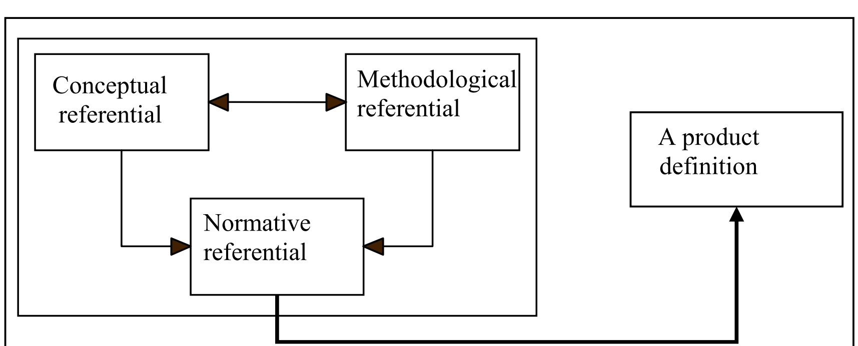

Figure 7. The semantic of the building product definition

The structure of referential frames which was set up must permit to define the building product compared to a semantics built around several actors point of view [15]. It permits to identify the product by particular characteristics established in the course of production in the first state of the system (state of design). However, the semantic definition obtained should be completed by a syntactic one. It is important to remember that it is a question of a systemic approach where it exist two types of equality between the components, a syntactic equality, and a semantic one [16].

In a semantic equality it is possible to define two different elements in their form but similar in their function as equivalents. As example a chair used to break a window, and a hammer, are thus equivalent in this case, they are used for the same function.

Our first definition of the building product in the preceding figure must integrate fully this aspect of semantic equality. A syntactic equality considers equivalent only similar elements. The equality hammer-chair becomes false from a syntactic point of view.

In order de define a syntactic framework for the semantic definition proposed above, we will be interested in the formal systems. A formal system is a system with only syntactic equality and rigorous reasoning [8]. (In the semantic definition of our product, the reasoning is not rigorous, because the actors reason by analogy, comparison, induction, etc. In the rigorous reasoning there is only one rule to reason: deductibility).

Following this approach the building product can be compared to a number "n" pertaining to a mathematical set. For example an unspecified construction, can be assimilate to a global set of products (general product of consumption), to a typological set (product from the same family), to a die set (product of the same constructive die) and to a components set from a purely formal point of view.

Compared to the mathematic construction of sets, a number "n" in a formal definition can be seen as pertaining to a general set R including all the real numbers, to sets K, J, and to set N including the natural numbers. Four sets of definition are obtained then, overlapping from the smallest to the largest, constituting a syntactic framework in which is defined the variable component "the building product" (Fig. 8).

Accordingly, the building product cannot have any possible semantic in this purely formal construction. The idea to present the building as element of socialization, element founder of a culture, etc., is thus not taken into account in this definition.

An undivided component of the building (beam, column, window, furniture, etc.) will be able to be defined on the fourth set, an element of structure on all the sets except the components set, a particular kind of building on the two first sets only, and a whole of buildings on the first set only.

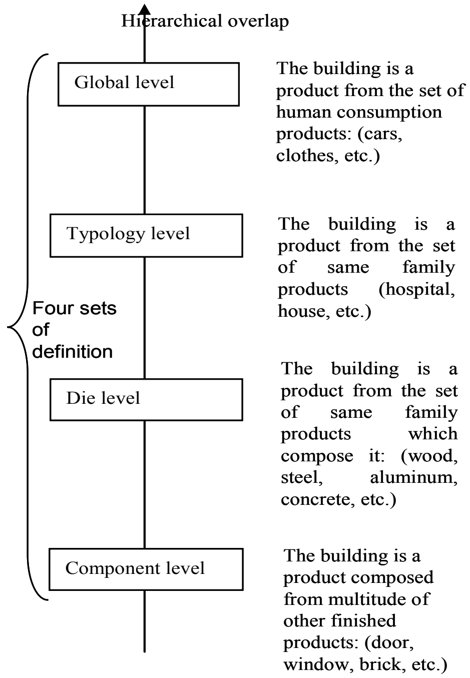

Figure 8. Syntactic structure of the building product definition

4.3 A conceptual model of the building product

By associating the syntactic framework to the semantic one, it becomes possible to characterize perfectly the production of the building system, a building product.

According to the conceptual model obtained, the building system will be able to produce, with the same means and referential tools, a whole of buildings in the global level, specific buildings in the typological level, structures of building in the die level, and even components of building in the last level, with the same objectivity and the same architectural vision that will be define in our referential framework. Each level will indeed utilize a methodological, conceptual and normative referential as shown in next page (Fig. 9).

A house will be defined in this model as: a whole of products developed in different trades (electric components, air-conditioning, floor covering, etc.) taking an architectural semantic conceived according to a referential framework (methodological, conceptual and normative). It will be defined also on a set larger compared to a constructive die: wood, metal, etc but always with a specific semantic to this level defined by the referential framework. In the third level the house is defined as a building distinguished by its function, extremely different from another type of building. Finally it is defined in a set which contains all the precedents and allows making a distinction compared to the physique and social environment of the house.

It is possible to define also in this diagram a simple component of a building, initially as a unified product, then as pertaining to a constructive die, then to a type of building, and finally as product influencing the external environment of the building product.

The informal model obtain allows to produce a building or just a component of building according to a semantic built around referential framework and a syntax structured by sets of appurtenance. The next paragraph is about a formal representation of this model adapted to data processing implementation

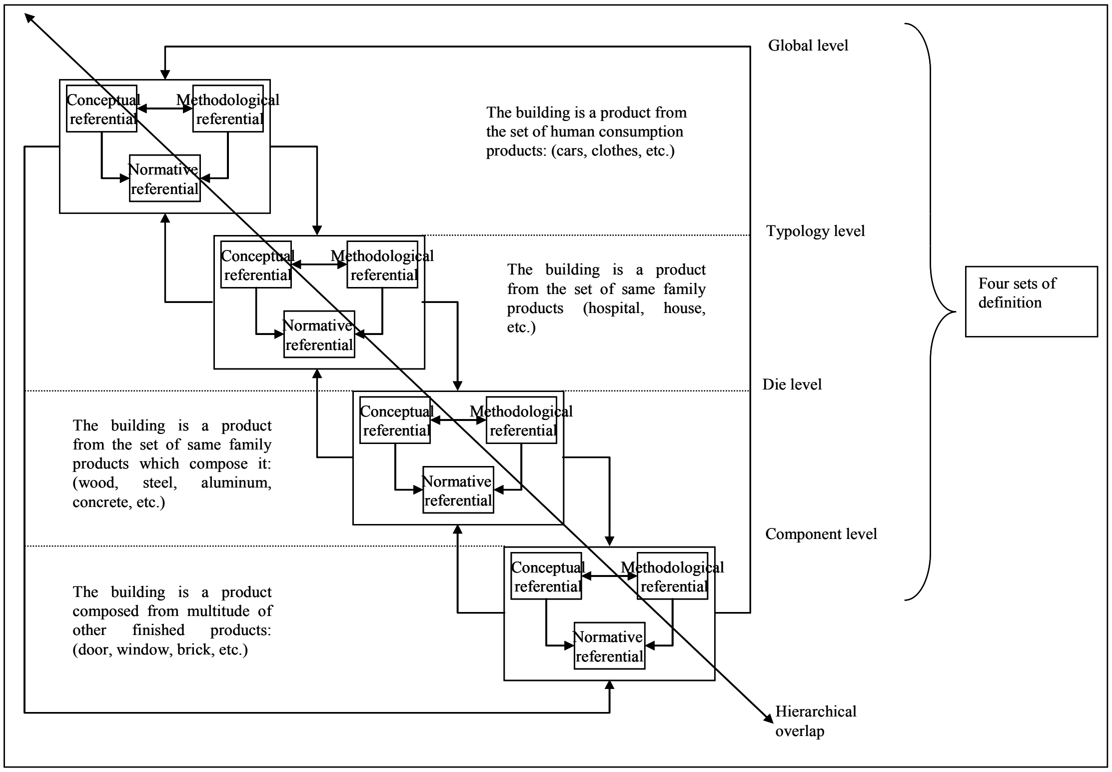

Figure 9. A Building product definition

4.4 UML model of the building system and the building product

The objective of the preceding informal conceptual models is to allow a better interworking between states. In a perspective to develop a representation adapted to data processing implementation a first formal transcription of it is presented in the (Fig. 10). It is modelled using UML formalism.

UML (Unified Modeling Language) is a means of expressing object models by disregarding their implementation; that means that the model provided by UML is valid for any programming language. UML is a language relying on a meta-model, a model of higher levels which defines the elements of UML (usable concepts) and their semantics (their significance and modes of use) [17].

In this representation all the modelled elements are regarded as objects (even if they are immaterial), able to inherit or given birth to another object, or to be associated to it [18]. Thus the "building system" object get associate with the "system’s state", "formalization" "cycle in v" objects by the respective relations "evolves", "produces" and "get organize". Those objects with which "building system" get associated, give birth to several other objects. The whole of these entities can be defined by specific attributes.

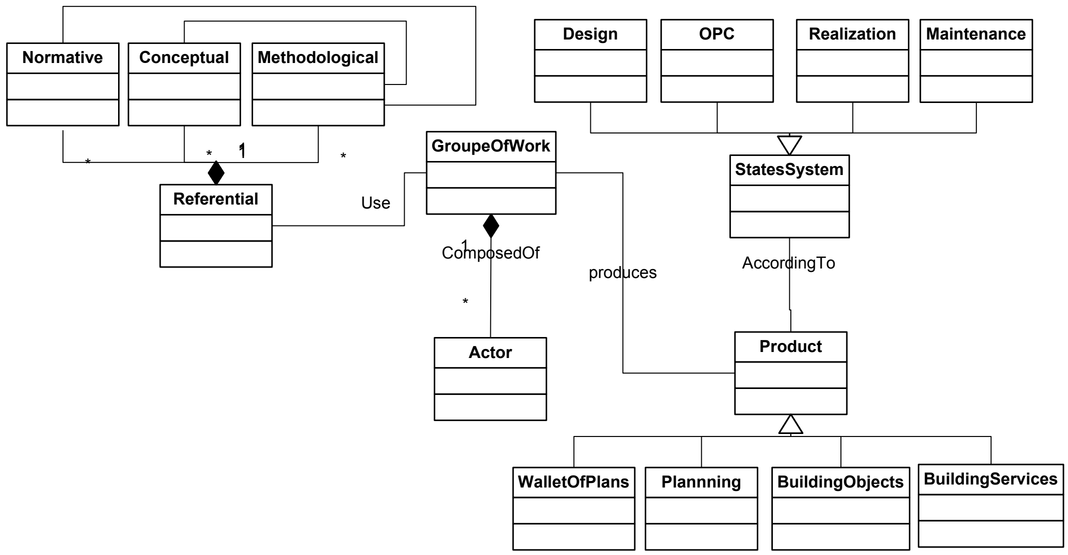

Figure 10. UML conceptual building model for interoperability

5 Validation and experimentation

Apply cooperative design in the actual context of the building sector is not easy to do. The traditional sequential approaches are still used in the background. In order to change this fact, the model of IAI (cf. chapter 2) regroups more than 300 software companies in all over the world, and in spit of this colossal mobilisation, the IFC model witch exists since ten years, is timidly used just for some experimentations.

Our model was experimented in a case of studies in the school of architecture of Marseille-Luminy. It was used in a workshop by students to work out a project presented to a committee in order to obtain the diploma of architect [19]. It servers also, to the development of a more detailed model for the aided design (by developing the referential introduced in chapter 3) [20]. The model is still in development and aim to be a complete representation of the building design process.

6 Conclusion

Setting up a framework of interoperability in the building sector should pass initially by a conceptual level of modelling. The various current models which are used as a basis for the collaborative design deal with only a part of the reality of the building product. These models reduce the building product to an assembly of physical objects. The paper proposed through a product definition more general and more complete model, taking base on a systemic approach and formalized in UML language. The application of our proposals in the background is very difficult for the moment, because of the traditional character of the building sector. Other models, even very important are still in the stage of experimentation and pain to be applied concretely too.

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