METHODOLOGY FOR INFORMATION FLOW MANAGEMENT IN THE COMMISSIONING OF LOW ENERGY BUILDINGS

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ABSTRACT:

Commissioning as a quality process plays an important role in the good progress of the design process of a building, especially in the case of a low energy building. This is due to the importance of the stakes and the technicality that go with such a project. This research project aims at assisting the designer and the commissioning committee in their respective goals. This assistance should allow sharing and avoid losing information through the different phases of the building design. We aim at creating a methodology to help building actors with the design decision and evaluation processes. This approach will lead in the near future to a software tool prototype. This prototype will allow applying this approach to all phases of the building life cycle.

KEYS WORDS: Architectural design, Commissioning, Low energy building, Flow of information.

I. INTRODUCTION

Low energy buildings are of great interest, in particular in current research. In fact, numerous solutions are explored to fit this need. Nevertheless, in many cases, low energy buildings did not achieve the expected performance. To increase the probability to meet the performance required by the owner, it is important to include in the building life cycle (design/construction/occupancy and maintenance) a quality control process such as commissioning.

The design and commissioning of low energy buildings are confronted with important difficulties. These are due to the transmission, the sharing and the loss of useful information along the building life cycle. Indeed, many testimonies (resulting from an investigation that was conducted by inquiries during the preparation of this study) illustrate that the different actors of the building meet problems (because of their different needs concerning data and their use of various tools) to communicate and to exploit in an optimal way the information they manipulate.

In order to avoid these difficulties, our research aims at assisting the actors of the building with the evaluation and the validation of the energy performance and comfort. Recent projects dealt with the integration of commissioning in the building life cycle. Notably, J.M. Hauglustaine presented work on sketch level [1-3], others on building occupancy [4,5] or on comfort and performance acceptance [6]. These works concentrated on one phase of the building life cycle. O.Akin developed an approach to integrate the commissioning of HVAC systems in the complete building design process [7]. But he focuses his work on one subsystem of the building.

The aim of this paper is to illustrate a methodology developed for design team actors which integrates commissioning into their tasks, considering the building as a complex system, composed of subsystems. This integration will allow verifying if all useful information is available to each actor; it will also make a performance validation after each actor's intervention.

In section II we will detail the context of our work. Section III is devoted to the statement of the difficulties related to flow of information in the design process of low energy buildings. Section IV finally describes the approach we adopt to avoid or reduce this inconvenience.

II. CONTEXT

To decrease the greenhouse gas emission of buildings, the European commission set up a set of requirements on the energy performance of buildings [8]. On the national level, the French government decided to divide by four the building energy consumption by 2050 (Building Factor 4:"BF4") [9]. A voluntary program called "Positive

Energy Building" was created to reach energy independence of the building.

II.1 Complexity of Building Factor 4 designs

Those new requirements have considerably influenced the way the design team approaches the conception of the building. Indeed, the success of a current building architectural design is to obtain a coherent system. This coherence is based on the following set of key factors: urban regulation, architecture, technical aspect, functionality, comfort, maintenance, durability and cost [10]. These «multicriteria» and therefore «multiactor» aspects make the realisation of the owner's objectives really difficult.

On the other hand, the design of low energy buildings requires particular attention in the choice of the envelope features of the building, the ventilation and heating systems, the energy used and the internal gains, notably from occupants and equipment [11]. All these criteria should have a coherent interaction, all along the building life cycle. To manage such a large amount of information related to different actors and criteria, it is important to set up a suitable control process.

II.2 The integration of commissioning on Buildings Factor 4 design

Commissioning is associated in the English approach to the acceptance phase of the building [12]. Previous work in Annex 40 [13] illustrates the interest in application of this approach to all phases of the building life cycle. In fact, commissioning can insure that there is no drift in any stage of progress of the design process and that the project is in coherence with the owner requirements. Another important point included in the latter is that it enables verification that the design team takes into account all the data they need to realise this operation properly.

Considering the reports concerning the difficulties met throughout the design phase and especially at the level of circulation of the information, it is imperative to relate the conception of low energy building with a rigorous commissioning process.

III. PROBLEMATIC BOUND TO THE FLUX OF INFORMATION

Along the building life cycle, the set of actors accumulates a very important quantity of heterogeneous information. They start with the detailed program relating the needs and constraints given out by the owner, then files describing the general aspects of the building (for example: concepts, functionality, construction, technique, equipment), followed by description of it's components and its operation and maintenance.

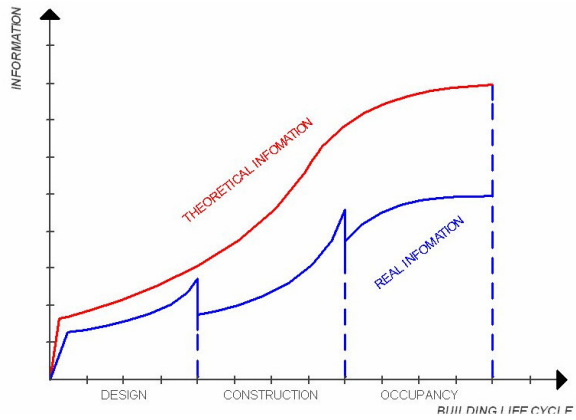

Figure 1: Representation of the flux of information along the building life cycle (Inspired on Baumann presentation)

We could represent the accumulation of information by an exponential curve until the occupancy phase where it increases softly (Figure 1). This curve gives us a vision of the speed of agglomeration of information through the phases of design and construction. Nevertheless, this representation is only theoretical. In reality, and as O.Baumann presented on prekickoff annex 47 meeting [14], an important part of that information disappears. The real curve looks more like the segmented curve represented in Figure 1. These information losses are due to several reasons, in particular, the failings in their transmission by the actors, the change of activities, the lack of efficient communication system, the lack of capability to organise the information into a hierarchy regarding the actors and building phases and the inefficiency of the procedures for making conclusions at the end of each phase.

Important breakpoints illustrated on the real information curve in Figure 1 are located on the passage between the major stages of the building life cycle. They appear between the design and construction phases, between the construction and occupancy phases and eventually in case of operator change.

These breakpoints correspond to passage of important documents. In order, we have the DCE "Dossier de Consultation des Enterprises" and the DOE "Dossier des Ouvrages Executés" (Figure 2) [15]. These files represent French regulations respective to contractual documents required to close design and construction steps.

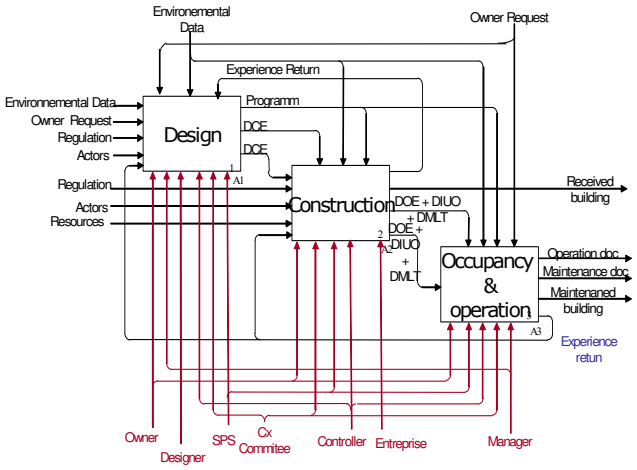

Figure 2: Representation of information flow through the major stages of the building life cycle

The lack that these two files knows, hinders very strongly the realization process, therefore, the performances described clearly (in the best cases) by the owner on the program of the project.

We concentrate our research on analysis of the "Design" phase to explore the efficiency of the methodology we will develop.

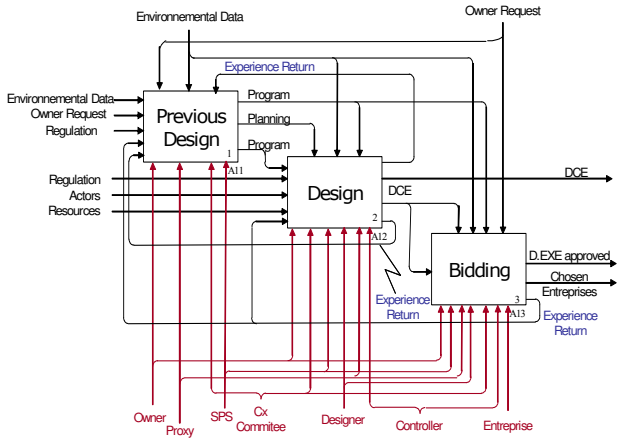

Figure 3: Representation of the flow of information across the design phase

The Figure 3 represents the circulation of the flow of information implemented with IDEF0[1] diagram [19]. This diagram allows us to describe different stages of this phase. It presents the necessary information in entries of each stage as well as those produced in exits. It puts in evidence the return of information from one stage to another. It also permits represention of the mechanisms (tools, actors…) that interfere in each step and the necessary constraints to the starting point of every one first, followed by those who influence its progress.

[1] IDEF0 is a method designed to model the decisions, actions, and activities of an organization or system.

To confirm our preliminary reports and hypothesis, an investigation implying all actors of the building (for example: an owner, an architect, an HVAC engineer, a manufacturer) has been conducted. The aim of this investigation was to evaluate the needs of the actors in term of tools, of decision aids and commissioning assistance firstly, then to know the difficulties that they meet when they deal with the conception of low energy buildings.

These investigations informed us a lot on the problems due to the circulation of information, to the apprehension of it by the actors, to the capitalization of it, as well as other problems met in the design of this type of buildings.

To synthesize the bibliographical review and the preliminary conclusions resulting from our investigation, we outline in the next section the major questions that arise.

III.1 Difficulties in the information flow along Building Factor 4 design process

III.1.1. Difficulties due to information circulation

The basic questions regarding the information flow are: Which information must circulate all along the low energy building design process? Are they all important for every stage? Do they (all information) have to be available at all stages of the conception? Are they all important to all actors?

We are going to try to answer summarily those that led us to our methodology. We will base our solution on the formation provided by the bibliographical review and our investigation.

What information circulates in this type of project?

The low energy building design necessitates an important quantity of information. This information concerns the envelope of the building: its orientation, its formal compactness, its solar and natural light apertures, its insulation [11]; the energy choice: multi energy, renewable energy or conventional; the systems choice: furnaces, heat pump, earth to air heat exchanger, solar and photovoltaic collector and other technologies tried or applied [16]; without forgetting to hold internal gains due to the occupants, plug loads and the lighting system [11].

To ensure a good behaviour of the building and to provide desired performance, it is necessary that all these data work like a unique and coherent system. To arrive at this, an "accurate" management of all these data is essential.

How to know the information impact (importance)?

It is not always pertinent to get all information. Indeed, "an excess of information kills information…". For each stage, and for each actor, it is necessary to have the useful information according to the level of progress.

In fact, providing too much or not enough information will strongly alter the design process. The actors would get lost if they try to take into account too much information, or if they do not have enough data.

Do we have to disregard or to eliminate some information?

No! It is good to keep all the information. This information could be useful at one of the steps of the building life cycle. However, it is useful and essential that every actor organizes the information, so that it can be used efficiently.

How to capitalize all the information?

Concerted engineering is a concept which is very widespread [10] in the architectural design domain. It is considered as a solution to the divergences which exist between the different stages of construction. These problems are also met in the facilities management domain [17]. In this domain, all trades have to share information bound to the facilities. On this account, many solutions aim to centralise and standardize the information [17]. This action permits all actors in facilities management to reach information, or to add modifications that are built-in and shared by them in a common reference data base. The IFC[2] are one of the solutions adopted to standardise this information [18].

Up to a point, this solution can be very interesting when we have to assemble, to structure and to digitize information. Nevertheless, it is difficult to apply it to all information in the building design process. For example, it is not possible to do it with freehand sketches (Figure 4).

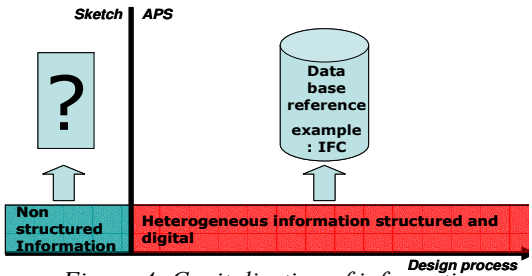

Figure 4: Capitalization of information

[2] **IFC** (Industry Foundation Classes)

III.1.2. Difficulties of the apprehension of information by the actors:

The common points between the different building actors are the program, the delays and the budget given out by the owner (sometimes attended by a proxy or the Design professional). In spite of the fact that they work all with the same program as the basis, and aim of their response (following their remuneration), every actor will try by his contribution to enhance his activity. This is because each of them has his own reference, which is used as a basis to extract and to produce information (Figure 5).

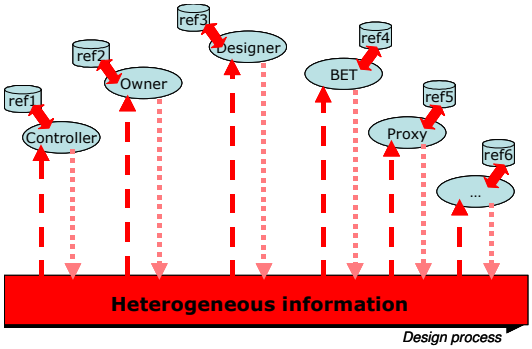

Figure 5: Representation of the use of information by the actors

In fact, the problem illustrated in Figure 5 is caused by the way the actors take up the information. The information accumulated throughout the design phases will serve to supply and to be supplied by the different trade guilds within the design process. Of course, the architect, the concrete engineer or the HVAC engineer don't need the same information to progress, because each of them has his own knowledge and his own mission. They are going to extract the information that corresponds to what we could call their own reference. The difficulty here is that very often, these actors don't really take "all" the information that relates to their work. This is due to the lake of knowledge of each actor knows about the global project. Using this partial information, the actors produce partial results.

How can all actors be provided a global and comprehensible vision of the project, its functional direction and the key points of its use?

Lots of studies have attempted to answer this question. They stipulate that shared knowledge by all actors allows better collaboration between the different actors of the design team and future building operators.

With this global knowledge the different actors (notably the future operator) can identify the useful

information for their mission. It remains to determine how to arrive at the definition of the global reference knowledge (Figure 6).

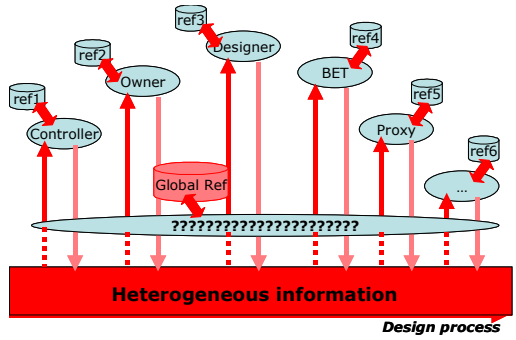

Figure 6:The global knowledge needed to resolve problems of multiple reference points of the actors

III.1.3. Complexity of multiples references in the design process

We spoke in the previous points about the project reference data base, an actor reference knowledge and the technical complexity of low energy buildings which can be preserved in another reference system we will name the "technical reference".

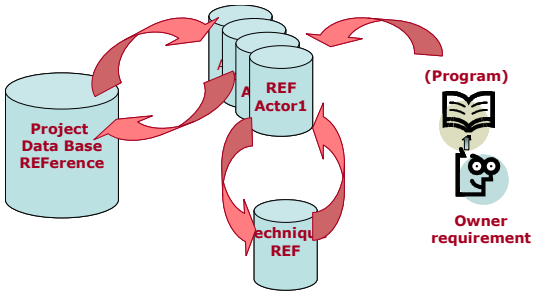

Figure 7: Representation of the different references intervening in the conception of low energy builduing

The aggregation of these different references (Figure 7) implies a complexity which we will have to manage.

III.1.4. Problems of information flow management throughout the design process

Why don't we reach the owner requiremens? How can we ensure that all actors have access to all the information they need and which is necessary to answer the owner requirements? How can we ensure that all information accumulated along the building life cycle is capitalized as well? How can we assure proper aggregation of all the references needed for the design of low energy buildings?

To answer these questions, a hypothesis was postulated on which this study is based. This hypothesis states that **commissioning as a quality control process represents the means to insure good management of information related to the performance of the building.**

To implement this hypothesis, we have constructed a bibliographical review and then a methodology. This methodology is divided into three parts which we consider essential:

- Decision aid
- Commissioning aid
- Flow information Management aid

This three steps are presented in the next section.

IV. METHODOLOGY

Much work has been done to improve and optimise the design process. These efforts aimed at guarantying that the result of this process meets with the owner's performance requirements. Nevertheless, these projects were not complete. They focus on one step of the process or one subsystem of the building system. We consider in particular four cases.

The LEMA laboratory of the University of Liege has performed studies [1-3] related to the development of a decision aid tool for the sketch phase. This tool takes into account the multiple actors and multi - criteria aspects bound to the sketching process. It integrates different performance evaluations into a sketch process. This evaluation allows verifying that performance required by the owner is achieved in the design stage (Figure 8).

Other work aimed to develop tools to assess the performance of buildings. These tools permit analysis of the information measured by sensors implanted in the buildings [4,5]. Information is valued through the usage of the system. It permits detection of all drift in a system. Nevertheless, these tools can be used in the occupancy step. The results are represented by Excel files or graphs.

The third case aims to create tools that test the specific equipment. For example: to measure the exhaust volume of a fan [6]. These types of tools permit verification of the performance of equipment in relation to its functionality and not to general functionality of the whole building. It can be used during the testing period of equipment.

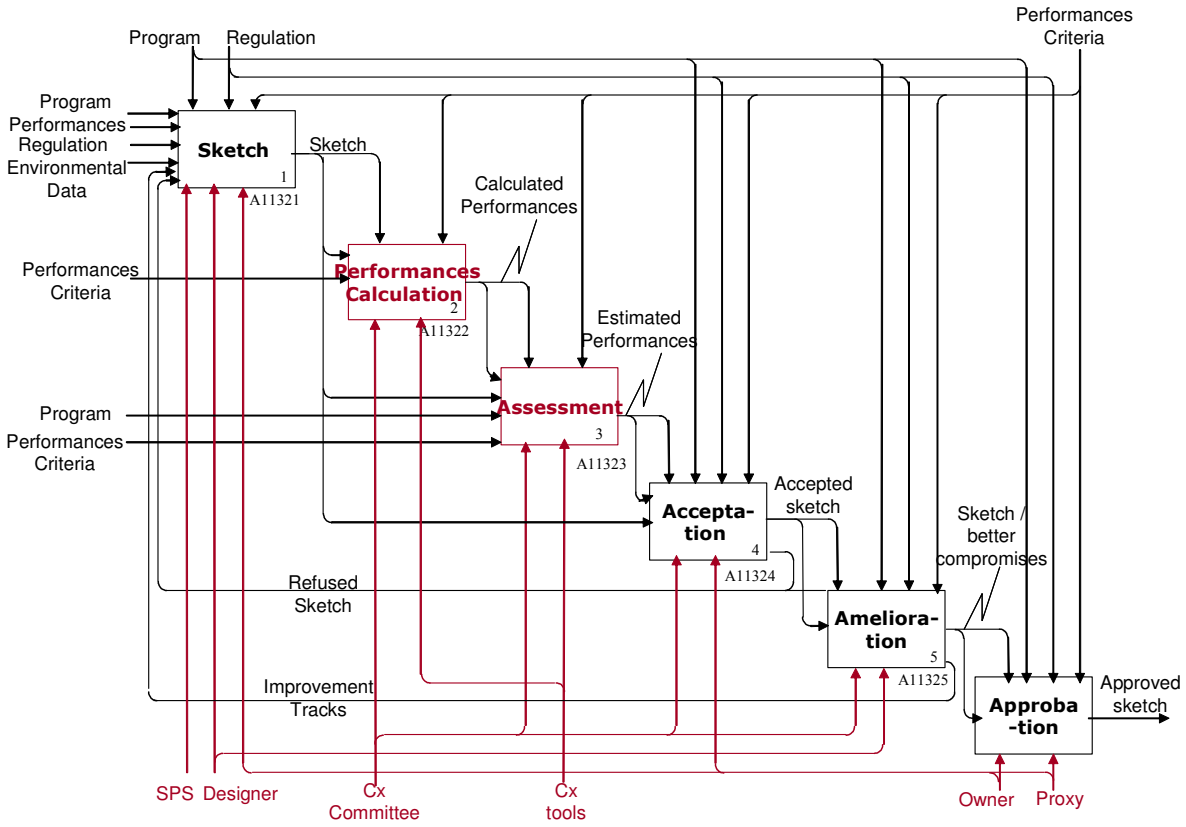

Figure 8: Representation of information flow through the process of commissioning in the Sketch phase (adapted from Hauglustaine [1], 2001)

Another case corresponds more closely to ours. It aims at integrating the process of commissioning in the entire building life cycle [7]. This study puts in place a predefined model representing the commissioning process through the design process. A second predefined model includes all information that circulates through the first model of the Commissioning process. To normalize their models they adopted the IFC. This approach is oriented towards the HVAC subsystem.

The methodology we suggest in this study comes closer to the one proposed by O. Akin [7]. It aims at covering all the design steps first and then the entire life cycle. It includes all the subsystems that compose the building system, notably, the envelope, and systems, services, and occupants.

To implement it we study firstly the design process of a low energy building. How does information circulate? Then, how can its circulation be optimized? After that, we integrate commissioning in the process. The commissioning has two fonctions in this methodology. Firstly, it permits control of the circulation of information flow; secondly, it permits the evaluation of energy performance.

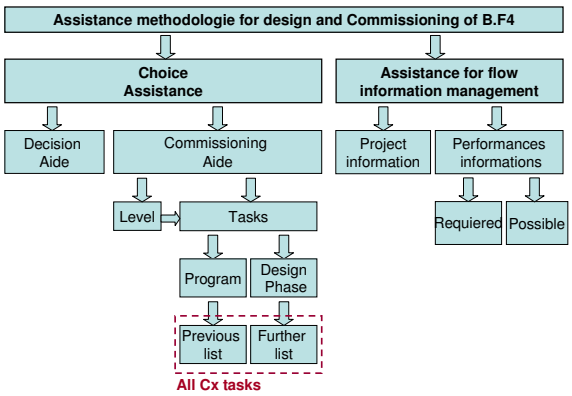

Figure 9: Representation of the structure of the methodology for information flow management

Figure 9 illustrates the structure of our methodology. We can't dissociate the study of the information flow circulation, the design and the commissioning process. We suggest in this first step of our study a global methodology which takes care of all these parameters. We aim at intervening in two levels:

1. Choice and decision assistance
2. Information flow management assistance

In the first level, the methodology will assist the building actors on:

- The choice of all parameters and aspects that compose low energy buildings (Figure 10).

- The commissioning committee in the definition of all the tasks of commissioning they have to apply in a particular low energy building. However this part will be divided in two.
  We start by defining the level (heavy, light, medium) of the commissioning to apply. This level of commissioning will give information about the preliminary list of tasks. Then this list will evolve depending on the evolution of the project. It will be completed according to new information introduced by the different choices of scenarios done by the design team.

  The results of the commissioning task will determine if we should pass to another step of the design process or not. If the results are not appropriate, another scenario will be defined by the design team. Then the new scenario will be evaluated a second time (Figure 10).

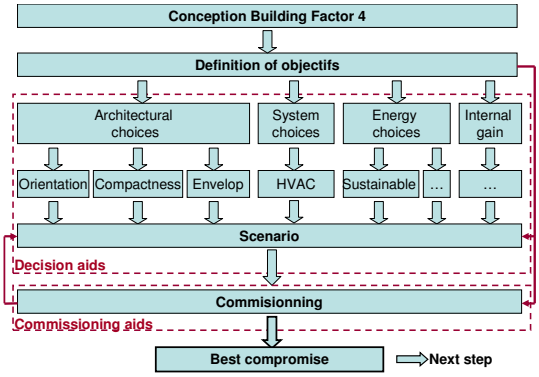

Figure 10: Representation of decision and commissioning aid methodology

In the second level, this methodology aims at providing assistance to information flow management in the design and the commissioning process.

- Firstly, this methodology will assure that the design team has on hand all the information necessary to optimize the design choices.

- Secondly, this methodology will assist the commissioning committee to extract the pertinent information to realise the task of commissioning. This assistance will be based on the information bounding of the design team choices, the owner requirements found in the program - and the environmental possibilities (Figure 11).

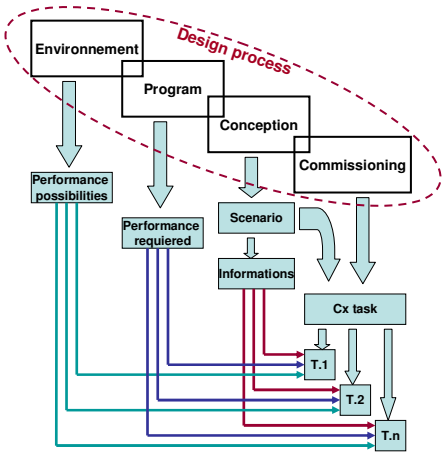

Figure 11: Representation of the methodology used for selecting the pertinent information for execution of commissioning tasks

V. CONCLUSIONS

In this article, we have tried to illustrate the need to apply a quality control process to the low energy building design process. This study introduces a methodology with steps in two levels of the low energy building design process: 1) Decision aid, and 2) commissioning assistance. This intervention will be emphasize two points: choice assistance and information flow management assistance.

Concerning choice assistance, this methodology will first, help the design team to select better components to construct the low energy building. Then it helps the commissioning committee to define the commissioning tasks which evaluate these choices.

About information flow management, this study aims at control along the design process that all the building actors get access to all the information they need to optimize their choices and execute commissioning tasks. That's what will give them all the possibilities to reach the performance required by the owner.

We will concentrate the future work on the development of a prototype tool to assist the commissioning committee on the definition and the execution of commissioning tasks. One of its functions aims at taking care of the circulation of information flow. This assistance will affect the domain of low energy buildings, particularly on the thermal aspect.

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