IDENTIFYING AND MODELING THE INTEGRATED DESIGN PROCESS OF NET ZERO ENERGY BUILDINGS

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ABSTRACT

High Performance Buildings (HPB), including Net Zero Energy Buildings (NZEBs) and nearly Zero Energy Buildings (nZEB) are emerging as an important market in Europe and around the world. However, there are very few studies that aim to model the process of HPBs and define key design processes, decisions and competencies of design teams. More importantly, there is hardly any documentation processes on tools currently being used to design high performance building. Therefore, the purpose of this paper is to identify, model and propose a generic integrated process maps for HPB. The generic process map focuses on the design phases steps, roles and tools used. The research methodology is based on literature review and a case study. With the help of a process modelling software (TIBCO), a Swiss office building (Green Office) is used to validate the produced process maps. The visual maps delivers insights on the integrated design process reporting on the means of improving the delivery of HPBs.

KEYWORDS: high performance, buildings, integrated; design process; maps, modelling

INTRODUCTION

Growing preoccupations concerning climate change, rising energy prices, human health and ecosystems preservation had led to an emergency claim for solutions in order to reduce energy consumption. This demand can be partly satisfied by the building industry. Indeed, the energy consumption of the US' residential and commercial building sector had grown from 7.9% in 2004 (IPCC 2007) to 40% in 2007 (EIA 2009). We can assume that the impact of this sector is still nowadays considerable.

An improvement in the environmental quality of the building industry would then partly stem the global depletion of natural resources. But even if technologies that would theoretically allow this improvement are already mature and economically viable, they aren't systematically used nowadays because they require an additional effort to be integrated into usual design processes which are well-known, well-developed but unfortunately insufficient in terms of performances.

The increasing demand for high performance buildings has created an opportunity to rethink and refine these design processes. This project aim to assist this transformation by putting onto paper clear, visual maps of integrated processes.

Research objectives

As a semester project, the goal of this report is to identify, model and propose a generic integrated process that can be used as a check-list to design high performance buildings with a focusing on three main questions which are resumed in figure 1:

1. The Steps: what series of phases an integrated process have to pass through and what are the determinant criteria for each step.

2. The Roles: repartition on the responsibilities and scope of work, who must do what, how and when.

3. The Tools: which software are used during the process and in what purpose.

The originality of this work resides in its approach. In most of the actual publications on the subject of Integrated Design Process, the focus is mainly on a single case study ([Korkmaz et al., 2010]) , on the comparison between Integrated and Conventional Design Process ([Molenaar et al., 2010] & [Molenaar et al., 2009]) or on the modelling tools that can be used in the design phase ([AIA, 2012]) but not on the process himself, the novelty in this report is the clear representation of the whole process with all steps, actors and tools compile into a single graphic.

Due to a limit of time, the conclusions of this report won't be sufficiently supported by real case study analysis. Thus, this work is only the beginning of the development of the so called generic Integrated Design Process map.

LITERATURE REVIEW

High Performance Building (HPB)

There is a global consensus on the main principles of HPB, here are the main ones:

• It has to be enough energy efficient to minimize its consumption over its whole life and so to allow mid/long term return on investment

• It needs to be a healthy place to live and work. Maximizing users' satisfaction, well-being and productivity. It is even more important because users are often more tolerant concerning comfort conditions in a HPB

• It require low impact on environment concerning endangered species, wildlife, wetlands, potable water quality, storm water disturbance, wind erosion, etc... The technologies required for these kinds of buildings are matures. The problem in located on the design process, in other words, on the appliance of these technics.

Design Performance Criteria for High Performance Buildings

According to the AIA [AIA, 2012], the consistent criteria for HPB are the following metrics:

Comfort metrics

Comfort must be the very first preoccupation of designers when creating a building whatever is its performances. Thus, the following metrics have to be closely took into account even more in a HPB.

Thermal Comfort

The temperature felt in the room must stay in a comfortable range depending on the season.

Visual Comfort

The lighting (artificial) and daylighting (natural) must be managed to avoid disturbing elements like glares or shadows.

Acoustic Comfort The level of both external and internal noises must be kept under a reasonable value.

Indoor Air Quality Include smells, humidity and C02 content in the calculation of indoor air renewal.

These metrics are fundamentals but often difficult to evaluate. Indeed, operative temperature, light sensitivity or noises tolerances can appear very different depending on individuals.

Energy consumption metrics

These metrics are objective, thus, they can be used to classify buildings into scales of energy quality.

EUI: Energy Use Intensity ratio between the real measurement of the annual energy consumption during occupancy and the building's gross square footage.

eGrid multiplier describing the electrical generation mix. It is used to relate consumption to effective emissions converting site energy to source energy in order to better understand the real environmental impact of the building.

pEUI: predicted Energy Use Intensity & EUIp : Energy Use Intensity propose Both are obtain by modeling the energy consumption. The difference between the two is that pEUI concern the energy consume on site and EUIp the source energy consumption including generation and transportation losses.

zEPI: zero Energy Performance Index ratio between the energy performance of a building and the average energy performance of similar ones (same occupancy, use, climate...). It vary from 0 (possible for zero-emission buildings) to 100.

Other resources management metrics

Many secondary metrics also need to be taken in account:

Sanitary Water Management Minimize consumption, often manage but a simple excel computation.

Storm Water Management Smart utilization of stormwater, more technical than sanitary water, it requires experts.

Impact on Wildlife, Wetlands... Animals' migration, pollution of potable water, soil erosion

We can see running thought all this non exhaustive list of criteria that the intervention and so the collaboration of many experts is necessary during the design of a HPB. The process must then create a multidisciplinary and collaborative environment among all the team members.

Adequate Design Process for High Performance Buildings

Conventional design processes are sequential, the work is done step by step. At first, architects design the building form, facade articulation and orientation, general aesthetic features, window area and placement. Only then, Engineers design the HVAC system in the context of the previously design envelope. Once the design is over, a constructor is chosen by bid. The Construction will then be executed in respect of the drawings and models created by the design team.

This method has significant advantages concerning per example the human factor by minimizing dispute risks but in an energy efficiency point of view, it is highly insufficient. Indeed, by nature, this process is rigid and linear. It decreases interaction and communication between the team members (figure 3). Thus, collaboration is weak in such a process and that put the project in danger.

Per example, no collaboration between engineer and architects during the facade design can't result in a both efficient and aesthetic as require by HPB. Similarly, the late involvement of the constructor potentially has dangerous effects: costs estimations and constructability issues aren't verified, it can result in more or less large costs growth during construction or occupancy.

Figure 4: The Mac-Leamy curve (ref 2) The Macleamy Curve (figure 42) graphically show the advantages of the integrated design process over the traditional design process concerning costs and efficiency. It illustrate the fact that, the earliest decisions are taken, the better it is. Indeed, it is much easier, less costly and more efficient to change the drawings of a building than the constructed building itself. By furnishing the main efforts during the design phase, IDP appear to be the most efficient way of obtain a high performance building for a reasonable cost.

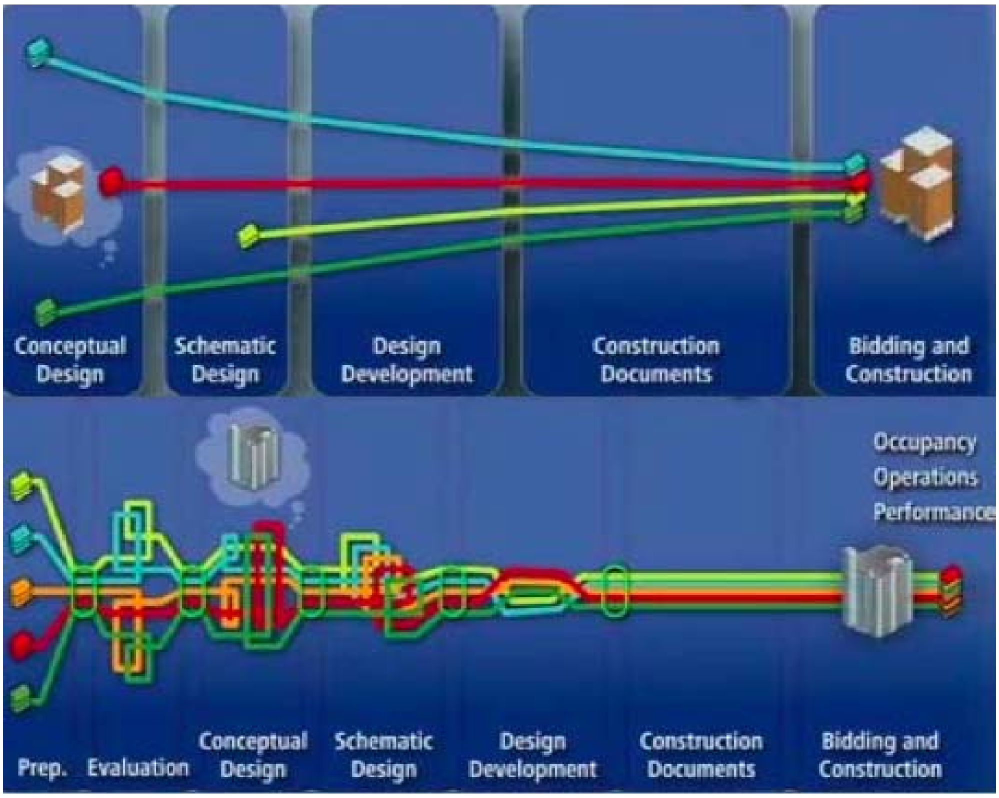

Figure 3: Conventional Design Process versus Integrated Design Process (ref Rocky Mountain Institute 2011)

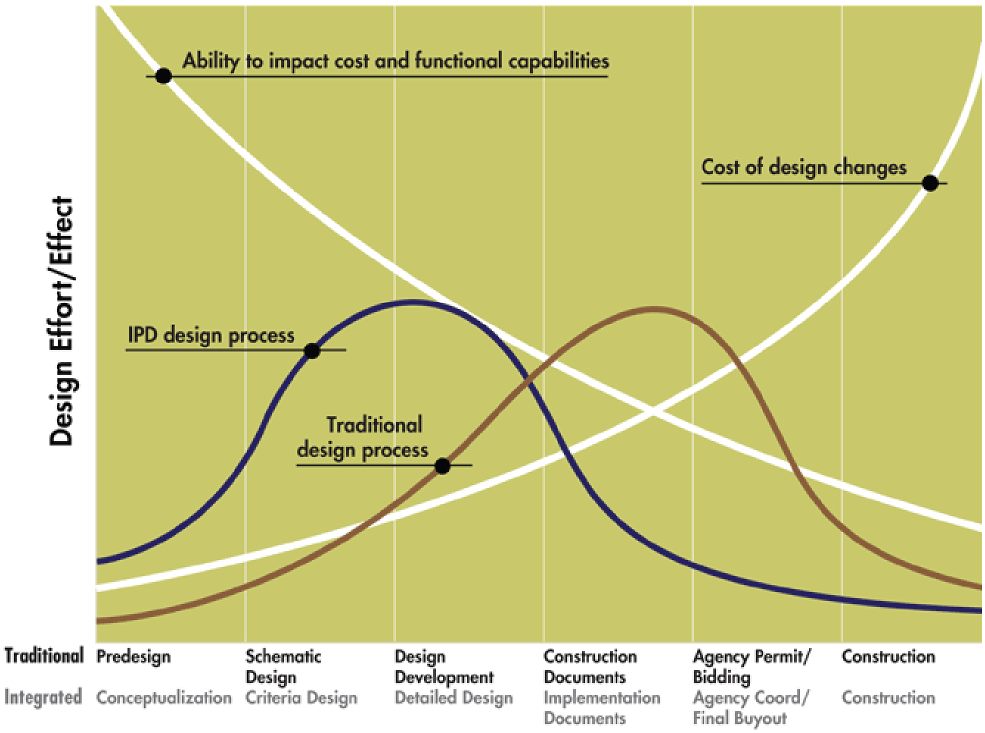

Figure 4: The Mac-Leamy curve (ref 2)

The Integrated Design Process

The concept of IDP have been developed from the need to create alternatives to Conventional design process. It consists in regrouping all the stakeholders (architects, engineers, constructor, suppliers, etc...) into a single team which will remain united from the outset to the end of the project.

IDP in Literature

The goal of this report is to synthesize the actual knowledge about integration into visual graphics of the integrated process, the require information are extracted from these papers:

References	Focus Study	Parameters	Gap	Findings
[Korkmaz et al., 2010]	The use of visualization tools in the design of an Early Childhood Learning Centre	- Influence of the Decision-Based Design Process Model - DBDPM as a design process guidance	This publication is set on a single case study,	- Wasteful approaches are common in integrated processes but can be eliminated with the help of visualization tools - Visualization tools and DBDPM are helpful but their use is a challenge
[AIA, 2007]	Information and guidance on principles and techniques of integrated project delivery	- Advantages of IPD over Traditional processes - Professional credit of IPD - Description of the IPD process	This publication is set on a single case study,	- IPD require a significant change in team members culture - Collaboration is very profitable to these changes
[AIA, 2012]	Energy modelling tools	- Communication in architectural firms - Engineers and energy modeller early involvement - Development and Usage of modelling tools	No mention of modelling tools	There is no particular findings in this study (no conclusion), it is more a catalogue of modelling tools to promote their use
[Weytjens and Verbeeck]	Results of several case studies involving design projects by architectural practices in Flanders, Belgium	- Chosen parameters involved in the design process for different case studies	No mention of modelling tools	- Sustainable design parameters differs on the project - Some parameters like system component are often addressed late in the design - Architects must consider energy and indoor climate performance in the early design stages.
[Molenaar et al., 2009]	State-of-the-art of project delivery methods	- Mind state of the building industry concerning IPD in the US	Few information about the course of the process	- Optimal Performance is easily achieve with IPD methods - The early involvement of constructor is important in meeting Sustainable Performances
[Molenaar et al., 2010]	The different levels of integration achieved in the design process depending on the design method	- Relationship between Integration and sustainable goals - Relationship between design methods and outcomes of case study projects	No descriptions of the process, nothingness on software tools	- The level of integration affects final project outcomes, especially sustainable goals - Level of integration is affected by attributes such as the owner commitment and involvement timing more than the method selected. - Green concept must be included early
[Holzer, 2009]	Understand the origin of the ongoing segregation of the different disciplines	- Connectivity and dependencies of architectural design within the overall planning process - Early design information	The course of the process is summarily addressed, it is an analysis of the problem	- The ongoing discipline segregation is naturally caused by the increasing complexity of building projects - A social effort is to be made to sense in collaborative design

	involved in building projects	requirements of designers and consultants	encountered by the building industry.	- Specific notation linked to distinct discipline are a main obstacle to information sharing

The Steps

The IDP require the complete involvement of all at the early stage of design and during all the steps of the project into a multidisciplinary and collaborative environment. It is only possible if everyone know when he must intervene and what is he asked to do, whence the necessity to graphically represent the steps. These steps can appear different depending on the project, the map presented below page will therefore require adaptation before application.

Team responsibilities

The team of an IDP is composed by all the stakeholders of the project (figure 43).

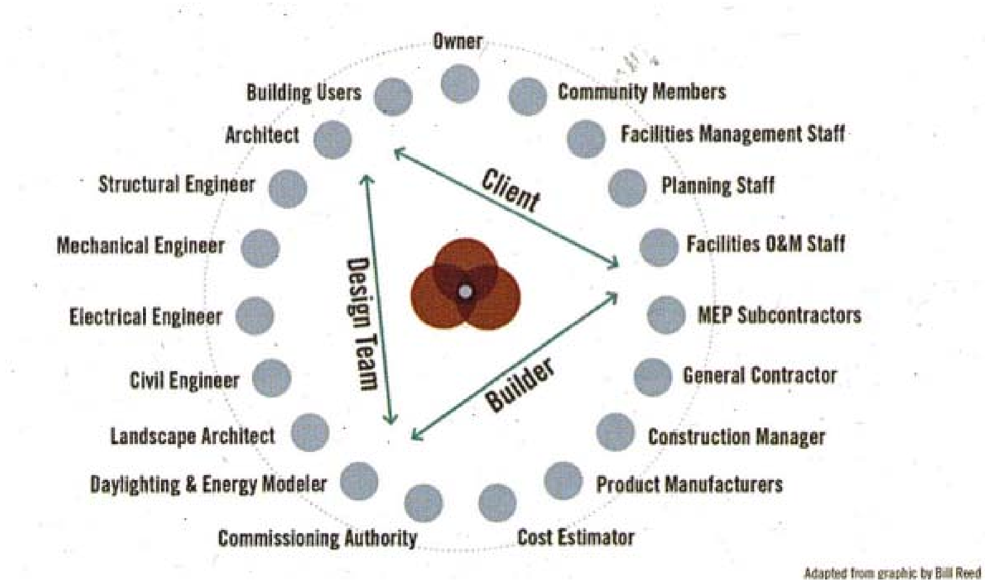

Figure 5: General Composition of an Integrated Team (ref 3)

There is no fixed schema of an IDP team composition. Depending on the project type, object, goals, or on the participants' qualifications, the required expertise can appear being very different (example of Green Offices).

The main issues to IDP are Interpersonal skills and chemistry, it is necessary to build trust and respect among the participants which is only possible if everyone knows his scope of responsibilities. These can be hard to set in function of the ability of the different players to communicate each other's. That is why IDP also require visualization tools like modelling software.

INTEGRATION OF MODELING TOOLS IN IDP

A modelling tools is a calculation engine that accept inputs (building geometry, system characteristics, operation schedule...) and produce outputs (performance comparison, compliance reports...).

These kind of tools are developed by many companies around the world, they differ in the inputs they accept, the sophistication of their engine or the character of their interface. There are many correlated reasons why performance modelling is vital to integrated design process, these reasons are explained in detailed in the literature (ref [AIA, 2012]).

Categories of software

According to the AIA, the different software used for design can be regrouped in four main categories (figure 6).

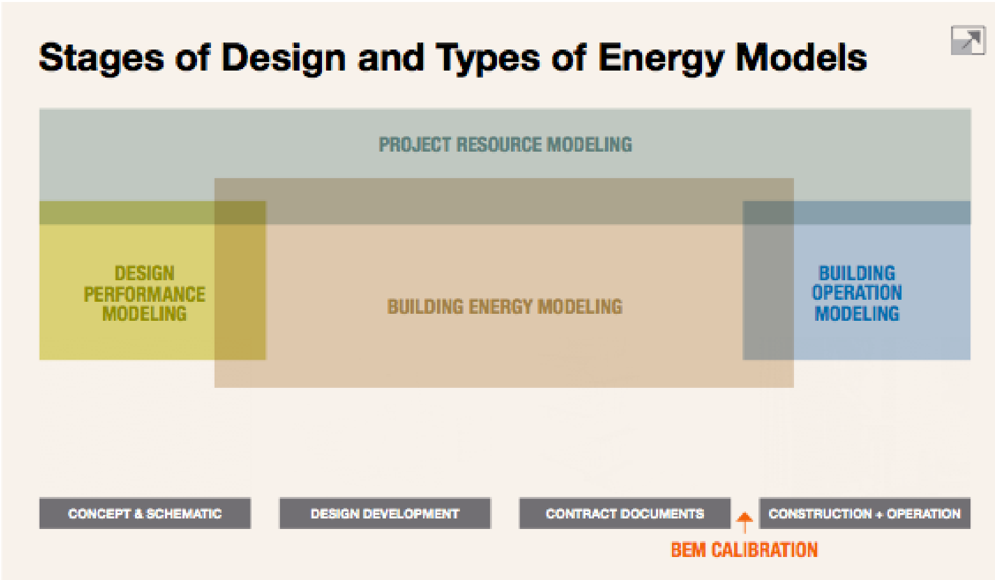

Figure 6: Categories of Tool used during the Design Process (ref [AIA, 2012])

Design Performance Modelling (DPM) less complex and time consuming than the Building Energy Modelling, this kind of software are developed in order to roughly predict building's performances in regards of energy efficiency, daylight penetration, glare control, thermal comfort, natural ventilation, and similar factors. DPM is use at the early stage of design to explore in real or almost real time a wide range of parameters.

Building Energy Modelling (BEM) Same function than the DPM but more accurate. It considers data or assumptions about building operation and maintenance.

Building Operation Modelling (BOM) Similar to BEM but base on real operation conditions (real-time weather, utility bills...). The main function of this software is the monitoring of the occupied building. It also allow the calibration of the BEM: comparison between forecast and operating consumption permit the identification of the BEM deficiencies and so to the improvement of the software usage.

Project Resource Modelling (PRM) Assesses resources issues that affect or are affected by the development of a project during the whole process. It shows the interrelationships among resources like consumption, efficiencies and conservation.

Some software can fit in many categories depending on their characteristics and possibilities.

Desirable characteristics of modelling tools

Most of all, modelling tools must be simple to use. Even if they are really powerful and complete, they have to be enough user-friendly en encourage their utilization. Indeed, due to the fact that they aren't part of the traditional methods, designers are reluctant to invest in tools they can hardly understand and control. In the following are several examples of modelling tools desirable characteristics:

- **Data transfer:** One of the most important but unfortunately still inexistent desirable characteristic of modelling tools is the ability to input data once and use it for several purpose or in several kind of modelling software.
- **Default system:** During early design phase, all the systems aren't yet designed. For those, the tool must be able to propose consistent default values that can allow simulation and comparison.
- **Robustness:** The tool must be able to deal with minor conflicts in the building design without the necessity of a human intervention.

- **Comprehensive resource:** The tool must be able to take in consideration several resource flows like water, materials, daylight, waste, comfort, etc...
- **Clear graphic outputs:** The results of the simulations must be understandable by people who aren't involved in the design process (agency, financial stakeholders...) and also allow illustrated and documented comparison.
- **Real-World performances:** This characteristic is, in a way, the most obvious. The results must reflect reality, otherwise, the forecast base on the tools outputs can appear completely dissimilar to the operating building performance. Thus, it is linked to calibration: the tool must be tested to be valuable.

The absolute objective of the building modelling tool industry is to develop the BIM (Building Information Modelling) that shall regroup all characteristics into a single software.

METHODOLOGY

The goal of this work is to propose a Generic Performance Process Map that could be used as a visual guideline support by companies in the building industry. But the development of such a map require more than a literature review of what is already existing. Indeed, the obtained model must be tested into real case studies to be consistent in the actual problematic and also to get credibility. Thus, this semester project follow a loop of development, test and review:

1. Extraction of the required information on actual integrated processes from the literature with a main focus on the three specific points (Steps, Roles, Tools).
2. Development of the maps of the design process based on the previous information.
3. Correction of the maps conceived in phase 2 during interviews of architects or engineers who were involved in HPB projects.
4. Discussion and review of the modifications in phase 3. Then comparison with literature back to phase 1.

To realize global and specific maps for IDP, the software TIBCO will be used. This software allow to draw clearly hierarchical scales, task charges suite and information flows.

RESULTS

Integrated Design Process Maps: Steps, Roles & Tools

The following documents are the ones that were presented during the interviews and on which the interviewed professional were asked to suppress, add, modify or order elements. The goal of the interview was to recompose the design process of the project they were involved in.

The Steps

Steps and associated Criteria were mainly extract from [AIA, 2007] (pages 24 to 31) and then completed by [Molenaar et al., 2010] and [Molenaar et al., 2009]. This document purpose is to give to a potential user an initial idea of what are the steps he have to pass through during his project. Full page versions in annex A.1.

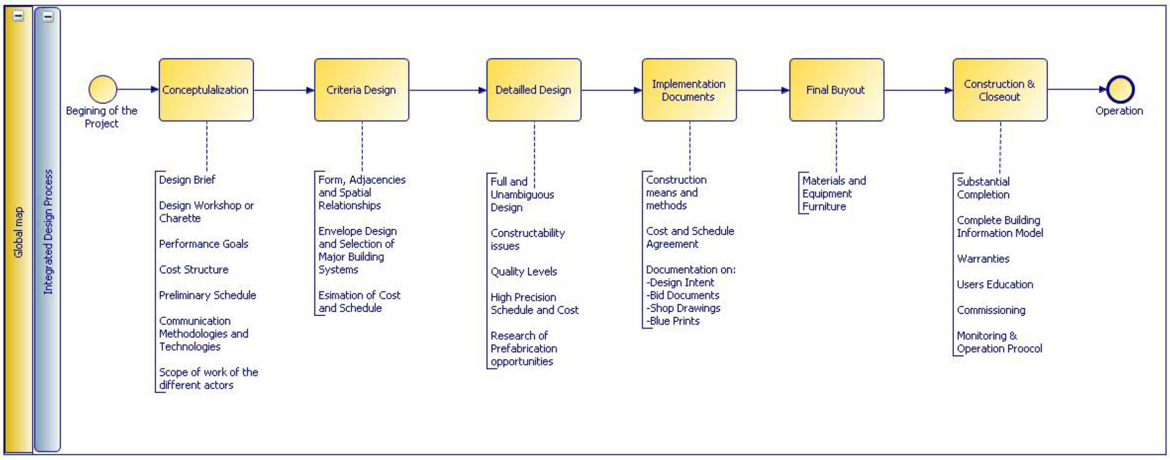

Figure 8: Global map of the integrated design process

In the following tabular, the different step of the design process are described.

Steps	Description
1. Conceptualization	1. Conceptualization What to be built, Who will build it, How it will be built
2. Criteria design	2. Criteria design Take Shape, Options Evaluated, Tested, Selected
3. Detailed design	3. Detailed design Concludes What. Documented Key decisions
4. Implementation Documents	4. Implementation Documents Complete determination and documentation
5. Buyout	5. Buyout Acquisition of all work, materials & equipment
6. Construction & Closeout	6. Construction & Closeout Commissioning, monitoring and Education of the future users

Competencies & Tools

Base on the initial model of [Korkmaz et al., 2010], the Performance Design Map was upgraded by [AIA, 2012] and the laboratory knowledge. Full page versions in annex A.2.

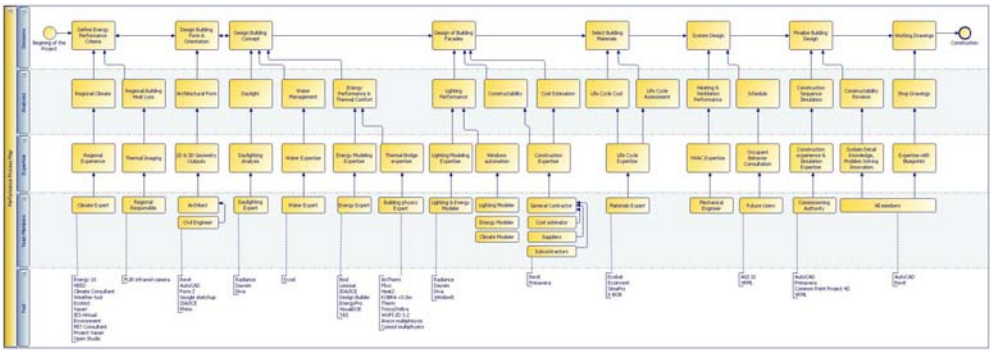

Figure 9: Performance Design Map

CASE STUDIES

Green Offices (Switzerland): knowledge and exchanges centre for sustainability

Figure 10: Green Offices Givisez, Switzerland

Conference (November the 14th 2012) and Interview (November the 20th 2012) of Mr Conrad Lutz in the complex of Lutz Architectures Sarl in Givisiez: Green Offices (figure 10 4). Green Offices is the first administrative Swiss building to receive the label Minergie-p-eco. he following tabular regroup the principal performances of this building compare to standards.

What	How much
Construction (few transformed materials)	53%
CO2 emissions	114,5%
SO2 emissions (ground and air acidity)	88%
Sanitary water	83%
Heat load (pellets stove)	89%
Hot water (mainly solar panel)	63%

It was realized by the architectural firm Lutz Architectes sárl.

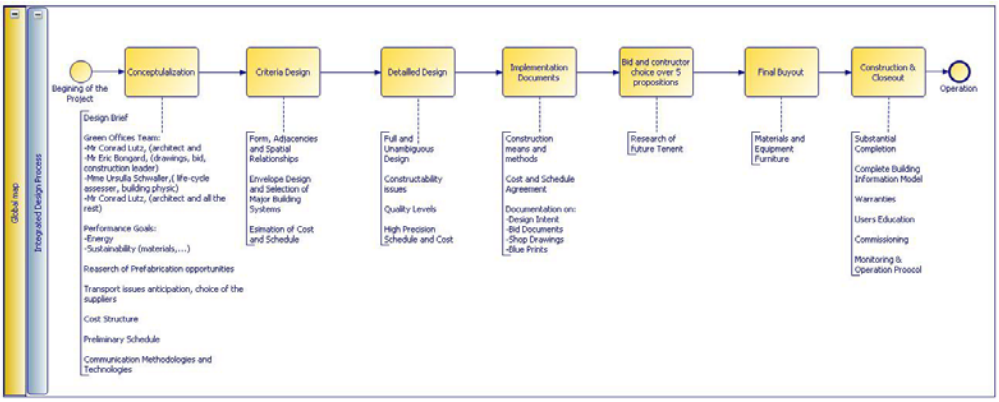

Figure 11: Global map of Green Offices

The main adds of Mr Lutz to the global map was in the conceptualization phase, he explained that all the decisions did in the beginning of the project had a great influence on the project itself. Per example, prefabrication opportunities were almost the first thing to do in order to select constructors and transportation means. Full page versions in annex A.3.

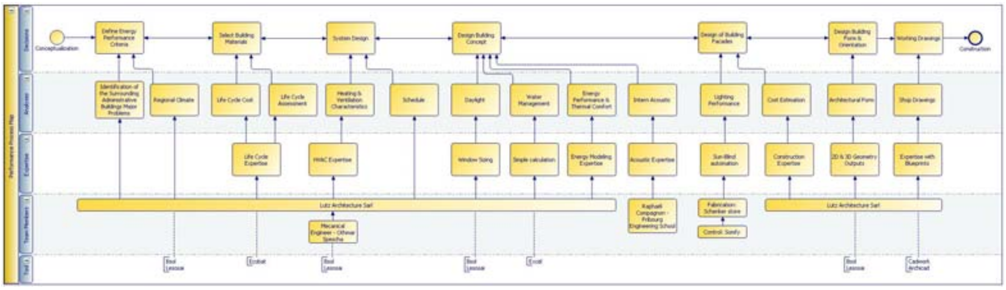

Figure 12: Performance Design Map of Green Office

This schema represent the performance design map of the Green Office Complex. Full page versions in annex A.4. The main changes are the followings:

• The way of representing wasn't appropriate because it implied that the design process were sequential, every decisions done the one after the other. The addition of double arrows mean that the process allows decisions reviews.

• Decisions were similar but some analysis hadn't been conducted (ex: thermal imaging of surrounding buildings), they were deleted.

• Expertise was only specify when extern expertise was effectively required.

• The Team members part shows which part of the design was directly handle by lutz architecture Sárl and at which step they require external help.

• The tool part was reduced to the ones used into the design in order to represent their range of action.

DISCUSSION & CONCLUSION

The obtained maps don't have the ambition to exactly represent the development process that took place during the design of Green Offices. The object of this study is not to perfectly represent the reality of case studies but more to collect elements and to receive remarks from architects, engineers or any members of the design community in order to be improved by experienced professionals and thus acquire value.

As said at the beginning of this report, the work presented here is a very inception of a standardized integrated design process, it isn't yet supported by enough case studies. Thus, there is still a lot of work to be done before to obtain a valuable result.

Another aspect that hadn't been considerate hear but stressed by Mr Lutz is the fact that the biggest challenge faced by this work is the acceptance by firms in the design industry.

FUTURE WORK

The work presented previously remain incomplete in regards of the developed maps consistency. Thus, the following tasks must now be perceived:

1. At first, more architects and engineers are to be met in order to refine, correct and complete the maps so they be representative of the building design industry state-of-the-art. In addition, meeting more professionals will make the maps known and perhaps accepted by members of this community.

2. Secondly, test the maps in the context of an ongoing project as an embedded observer, to compare in real time the course of the project and the maps. In this conditions, it is easier to cease particular and consistent elements that cannot be catch during interviews.

3. Finally, develop a planning software dedicated to design in cooperation with a computer department.

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