INTEGRATION OF HIGH ENVIRONMENTAL QUALITY COMFORT REQUIREMEMENTS DURING THE RETROFITTING OF EDUCATIONAL BUILDINGS

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ABSTRACT

A important part of educational buildings must be retrofitted in many European countries, in the next years, for historical and demographic reasons. These retrofittings must be carried out with a limitation of energy consumption and a better indoor comfort. In this context, Annex 36 of International Energy Agency aims at promoting energy efficient measurements of educational buildings in the retrofitting process. In the same time, in France, decision makers want to integrate high environmental quality comfort requirements. These requirements are defined in order to better control external environmental impacts and to create a healthy and comfortable indoor environment. However, decision makers and designers have to make face to the complexity of the retrofitting of educational buildings and of the comfort notion. In order to integrate the acoustic, visual and thermal requirements, a specific approach must be developed. This paper exposes the high comfort constraints inherent in the retrofitting of educational buildings. Then an iterative integration process is presented within a study case in Rhône-Alpes Region.

KEYWORDS

Comfort, educational building, retrofitting, environmental quality, integration process, decision makers

1. INTRODUCTION

In the next years, an important part of educational buildings will be retrofitted for historical and demographic reasons. These retrofitting project must be carried out with a limitation of energy consumption and a better indoor comfort. High requirements are defined in order to control external environmental impacts and to create a healthy and comfortable indoor environment. They must be integrated during the refurbishment process.

However, due to the lack of methods dedicated to decision makers regarding the improvement of comfort, the retrofitting project does not optimize the integration of comfort requirements. Thus, in order to integrate the acoustic, visual and thermal requirements, the complexity of the global comfort requires the development of a new approach.

In the first part, we analyse the specific high environmental quality (HQE) comfort constraints and requirements inherent in the retrofitting of educational buildings in France. Then we develop an integration methodology for comfort requirements which consists of an iterative and multiple criteria approach. At last, we show, within a study case in Rhône-Alpes Region (RRA), how this integration process can help decision makers to optimize a high quality comfort.

2. HIGH ENVIRONMENTAL QUALITY COMFORT CONSTRAINTS

2.1. Constraints during the retrofitting of educational buildings

Before proposing an integration process, the retrofitting constraints must be identified. At the opposite to a new building project, an existing building provides useful information which can be made available via a diagnosis. This will help to determine retrofitting constraints and to provide the possible technical choices for retrofitting the building. Site plan, architectural drawings, orientation, building foundations or envelop can be defined. They are many constraints to consider for the design and the accomplishment of retrofitting.
We give some important constraints related educational buildings:

- Works planning often must be coordinated with the school occupation planning. Moreover, it is possible to know the wishes of building managers, teachers and students by surveys. For example, user evaluation about existing comfort can be made before starting retrofitting project.
- Obviously economical constraints have a high weight in the retrofitting for decision makers. The choice to construct a new building or to retrofit the existing one are often made according to cost constraints. For retrofitting, several costs consideration are possible: historical cost, investment cost, realization cost, maintenance and exploitation costs, energy costs, demolition and recycling costs.
- Regulation constraints differ between retrofitting and new building. For instance, in France, building regulations about thermal, acoustic or visual comfort mainly affect new building and not retrofitting operation. However these regulations, norms or certifications give references for building actors.

2.2. High Environmental Quality comfort requirements

Usually several approaches are proposed to describe indoor comfort. However, global comfort is a complex physiologic and psychological building notion. Specific requirements are defined for each type of comfort (Tables 1, 2, 3).

TABLE 1
Acoustic requirements for a classroom

Indicators	Acoustic regulation[1]	RRA[2]	HQE[3]
Isolation with circulation	≥ 28dB(A)	≥ 32dB(A)	≥ 40dB(A)
Isolation with an other classroom	≥ 44dB(A)	≥ 43dB(A)	≥ 45dB(A)
Equipment noise level	≤ 33dB(A)	≤33dB(A)	≤25dB(A)
Reverberation Time	0.4 < T ≤ 0.8 s	0.4 < T ≤ 0.8 s	0.6 < T ≤ 0.8 s

[1] French decree 9/01/1995 - [2] Rhône-Alpes Region - [3] Acoustical engineering (GIAC)

TABLE 2
Visual requirements for a classroom

Indicators	AFE[1]	Promotelec[2]	Norm[3]	RRA = HQE
Daylight factor	-	-	> 1%	>2% (80% classrooms >2.5%)
Table illuminance Lighting uniformity	325 lux 0.8	335 lux 0.8	300 lux 0.7	335 lux 0.8
Blackboard illuminance Lighting uniformity	425 lux 0.5	400 lux 0.5	500 lux -	400 lux 0.5
Colour temperature	≅ 4000K	3000 < T < 4000K	-	3000 < T < 4000K

[1] French association recommandations - [2] French seal of quality - [3] CIE S 008/E-2001

According to the decision makers' aims, the system of reference can be different. We can find the regulation requirements, the retrofitting decision makers requirements and the High Environmental Quality ones. The last one, named HQE in France, is as a specific action developed to answer to the international demand for green building with the sustainable buildings concepts. Even if today there is not an HQE certification levels, some comfort levels can be proposed for a project.

TABLE 3
Thermal requirements for a classroom

Criteria	Indicators	French regulation[1]	RRA [2]	HQE[3]
Winter comfort	Air temperature	≤ 19 °C	≤ 19 °C	-
	Operative temperature Top	-	20°C< Top < 24°C	-
	Horizontal asymetric radiation	-	< 5°C	< 5°C
	Vertical asymetric radiation	-	< 10°C	< 10°C
	Air speed	-	< 0.15 $m.s^{-1}$	-
	Relative humidity	-	30%< Hr < 70%	-
	Vertical temperature gradient	-	< 3°C	< 4°C
Summer comfort	Air temperature	< 27°C	-	-
	Operative temperature	-	23°C< Top < 26°C	-
	Air speed	-	< 0.25 $m.s^{-1}$	-
	Relative humidity	-	30%< Hr < 70%	-
	Vertical temperature gradient	-	< 3°C	-

[1] French thermal regulation 2000 -[2] NF EN ISO 7730 -[3] System of reference

Others requirements can be added as the ventilation rate which must be superior to $18m^3/h$/person in an educational building. Thus, numerous key indicators can be used to identify comfort, but they depend on selected references: regulation, norms, HQE approach or decision makers targets. However, a classic multiple criteria evaluation of HQE approach or of comfort performances does not allow to integrate comfort requirements in a project.
Thus, the retrofitting constraints and comfort requirements being identified, a specific integration methodology can be developed.

3. DEVELOPMENT OF AN INTEGRATION METHODOLOGY

A retrofitting educational building project is a linear operation with several steps from the beginning of the project until the end of it: diagnosis, design, planning and construction. A diagnosis and comfort evaluation can represent the first step in a classic linear approach, and can also be considered as a step in the global life cycle of the educational building. So, this loop model allows to integrate comfort requirement in the lifetime of the building (Figure 1).

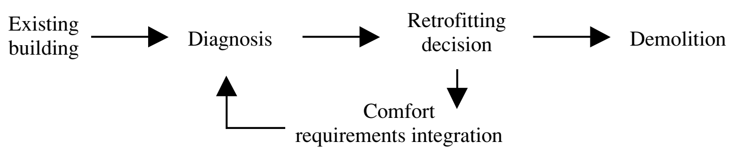

Figure 1: Global Comfort Requirements integration

Furthermore, considering the complexity of global comfort requirements, an iterative process can be planned during the retrofitting operation. Each retrofitting step allows to evaluate the integration of various comfort solutions.
For instance, between the first project version (step i) and the detailed project (step i+1), the integration process needs to identify the environment of the project: regulation, economic,

environmental constraints, building actors' contributions (i.e. architects, engineers, occupants), decisions makers' targets (i.e. Rhône-Alpes Region) and high environmental quality comfort requirements (Figure 2).

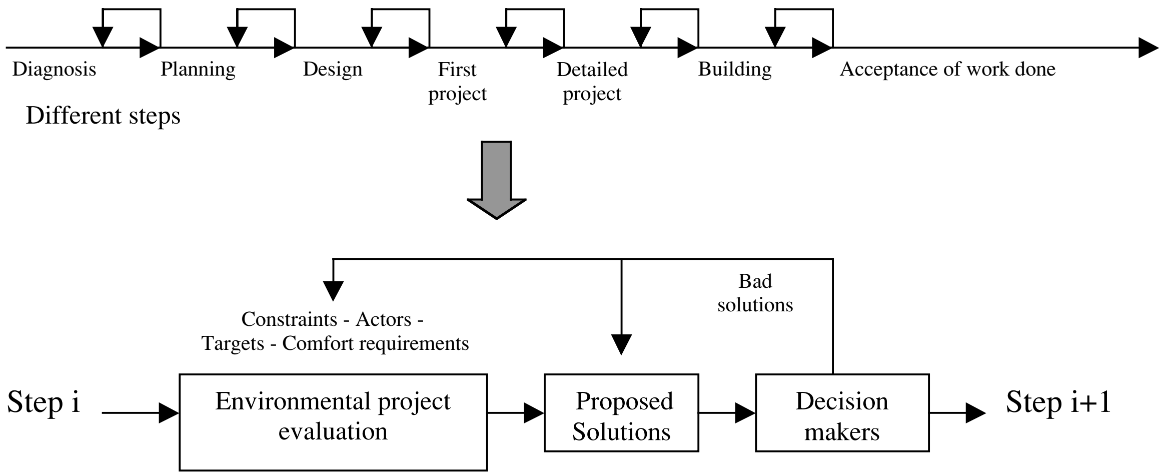

Figure 2: Iterative process of comfort requirements integration during retrofitting

With this environmental knowledge, several solutions can be proposed for the development of retrofitting project. They should be accepted by decision makers before starting a new step.
During the progress of the decision procedure, the cost criteria become more important for the decision makers. The initial environmental quality priorities about comfort are more difficult to integrate than economic priorities. Every building actor gives different value to each criterion. Thus, in order to assess and to control the integration of comfort in the retrofitting project, we propose the Promethee I methodology (Preference Ranking Organisation METHod for Enrichment Evaluations). This multiple criteria approach allows to compare different alternatives with rankings (Figure 3).

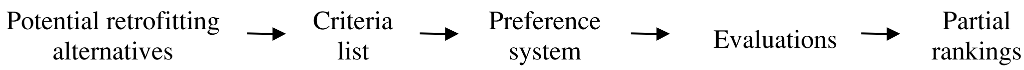

Figure 3: Main steps of Promethee I methodology

Indifference or gradual degrees of preference can be associated to the deviations observed between the evaluations. A clear view of the conflicting character of the criteria and the influence of a particular set of weights can be displayed. It allows to calculate positive preference flow (Φ+) and negative preference flow (Φ-) for each alternative. Partial rankings can be obtained. With Promethee I, decision makers have a multiple criteria decision aid which allows to determine the best retrofitting alternatives. To illustrate this methodology, we propose a case study of a French school.

4. A CASE STUDY

4.1. Project description

The Monge secondary school has been built at Chambery (France) in 1969. The study of the retrofitting project of this technical school is in progress, the decision makers being Rhône-Alpes Region. The project concerns the rehabilitation of the existing buildings and the construction of some small buildings.

The existing school is occupied by about 1800 students in various technical fields. For some activities teaching is done in large metallic structure workshops. Most of the spaces are to be refurbished because of bad conditions, lack of functionality (i.e. elevators) and overheating problems. Moreover, new educational programs require a refurbishment of the classrooms, the electricity and the computer network.
People satisfaction regarding the existing building was studied thanks to an enquiry with questionnaires. The analysis of the answers and comfort monitoring provides data about diagnosis of the existing building.
About thermal comfort, the level of temperature is good for 40% people, and acceptable for added 52%. There are overheating problems according to 60% people in the afternoon, and 30% in the morning with an overheating because of the sun for 50%. Coolness feeling exists according to 46% people in the morning.
About visual comfort, 22% have quoted sometimes a problem of poor light at the blackboard and 50% problem of reflections or glare from the blackboard.
About acoustic comfort, there is some dissatisfaction relative to noise insulation : noise from outside for 52% people, noise from neighbouring rooms for 50%, noise from corridors for 48%, noise from equipment in the room for 48%.
The Rhône-Alpes Region has specified different comfort criteria for the project: visual comfort (daylighting and artificial lighting), thermal comfort (especially summer comfort).
The retrofitting will also take into account the enhancement of the safety and the security. In this context, we study the high environmental quality comfort integration.

4.2. Application of integration methodology

In this study case, we present results obtained with a short list of main comfort criteria. The different alternative solutions are the existing building (diagnosis), the first retrofitting project, High Environmental Quality and Rhône-Alpes Region' requirements.
The table 4 shows the different performances of the criteria for each alternative retrofitting comfort solutions.

TABLE 4
Comfort performances for Monge School

Criteria / Alternatives	Diagnosis	Project	HQE	RRA
Acoustic isolation, savings in relation to regulation	- 21 dB	10 dB	35 dB	5 dB
Daylight factor	0,5%	1%	2%	2,5% (80% classrooms)
Artificial light, average blackboard illuminance	96 lux	266 lux	335 lux	335 lux
Summer comfort, occupancy time percentage with Top<26°C	55%	82%	100%	100%

Some components of the preference system used in the Promethee approach are given in the table 5.

TABLE 5
Parameters for Promethee I

Criteria / Parameters	Weight	Indifference	Preference
Acoustic isolation, savings in relation to regulation	1	1 dB	3 dB
Daylight factor	1	1%	3 %
Artificial lighting, average blackboard illuminance	1	25 lux	50 lux
Summer comfort, occupancy time percentage with Top<26°C	1	50%	10%

Promethee calculates positive and negative preference flows for each alternative. The positive flow expresses how much an alternative dominates the other one, and the negative flow how much it is dominated by the other one. Based on these flows, the Promethee I partiel ranking is obtained (Figure 5).

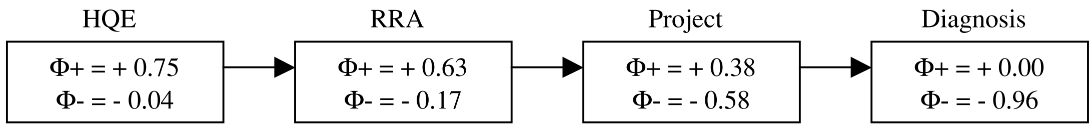

Figure 5: Promethee I partial ranking

The HQE actions dominates all the others. The difference with decision makers' solution is relative to acoustic and daylighting criteria. Then the decision makers' solution dominates the first retrofitting project and the existing diagnosis.
This study shows that the first retrofitting project for Monge secondary school can be improved if we consider HQE and decision makers' requirements by the iterative process.
However, in each use of multiple criteria approach, several analytical tests (i.e. comparison to test data, sensitivity analysis, feedback loop analysis) are necessary to validate these results. In this study case, the sensitivity analysis showed that the partial ranking is stable with variations of components of the preference system.

5. CONCLUSION

The analysis of high environmental comfort constraints and requirements leads to develop an integration process in the retrofitting of educational buildings. The proposed approach provides a new method to integrate the numerous requirements of a global comfort. Each alternative retrofitting solution can be evaluated by a partial ranking in an iterative process. For the decision makers, it allows to finalize the selection of a best comfort solution during the retrofitting operation. Thus, several actions can be studied during the different retrofitting steps of educational buildings. However, a sensitivity analysis must be applied with the multiple criteria approach. The study case shows the feasibility of this approach and illustrates some obtained results. Other study cases have to be done to complete the operational validation and to develop a systematic complete process of integration of high comfort requirements.

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