ORME: A MULTICRITERIA RANKING METHODOLOGY FOR BUILDI

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ABSTRACT

Rating or ranking techniques are often used for checking compliance with regulations, evaluating the efficiency of a retrofit, or even labelling a building. However, the building is, in most cases, rated on very few parameters – when not only one - among many building qualities that should be taken into account.

Within the frame of the Joule-Thermie OFFICE project[1], a multicriteria ranking methodology, based on the ELECTRE family algorithms, is being developed. The aim of this methodology is to rate or rank office buildings according to an extended list of parameters, including:

- energy use for heating, cooling and other appliances;
- impact on external environment;
- indoor environment quality,
- cost.

A typical application of such a method is to determine if a retrofit scenario is globally better than another one, for a given building. The contribution presents the principles used in the method, and some examples of application on real buildings. Only a summary of the methodology can be presented in this handbook. More information will be given in a complete report [Roulet et al; 1999].

KEYWORDS

Buildings, retrofit, rating, evaluation, energy, environment, comfort, multicriteria

INTRODUCTION

A rating or ranking methodology is a whole set of methods aiming to rate or to sort buildings according to some criteria. This set should contain:

- The list of criteria to be considered
- The methods to assess the considered building parameters
- A rating or ranking method to compare the assessed parameters to criteria and to rate or sort the buildings.

The method should be applicable to existing buildings, before and after retrofit, and should be able to assess the improvement gained by a retrofit.

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[1] In Switzerland, this project is sponsored by the Swiss Federal Office for Education and Science.

ORME is for Office Ranking MEtodology. The aim of ORME is to sort office buildings according to their energy use, cost, impact on external environment, and indoor environment quality. In most inter-building comparisons, and in most cases when ranking buildings, only one criterion (e.g. cost, energy use, etc.) is considered at a time. New in the methodology presented here is the use of multicriteria analysis to simultaneously take account of several criteria.

PROPOSAL FOR A RANKING METHODOLOGY

It would be convenient to follow the so-called "American" approach, and use the multiatribut utility theory to provide a method giving a kind of grade to the considered building, taking account of the most important parameters characterising the building. It should however be acknowledged that a single figure rating, combining in a smart and commonly accepted way all the figures corresponding to the various performances is difficult, if not impossible, to define. Therefore, ORME is based on an "European" approach, using a set of indices, each one addressing a particular aspect of the building performance, to establish outranking relations between buildings. The analysis of these relations allows the ranking of the buildings with respect to standards, best practice, or before-and-after retrofit performance.

Ranking methods

There are many ranking methods in a multi-criteria context. Alain Schärlig [1990] gives a complete overview with numerous examples. An "European" approach is chosen for ORME, not only because OFFICE is an European project, but mainly because it presents several important advantages for the purpose ORME is being developed:

1. Information of the partial attribute evaluation is not "lost" on the single figure indicating the overall performance. Minor advantages of many attributes do not compensate a major drawback of a single attribute.
2. The outranking relation takes into account several qualitative principles, for example the thresholds of preference, indifference or veto on the comparison of a pair of objects take into account uncertainty in the attribute evaluation, vagueness in the human preference expression, indiscernibility of very close objects.
3. Slight preference is considered as it is in reality i.e. as not transitive: When *a* is slightly preferred to *b*, and *b* to *c*, it is not certain that *a* be preferred to *c*.
4. Objects that cannot be compared are declared incomparable instead of being ranked arbitrarily.

More details on the practical use of partial aggregation methods are given by Meystre [1994] and in a newer book of Alain Schärlig [1996]. The most known and used partial aggregation methods are ELECTRE family developed by Bernard Roy [1985].

Proposed ranking method

ORME is built on the basic ideas of ELECTRE, of Roy [1985]. It also take profit of the "closeness relation" introduced by Slowinski and Stefanofski [1994].

The basic points of ORME are the following:

1. Definition of a list of criteria on which ranking is based. Their relative importance (or in other words their weight) is also assigned.
2. Definition of a standard building respecting national standards and guidelines. Definition also of one or more buildings representing best practice examples.

3. Evaluation of building performances for each individual criteria. This evaluation will be done on a physical scale. There is no need to pass to a scale of values, i.e. notes. For example energy use will be in kWh/m².
4. Comparison of performances of buildings two by two. One of these could be the standard or a best practice building. This comparison, based on absolute or relative differences, gives for each criterion a concordance index and a discordance index to the affirmation "the buildings outranks the reference and/or the best practice building"

To do so, a threshold of preference **p**, indifference **q** and veto **v** for each criterion is defined. **p** indicates the performance difference allowing a firm affirmation "**a** is preferred to **b**". If performance difference is larger than **p**, **x** outranks **s** (or **x** is preferred to **s**) with a concordance index $c_i = 1$. If the performance difference is between **q** and **p** then $0<c_i<1$. If the performance difference is between **$-q$** and **v**, the discordance index is $0<d_i<1$, and difference higher than v_i implies discordance index $d_i=1$ (i.e. strong opposition to the affirmation).

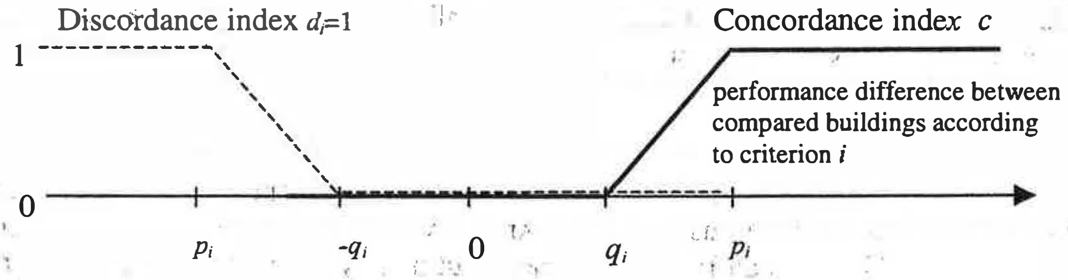

Figure 1: Definition of concordance and discordance indexes using indifference, preference and veto thresholds.

5. Once individual concordance and discordance indexes are calculated for each pair of compared buildings a global outranking relation between buildings must be established. This outranking relation is either **R** (incomparable), **P** (preferred), or **I** (indifferent).

CONSIDERED CRITERIA

In order to be practical, a multicriteria analysis should not consider too many criteria. We limited ourselves to about ten, representing an acceptable compromise between feasibility and detailed description. Those criteria, listed in Table 1, and explained below, were selected out of a list of more than 24 criteria.

Criteria related to energy use

Since energy is a flow, the boundaries of the building should be defined first. It is the envelope (walls, roof, ground) of the heated space of the building and the delivery point of purchased energy (meter, oil or liquid gas tank, coal storage area). Grey energy or energy losses upstream the building are not considered here, but in the environmental criteria. The proposed criteria (see Table 1) are normalised to gross heated floor area.

Criteria related to waste production

Waste production is estimated from the energy use, using statistical data on waste production per kWh for each fuel in Europe [Suter et al, 1996]. Waste production is normalised the same way as for energy. Among the numerous waste products generated by energy use (such as VOC's, SO_2, NO_x), we limited ourselves to CO_2 and radioactivity.

Table 1: Criteria adopted in this study, together with their indifference, preference and veto thresholds as well as average weights. Thresholds on differences are either absolute, or relative (in percent).

	Criterion		**Unit**	**Threshold levels**			**Aver. Weight**
				q_i	p_i	v_i	
Energy	Annual normalised energy use for heating	E_h	kWh/m²	10	50	100	105
	" " " for cooling	E_c	kWh/m²	10	50	100	99
	" " " for other appliances	Eo	kWh/m²	10	50	100	86
	Normalised heat loss coefficient	H	W/(K·m²)	0.1	0.3	1	95
	Normalised cost of building	C	ECU/m²	3%	50%	x 2,5	118
Env.	Annual normalised carbon gas emission	$E\ CO_2$	kg/m²	3	10	50	51
	Annual normalised nuclear wastes emission	$E\ NW$	Bq/m²	30%	50%	x 10	61
I	Predicted Percentage of Dissatisfied	PPD	%	2%	7%	15%	131
	Outdoor airflow rate per person	Qv	m³/(h.p.)	10%	50%	<10	127
	Noise level at working place	NL	dB	2	5	20	127

Criteria related to indoor environment quality (IEQ)

Thermal comfort is certainly the main criterion for IEQ. This can be assessed by the predicted mean vote (PMV) according to EN/ISO 7730 [1993] either through enquiries, or through measurements using comfort meters or thermal environment analysers.

The criteria linked to indoor environment quality are numerous, even when the list is restricted to parameters that can be assessed by simulations. For example:

- Carbon gas concentration indoors [ppm], as a measure of outdoor airflow rate per person;
- Number of people per room (planned value), to distinguish between open and cellular office buildings;
- Number of people per m² floor area, as an image of occupancy;
- Average distance between occupants and the closest window;
- Lighting level at work place;
- Noise level at workplace;
- Control of occupants on temperature, ventilation and lighting, and presence of operable windows.

Most of these parameters are difficult to assess, or cannot even be obtained. Therefore, we restricted the IEQ parameters to PPD, outdoor airflow rate per person, and noise level.

WEIGHTS

An important step is to give weights to the various criteria. The weights are the means to provide the method with the importance given to each criterion by the user of the method. Weighting is a subjective operation, and there are, *a priori,* as many sets of weights as there are experts. In order to sit the method on solid bases, we collected sets of weights from the OFFICE participants, asking them to give notes (say from 0 to 10) to each criterion from the point of view of a building owner, of an architect, and of an occupant. These sets were normalised and statistically interpreted.

It was seen that, for each criterion, there is a large dispersion of weights: the standard deviation is of the same magnitude than the average values. However, the average values (shown on Table 1) do not differ much among supposed judges (owner, architect, and user). On average, energy and IEQ criteria are judged equivalent (Table 2), and much more important than economic and environmental criteria, also judged nearly equivalent. The frequency distribution of attributed weights () also shows this difference, and an astonishing similarity between energy and IEQ on one hand, and economic and environmental criteria on the other hand.

Table 2 Statistical results form enquiry on weights for each group of criteria.

	Average				Standard Deviation			"Standard"	
	Owner	User	Archit.	Global	Owner	User	Archit.	Uniform	Equilib.
Energy	373	350	436	386	389	372	389	446	400	250
Cost	152	94	109	118	155	157	104	124	100	250
Environ.	114	100	122	112	153	184	141	166	200	250
IEQ	361	456	333	384	303	287	366	264	300	250

The last two columns of Table 2 show, for comparison, uniform weights and weights giving the same importance to each group of criteria.

SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to determine the effects of changing weights or threshold levels on the final judgement, the resulting ranking of buildings. Six European office buildings, one each from Denmark, France, Germany, Greece, and two from Switzerland were used as samples for this analysis.

Changing weights

The ranking process was applied to the six buildings using the same threshold values but all the eight received weights sets. Cost, noise level, and ventilation rate were not available at the time of this study and therefore were not taken into account.

The ranking order of the buildings was found very similar for all sets of weights. The only difference was that the Greek and German buildings were found indifferent with some weights sets, and ranked close to each other with other sets. A similar result was obtained when comparing the retrofitted and original buildings.

Changing threshold levels

For this study, we used the first nine criteria of table 1 and the global average weight set. The threshold levels for noise are fairly well defined [Rogers and Bruen, 1997] and do not need to be changed. Therefore, there are 28 threshold levels to be changed to perform the sensitivity analysis. The ELECTRE-III code was run 28 times, changing at each run several threshold levels by ±24%, according to a Plackett Burman design[2]. This study, comparing an original building and its retrofitted status has shown that

- The retrofit is better than initial in all cases.
- The concordance index of hypothesis "retrofit better than initial" does not change by more than ±3% when threshold levels are changed by ±24%
- The concordance index of hypothesis "initial better than retrofit" does not change by more than ±5% for the same conditions.

For that building at least, the results do not strongly depend on threshold levels. This study will be repeated with other buildings.

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[2] For more information on experimental design, see for example [Box, Hunter and Hunter, 1978]

CONCLUSIONS

Figure 4 shows that it is not easy to decide if a retrofit strategy clearly improves the building for all its aspects. It is however possible, using modern tools, to rank buildings according to several criteria. When ELECTRE-III is used, the rank of a building in a series does not change much when the weights given to the various criteria or the threshold levels for veto, preference or indifference are changed within a realistic range.

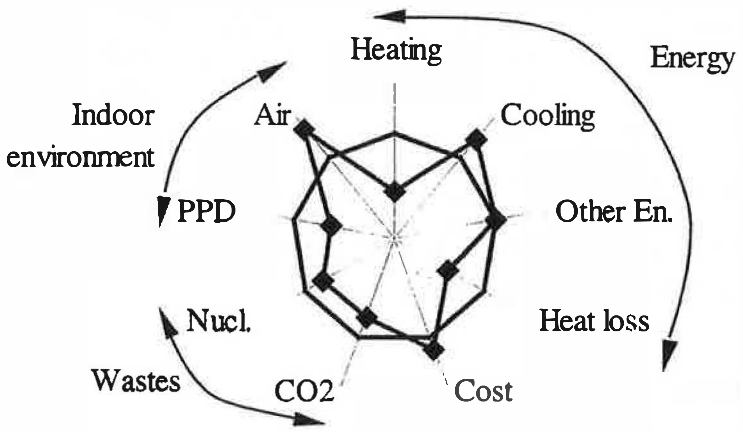

Figure 4: Ration of value after and before retrofit for nine criteria in a Swiss building. The building is better, according to a given criterion, when inside the decagon.

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