Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 09, Issue, 11, pp. 31443-31455, November, 2019

REVIEW ARTICLE OPEN ACCESS

CONTRIBUTION TO AN INFORMED CHOICE OF SOCIAL HOUSING IN CAMEROON THROUGH THE USE OF A MULTICRITERIA METHOD OF ANALYSIS: A DECISION-MAKING TOOL

[1]Alain Bernard ATANGANA TABI and *[2]Aimé ELIME BOUBOAMA

[1]Department of Civil Engineering and Urban Planning, National Advanced School of Engineering, University of Yaoundé I, P.O. Box. 8390, Yaoundé, Cameroon
[2]Departments of Industrial and Mechanical Engineering, National Advanced School of Engineering, University of Yaoundé I, P.O. Box. 8390, Yaoundé, Cameroon

ARTICLE INFO

Article History:
Received 03rd August, 2019
Received in revised form
26th September, 2019
Accepted 11th October, 2019
Published online 30th November, 2019

Key Words:
Multi-criteria analysis, Social housing, Decision support, Financial sustainability.

Corresponding author:
Aimé ELIME BOUBOAMA

ABSTRACT

Cameroon's population growth is very high and makes access to housing difficult over time. The decision-making engineering that governs production the current planning and social housing presents many weaknesses. Among them, the production rates are very insufficient and the dominant constructive system is the reinforced concrete - hollow cement bonded hitch. The major challenge of the article is to propose an alternative decision-making approach to better integrate locally abundant materials in the various agro-ecological zones of Cameroon. A detailed analysis of the socio-economic and technical data is carried out. Multicriteria analysis, coupled with fuzzy logic, classifies constructive systems according to their degree of consensus with respect to the criteria considered. For the sake of financial viabilisation, the best constructive systems are analyzed by making a comparison between the public contracting and the public-private partnership approaches. The reinforced concrete (structural material) - solid wood (wall material) system has a satisfactory overall agreement.

Citation: Alain Bernard ATANGANA TABI and Aimé ELIME BOUBOAMA. 2019. "Contribution to an informed choice of social housing in cameroon through the use of a multicriteria method of analysis: a decision-making tool", *International Journal of Development Research*, 09, (11), 31443-31455.

INTRODUCTION

This article is a contribution to inform the choice of the most suitable system to be used for the construction of social housing in Cameroon.

Building: A Complex System

A constructive system is «a group of industrialized components» (Larousse 2015). Gobin (2003) describes a building as the putting together of six functional sub-components as defined in Table 1. Therefore, a building is a complex building system in which none of the components can be analysed in isolation. The lifespan of a building includes six main phases whose description is based on (Chatagnon, 1999) and (ADEME, 2002).

The « Preparation » phase

The « Preparation » phase is the duty of the project owner (PO) in the first place.

The « Conception » phase

The conception phase is implemented by the conception team (Maître d'oeuvre, architects, BE), and it always involves four steps:design sketch, preliminary design, final design, project study, where the general conception of the project is approved by the PO.

The «Company Consultation» phase

This phase is devoted to the signature of work contracts with selected building companies.

The « Works » phase

During this phase, all stakeholders mentioned above are involved. It includes various steps:the preparation of the worksite, management (technical, administrative and financial) of the project, the acceptance of works (this phase might be completed by interior design, which calls for an interior designer).

Tableau 1. Decomposition of a building in six constructive sub-components (Gobin, 2003)

N°	Sub-component	Definition
1	Adaptation	Group of components that provide for its insertion into the site and various connections to the various networks.
2	Structure	Group of components that provide for the superposing of activity areas.
3	Body	Group of components that provide for the performing of activities safe from weather conditions (waterproof and airproof).
4	Partition	Group of components that define the boundaries of activity areas and access zones.
5	Equipment	Group of components that provide for the use of tools, the necessary power for the maintenance of the atmosphere, as well as water and power supply.
6	Perfecting	Group of components that ensure the finishing of each of the previous sub-components.

Table 1. Fixed parameters of the construction system to be considered later

7. Fix parameters	8. Parameters to be analyzed	9. Parameters to be considered later
10. -Location -Use 11. -Geometry 12. -Dimensions of doors and windows 13. - Dimension of construction elements and products	14. -Type of bearing structure 15. -Roofing materials 16. -Partition materials 17. -Structure materials	18. -Integration of water, power and ventilation supply networks 19. - Social acceptability of the construction solution 20. - choice of various technical equipment 21. - Foundation works

Table 3. List of performances of the constructive du system for each usage function (Gobin, 2003)

N°	Usage functions	Definition and targets
1	Provide space to carry out activities	Service rendered by the house that enables the customer to be provided with the necessary space to perform various actions carried out either within the family circle, or with people outside. Target : Inner dimensions
2	Protect property and tools as well as human beings	Service rendered by the house that enables the customer to preserve (but also to use) his or her property and tools in spite of the various attacks from the climate, the environment or voluntary actions of other people. Target 1: Designing of the infrastructure 22. - Resistance to the wind 23. - Resistance to shocks 24. - Resistance to earthquakes 25. - Resistance to charges 26. - Mastery of the settlement and the distortion of the infrastructure 27. 28. Target 2: Fire security - Resistance to fire - Reaction to fire Target 3: Resistance of the infrastructure - Water tightness - Air tightness - Resistance to condensation threats - Resistance to external constraints
3	Provide equipment and tools	29. Service rendered by the house that enables the customer to use tools needed by his or her activities and to enjoy his or her property. 30. 31. Target : Inclusion of networks
4	Provide an atmosphere	32. Service rendered by the house that enables the customer to adapt the inner atmosphere to the outer atmosphere. 33. 34. Target : Comfort performance 1. - Acoustic 2. - Visual 3. - Hygrothermal 4. - Olfactive 5. - Air quality 6. - Vibration of the floor
5	Master relationships	Service rendered by the house that enables the customer to filter, prevent or ease his or her contacts with other people outside and with natural elements of his or her environment. 35. Target : Designing and choice of leaves and frames
6	Interaction with the environment	Service rendered by the house that enables the customer to live within a site without adversely affecting it. 36. Target 1 :Environmental impacts 37. Target 2 : Respect of accepted covering ranges
7	Semiological function	Quality of the actual experience of the user in the house. This is what makes the difference between a set of hardscrabble technical components and the ownership of the house. Target: Type of sheathing (texture, color, etc.)

The« Utilization / exploitation » phase

When the building is constructed and accepted, it moves into the utilization phase: power, water and product consumption and waste production.

The « End of life » phase

The end of life phase of a building generally means its demolition.The building is demolished, and its constitutive materials and products are eliminated (waste disposal site or incineration) or reclaimed for recycling or re-use. This article is on the informed choice of a building system that is made essentially during the final design project. More specifically, we are interested in the structure - body – partition model (table 2). What follows in this article is therefore is at the level of the APD phase of the design of a building. Many parameters are fixed before and define a global solution.

Performance criteria and requirements for the sustainable management of constructive systems

The overall process of constructing a building has as final end to offer optimal conditions for the user to carry out his or her activities. According to Gobin, seven indispensable usage functions may clarify these conditions (Gobin 2003). They help to carry out a certain number of tasks, taking into account external physical perturbations (climate, bad weather, environment) as well as social ones (communities, other users of the building, regulatory bodies). The design of a sob-component or component of the building involves the listing of envisaged performances according to each of the defined usage functions. In the case of a constructive system, the envisaged usage performances are summarized in Table 3. Economic La characterization is not included in the list of usage performances, because as pointed out by Gobin (Gobin 2003), the notion of cost does not exist physically. However, it corresponds with a protocol that is found in the choice of performances. Similarly, the industrialization, transport and lifting capacities of the constructive system are not represented, because they are not also part of usage performances. However, as economic characterization, they play a key role in the design process.

Choice of the Architecture Model of the Building

Description of the model of the building hosting social housing: As construction model for social housing, a four-storey building was chosen, including a ground floor and four levels with identical room configuration (Figure 1). Each level is made up of four apartments of T3 type, each covering 83.6 m², and two apartments of T4 type, with a surface area of 117.36 m² each. The choice of this model is justified on the first hand by the fact that itwas inspired by the buildings constructed by SIC Company in Yaoundé Mfandena, and also by the fact it complies with the requirements of Order No. N009/E/2/MINDUH of 21 August 2008 (MINDUH, 2008) to restrict the number of storeys in a building destined for collective use to four and the maximum height to sixteen meters.

Defining the Problemand Multicritria

The multi-criteria problem raised in this article is that of prioritizing the choice of constructive solutions (structure – body – partition), compatible with the requirements of sustainable development of social housing.The choice decision can thus be guided by a selection arising from the allocation of each solution to a given category or by their classification (from the most profitable to the less profitable for example). To specify the problem better, three components should be defined: the identification and the justification of criteria translating the viewpoints of actors, the definition of a set of potential choices (predictable constructive solutions) and the drafting of a preferential structure within each criterion (Mangin, 2004).

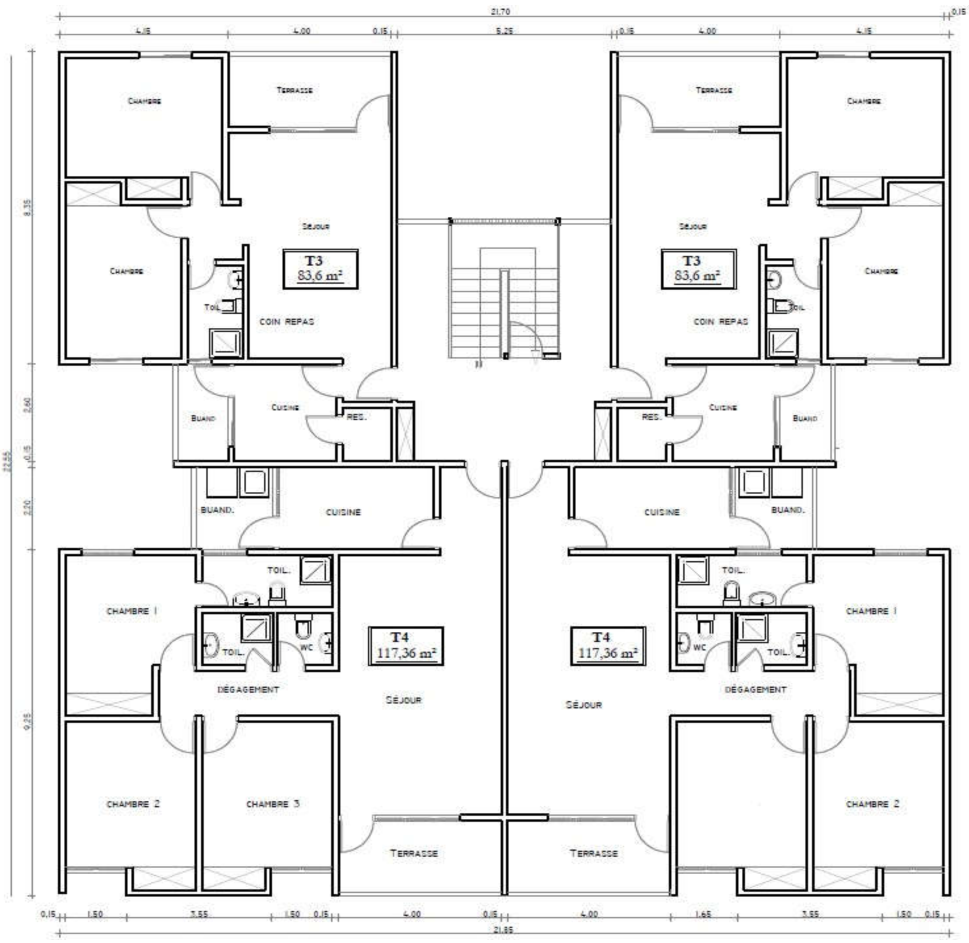

Figure 1. Plan of the standard storey of the model of the building under consideration

Table 4. Summary of selected criteria of choice

Environmental criteria	Health criteria	Technical performance criteria	Socio-economic criteria
- Climate change (CO_2 emissions) - Water consumption during construction phase	Chemical pollutant emission potential into surrounding water sources	- Acoustic comfort - Fire security - Hygrothermal comfort	Cost of works Duration of works

Table 5. Required elements of constructive solutions considered

Structure	Body	Partition	Floor	Roof
Reinforced concrete	Hollow concrete blocks of 15 + mortar and cement coating	Hollow concrete blocks of 12 + mortar and cement coating	Voided slab 16+4	7/10th aluminum thick sheets
Glued laminated wood	Earth blocks stabilized with cement	Hollow concrete blocks of 12 + paneling over the 2 sides	12 cm-thick reinforced concrete solid floor	Vibro-cement tiles
	Stacked plank lumber (solid wood)	Stacked plank lumber	Mixed floor wood-concrete	Vibro-cement tiles

Identification and justification of criteria

A criterion is the qualitative or quantitative expression of a viewpoint, aptitudes or objectives on the basis of which a judgment can be made. In order to get closer to requirements for a sustainable management of social housing, three types of criteria are usually used, namely:

- **Ecological criteria**: environmental and health impacts and availability of building materials.
- **Performance criteria of constructive systems**: Resistance to fire, duration of construction works and thermal comfort.
- **Socio-economic criteria**: the implementation cost of systems, the social impact of constructive solutions and the duration of works.

Set of choices: The set of choices refers to the set of actions on which the choice of the decision-maker will be made. This corpus includes 84 constructive solutions aimed at providing social housing in Cameroon. Each envisaged solution is a mix of the following sub-components elements presented in Table 5. The combination of required elements resulted in 84 possible constructive systems (Table 6).

Preference structure: The preference structure is designedbased on an indicator that correctly indicates the criterion and helps to differentiate the performance of each action.

Resistance to fire criterion: This criterion was assessed on the basis of the French method described in the Order of 21 April 1983 to determine the element's degree to Resistance to fire.

Water consumption during construction works criterion: This criterion indicates the quantity of water needed to use the various volumes of building materials. The preferred value of this criterion is decreasing.

Climate change: Climate change is assessed by quantifying the mass of CO2 emissions of each constructive system. This criterion is preferably decreasing.

Acoustic comfort: For this criterion, the acoustic fading index of air noise will be used as indicator. It will be assessed on the basis of the mass rule (equation 2.3) (Arlaud et al., 2005).
With:

$\boldsymbol{Rw} = -15 + \mathbf{118}\boldsymbol{M} - \mathbf{119}\boldsymbol{M}\mathbf{2} + \mathbf{50}\boldsymbol{M}\mathbf{3} - \mathbf{7}$; (2.3)
RwAcoustic fading index
$M = \log(m)$; $m in kg/m^2$ ($mass$ of $unit f per surface$unit)

METHODOLOGY

Comparative analysis of some aids to multi-criteria choice: The most used aids to multi-criteria choice in dealing with the challenges cited earlier include the Analytical Hierarchy Process (AHP) (Saaty, 1990) and the Multi Attribute Utility Theory (MAUT) (Abdellaoui et Gonzales, 2013). AHP is a method used to solve very complex issues where the user's judgment and experience are needed, while speeding up the decision-making process. It's one of the most widely used ads to multi-criteria choice because it helps the decision maker to identify his problem, and most precisely because it proposes a method to assess important parameters. It uses binary combinations of each hierarchical level compared to elements of the higher level. AHP involves four steps:

Step 1: prioritizing criteria and sub-criteria, from the most important to the least important.
Step 2: Devising a matrix by comparing criteria on a two by two basis. As a matter of fact, the various branches of the same level are compared two by two by giving a score between 1 and 9 depending on how we perceive the difference between the two criteria. As such, we are provided with all this value system to fill this matrix called judgment matrix, binary comparison matrix or relative importance matrix.
Step 3: Once the matrix is obtained, we proceed to carry out successive transformations in order to get to the weight values associated to each objective. The most common transformations include the matrix normalization method.
Step 4: Then we proceed to verify the consistency of the result.

AHP has many advantages, including the attainment of a compromise between the various opinions, taking into account the inter-dependence of elements and assessing the logical coherence of the opinions used. However, building up the priority of criteria (through binary comparison for instance) means that we implicitly admit that all the criteria can perfectly be compared with each other, and this could be difficult to prove. In our own case, it is theoretically difficult to prove that CO2 emission is 2, 3 or 4 times higher than resistance to fire for a given constructive system and vice versa. Also, the implementation of this technique may not be easy in this case which involve many actors (ecologists, wood industrialists, engineers, architects, potential beneficiaries, and geotechnical engineers), a host of criteria (about ten) and alternatives (84 systems that have to be compared. Under such conditions, the risk for incoherence becomes higher. Another disadvantage of AHP has to do with normalization mentioned in step 3, which, in our analysis, may pose the problem of

Tableau 6. Ensemble des actions (systèmes constructifs) potentielles

Solutions constructives	STRUCTURE	ENVELOPPE	PARTITION		PLANCHER		COUVERTURE
			Remplissage	Enduit	Matériau 1	Matériau 2	
SOLUTION 1	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 2	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 3	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete for hollow slab RC 16+4	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 4	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete for hollow slab RC 16+4	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 5	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 6	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 7	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 8	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 9	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Concrete for hollow slab RC 16+4	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 10	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Concrete hollow slab RC 16+4	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 11	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 12	Reinforced concrete	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Wood Plancher mixte Wood - béton	Concrete for floor	Vibro-cement tiles
SOLUTION 13	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 14	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 15	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete for hollow slab RC 16+4	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 16	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete hollow slab RC 16+4	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 17	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 18	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 19	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 20	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 21	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Concrete for hollow slab RC 16+4	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 22	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Concrete hollow slab RC 16+4	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 23	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 24	Reinforced concrete	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 25	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 26	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 27	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete for hollow slab RC 16+4	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 28	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete hollow slab RC 16+4	Rough cement masonry for hollow slab units	Vibro-cement tiles

……………Continue

SOLUTION 29	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 30	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood Plancher mixte Wood - béton	Concrete for floor	Vibro-cement tiles
SOLUTION 31	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 32	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 33	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Concrete for hollow slab RC 16+4	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 34	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Concrete hollow slab RC 16+4	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 35	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 36	Reinforced concrete	Voided burnt clay brick15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Mixed concrete wood floor	Concrete for floor	Vibro-cement tiles
SOLUTION 37	Reinforced concrete	Stacked plank lumber ép10 cm	Stacked plank lumber ép10 cm		Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 38	Reinforced concrete	Stacked plank lumber ép10 cm	Stacked plank lumber ép10 cm		Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 39	Reinforced concrete	Stacked plank lumber ép10 cm	Stacked plank lumber ép10 cm		Concrete for hollow slab RC 16+4	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 40	Reinforced concrete	Stacked plank lumber ép10 cm	Stacked plank lumber ép10 cm		Concrete hollow slab RC BA 16+4	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 41	Reinforced concrete	Stacked plank lumber ép10 cm	Stacked plank lumber ép10 cm		Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 42	Reinforced concrete	Stacked plank lumber ép10 cm	Stacked plank lumber ép10 cm		Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 43	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 44	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 45	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete for hollow slab RC 16+5	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 46	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete hollow slab RC 16+5	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 47	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 48	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 49	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 50	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 51	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Concrete for hollow slab RC 16+5	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 52	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Concrete hollow slab RC 16+5	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 53	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 54	Wood	Voided cement blocks of 15 + 2cm cement mortar coating on two sides	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 55	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 56	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 57	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete for hollow slab RC 16+5	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 58	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete hollow slab RC 16+5	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 59	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th

……………..Continue

SOLUTION 60	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 61	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 62	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 63	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Concrete for hollow slab RC BA +5	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 64	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Concrete hollow slab RC 16+5	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 65	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 66	Wood	Clay bricks stabilized with cement10cm thick	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 67	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 68	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 69	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete for hollow slab RC 16+5	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 70	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Concrete hollow slab RC 16+5	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 71	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 72	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ 2cm cement mortar coating on two sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 73	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 74	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 75	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Concrete for hollow slab RC 16+5	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 76	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Concrete hollow slab RC 16+5	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 77	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 78	Wood	Voided burnt clay brick 15x20x50	Voided cement blocks of 12	+ paneling 2 sides	Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles
SOLUTION 79	Wood	Stacked plank lumber10cm thick	Stacked plank lumber10cm thick		Solid block RC 12 cm		Ribbed aluminum thick sheet of 7/10th
SOLUTION 80	Wood	Stacked plank lumber10cm thick	Stacked plank lumber10cm thick		Solid block RC 12 cm		Vibro-cement tiles
SOLUTION 81	Wood	Stacked plank lumber10cm thick	Stacked plank lumber10cm thick		Concrete for hollow slab RC 16+5	Rough cement masonry for hollow slab units	Ribbed aluminum thick sheet of 7/10th
SOLUTION 82	Wood	Stacked plank lumber10cm thick	Stacked plank lumber10cm thick		Concrete hollow slab RC 16+5	Rough cement masonry for hollow slab units	Vibro-cement tiles
SOLUTION 83	Wood	Stacked plank lumber10cm thick	Stacked plank lumber10cm thick		Wood for mixed floor concrete-wood	Concrete for floor	Ribbed aluminum thick sheet of 7/10th
SOLUTION 84	Wood	Stacked plank lumber10cm thick	Stacked plank lumber10cm thick		Wood for mixed floor concrete-wood	Concrete for floor	Vibro-cement tiles

scale effect and that of eventual offsets. By normalizing, the tendency is to over-assess differences between two alternatives whose values are globally close to each other. We may therefore include values without real value. Offset refers to the tendency of including alternatives with very high scores in on criteria family and very poor scores in another criteria family.
MAUT is based on research works carried out by Von Neumann and Morgenstern (1944) on utility. Its principle is as follows: the decision-maker is supposed to affect one utility to each of potential actions (possible choices of constructive systems) involved, taking into account each of the criteria (attributes) individually, and by considering which utility produces each criteria for the action involved.

This method is implemented in four steps:

Step 1**:** Determining threshold values for each criterion.
Step 2**:** Defining individual utility functions. These functions may be established based on the intrinsic requirement associated to each criterion. They may be of exponential or linear nature and their parameters are identified according to the decision-maker.
Step 3**:** Assessing the weight of each criterion. This weight may be deducted through the decision-maker's experience and choices.
Step 4**:** Construction of the multi-attribute global utility function. This global function is basically one p-uplet (p being the number of criteria) of individual utility functions where the values of each potential action are classified in order to identify the best actions.

The last step raises the issue of the choice of the appropriate manner in which to decompose the global utility function (additive, multiplicative, multi-linear decomposition), and that of the thorough verification of hypotheses used to carry out the type of decomposition chosen. For example, the independence of criteria may lead to a multi-linear-type decomposition. The advantage of using utility functions is that you can avoid weighting criteria. Although they are useful on a theoretical point of view (especially when coupled with probabilistic models), these functions are difficult to implement in front of true decision-makers. Given that each decision-maker has his own preferences, each will have his own utility function. Therefore, it is necessary to resort to arbitration, which may be sometimes very complex, in order to take good decisions. Also, without numerical representations, these functions are difficult to construct and to operate (Abdellaoui et Gonzales, 2013). The MAUT approach is complex and difficult to use, especially due to the fact of a decision-maker to figure out the utility associated to a given performance. Also, it is totally compensatory, in that a poor score of a potential action on a given criterion may be fully compensated by a good score in another criterion. The ELECTRE approach is used to construct preferences easier than the MAUT, based on a weighting system such as AHP. ELECTRE also helps to overcome the eventual failures presented earlier, by including, through pseudo-criteria, criteria such as indifference, preference and veto. The indifference threshold is used to define the point from which two alternatives are considered as equivalent. The preference threshold sets the point from which one alternative is preferred from the other. Finally, the veto threshold indicates the maximum gap between two alternatives for a given criterion. It will therefore affect the potential compensatory effects mentioned earlier by discarding actions whose performances are too poor for one or several criteria. For these reasons, ELECTRE seems to be the most suitable approach to our decision issue.

Electre TRI Method

Principle

ELECTRE TRI consists in comparing a constructive solution with a fictitious solution *a,* whose performances are indicated for each criterion. The aim is to tell in each case if the overgrading relation *S* is globally true for a couple of actions. To that end, each of criteria C_i will be attributed two powers. The first one is a voting for the global overgrading of b, and the second one a power to veto against this overgrading.

Power given to a to globally overgrade b: This power is graded k_i and indicated for each C_i criterion. The « vote » thus expressed by the criterion will be weighted through a value that will represent the relative importance given to this criterion by decision-makers compared to all the other criteria. All the values related to each of the criteria retained for this article is the main determinant of a choice strategy. Depending on the set of values considered, only one criterion will not necessarily impose overgrading. For each of the strategies envisaged in this article, there is a corresponding set of k_i values. There are various ways of putting up strategies. In our case, we gave priority to a construction which is mainlyintuitive. It entails a simulation of various weighting scenarios representing possible viewpoints of all persons involved. It therefore allows considerable time saving in the analysis process. In real situation, it is very costly to collect and then roll up the opinion of each stakeholder. Identifying various sets of strategy weighting also has the advantage of identifying actions whose level of multi-criteria consensus remains stable in the event of varying opinions of potential stakeholders.

Power of veto against upgrading: For a criterion, it is expressed as a veto threshold showing the maximum difference of performances for which the upgrading of *b* by *a* is denied, irrespective of the performances of other criteria. However, the power of veto allows a criteria enjoying it to opposed upgrading, that is contradicting the asserting that «*a* is at least as good as *b*».

Upgrading procedure: In the process of global (or multi-criteria) comparison of two actions *a* and *b*, ELECTRE methods are interested in the issue of upgrading (*a S b*), that is, in the question « is action *a* globally at least as good as action *b* ?». This question is « asked » to each criterion, which will decide to vote for or against this assertion. It will be eventually assumed that (*a S b*) is globally true if a « majority » of criteria have voted in this direction. But a second condition to admit (*a S b*) is that none of the criteria among those which did not vote in favor of (*a S b*) should not strongly oppose the majority and impose its veto.

For the global comparison of action *a*with action *b*, each C_i criterion is thus provided with:

- The function $\varphi_i(a\ S_{Ci}\ b)$ with values in [0,1] ;
- A weight k_i indicating its voting power ;
- A threshold value v_i vesting it with a power of vetoon the issue of global upgrading.

Function φ_i *(a* S_{Ci} *b)* represents the extent to which the assertion « *a* over weigh s*b* » is true for criterion C_i. It is generally defined as follows:

φ_i equals 1 if criterion Ci fully corroborates assertion a SCi b*.* *In other words, action a is strongly preferred to b, which is expressed by relation:*

$$g_j(a) > g_i(b) - q_j(b)$$

gj (a) and gj(b) respectively refer to the performances of actions a and b for criterion Cj ; qjis the indifference threshold for criterion j, set at 0.25.

φi equals 0 if criterion Ci does not corroborate assertion a SCi b. Action b is therefore strongly preferred to a, which is expressed by:

$$g_j(a) \le g_j(b) - p_j(b)$$

pjis the preference threshold for criterion j, set at1 in this thesis.
φi carries an intermediate value between 0 and 1, as defined by relation

$$c_j(a,b) = \frac{p_j(b) - (g_j(b) - g_j(a))}{p_j(b) - q_j(b)}$$

si $g_j(b) - p_j(b) < g_j(a) \le g_j(b) - p_j(b)$

In order to take into account the votes of criteria and eventual vetoes, two indicators are provided:

the concordance index c (a, b) de la famille de critères Ci ;
the discordance index of a Ci criteriondi (a,b).

$$c(a,b) = \frac{\sum \varphi_i(aS_{Ci}b)k_i}{\sum k_i}$$

The numerator stands for the overall weight of criteria voting for the establishment of upgrading, weights that may be lowered by factor φi (a SCib) when there is weak preference forb, cancelled by this same factor when there is clear preference for b. The denominator is the total weight of criteria. Through this relation we therefore obtain a figure between 0 and 1 representing the coalition of criteria voting for the upgrading of a by b.

The discordance index is defined as follows:

- $d_i(a,b) = 1$ if $g_i(b) > g_i(a) + v_i(a)$
- $d_i(a,b) = 0$ if $g_i(b) \le g_i(a) + p_i(a)$
- $d_i(a,b) = (g_i(b) - g_i(a) - p_i(a)) / (v_i(a) - p_i(a))$ in default.

It represents the extent to which a criterion is opposed to the establishment of global upgrading (a S b). $v_i(a)$ is the veto threshold for criterion i, set at 3.

Therefore, to compare two actions a and b, proposition (a S b) is verified if and only if the following condition is fulfilled:

$\sigma(a, b) \ge \lambda$, $0 \le \lambda \le 1$.

Function σ is the credibility index of proposition (a S b) used in ELECTRE III et ELECTRE TRI-B techniques and defined as follows:

$$\sigma(a,b) = c(a,b) \qquad if\ \overline{F(a,b)} = \emptyset$$
$$\sigma(a,b) = c(a,b) \coprod_{j/C_j \in F} \frac{1 - d_j(a,b)}{1 - c(a,b)} \quad if\ \overline{F(a,b)} \neq \emptyset$$

With:
F: set of Ci criteria;
$\bar{F}(a,b) = \{C_j \in F \mid d_j(a,b) > C(a,b)\}$.

The term « product » appearing in the definition of σ is only to possibly reduce c (b, a) in the event of a veto. As a matter of fact, the set of criteria likely to exert a power of veto is $\bar{F}$ set (its elements are criteria for which the discordance index is higher than the concordance index of family F). A discordance index of value 1 systematically cancels σ. A criteria gi whose discordance index is situated between c(a,b) and 1, reduces σ by multiplying it by relation $(1-d_i(a,b))/(1-c(a,b))$. Thus,$c(b, a) \ge \sigma(b, a)$. Thus, it can be deduced (using condition $\sigma(b, a) \ge \lambda$) that $c(b,a) \ge \lambda$. In other words, a first condition needed for upgrading is that the percentage of votes in favour of upgrading (percentage represented by concordance index c (b,a)) is higher or equal to λ. In ELECTRE, figure λ is a parameter of the model also situated between 0 and 1. It is called section threshold and its values generally vary between 0.5 and 1. 0.67 value is often used. Setting parameter λ at 0.7 for example means requiring at least 70% of votes in favour of upgrading (votes of family F criteria, overweight taken into account). This parameter eventually shows the severity imposed to the model by the decision maker to obtain a more aggregated result. The more λ is closer to 1 the higher is the severity. However, this first condition is not enough. The second condition is that the « produced » term, multiplied to c (a,b) should not reduce the value of σ below the value of λ, which means that no criteria should not strongly oppose the implementation of overweight (a S b).

Application

Hypotheses of the upgrading method

Hypothesis 1: The intra-criteria performance is characterized by a discrete rating scale ranging from 0 to 5. 0 mark is exclusive. Marks are attributed after the assessment of data distribution, taking into account the criterion preference trend. Let m_i be the average value of the random value informing criterion i; let σ_i be its mathematical expectation. Generally, data distribution is such that, in 99% of cases, all values range between $m_i - 3\sigma_i$ and $m_i + 3\sigma_i$. This gap was divided into 5 segments of equal length, and each segment was evenly divided into 3 parts. Each part was attributed a 0.25 value. Therefore, through this breakdown, it is possible to perfectly equate the value of the indicator and its performance.

Hypothesis 2: Indifference, preference and veto thresholds
Within a given criterion, two constructive systems (a) and (b) will be said to be indifferent if the gap between their performances is 0.25. Given the rating scale which is discrete and has few levels, a 0.5 gap in the performance already entails a preference within a criterion. The preference threshold refers to the slightest difference (in absolute terms)

Table 7. Profile parameters setting categories for multi-criteria consensus

	CO2 Emission	Impact on health	Water consumption	Wall acoustic isolation	Floor acoustic isolation	Walls resistance to fire	Structure's resistance to fire	Thermal flux	Cost	Duration of works
Low profile low consensus	0	0	0	0	0	0	0	0	0	0
High profile Low consensus	3	2.5	3	2	2	2	1.75	2	1.75	2
Low profile Moderate consensus	3	2.5	3	2	2	2	1.75	2	1.75	2
High profile Moderate consensus	4	3.5	4	3	3	3	3	3	2.5	2.75
Low profile High consensus	4	3.5	4	3	3	3	3	3	2.5	2.75

Tableau 8. Criteria overweighing strategies (in %)

	CO2 Emission	Impact on health	Water consumption	Wall acoustic isolation	Floor acoustic isolation	Walls resistanc e to fire	Structure's resistance to fire	Therma l flux	Cost	Duration of works
strategy 1	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	60.00	4.44
strategy 2	20.00	20.00	20.00	3.33	3.33	3.33	3.33	3.33	20.00	3.33
strategy 3	8.00	8.00	8.00	12.00	12.00	12.00	12.00	12.00	8.00	8.00
Strategy 4	10	10	10	10	10	10	10	10	10	10
Strategy 5	10	7.5	7.5	5	5	15	15	10	20	5
Strategy 6	15	20	15	5	5	5	5	5	20	5
Strategy 7	25	5	5	5	5	15	15	10	10	5
Strategy 8	5	25	5	5	5	15	15	10	5	10
Strategy 9	15	5	15	5	5	5	5	5	10	30
Strategy 10	10	5	5	5	5	15	15	15	10	15
Strategy 11	25	25	10	1	1	5	5	1	25	2
Strategy 12	10	10	10	2	2	3	3	10	25	25
Strategy 13	0	0	0	22	22	22	22	12	0	0
Strategy 14	25	25	25	1	1	1	1	1	20	1
Strategy 15	0	0	0	10	10	10	10	10	10	40
Strategy 16	20	20	20	1	1	1	1	1	15	20
Strategy 17	15	15	20	10	10	10	10	10	0	0
Strategy 18	1	1	1	1	1	12.5	12.5	25	25	20
Strategy 19	5	5	5	5	5	5	5	5	5	55
Strategy 20	15	17.5	6	6	7.5	7.5	7.5	10	15	8

between two marks within a criterion, from which the preference of an action (constructive system) for another within a criterion can be established. The veto threshold is the value from which the difference in performance for (a) and for (b) is considered as too important to accept an upgrading of (b) by (a). It was set at3.

Hypothesis 3: Multi-criteria selection is organized into three categories of multi-criteria consensus: « High », « Intermediate » and « Low ». The limit between the various categories actually represents « fictitious constructive systems » or « profiles ». The process of upgrading is implemented by comparing a given constructive system with a fictitious system. Parameters of various profiles are indicated in Table 7.

Hypothesis 4. Envisaged strategies (game systems of criteria weight). In this study, 20 different strategy systems were envisaged. Each strategy gives a quantified importance, representing possible viewpoints of various actors.

RESULTS AND DISCUSSIONS

Constructive systems' level of belonging to categories of multi-criteria consensus

a. **Case of the « high consensus » consensus:** In the category of high category levels, solutions may be classified into four groups (sub-classes) of levels of belonging (Table 8), namely:

- group 1 : level higher than 90 % ;
- group 2 : level ranging between 80 and 90 % ;
- group 3 : level ranging between 70 and 90 % ;
- group 4 : level ranging between 60 and 70 %.

It appears that solutions in group 1 are labeled « 37 », « 38 », « 39 », « 40 » and « 41 » (table 3.6). They are related to constructive systems that are organized as follows:

- structure : reinforced concrete;
- body : stacked plank lumbers;
- partition : stacked plank lumbers;
- floor: solid concrete slab or core slab of 16+ 4 or mixed slab wood – concrete;
- cover: aluminum thick sheets $7/10^e$ or cement mortar tiles.

In group 2, constructive systems are as follows: « 79 », « 80 », « 81 », and « 82 » (table 6)

These are mainly constructive systems organized as follows:

- structure : glued laminated wood;
- body : stacked plank lumbers;
- partition : stacked plank lumbers;
- floor : solid concrete slab or core slab of 16+ 4 or mixed slab wood – concrete;
- roofing: aluminum thick sheets $7/10^e$ or cement mortar tiles.

Table 9. Level of belonging of constructive solutions in the high consensus category

HIGH COMPROMISE				
	Level of belonging	Solution	Description	
group 1	C≥90%	37	Structure :	RC
		38	Body :	Stacked plank lumber
		39	Partition :	Stacked plank lumber
		40	Floor :	Solid slab in RC th = 12cm
		41		Core slabth = 16+4 cm
				Mixed slab Wood-Concrete
		42	Roofing	Thick sheet 7/10th
				Vibro-cement tiles
group 2	80%≤C≤90%	79	Structure :	Wood
			Body :	Stacked plank lumber
		80	Partition :	Stacked plank lumber
			Floor :	Solid slab in RC th = 12cm
		81		Core slab th = 16+4 cm
		82	Roofing	Thick sheet 7/10th
				Vibro-cement tiles
group 3	70%≤C≤80%	65	Structure :	Wood
			Body :	Cement BTS th= 10cm
			Partition :	Voided cement blocks of 12 + 2cm paneling on 2 sides
		66	Floor :	Mixed slab Wood-Concrete
			Roofing	Thick sheet 7/10th
				Vibro-cement tiles
group 4	60%≤C≤70%	15	Structure :	RC ; Wood
		16	Body :	Voided cement blocks of 15 ; Cement BTS th = 10cm ; Stacked plank lumber
		19	Partition :	Voided cement blocks of 12 + 2cm paneling on two sidesor + 2cm mortar coating on two sides
		20	Floor:	Solid slab in RC th = 12cm
		21		Core slab th = 16+4 cm
		22		Mixed slab Wood-Concrete
		23	Roofing	Thick sheet 7/10th
		24		
		51		
		52		
		55		
		56		
		57		
		58		
		59		
		60		
		61		
		62		
		63		Vibro-cement tiles
		64		
		69		
		70		
		71		
		72		
		75		
		76		
		77		
		78		
		83		
		84		

Group 3 is essentially made up of constructive systems No. 65 and 66 (table 6). These systems are divided as follows:

- structure : glued laminated wood;
- body : stabilized earth blocks;
- partition : voided pressed wood, protected by paneling on both sides;
- mixed slab wood – concrete;
- roofing: aluminum thick sheets of 7/10th or cement mortar tiles.

Group 4 includes constructive solutions of the lowest level of belonging than the former (60 to 70%). It is globally presented as follows:

- structure : reinforced concrete or glued laminated wood;
- Body : Voided cement blocks of 15 ; cement BTS;thickness = 10cm ; Stacked plank lumbers ;
- Partition : Voided cement blocks of 12 + 2cm paneling on both sides or 2cm mortar coating on both faces
- roofing:aluminum thick sheets of 7/10th or cement mortar tiles.

Case of the « intermediate consensus » category

The results of levels of belonging to intermediate compromise categories are presented in table 9. The structure of constructive systemis dominated by solutions « 45 », « 46 », « 47 » and « 48 » which constitute group 1, and solutions « 1 », « 2 », « 3 », « 4 », « 5 », « 6 », « 7 », « 8 », « 9 », « 10 », « 11 », « 12 », « 13 », « 14 », « 25 », « 26 », « 31 », « 32 »,

Table 10. Level of belonging for constructive systems with intermediate compromise

	Level of belonging of constructive system	Solution	Description	
Group 1	C≥80%	45	Structure :	Wood
			Envelope :	Voided cement blocks of 15
		46	Partition :	Voided cement blocks of 12 + 2cm biface cement coating
			Floor :	Mixed slab Wood-Concrete
		47		Solid slab in RC th = 12cm
				Core slab th = 16+4 cm
		48	Cover	Thick sheet 7/10th
				Vibro-cement tiles
Group 2	60%≤C<80%	1	Structure :	RC ; Wood
		2	Envelope :	Voided cement blocks of 15 ; Cement BTS th = 10cm ; voided BTC 12*20*50
		3	Partition :	Voided cement block of 12 + 2cm biface paneling or + 2cm biface mortar coating
		4	Floor :	Solid slab in RC th = 12cm
		5		Core slab th = 16+4 cm
		6		Mixed slab Wood-Concrete
		7	Roofing	Sheet metal tray 7/10è
		8		
		9		
		10		
		11		
		12		
		13		
		14		
		25		
		26		
		31		Vibro-cement tiles
		32		
		33		
		34		
		43		
		44		
		53		
		54		
		73		
		74		

« 33», « 34 », « 43 », « 44 », « 53 », « 54 », « 73 » and « 74 » which are part of group 2. The level of belonging of group 1 is higher than 80 %, while that of group 2 ranges between 60 and 80 %. Group 1 is made up of buildings whose structure is in glued laminated wood, with an body and partition respectively made of voided blocks of 15 cm, and voided blocks of 12, with biface coating in each case. Roofing options include two possibilities chosen at the outset, which is aluminum tiles of 7/10thant cement mortar tiles. In group 2, the building can be made of glued laminated wood or in reinforced concrete. The body can consist of voided cement blocks of 15 cm, stabilized clay bricks or burntclay bricks. Partitions can be made with cement voided blocks of 12 cm, stabilized clay bricks or voided clay bricks. Systems of group 3 can be made with the three types of floor chosen beforehand.

Conclusion

This article was devoted to the multi-criteria selection of constructive systems for the construction of social housing. Three families of criteria dealing with (environmental/health CO2 emissions, pollution potential of surrounding water sources, water consumption during construction works) technical (acoustic comfort, fire security, Hygrothermal comfort) and socio-economic (cost and duration of works) aspects were brought under consideration. 84 constructive solutions, differing by the materials used for the structure (reinforced concrete, stacked lumber wood, voided blocks or paneling), the floor (wood – concrete, core slab or solid slab) and the roof (cement mortar tiles 7/10th thick aluminum sheets) were considered. The selection of each criterion was justified. The selection method used is a combination of the ELECTRE TRI method (which organizes possible choices into three main groups depending on the level of compromise (high/moderate/low) and fuzzy logic. It appeared that reinforced concrete (for the structure) – stacked lumber wood maximizes both the criteria involved and the level of belonging to the category of high compromise. It clearly overrides the reinforced the system consisting of reinforced (for the structure) – core slab (for fillings) usually used in Cameroon.

REFERENCES

BUCREP, (2005). «Caractéristiques de l'habitat et cadre de vie des populations,» 3iemeRGPH, vol. II, tome 05, 161p.

Cameroun, PR. 2006. Cadre juridique des contrats de partenariat au Cameroun. Yaoundé : s.n., 2006. p. 44. 7.

DGUHC,(2003).«Connaître les besoins locaux en logements: Guide méthodologique,»115p.

Direction régionale de l'Environnement de l'Aménagement et du Logement. 2015. Etude comparative des coûts de construction entre Wood, brique et parpaing. France : s.n., 2015. p. 20. 14.

ETAT DES LIEUX ET DIAGNOSTIC DU FINANCEMENT DU LOGEMENT SOCIAL AU CAMEROUN. Yaoundé : s.n., 2010. p. 35. 1.

2006. LOI N° 2006/012 DU 29 DECEMBRE 2006 FIXANT LE REGIME GENERAL DES CONTRATS DE PARTENARIAT. Yaoundé: s.n., 2006. p. 10. 8.

MINDUH. 2008. ARRETE N° 0009/E/2/MINDUH DU 21 août 2008 Fixant les normes d'habitat social. Yaoundé : s.n., 2008. p. 6. 4.

MINDUH,(2010).«Strategy Nationale de financement du logement social au Cameroun,» Yaoundé,41p.

Pettang C.,(1998).Diagnostic de l'Habitat urbain au Cameroun, vol. I, Presses Universitaires de Yaoundé, 174p.

SOes (2015) Chiffrs clés du climat - France et Monde.

- http://www.beac.int
- http://www.banquemondiale.org
- http://www.cndp.com

****