AUTHOR(S): SEDDIKI, M., ANOUCHE, K. and BENNADJI, A.

TITLE: An integrated Delphi-FAHP-PROMETHEE for the thermal renovation of masonry buildings in Algeria.

YEAR: 2016

Publisher citation: SEDDIKI, M., ANOUCHE, K. and BENNADJI, A. 2016. An integrated Delphi-FAHP-PROMETHEE for the thermal renovation of masonry buildings in Algeria. In Amoêda, R., Lira, S. and Pinheiro, C. (eds.) Proceedings of the 5th international conference on heritage and sustainable development (Heritage 2016), 12-15 July 2016, Lisbon, Portugal. Barcelos: Green Lines Institute, pages 171-180.

OpenAIR citation: SEDDIKI, M., ANOUCHE, K. and BENNADJI, A. 2016. An integrated Delphi-FAHP-PROMETHEE for the thermal renovation of masonry buildings in Algeria. In Amoêda, R., Lira, S. and Pinheiro, C. (eds.) Proceedings of the 5th international conference on heritage and sustainable development (Heritage 2016), 12-15 July 2016, Lisbon, Portugal. Barcelos: Green Lines Institute, pages 171-180. Held on OpenAIR [online]. Available from: https://openair.rgu.ac.uk

An integrated Delphi-FAHP-PROMETHEE for the thermal renovation of masonry buildings in Algeria

M. Seddiki & K. Anouche
The University of Science and Technology Mohamed Boudiaf, Oran, Algeria

A. Bennadji
The Robert Gordon University, Aberdeen, Scotland, United Kingdom

ABSTRACT: In Algeria, the residential and tertiary sectors are the ones with the highest energy consumption making use of 34% of the total energy. The government has launched a thermal renovation program for existing buildings to reduce the energy consumption. The existing stock has 1.050.000 of masonry dwelling built before 1945. Masonry buildings represent a cultural heritage. Thermal renovation of masonry buildings in Algeria requires a comprehensive approach as it simultaneously involves a multitude of decision makers that can express a multitude of criteria. This paper presents an integrated method that combines the structured group interaction method Delphi, the Fuzzy Analytical Hierarchy Process (FHAP), and the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) for the thermal renovation of masonry buildings with a heritage value. The aim of the proposed method is to rank the thermal renovation solutions using a fuzzy multi-criteria and multi-decision makers approach. A case study using the proposed method to obtain a full ranking of thermal renovation options is detailed in the paper.

1 INTRODUCTION

The Algerian government has launched in 2016 a national energy saving program to reduce the high energy consumption in the residential sector. This program is led by the national agency for the promotion and the rationalization of the energy use (APRUE). It aims the thermal insulation of 100.000 houses per year. The national fund for energy management (FNME) will provide 80 percent of the costs related to these interventions (Abdelkader, 2015).

Masonry buildings (see Fig. 1) constitute a large part of the existing housing stock in Algeria. The majority of masonry buildings were built during the French colonial period. These buildings represent a valuable architectural heritage. They were constructed according to traditional techniques and materials, with load bearing walls of stone masonry, vaulted brick floor and metal beams (Heraou, 2011). The masonry buildings are subject in Algeria to a wide preservation program, many buildings rehabilitation are undertaken across the country. In 2016, the government envisages the diagnostics of 300.000 dwellings. Rehabilitation operations will be launched following these diagnostics. These actions will be conducted and financed by the government. The buildings rehabilitation will concern only common parts of buildings (exterior facades, yard, cellars, entrance halls, stairwell, accessible and inaccessible terraces, and pitched roofs) (Addab, 2015).

The energy-saving program in the residential sector and the rehabilitation of masonry buildings program offer a great opportunity to perform the thermal renovation of masonry buildings. This will balance between the improvement of the thermal performance of the existing buildings stock and the perseveration of masonry buildings. However, the choice of improvement alternatives during their thermal renovation is a complex decision because it involves different stakeholders (actor concerned with the preservation of buildings, actor concerned by the reduction of energy consumption, building users, and so on) that can express a multitude of criteria (economic, energy, cultural, historical, and so on). Due to the multi-decision makers and multi-criteria character of the thermal renovation of masonry buildings in Algeria it is difficult to find solutions that can optimize all the criteria at once. Therefore, it would be more appropriate to find consensus solutions. The multiple-criteria decision analysis is a useful tool for this type of problem; it evaluates different solutions taking into account both the preferences of decision makers and the different criteria.

Another issue is that uncertainties concerning the decision makers' preferences could affect the evaluation of the thermal renovation solutions therefore, those uncertainties should be taken into account (Zheng, et al., 2009).

Figure 1. Algerian neoclassical colonial building built in masonry.

This paper proposes an integrated method that combines the structured group interaction method Delphi, the Fuzzy Analytical Hierarchy Process (FHAP), and the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) for the thermal renovation of masonry buildings with a heritage value. The proposed method aims to rank the thermal renovation solutions using a fuzzy multi-criteria and multi decision makers approach.

The paper is divided into five-part, the following section presents a literature review concerning the application of multi-criteria decision aid methods in the field of cultural heritage, part 3 develops the method used in the paper, part 4 provides the results of the application of the method on a case study, while section 5 presents conclusions and directions for future research.

2 LITERATURE REVIEW

2.1 *Multi-criteria decision aid method and cultural heritage*

Dutta & Husain (2009) developed a complete aggregation Multi-Criteria Decision Aid method (MCDA) for the classification of heritage sites. It has the advantage to take into account the preferences of different stakeholders. The application of this method was illustrated by the classification of several heritage buildings in Calcutta. The complete aggregation approach gives a note to all scenarios whilst basing the score on the most important criteria. However, this approach presents several limitations. It allows the compensation of low score in criteria with good results on several other criteria. Also, it is necessary to carry out a coding while taking into account both quantitative and qualitative criteria. Fuentes (2010) also used a complete aggregation MCDA method for the systemic evaluation of the potential of reuse of old agricultural building in central Spain. Wang & Zeng (2010) presented a comprehensive methodology for the selection of historical buildings reuse. The process was to develop a team including architects, historians, developers, owners, experts and entrepreneurs, the team should clearly define the criteria for reuse and determine alternatives. The most important criteria for the selection of the reuse of historical buildings have been identified due to Delphi method. Subsequently, these criteria were used to develop a global decision aid technique. Ferretti et al. (2014) proposed the multi-criteria analysis technique MAVT (multi-attribute values theory) to evaluate and rank the different cultural heritage projects according to their potential of reuse for tourism purpose. The buildings were considered on multiple criteria basis (historical, aesthetic, economic, and environmental) the assessment of each criterion took into consideration the preferences of different actors (public government, architects, architectural historians, owners).

Zagorskas et al (2014) applied TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method to select the best insulation option for historic buildings among five internal insulation materials. This method takes into account five criteria: cost of the material, complexity of the installation, heat transfer coefficient, loss of space, and moisture properties of the material. The relevance of this method compared to all the other methods cited previously is to take into account the specificity of the thermal renovation of masonry buildings with a heritage value. However, it has several limitations such as the method can be applied only for the internal insulation of buildings, it does not take into account the preferences of different decision makers, and the method is completely compensatory.

Following the review of literature it is possible to conclude that most of MCDA methods applied in the cultural heritage use the complete aggregation approach. Moreover, MCDA methods were rarely applied for the thermal renovation of masonry buildings with a heritage value. To the best of our knowledge, none of the existed method takes into account simultaneously: (1) the specificity of the thermal renovation of masonry buildings with a heritage value, (2) a multitude of criteria and thermal renovation solutions expressed by several decision makers to get a global ranking of the actions, (3) additional constraints such as the maximum budget allocated to the operation, (5) uncertainties regarding the decision makers' preferences. Furthermore, there is no application of the partial aggregation MCDA methods PROMETHEE in this area in the literature.

This paper proposes an integrated Delphi-FHAP-PROMETHEE decision aid method for the thermal renovation of masonry buildings with a heritage value. Mardani et al. (2015) have provided a comprehensive literature review concerning the application of the fuzzy MCDA in various fields. So far, there is no study that has integrated these three techniques in the field of cultural heritage.

2.2 *Integrated approach Delphi – Fuzzy HAP- PROMETHEE*

2.2.1 *PROMETHEE methods*

The advantage of the MCDA PROMETHEE methods is to use the partial aggregation approach which consist to compare the actions pairwise, and to check under certain conditions if one of two actions clearly outranks the other or not. PROMETHEE methods do not allow compensation between criteria. They allow taking into account several quantitative and qualitative criteria without having to do any coding or change the indicators (Macharis, et al., 2004). PROMETHEE methods include the group decision support system PROMETHEE GDSS, PROMETHEE V (optimization under constraints), and other extensions. With PROMETHEE GDSS it is possible to take into account simultaneously a multitude of criteria expressed by several decision makers to get a global ranking of the alternatives (Macharis, et al., 1998). PROMETHEE V allows adding additional constraints required by the decision makers, such as the number of alternatives to be selected, the maximum budget allocated to the operation, and incompatibilities between actions (Brans, 1992).

2.2.2 *Delphi method*

Delphi is a structured group interaction method. It works through multiple rounds of opinions collection and anonymous feedback. It is a useful tool to obtain a consensus of opinion from a group about an issue not subject to an objective solution. Keeney et al. (2006) provided an excellent state of the art on its application. The association of the Delphi method into PROMETHEE methods permits to improve the communication among the decision makers. Furthermore, it facilitates the process of the definition of evaluation criteria and alternatives.

2.2.3 *Fuzzy AHP method*

The fuzzy AHP method is a combination between the Analytic Hierarchy Process AHP method (Saaty, 1977) and the fuzzy numbers (Bellman & Zadeh, 1970). The advantage of the AHP method is to provide specific guidelines in order to define the weight (importance) of the criteria. AHP method is built on the pair-wise comparison model for determining the weights for every unique criterion. However, in the pair-wise comparison, the perceptions and judgments of human are represented by linguistics and vague patterns. The AHP method does not take into account uncertainties associated with these judgments. To consider those uncertainties, fuzzy set theory is frequently integrated with AHP method (Gupta, et al., 2012). The combination of the Fuzzy AHP with PROMETHEE methods provides specific guidelines to take into account uncertainties concerning the decision makers' preferences.

3 METHODOLOGY

This section presents an integrated Delphi-FAHP-PROMETHEE group decision aid method to rank different renovation solutions. The method consists of several sequential steps as indicated in Figure 2; first, the group decision is constituted. Then, the building is investigated. Then after, through Delphi method the criteria and the thermal renovation solutions are defined. Later, individual pairwise comparison is carried out across FAHP to obtain the weights of the decision criteria. Finally, the rest of the calculations are completed via PROMETHEE methods. The details of the proposed methodology are presented as follows:

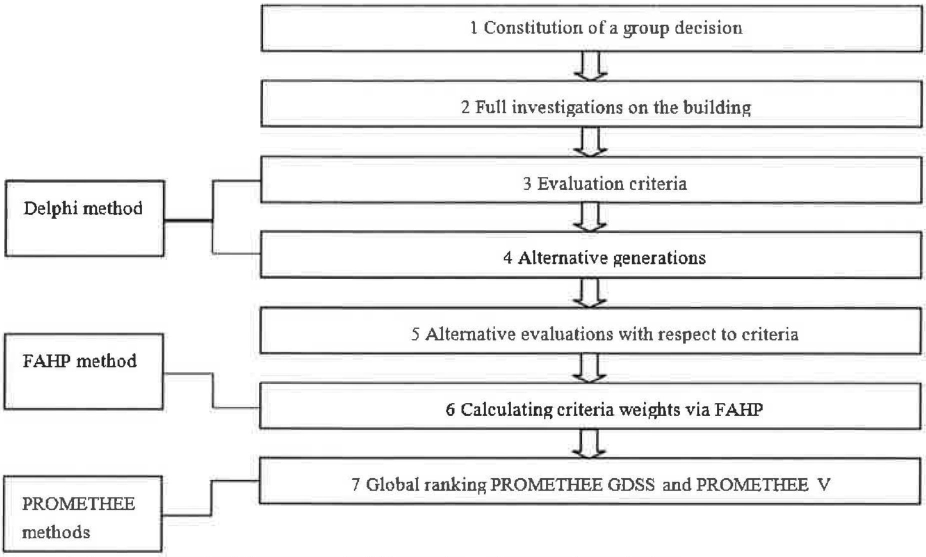

Figure 2. Proposed methodology to rank different thermal renovation solutions.

3.1 *Constitution of a group decision*

The first step is to form a group consisting of the different decision makers involved in the thermal renovation project (actor concerned with the preservation of buildings, actor concerned by the reduction of energy consumption, owners, and so on).

3.2 *Full investigation on the building*

Following the constitution of the decision makers group, a complete documentation of the building would be performed (exanimating the climate zone, the internal organization, the construction method, the aesthetics of the building, the energy consumption, and so on) in order to sensitize the various decision makers about the current situation of the building.

3.3 *Evaluation criteria*

The thermal renovation solutions will be evaluated on a multiple criteria basis. The definition of the evaluation criteria requires the application of several rounds of Delphi method. First using interviews, individual lists of criteria are obtained; each decision maker is asked individually to express their evaluation criteria taking into accounts different aspects such as economic, environmental, cultural, and architectural. The criteria can be for example investment cost, energy consumption decrease, and so on. Secondly, all the individual lists will be combined to form a complete list which is shared with all decision-makers. They are invited to review this information, to revise, and resubmit their initial individual list. This process is repeated until the participants decide that they cannot reduce further the number of criteria in the list.

3.4 *Alternative generations*

Once the investigation on the building is completed and the evaluation criteria are defined, the group decision should formulate thermal renovation alternatives. The thermal renovation solutions will take into account only the common area, and will concern only the insulation of the building envelope (external roof insulation, external wall insulation, and so on). This step can be performed with an open discussion among decision makers or through the same process used for the evaluation criteria selection.

3.5 *Alternative evaluation with respect to criteria*

Each alternative should be evaluated in terms of all the criteria. These evaluations can be quantitative (obtained from thermal dynamic simulation tool, accounting calculations etc) or qualitative (obtained from expert judgments, interviews, and so on).

3.6 *Calculating criteria weights via FAHP*

The decision makers would express their preferences concerning the criteria though FAHP. First, each decision makers should perform a pairwise comparison of the criteria regarding the global objective (thermal renovation). These comparisons allow evaluating the criteria weights using a fuzzy linguistic scale (see Fig. 3). The linguistic scale permits to take into account uncertainties concerning the decision maker's preferences. This information should be converted (see Table 1) to fuzzy triangular numbers (l, m, u). The parameters "l", "m", and "u" respectively express the smallest values, the most possible value, and the largest possible value. Then a pairwise comparison matrix of each decision maker would be obtained. After, the weighted comparison matrix of all decision makers should be defined. Finally, the normalized criteria weights (wj) would be determined. For further detail about the FAHP process see Gupta et al. (2012).

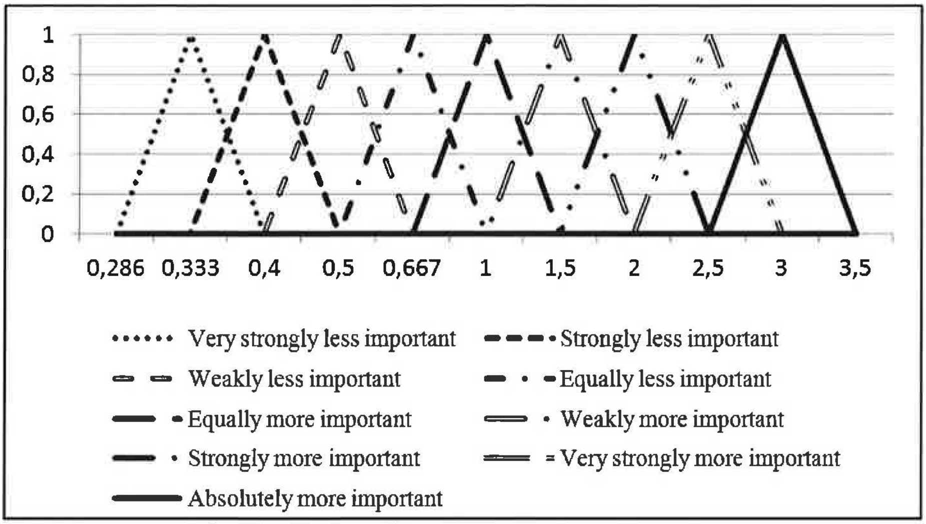

Figure 3. Linguistic scale of the criteria weights.

Table 1. Triangular fuzzy conversion scale source (Gupta, et al., 2012).

Linguistic scale	Triangular fuzzy scale	Reciprocal linguistic scale	Triangular fuzzy reciprocal scale
Just equal (JE)	(1, 1, 1)	Just equal (JE)	(1, 1, 1)
Equally more important (EMI)	(0.5, 1, 1.5)	Equally less important (ELI)	(0.667, 1, 2)
Weakly more important (WMI)	(1, 1.5, 2)	Weakly less important (WLI)	(0.5, 0.667, 1)
Strongly more important (SMI)	(1.5, 2, 2.5)	Strongly less important (SLI)	(0.4, 0.667, 1)
Very strongly more important (VSMI)	(2, 2.5, 3)	Very strongly less important (VSLI)	(0.333, 0.4, 0.5)
Absolutely more important (AMI)	(2.5, 3, 3.5)	Absolutely less important(ALI)	(0.286, 0.33, 0.4)

3.7 *Global ranking PROMETHEE GDSS and PROMETHEE V*

To establish the global ranking PROMETHEE GDSS of the alternatives, preference functions (Pj(a,b)) should be specified for each criterion. They represent for each pair of alternatives “a”, “b”, the preference intensity of “a” over “b”. There are six different types of criterion according to the preference of the decision makers (Brans, et al., 1986). A multi-criteria preference index is defined as in equation (1).

$$\pi(a,b)=\sum_{j=1}^{k} w_j \times P_j\ (a,b) \tag{1}$$

Where π (a, b) expresses the preference degree of “a” over “b” regarding all the criteria, it varies from 0 to1, and “w_j” is the normalized weights of the criterion “j” obtain from the fuzzy judgement matrix.

Then the individual leaving flows, entering flows, and net flows for each decision maker have to be calculated:

The leaving flow Phi+ (Ø+) represents a strength measure, it expresses how alternative “a” is outranking all the others alternatives, and it is calculated through equation (2)

$$\emptyset^{+}(a)=\frac{1}{n-1}\sum_{b\neq a}\pi\ (a,b) \tag{2}$$

The entering flow Phi- (Ø-) represents a weakness measure, it expresses how alternative "a" is outranked by all the others alternatives, and it is calculated with equation (3)

$$\emptyset^{-}(a) = \frac{1}{n-1} \sum_{b \neq a} \pi(a,b) \tag{3}$$

The net flow Phi (Ø) represents the difference between the leaving flow and the entering flow as shown in equation (4)

$$\emptyset(a) = \emptyset^{+}(a) - \emptyset^{-}(a) \tag{4}$$

Finally, the global net flows of the group decision should be calculated directly by the weighted sum of the individual flows as shown in equation (5). The global net flows provide directly the PROMETHEE GDSS ranking of the alternatives following the decision maker's preferences.

$$\emptyset_g(a) = \sum_{s=1}^{s} w_s \ \emptyset^{s}(a) \tag{5}$$

Where "w_s" is the normalized weight assigned to each decision maker.

Additional constraints can be introduced according to the requirements of the decision makers through PROMETHEE V. A binary variable (0-1) "x_i" is associated with each action "a_i":

$x_i = 1$ means that the action "a_i" is selected, $x_i = 0$ means it is not. The aim is to select the actions so that the sum of the Phi net flows of these actions is maximum as shown in equation (6).

$$max \sum_{i=1}^{n} \emptyset\ (a_i) x_i \tag{6}$$

4 CASE STUDY

An apartment situated on the top floor of a neoclassical colonial collective building located in Oran Algeria was adopted as a case study to test the applicability of the proposed method. The case study was constructed in masonry between the late 19 and early 20 century. Four decision makers (DM) participated in this study (step1). DM1 was a representative of the national agency for the promotion and the rationalization of the energy use (APRUE) in charge of the energy consumption reduction in the residential sector in Algeria. DM 2 represented the department of urban planning and construction (DUC) which has a great experience and an important role in the masonry buildings preservation in Algeria. DM3 was the owner of the selected flat and DM4 was an expert in the thermal renovation of masonry buildings.

An investigation on the case study was carried out (step 2).The total volume of the flat is 580m^3, the area is 145m^2, and it is occupied by a five-person family. The annual energy consumption is about 16.583kWh; it is well over the national average consumption of a dwelling which is about 12.180kWh (APRUE, 2007). The flat is equipped with a gas heating system, a gas hot water system, and an electric air conditioner. The exterior masonry walls have a thickness of 55cm and a U-value of 1.19W/m^{2}K. The roof is built in vaulted brick floor and metal beams; it has a U-value of 1.69W/m^{2}K. The windows are all single glazed with a U value 5.68W/m^{2}K.

After the investigations on the building, several rounds of the Delphi method were performed (step 3 and step 4). All the decision makers agreed on 5 evaluation criteria, and 15 thermal renovation alternatives. Then all the alternatives were evaluated in terms of the selected criteria (step 5 see Table 2). After, the normalized criteria weights (wj) of all the decision makers were determined as indicated in step 6. Table 3 indicates the weighted comparison matrix of all the decision makers. The normalized criteria weights were as follow: the energy consumption decrease (0.209), the investment cost (0.194), the summer comfort (0.200) the loss of building historic aesthetic features (0.196), and the risk of the fabric decay (0.201). The FHAP shows that the decision makers considered almost all the criteria as equally important.

Table 2. shows the evaluation of all the alternatives in term of the selected criteria.

Codes	Actions (thermal renovation solutions)	C1	C2	C3	C4	C5
		%	Algerian Dinars	Hour	Qualitative	Qualitative
A1	Exterior insulation of the main facade with 10cm of expanded polystyrene	11	50000	252	Very high	Very high
A2	Exterior insulation of the main facade with 10cm of cellular concrete	11	70000	250	Very high	Low
A3	Exterior insulation of the main facade with 10cm of wood fiber	11	55000	256	Very high	Low
A4	Exterior insulation of the main facade with 6cm of lime hemp plaster	7	60000	256	Very low	Very low
A5	Exterior insulation of the secondary facade and courtyard with 10cm of expanded polystyrene	9	40200	256	Medium	Very high
A6	Exterior insulation of the secondary facade and courtyard with 10cm of cellular concrete	9	56280	254	Medium	Low
A7	Exterior insulation of the secondary facade and courtyard with 10cm of wood fiber	9	44220	258	Medium	Low
A8	Exterior insulation of the secondary facade and courtyard with 6cm of lime hemp plaster	6	48240	258	Very Low	Very Low
A9	Exterior insulation of the roof with 10cm of expanded polystyrene	26	145000	132	Very low	Low
A10	Exterior insulation of the roof with 10cm of wood fiber	26	159500	142	Very low	Low
A11	Exterior insulation of the roof with 15cm of expanded polystyrene	29	217500	120	Very low	Low
A12	Exterior insulation of the roof with 15cm of wood fiber	29	232000	129	Very low	Low
A13	Double glazing window installation.	21	227500	242	Medium	-
A14	Double windows installation	19	233400	245	Very low	-
A15	Secondary glazing installation	9	70000	258		-

C1: Energy consumption decrease; C2: Investment cost; C3: Summer comfort (expressed by the number of hours where the indoor air temperature exceeded 26 °C), C4: Risk of the loss of building historic aesthetic features, C5: Risk of the fabric decay.

Table 3. Weighted comparison matrix of all the decision makers.

Criteria	C1	C2	C3	C4	C5
C1	(1, 1, 1)	(1.05,1.55,2.05)	(0.5,1,1.5)	(0.96,1.46,1.90)	(0.5,1,1.5)
C2	(0.55,0.67,1.05)	(1, 1, 1)	(0.667,1,2)	(0.667,1,2)	(0.68,1.15,2.07)
C3	(0.667, 1, 2)	(0.5, 1, 1.5)	(1, 1, 1)	(0.5, 1, 1.5)	(1, 1, 1)
C4	(0.5,0.66,1)	(0.65,1.04,1.7)	(0.667,1,2)	(1, 1, 1)	(0.66,1,2)
C5	(0.86,1,1.85)	(0.5,1,1.5)	(1, 1, 1)	(1.05,1.55,2.05)	(1, 1, 1)

C1: Energy consumption decrease; C2: Investment cost; C3: Summer comfort, C4: Risk of the loss of building historic aesthetic features, C5: Risk of the fabric decay.

Under Visual PROMETHEE software (VP Solutions & Mareschal, 2012) it was possible to get a complete ranking PROMETHEE GDSS according to the decision maker's preferences (step 7). For this purpose three additional constraints (number of actions to select, incompatibilities between actions, maximum budget available) were added since there were 15 alternatives and only 4 could have been selected simultaneously, the maximum budget available was about 550.000 Algerian Dinars. These constraints were taken into account through PROMETHEE V method.

The constraint of the number of actions to select is indicated in equation (7).

$$\sum_{i=1}^{n} x_i = 4 \qquad (7)$$

The constraints of the incompatibilities between actions (A) as shown on table 4 are indicated in equations 8, 9, 10, and 11 below.

$$A1 + A2 + A3 + A4 = 1 \qquad (8)$$

$$A5 + A6 + A7 + A8 = 1 \qquad (9)$$

$$A9 + A10 + A11 + A12 = 1 \qquad (10)$$

$$A13 + A14 + A15 = 1 \qquad (11)$$

The constraint of the maximum budget available is expressed in equation 12.

$$\sum_{i=1}^{n} b_i \times x_i \leq 550.000 \qquad (12)$$

The results (see Fig. 4) indicate that the most preferred actions according to the group decision preferences are respectively action A7 with a phi net flow of 0.124, action A11 with a phi net flow of 0.121, action A13 with a phi net flow of 0.056 and action A4 with a phi net flow of -0.016. These actions allow reducing 60 percent of the total building energy consumption while ensuring the preservation of the building.

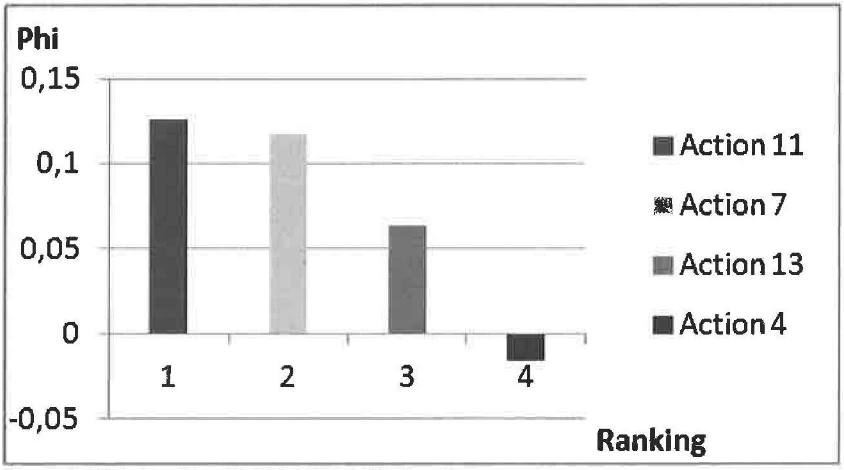

Figure 4. Global ranking PROMETHEE GDSS under constraints.

5 CONCLUSIONS

The importance of the thermal renovation of masonry buildings in reducing the energy consumption and preserving the cultural heritage can never be over emphasized. The relevance of this paper is to consider each project of thermal renovation of masonry building with a heritage value as a complex decision making process involving several stakeholders with different and uncertain preferences. This paper proposes an integrated Delphi-FHAP-PROMETHEE group decision aid method to rank different thermal renovation solutions. The contributions of the proposed method compare with the previous methods reviewed are to use: (1) Delphi method to improve the communication among the decision makers, (2) FAHP to take into account uncertainties concerning the decision makers preferences, (3) PROMETHEE GDSS group decision to get a global ranking of the thermal renovation solutions taking into account the preferences of different decision makers, (4) PROMETHEE V to consider additional constraints.

The results showed that it was possible to get a full ranking of the renovation solutions. The best compromise solutions were respectively the exterior insulation of the secondary facade and courtyard with 10 cm of wood fiber (A7), the exterior insulation of the roof with 15 cm of expanded polystyrene (A11), the double glazing window installation (A13), and the exterior insulation of the main facade with 6 cm of lime hemp plaster (A4). However, the proposed method has several limitations. The method does not take into account uncertainties related to the evaluation of the renovation solutions. Also, it does not take into account the combination of solutions. For that, future research is recommended to covert those limitations.

REFERENCE

Abdelkader, B. 2015. *Lancement du nouveau programme d'efficacité énergétique en 2016*. Oran: SARL Edimarcom-Dist. Available at: http://www.carrefourdalgerie.com/archive/pdf/2015/04/16-04-2015.pdf.

Addab, M. 2015. *Réhabilitation du vieux bâti: Diagnostic de plus de 300.000 logements*. Oran: Le Quotidien d'Oran. Available at: http://www.lequotidien-oran.com/index.php?news=5214534&archive_date=2015-06-03.

APRUE. 2007. *Consommation énergétique finale de l'Algérie*. Algérie: Agence Nationale pour la Promotion et la Rationalisation de l'Utilisation de l'Energie.

Bellman, R. E. & Zadeh, L. A. 1970. Decision-Making in a Fuzzy Environment. *Management Science*, 17(4), pp. B-141; B-164.

Brans, J. P. 1992. PROMETHEE V: MCDM problems with segmentation constraints. *Information systems and operational research*, 30(2), pp: 85.

Brans, J. P., Vincke, P. & Mareschal, B. 1986. How to select and how to rank projects: The PROMETHEE method. *European Journal of Operational Research*, 24(2), pp. 228-238.

Dutta, M. & Husain, Z. 2009. An application of Multicriteria Decision Making to built heritage. The case of Calcutta. *Journal of Cultural Heritage*, 10(2), pp. 237-243.

Ferretti, V., Bottero, M. & Mondini, G. 2014. Decision making and cultural heritage: An application of the Multi-Attribute Value Theory for the reuse of historical buildings. *Journal of Cultural Heritage*, 15(6), pp. 644-655

Fuentes, J. M. 2010. Methodological bases for documenting and reusing vernacular farm architecture. *Journal of Cultural Heritage*, 11(2), pp. 119-129.

Gupta, R., Sachdeva, A. & Bhardwaj, A. 2012. Selection of logistic service provider using fuzzy PROMETHEE for a cement industry. *Journal of Manufacturing Technology Management*, 23(7),pp 899-921.

Heraou, A. 2011. Evolution des politiques de l'habitat en Algerie. [online MA Thesis] Department of architecture, University of Sétif. Available at: http://www.univ-setif.dz/MMAGISTER/images/facultes/ARCH/HERAOU%20ABDELKRIM.pdf.

Keeney, S., Hasson, F. & Mckenna, H. 2006. Consulting the oracle: ten lessons from using the Delphi technique in nursing research. *Journal of advanced nursing*, 53(2), pp. 205-212.

Macharis, C., Brans, J. P. & Mareschal, B. 1998. The GDSS PROMETHEE procedure a PROMETHEE–GAIA based procedure for group decision support. *Journal of decision systems*, 7, pp. 283-307.

Macharis, C. et al. 2004. PROMETHEE and AHP: The design of operational synergies in multicriteria analysis.: Strengthening PROMETHEE with ideas of AHP. *European Journal of Operational Research*, 153(2), pp. 307-317.

Mardani, A., Jusoh, A. & Zavadskas, E. K. 2015. Fuzzy multiple criteria decision-making techniques and applications – Two decades review from 1994 to 2014. *Expert Systems with Applications*, 42(8), pp. 4126-4148.

Saaty, T. L. 1977. A scaling method for priorities in hierarchical structures. *Journal of mathematical psychology*, 15(3), pp. 234-281.

VP solutions., Mareschal. 2012. The Visual PROMETHEE Academic Edition.

Wang, H. & Zeng, Z. 2010. A multi-objective decision-making process for reuse selection of historic buildings. *Expert Systems with Applications*, 37(2), pp. 1241-1249.

Zagorskas, J. et al. 2014. Thermal insulation alternatives of historic brick buildings in Baltic Sea Region. *Energy and Buildings*, 78, pp. 35-42.

Zheng, G. et al. 2009. Application of Life Cycle Assessment (LCA) and extenics theory for building energy conservation assessment. *Energy*, 34(11), pp. 1870-1879.