Modern Environmental Science and Engineering (ISSN 2333-2581)
August 2017, Volume 3, No. 8, pp. 565-569
Doi: 10.15341/mese(2333-2581)/08.03.2017/006
Academic Star Publishing Company, 2017
www.academicstar.us

Restoration, Water Harvesting, and Scenic Beautification: A Sustainable Model of Harmony in Pátzcuaro, Michoacán, Mexico

Marcial Reyes Cazarez, and Rigoberto Tovar Aguilar

PatzcuaroInstitute of Technology, Avenida Tecnologico No. 1, Tzurumutaro, Pátzcuaro, Michoacán, México

Abstract: In light of the current EU guidelines in the energy field, improving building envelope performance cannot be separated from the context of satisfying the environmental sustainability requirements, reducing the costs associated with the life cycle of the building as well as economic and financial feasibility. Therefore, identifying the "optimal" energy retrofit solutions requires the simultaneous assessment of several factors and thus becomes a problem of choice between several possible alternatives. To facilitate the work of the decision-makers, public or private, adequate decision support tools are of great importance. Starting from this need, a model based on the multi-criteria analysis "AHP" technique is proposed, along with the definition of three synthetic indices associated with the three requirements of "Energy Performance", "Sustainability Performance" and "Cost". From the weighted aggregation of the three indices, a global index of preference is obtained that allows to "quantify" the satisfaction level of the i-th alternative from the point of view of a particular group of decision-makers.

The model is then applied, by way of example, to the case-study of the energetic redevelopment of a former factory, assuming its functional conversion. Twenty possible alternative interventions on the opaque vertical closures, resulting from the combination of three thermal insulators families (synthetic, natural and mineral) with four energy retrofitting techniques are compared and the results obtained critically discussed by considering the point of view of the three different groups of decision-makers.

Key words: multi-criteria analysis, AHP, building envelope, energy retrofitting, sustainability

1. Introduction

As part of decision support systems, multi-criteria analysis is an evaluation methodology of different alternatives to the solution of a problem on the basis of a number of predefined criteria that are shared by the actors involved. There are several multi-criteria analysis techniques and their application covers several sectors.

An important step in the construction of a multi-criteria model is the choice of a set of indicators that from objective data allow to synthetically "measure" the satisfaction level of various alternatives with respect to the predetermined criteria. The indicators and criteria should be sufficiently representative of the problem in question and relate to the objectives to be achieved. Their relative weight should also express an opinion that is shared by the decision makers.

In recent years, the use of these techniques has also increased in the development of procedures for the evaluation and choice of energy-environmental regeneration strategies of both historic and contemporary buildings [1-8]. Along with the aim of reducing energy consumption in winter and summer, translated into various regulatory requirements, there is also the concept of the optimal level of energy performance costs, i.e., a design founded on a balance between costs and benefits in the life cycle of the

Corresponding author: Marcial Reyes Cázarez, Master of sciences on wood technology, research areas/interests: management to natural resources and research on community-based. E-mail: mreyes@itspa.edu.mx.

building. Another aspect currently being discussed is the measurement of theenvironmental sustainability of the intervention through appropriate indicators.

2. Description of the Proposed Model

The model presented in this paper makes use of the AHP multi-criteria analysis technique [9], which stands for Analytic Hierarchy Process, and is based on three assessment criteria of the ith alternative housing retrofit technique: 1) Energy Performance, “EP”; 2) Sustainability Performance, “SP”; 3) Cost, “C”. The “EP” criterion is associated to four indicators: 1.1) “EP_{gl}” Global Energy Performance Index evaluated in accordance to the calculation procedures set out by current national legislation (UNI/TS 11300); 1.2) “MP”, Moisture Performance indicator, which considers the hygrometric behaviour under a steady state according to the UNI 13788 [10]; 1.3) “Y_{ie}”, periodic thermal transmittance, which considers the thermal behaviour under dynamic conditions, calculated according to UNI 13786 [11]; 1.4) “$A_{sol,eq}/A_u$”, summer solar equivalent area per usable floor space units, which allows for the control of solar radiation through the glass casing components and is based on Attachment 1 to the Decree of June 26, 2015 [12]. The “SP” criterion examines the sustainability of the building envelope retrofit solutions, both in terms of the environmental impact of the materials used, while also considering, albeit in a qualitative way, other aspects such as the maintainability, reversibility and recyclability of the components. The environmental impacts are assessed according to a simplified LCA, *Life Cycle Assessment* that, through an *expert-based* weighting system [13-15] aggregates a single synthetic indicator of six categories of environmental impact (GWP, AP, EP, ODP, POCP, PE*nr*). From an operational point of view, the software *“Athena Impact Estimator for Buildings”*, developed in 2002 by the Canadian Research Institute, *Athena Sustainable Materials Institute* (ASMI) is used for the LCA analysis. The maintainability and reversibility of the technological solutions are measured through two qualitative indicators, “I_{MAIN}” and “I_{DfD}” respectively, based on scoring systems [15]. The criterion “C” is ultimately associated with the two indicators of economic convenience, *Pay Back period* (PB) and *Profitability Index* (PI). A 5% discount rate, already corrected for inflation (European Commission, 2007-2013) is adopted. The period of analysis is assumed to be 25 years and that the life of the building envelope is redeveloped.

Having defined the criteria and indicators used in the model, it is possible to assemble the decision matrix for the comparison of “n” intervention alternatives and “Ai” for the building envelope energy retrofits (Table 1). The compilation of the matrix provides, for each technical alternative, the evaluation of the nine indicators ($EP_{gl,nr}$, Y_{IE}, $A_{sol,eq}/A_u$, MP, I_{LCA}, I_{DfD}, I_{MAIN}, PB, PI) in the respective units of measurement. After normalizing the elements of the matrix, it is possible through an *expert-based* weighting system to aggregate the nine indicators into three synthetic indices:

$$I_{EP} = a_1 EP^*_{gl,nr} + a_2 Y^*_{IE} + a_3 \frac{A_{sol,eq}}{A_{su}}^* + a_4 MP^*$$

$$I_{SP} = b_1 I^*_{LCA} + b_2 I^*_{DfD} + b_3 I_{MAIN}{}^*$$

$$I_C = c_1 PB^* + c_2 PI^*$$

where the coefficients a_1, a_2, a_3, a_4, b_1, b_2, b_3, c_1, c_2 express the relative weights, while the apex “*” expresses the normalized value of the indicator.

For the resolution of the matrix, the “SAW” technique is adopted [16] through which it is possible to define the following global index, I_{ERES}, “*Energy Retrofit and Environmental Sustainability Index*”:

$$I_{ERES} = w_1 I_{EP} + w_2 I_{SP} + w_3 I_C$$

The attribution of the relative weights of the criteria and indicators associated with each method is through thepairs comparison technique. In particular, a study was carried out considering three different profiles of *decision makers* in order to have a sample that is representative of different points of view and needs [17]. The decisionmakers consulted belong to the following three categories: 1) *Public Administrators* (P.A.); 2) *Private Investors* (P.I.); 3) *Technicians* (T.). Table 2 reports the relative vectors of the weights.

A sample of twenty industry experts including university professors, graduates and professional consultants [17] were consulted to calibrate the vector of the weights of the indicators (Table 3).

3. Application of the Model

The described model is a further development of a reuse methodology whose description and application is reported in detail in a previous work by the authors [18]. Regarding the energy retrofit of the envelope of a factory, 20 alternative interventions on the transparent vertical closureswere compared, resulting from the combination of three thermal insulators groups — synthetic, mineral and natural — withfour energy retrofitting techniques (Table 4): 1) *External Thermal Insulation Composite Systems* (ETICS), group “A_1”; 2) *Internal Thermal Insulation Composite Systems* (ITICS), group “A_2”; 3) *Overcladding/Ventilated Façade*, group “A_3”; 4) *Recladding*, group “A_4”.

The synthetic insulating materials considered in the analysis are: sintered polystyrene foam treated with graphite, EPS +graphite, group “I_1”; PU foam, *PU-rigid foam*, group “I_2”. Among the mineral insulating materials, there is *Rockwool*and calcium silicate hydrate (C-S-H)slabs: these insulating belong to the group known as “I_3”. Finally, *Wood Fiber*is the natural insulation, “I_4” group. The generic alternative to the retrofitting of the building enevelope will therefore be identified with the pair “A_i-I_j” (Table 5). Two Internal Thermal Insulation Composite Systems (ITICS) are taken into consideration: 1) Direct application of the insulating panels to the existing wall; 2) realisation of a counter wall separatedfrom the existing wall by an air gap. *Overcladding* (O.C.) is generally the overlayyingonto the existing facade of a new envelope. In this case, it was considered as a covering system consisting of sandwich panels and an anchorage to the substructure of the existing wall, creating an air gap. The panel has two aluminum sides and a central insulating core of either polyurethane (A_3-I_2) or rockwool (A_3-I_3). The technology of the ventilated façade is different from overcladding since it has an external face, ventilated air cavity and an insulating layer attached to the existing wall. The outer layer, supported and anchored to the existing wall by means of metal sections, can be made of various materials; the analysis considered an external face consisting of either 10 mm Gres stone slabs (A_3-I_j-Gres) or 4 mm aluminum composite panels (A_3-I_j-Alum). Finally, *recladding* includes the demolition of the existing vertical closures and the realising of a new envelope with temperature-humidity characteristics that meet regulatory requirements.

After evaluating, for each alternative, the indicators described above, the decision matrix was drawn up (Table 5).The next phase involved the standardization and calculation ofthe I_{ERES} according to the three profiles of the decision makers involved.

4. Results

The results are presented below in graphs (Fig. 1). The technical solutions with a higher I_{ERES}, those that are “preferred” by the three categories of decision-makers, belong to the ETICS “A_1” group. In particular, the alternative “A_1-I_4” with external insulation in wood fiber has the highest index value for each of the three decison makers. This is followed by, with slightly a lower I_{ERES}, the three internal insulation solutions, “A_2-I_2” with polyurethane foam panels, “A_2-I_4” with fiber wood panels, and “A_2-I_{3B}” a counter wall with gypsum and rock wool fiber-reinforcedslabs. The two overcladding solutions with polyurethane sandwich panels, “A_3-I_2”, or in rockwool, “A_3-I_3”, have I_{ERES}values close to those of the internal insulation alternatives.The alternative “A_3-I_2” has, from the point of view of public (PA) and technical (T) decision makers,an higher I_{ERES} index compared than that of the alternatives “A_2-I_2”, “A_2-I_4”, “I_{3B}-A_2” and “A_3-I_3”. The four solutions of the group “A_1” and the solution “A_2-I_2” are particularly “preferred” by the Private Investor that gives a greater relative weight to the “C” criteria.

References

[1] IPCC, Climate change 2013: The physical science basis, in: Stocker T. F., D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (Eds.), *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013, p. 1535.

[2] IPCC, Climate change 2007: Synthesis report, in: Core Writing Team, Pachauri R. K. & Reisinger A. (Eds.), *Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, IPCC, Geneva, Switzerland, 2007, p. 104.

[3] T. Ming, Renaudde Richter, Wei Liu and Sylvain Caillol, Fighting global warming by climate engineering: Is the Earth radiation management and the solar radiation management any option for fighting climate change?, *Renewable and Sustainable Energy Reviews* 31 (2014) 792-834.

[4] Yaning Chen, li Wei-hong, Xu Chang-chun and Hao Xin-ming, Effects of climate change on water resources in Tarim River Basin, Northwest China, *Journal of Environmental Sciences* 19 (2007) (4) 488-493.

[5] Yang Nan, Men Bao- hui and Lin Chun-kun, Impact analysis of climate change on water resources, *Procedia Engineering* 24 (2011) 643-648.

[6] UNOCHA, Afghanistan; Floods in Guzargah-e-Nur district in Baghlan province, Situation Report No. 11 as of 1400h (local time) on 11 June 2014, United Nation Office for the Coordination of Human Affairs, 2014.

[7] NEPA, Afghanistan Initial National Communication to the United Nations Framework Convention on Climate Change, National Environmental Protection Agency report, Kabul, Afghanistan, 2009.

[8] FAO, A review of drought occurrence and monitoring and planning activities in the Near East Region, UN Food and Agriculture organization and National Drought Mitigation Center University of Nebraska-Lincoln, Nebraska, USA, 2008.

[9] CSO, *Central Statistic Origination the Handbook of Population Estimation for theYear 2015*, 2015.

[10] Kamal, The River Basins and Watersheds of Afghanistan, Afghanistan Information Management Service (AIMS), May 10, 2004.

[11] World Bank, Water Resource Development in Northern Afghanistan and Its Implications for Amu Darya Basin, world bank working paper No 36, 2004.

[12] USGS, Digital Elevation Model of Afghanistan, US geological services.

[13] AMA, Monthly Meteorological Data of Kunduz River Basin, Afghanistan Meteorological Authority, 2014.

[14] University of East Anglia Climatic Research Unit (CRU), Phil Jones and Ian Harris, *CRU TS3.21: Climatic Research Unit (CRU) Time-Series (TS) Version 3.21 of High Resolution Gridded Data of Month-by-month Variation in Climate (Jan. 1901-Dec. 2012)*, NCAS British Atmospheric Data Centre, 2013, 24th September 2013.

[15] F. H. Chen, Huang Wei, Jin LiYa, Chen Jian Hui and Wang Jin Song, spatiotemporal precipitation variations in the arid Central Asia in the context of global warming, *China Earth Sci.* 54 (2011) 1812-1821.

[16] Chonghua Yin, Yinpeng Li and Peter Urich, SimCLIM Data Manual, CLIM systems Ltd, 2013, Hamilton 3210 New Zealand, 2013.

[17] G. Flato, J. Marotzke, B. Abiodun, P. Braconnot, S. C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, Evaluation of climate models, in: Stocker T. F., D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[18] R. H. Moss, Jae A. Edmonds, Kathy A. Hibbard, Martin R. Manning, Steven K. Rose, Detlef P. van Vuuren, Timothy R. Carter, Seita Emori, Mikiko Kainuma, Tom Kram, Gerald A. Meehl, John F. B. Mitchell, Nebojsa Nakicenovic9, Keywan Riahi, Steven J. Smith, Ronald J. Stouffer, Allison M. Thomson, John P. Weyant & Thomas J. Wilbanks, The next generation of scenarios for climate change research and assessment, Vol. 463, 11 February 2010.

[19] Vuurena. Detlef P., Jae Edmonds, Mikiko Kainuma, Keywan Riahi, Allison Thomson, Kathy Hibbard, George C. Hurtt, Tom Kram, Volker Krey, Jean-Francois Lamarque, Toshihiko Masui, Malte Meinshausen, Nebojsa Nakicenovic, Steven J. Smith and Steven K. Rose, The representative concentration pathways: An overview, *Climatic Change* 10 (2011) 5-31

[20] E. Mcleod, Benjamin Poulter, Jochen Hinkel, Enrique Reyes and Rodney Salm, Sea-level rise impact models and environmental conservation: A review of models and their applications, *Ocean & Coastal Management* 53 (2010) (9) 507-517.

[21] CLIM systems, SimCLIM2013 essential book1 (Version 3.0), CLIM systems Ltd, Flagstaff, Hamilton 3210, New Zealand, 2013.