SEDDIKI, M., BENNADJI, A., LAING, R. and GRAY, D. 2021. User-friendly tool to enable individual homeowners to invest in energy efficiency. In *Abdelmohsen, S., El-Khouly, T., Mallasi, Z. and Bennadji, A. (eds.). Architecture in the age of disruptive technologies: transformation and challenges: proceedings of the 9th Arab Society for Computer Aided Architectural Design 2021 (ASCAAD 2021), 2-4 March 2021, [virtual conference]*. Aberdeen: Robert Gordon University, pages 750-756. Hosted on CumInCAD [online]. Available from: http://papers.cumincad.org/cgi-bin/works/paper/ascaad2021_155

User-friendly tool to enable individual homeowners to invest in energy efficiency.

SEDDIKI, M., BENNADJI, A., LAING, R. and GRAY, D.

2021

OpenAIR @RGU

This document was downloaded from https://openair.rgu.ac.uk

CC BY NC

USER-FRIENDLY TOOL TO ENABLE INDIVIDUAL HOMEOWNERS TO INVEST IN ENERGY EFFICIENCY

MOHAMMED SEDDIKI, AMAR BENNADJI, RICHARD LAING
The Scott Sutherland School of Architecture and Built Environment, Robert Gordon University,
Garthdee Road, Aberdeen, AB10 7GJ, United Kingdom
Email address: m.seddiki@rgu.ac.uk; a.bennadji@rgu.ac.uk; r.laing@rgu.ac.uk

AND

DAVID GRAY
Cultural and Creative Business School, Robert Gordon University
Email address: david.gray@rgu.ac.uk

Abstract. Buildings are an important source of CO2 emissions and account for almost a third of final energy consumption globally. The necessity to achieve energy efficiency standards in new and existing buildings is now recognised. The residential sector consumes 25% of the global energy and is responsible of 17% of the global CO2 emissions. EU governments have developed different support measures to decrease energy consumption in the residential sector. However, energy renovation by individual homeowners is lagging because the support measures do not take into account concerns of homeowners. This study is part of Sustainable housing for strong communities (Stronghouse) project, which aim to propose new tools and redesign support measures based on a better understanding of the drivers that motivate homeowners. This paper proposes a new user-friendly web-based multi-criteria decision-making tool that aims to empower homeowners to select the appropriate energy improvement method for their home fitting their criteria. The set of criteria that will be included in the application will be based on the preferences of residents obtained through questionnaires. A layered approach will be used to develop the proposed web application.

Keywords: *Decision support tool, multi-criteria decision-making, thermal renovation, homeowners*

USER-FRIENDLY TOOL TO ENABLE INDIVIDUAL HOMEOWNERS TO INVEST IN ENERGY EFFICIENCY

ملخص. تعد المباني مصدرًا مهمًا لانبعاثات غاز ثاني أكسيد الكربون وتمثل ما يقارب ثلث الاستهلاك النهائي للطاقة على مستوى العالم. إن تحقيق معايير الكفاءة الطاقوية في المباني الجديدة والموجودة أصبح ضرورة معترفا بها . يمثل قطاع السكن 25٪ من اجمالي استهلاك الطاقة العالمية وهو مسؤول عن 17٪ من انبعاثات غاز ثاني أكسيد الكربون على مستوى العالم. لقد طورت حكومات الاتحاد الأوروبي العديد من وسائل الدعم للتقليل من كمية استهلاك الطاقة في قطاع السكن، وبالرغم من ذلك، فأن عمليات التجديد الطاقوي التي يقوم بها ملاك المساكن لا ترقى إلى المستوى المطلوب لأن وسائل الدعم لا تأخذ اهتماماتهم بعين الاعتبار. هذه الدراسة هي جزء من مشروع "سكن مستدام لمجتمعات قوية" والذي يهدف إلى اقتراح أدوات جديدة وإعادة تصميم تدابير الدعم بناءًا على فهم أمثل للدوافع التي تحفز ملاك المساكن. تقترح هذه الورقة أداة صنع قرار جديدة، سهلة الاستخدام ومتعددة المعايير قائمة على شبكة الأنترنت والتي تهدف إلى تمكين ملاك المساكن من اختيار طريقة التحسين الطاقوي المناسبة لمنازلهم والتي تناسب معاييرهم. ستعتمد مجموعة المعايير التي سيتضمنها التطبيق على تفضيلات السكان التي تم الحصول عليها من خلال الاستبيانات. سيتم استخدام نهج متعدد الطبقات لتطوير تطبيق الانترنت المقترح.

الكلمات المفتاحية: *أداة دعم القرار، اتخاذ القرار متعدد المعايير، التجديد الحراري، ملاك المنازل.*

1. Introduction

In Europe, buildings account for almost 40% of the energy consumption and 36% of CO2 emissions. According to the new version of the energy performance of buildings directive (2018/844/EU), European Union countries must establish strong long-term renovation strategies, aiming at decarbonising the national building stocks by 2050. Renovation of existing buildings could reduce the EU's CO2 emissions by about 5%. Current rates of energy renovation by individual homeowners are insufficient to achieve the necessary change in energy use (only about 1% of the building stock is renovated each year) (European-Commission, 2019).

Many scholars have indicated that non-adequacy of support measures represent a major hindrance to the adoption of energy renovation by individual homeowners and have emphasized that EU Member States should identify an adequate set of support measures by involving homeowners in the preparation and implementation of their strategies (Economidou et al., 2020). Other studies have considered the lack of methodological support in order to select the best thermal renovation solution as the main barrier that hinder the adoption of energy efficiency measures of homeowners (Seddiki and Bennadji, 2019).

There have been several projects that aimed to provide simple interfaces to assist homeowners in their renovation project (Lee et al., 2014). However, available tools mainly focus on carbon emissions, energy reduction and financial aspects. They do not take into consideration the fact that the selection of the best renovation solutions among a vast diversity of alternatives (thermal insulation, biomass, solar energy,) is a complex decision, which includes analysing different criteria (investment cost,

available grants, type of buildings, etc.), and engaging many stakeholders potentially, holding conflicting views.

Multiple-Criteria Decision Making (MCDM) analysis is a useful tool for these types of complex problems; it evaluates different solutions by taking into account several criteria and the opinions of various stakeholders. MCDM methods were widely applied for the thermal renovation of existing buildings. However, the majority of developed MCDM methods are not adapted to be used by homeowners due to their complexity.

The originality of this paper is to propose a new user-friendly web-based multi-criteria decision-making tool that aims to empower homeowners to select energy efficiency measures for their home fitting their criteria.

2. Literature review

As indicated in table 1, MCDM methods have been widely used for the thermal renovation of existing buildings. They were applied at an individual level (e.g. for the selection of the best insulation solution for a single building) and a neighbourhood level (e.g. for the selection of the best district heating system for a residential area). Moreover, the review of the literature indicates that the available MCDM methods require complex computations and are not adapted to be used by homeowners.

TABLE 1: Main works available in the literature concerning the application of MCDA methods in thermal renovation of buildings (adopted from Seddiki et al., (2018))

Authors	Fields of application	MCDA methods	Scales of application
(Medineckiene and Björk, 2011)	Thermal renovation of residential buildings	AHP,SAW,MEW, COPRAS	Individual level
(Zagorskas et al., 2014)	Selection of insulation option for historic buildings	TOPSIS	Individual level
(Zheng et al., 2009)	Building energy conservation	FAHP	Individual level
(Seddiki et al., 2016)	Thermal renovation of residential buildings	Delphi-Swing-PROMETHEE	Individual level
(Seddiki M, 2018)	Thermal renovation of residential buildings	FAHP-FPROMETHEE	Individual level
(Kontu et al., 2015)	Selection of heating system for residential buildings	SMAA	Neighbourhood level
(Lu et al., 2015)	The design optimization of the renewable energy system sizes in low/zero energy buildings.	Multi-objectives optimization using NSGA-II	Neighbourhood level

(Catalina et al., 2011)	The selection of the best combination of renewable energy systems for residential buildings.	ELECTRE III	Neighbourhood level
(Seddiki et al. 2019)	Multi-criteria evaluation of renewable energy alternatives for electricity generation in residential buildings	FAHP-FPROMETHEE	Neighbourhood level
ELECTRE: Elimination and Choice Expressing the Reality; SMAA: Stochastic Multi-criteria Acceptability Analysis; AHP: Analytical Hierarchy Process; SAW: Simple Additive Weighting; MEW: Multiplicative Exponential Weighting; COPRAS: Complex Proportion Assessment; TOPSIS: Technique for Order of Preference by Similarity to Ideal Solution; FAHP; Fuzzy AHP			

3. Methodology

3.1. PHASE 1:

This phase aims to identify evaluation criteria and energy improvement solutions. It includes two main activities. The first activity aims to define a pre-screening list of criteria and renovation solutions; it will involve an in-depth data collection through literature review and face-to-face interviews with experts, stakeholders and decision-makers. Then, in the second activity, the preliminary set of criteria and renovation solution will be narrowed based on the preferences of residents obtained through questionnaires.

3.2. PHASE 2:

This phase aims to develop a new multi-criteria model. This phase will evaluate different multi-criteria methods and conclude which aspects are relevant to include in the proposed model.

3.3. PHASE 3:

This phase aims to develop a user-friendly web-based decision support tool. A layered approach will be used to develop the proposed system, which is comprised of three distinct but interconnected user interface, application and data layers:

- User interface layer, comprised of an individual interface and a group interface, incorporates a language module and a presentation module.
- Application layer hosts all the functional modules, which implement the proposed methodology in phase 02.
- Data layer stores all the necessary data for the decision problem.

The web application will provide a repository of available energy efficiency measures as well as a set of evaluation criteria (defined by a questionnaire in phase 1). The application will also provide default values of weighting criteria that could be easily modified to suit the homeowners' specific needs and preferences as indicated in Khelifi et al., (2006). From the homeowner's point of view, the proposed web application consists of several sequential steps as presented in figure 1.

First, the user of the application should provide information about the building (e.g. location, building type and form, energy consumption, current house conditions, etc.), then should define the energy performance target (e.g. local building regulations, EnerPHit renovation certification, etc.). After, the user should indicate the evaluation criteria and provide the importance of each criterion. Finally, the multi-criteria decision starts and the system recommendations are presented to the user. If the user is satisfied with the results, the process finishes here with recommendations. However, if the results are not satisfactory, a sensitivity analysis should be performed. Firstly, the importance of each criterion should be investigated. Secondly, the set of selected criteria should be examined. Finally, if the results are still not satisfactory, the energy performance target should be revised.

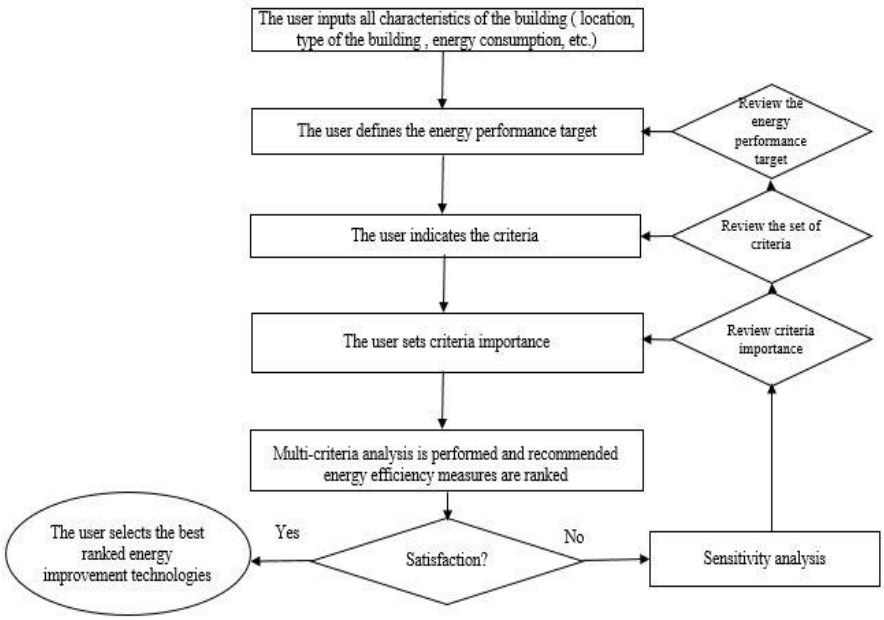

Figure 1. General algorithm of the proposed web application.

4. Conclusion

Although EU governments have developed different supports measures to encourage homeowners to invest in energy efficiency, renovations rates are insufficient to achieve EU energy reduction targets. One of the main barriers that hinder homeowners from adopting energy efficiency measures is that available tools and supports measures do not take into consideration their criteria and preferences. Whereas multi-criteria decision methods allow to integrate preferences of residents in the renovation decision process, such methods are not adapted to be used by homeowners due to their complexity. The originality of this paper is to propose a new user-friendly web-based multi-criteria decision-making tool that aims to empower homeowners to select energy efficiency measures for their home fitting their criteria.

Acknowledgements

This paper is part of Stronghouse project, which is co-funded by European Regional Development Fund (ERDF) under the umbrella of Interreg North Sea Region. The 14 partners involved in the project are from Netherlands, Belgium, Germany, Denmark, Sweden and the United Kingdom.

References

CATALINA, T., VIRGONE, J. & BLANCO, E. 2011. Multi-source energy systems analysis using a multi-criteria decision aid methodology. Renewable Energy, 36, 2245-2252.

ECONOMIDOU, M., TODESCHI, V., BERTOLDI, P., D'AGOSTINO, D., ZANGHERI, P. & CASTELLAZZI, L. 2020. Review of 50 years of EU energy efficiency policies for buildings. Energy and Buildings, 225, 110322.

EUROPEAN-COMMISSION. 2019. Energy performance of buildings directive [Online]. Available: https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en.

KHELIFI, O., LODOLO, A., VRANES, S., CENTI, G. & MIERTUS, S. 2006. A web-based decision support tool for groundwater remediation technologies selection. Journal of Hydroinformatics, 8, 91-100.

KONTU, K., RINNE, S., OLKKONEN, V., LAHDELMA, R. & SALMINEN, P. 2015. Multicriteria evaluation of heating choices for a new sustainable residential area. Energy and Buildings, 93, 169-179.

LEE, S. H., HONG, T. & PIETTE, M. A. 2014. Review of existing energy retrofit tools. Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States).

LU, Y., WANG, S., ZHAO, Y. & YAN, C. 2015. Renewable energy system optimization of low/zero energy buildings using single-objective and multi-objective optimization methods. Energy and Buildings, 89, 61-75.

MEDINECKIENE, M. & BJÖRK, F. 2011. Owner preferences regarding renovation measures – the demonstration of using multi-criteria decision-making. Journal of civil engineering and management, 17, 284-295.

SEDDIKI M, A. K., BENNADJI A 2018. Integrated FAHP-FPROMETHEE for thermal insulation of masonry buildings. Facilities, 36.

SEDDIKI, M., ANOUCHE, K., BENNADJI, A. & BOATENG, P. 2016. A multi-criteria group decision-making method for the thermal renovation of masonry buildings: The case of Algeria. Energy and Buildings, 129, 471-483.

SEDDIKI, M. & BENNADJI, A. 2019. Multi-criteria evaluation of renewable energy alternatives for electricity generation in a residential building. Renewable and sustainable energy reviews, 110, 101-117.

ZAGORSKAS, J., ZAVADSKAS, E., TURSKIS, Z., BURINSKIENE, M., BLUMBERGA, A. & BLUMBERGA, D. 2014. Thermal insulation alternatives of historic brick buildings in Baltic Sea Region. Energy and Buildings, 78, 35-42.

ZHENG, G., JING, Y., HUANG, H., ZHANG, X. & GAO, Y. 2009. Application of Life Cycle Assessment (LCA) and extenics theory for building energy conservation assessment. Energy, 34, 1870-1879.