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A systematic review of passive energy consumption optimisation strategy selection for buildings through multiple criteria decision-making techniques

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A R T I C L E I N F O

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A B S T R A C T

Buildings account for a significant proportion of global energy demand, which is testament to population growth and changes to life patterns. Experts in energy studies have continued to identify passive energy consumption optimisation strategies as viable approaches for curbing the menace of steadily rising energy demand in buildings. However, the implementation of a logical procedure for selecting suitable passive strategies for use in buildings remains a challenge. Also, existing studies have mainly focused on a very limited number of passive strategies, selection criteria and selection methods. Therefore, this study aims to generate a very comprehensive list of the most prevalent passive energy consumption optimisation strategies, their selection criteria, and the multiple criteria decision analysis/making (MCDA/MCDM) techniques that aided the selection process, via a combination of preferred reporting items for systematic reviews and meta-analyses (PRISMA) and procedure for performing systematic reviews (PPSR) approaches. To ensure comprehensiveness, the study extracted information from a wide range of large and multidisciplinary databases (such as Web of Science and Scopus) as well as smaller but engineering and science disciplines specific databases (such as Compendex, GEOBASE, GeoRef, and Inspec). It was concluded that the existing literature focused on a very small number of passive strategies especially optimizing the insulation layer, using naturally ventilated envelope, and using sun shading devices. Cost and energy saving potentials were considered as the selection criteria in most of the previous studies, and analytical hierarchy process (AHP) was the most popular selection technique, which may not be suitable for under all scenarios.

1. Introduction

The world has undergone a significant transformation in terms of population growth, especially during the last decades [1]. According to a United Nations report in 2019, the world's population has increased from about 2.53 billion in 1950 to more than 7.79 billion in 2020, which equates to approximately a 207.9% rise [2]. According to another complimentary report, there was approximately a 55% rise in the global population between 2018 and 2020 [3]. These rising global population trends are predicted to continue, with a projection of over 10.9 billion by 2100 (i.e., a 40% increase) [4]. According to the predicted population growth, depletion of all current primary energy resources by the next 133 years is anticipated.

One of the most important themes for the United Nations' Sustainable Development Goals (SDGs) is the creation of "Sustainable Cities and Communities" [5], and the reduction of global energy consumption has been continuously described as crucial to the realisation of this theme [6]. Buildings represent one of the most fundamental needs for people, irrespective of their locations in the world [7]. In other words, buildings, as shelters for the current and future population, have multiple types including residential [8], educational [9], commercial [10], industrial [11], medical [12], military [13], and religious [14] buildings, and therefore play crucial roles in human's lives. Despite the mentioned critical roles of buildings, their corresponding energy usage has always been a challenging issue for countries [15]. Buildings are responsible for consuming over 40% of the global energy consumption [16,17] and emitting about 35% of the world's total Green House Gases (GHG) [18,

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List of abbreviations

ACH	Air Change per Hour
AHP	Analytical Hierarchy Process
BIM	Building Information modelling
BWM	Best-Worst Method
COPRAS	Complex Proportional Assessment
DG	Direct Gain
DSF	Double Skin Façade
EDAS	Evaluation based on distance from average solution
ELECTRE	Elimination and Choice Expressing Reality
ETICS	External Thermal Insulation Composite Systems
GHG	Green House Gas
HVAC	Heating, ventilation, and air conditioning
KCA	Keywords co-occurrence analysis
LAI	Leaf Area Index
LPSHW	Lattice Passive Solar Heating Walls
LR	Literature Review
MCDA	Multiple Criteria Decision Analysis
MCDM	Multiple Criteria Decision-Making
MIT	Massachusetts Institute of Technology
MSF	Multi Skin Façade
O&M	Operational and Maintenance
PCM	Phase Changing Material
PSG	Passive Strategy Group
PSSC	Passive Strategy Selection Criteria
PPSR	Procedure for Performing Systematic Reviews
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SAW	Simple Additive Weighting
SDG	Sustainable Development Goal
SLR	Systematic Literature Review
SSF	Single Skin Façade
SWARA	Stepwise Weight Assessment Ratio Analysis
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
WoS	Web of Science

19]. It is therefore imperative to deduce an apt solution for reducing the amount of energy consumption in buildings.

Generally, energy consumption optimisation in the building industry can be divided into two broad groups called active strategies and passive strategies [20]. Active energy consumption optimisation strategies are associated with taking advantage of mechanical or electrical appliances for reducing energy consumption in buildings. More specifically, these strategies focus on the usage of renewable energy to design and renovate buildings besides using fossil energy as least as possible [21]. For instance, Reducing the load on the electricity grid by installing photovoltaic panels on the façade or roof of buildings, taking advantage of biomass boilers or geothermal energy, and installing wind turbines on the rooftop of buildings are all considered active energy consumption optimisation strategies [22,23]. Although active strategies can help the buildings reduce energy consumption, high prices of buying the required appliances and high Operational and Maintenance (O&M) costs have always been regarded as disadvantages of active strategies [24].

On the other hand, passive energy consumption optimisation strategies try to reduce energy consumption by using the potential of the building's structure and the environment. In other words, passive energy consumption optimisation strategies do not use any electrical or mechanical appliances to optimize energy consumption, making them very cost-effective in comparison to active strategies [25]. For example, taking advantage of sun shading devices, garden roofs, or Double Skin Façades (DSFs) in buildings are regarded as passive energy consumption optimisation strategies [26,27]. Another key feature of passive strategies is that they can be implemented on historical buildings as well as contemporary buildings, which is regarded as very useful for preserving the numerous heritage sites around the world [28]. Despite the mentioned benefits of passive strategies, being highly dependent on the geographical area of buildings is a disadvantage of passive strategies, which is solvable by considering relevant selection criteria such as "Compatibility with climate" in the decision-making process.

There have been some review studies within the existing body of knowledge that provide very useful general insights about passive energy consumption strategies. For instance, Brito-Coimbra et al. [29] reviewed passive strategies related to the façades of buildings, while Sawadogo et al. [30] reviewed the usage of Phase Changing Materials (PCMs) as a passive energy consumption optimisation strategy in buildings. Sharifi et al. [18] focused on reviewing the usage of a passive strategy called roof pond in the building industry. Nugroho's [31] review investigated living walls as another passive strategy in buildings. Zhang et al. [32] provided a review of studies related to combined natural ventilation techniques in sustainable buildings. Ismaiel et al. [33] conducted a literature review about the thermal bridges in masonry walls in which improvement of them was introduced as a passive strategy. Shafigh et al. [34] reviewed the application of thermal mass as a passive strategy in optimizing energy consumption in buildings and focused on concrete. Wong [35] undertook a review on designing and implementing natural daylighting to reduce the energy requirement of buildings. Comprehensive reviews on solar chimneys and the energy-saving potentials of Trombe walls as passive energy consumption optimisation strategies were respectively conducted by Maghrabie et al. [36] and Sergei et al. [37]. It can be observed that all the mentioned studies focused on similar but very limited number of passive strategies.

While a few other review studies broadened the scope of the number of different passive strategies considered, their regional focus was very narrow. For example, passive energy consumption optimisation strategies regarding China were reviewed by Lin et al. [38]. Amirifard et al. focused on Canada in their review regarding multiple passive strategies [39]. Saber et al. [40], Al Mohsen et al. [41], Ibanez Iralde et al. [42], Bano and Sehgal [43], Wang et al. [44], Flores et al. [45], and Aflaki [46] et al. reviewed multiple passive strategies related to the United Kingdom, Iraq, Spain, India, Germany, Philippines, and Malaysia, respectively. As valuable and educating as the compilations of these studies were, their sole focus on a specific climate as well as the omission of a logical protocol for selecting the optimum passive strategy were identified as one of their most significant limitations.

All the examined Literature Reviews (LRs) regarding passive strategies are gathered in Table 1 and denoted by LR1-LR17. On the one hand, LR1-LR10 considered limited number of passive strategies for unrestricted geographical locations. On the other hand, LR11-LR17 considered a more diverse range of passive strategies but for very specific locations or countries.

Providing a procedure for selecting the best passive energy consumption strategy is a challenging task due to the existence of multiple criteria including energy-saving potential, life cycle cost, availability, and installation time. Multiple Criteria Decision Analysis (MCDA)/Multiple Criteria Decision-Making (MCDM) methods have the ability to solve problems having complex hierarchies within the context of passive energy consumption optimisation strategies in buildings. The mentioned methods can select the best alternative from numerous criteria, based on predefined characteristics, which has made them very relevant to researchers from across a variety of disciplines [50–53] including the built environment [54–57]. Some researchers have also focused on providing literature reviews regarding the application of MCDA/MCDM

Table 1
Existing literature reviews on passive strategies within the body of knowledge.

Code	Author	Year	Location of the main author	Location covered	Passive strategies covered	Main findings	Ref
LR1	Ismaiel et al.	2022	Canada	General	Reducing thermal bridge in masonry walls	The material and shape of ties are the most important factors in the thermal resistance of masonry walls and must carefully be considered.	[33]
LR2	Maghrabie et al.	2022	Egypt	General	Using solar chimney	1) The inclined solar chimney performance is preferable in comparison to the vertical one 2) The Air Change per Hour (ACH) increases linearly with increasing solar intensity	[36]
LR3	Brito-Coimbra et al.	2021	Portugal	General	Using façade-related passive strategies	1) Using sun shading devices is more preferable in comparison to other façade-related passive strategies 2) Energy-saving potential of the passive strategies was evaluated by researchers, however, the feasibility applying them on buildings was neglected	[29]
LR4	Sawadogo et al.	2021	France	General	Using PCMs	Fatty acids and eutectics are preferable PCMs due to their renewable nature and specific thermophysical properties	[30]
LR5	Zhang et al.	2021	Australia	General	Using natural ventilation	1) Passive ventilation strategies are highly dependent on local climate conditions, experimental settings, and prediction methods, and therefore the best combination is different for each case study. 2) Combination of passive ventilation strategies leads to more efficient scenarios in comparison to single strategies.	[32]
LR6	Nugroho	2020	Indonesia	General	Using living wall	1) System design is the key point for achieving more energy-efficient solutions and better thermal environment performance in living walls. 2) Application of living walls is highly dependent on climate and the type of vegetation used.	[31]
LR7	Sergei et al.	2020	China	General	Using Trombe wall	1) The amount of solar energy a Trombe wall can accumulate is highly dependent on glazing. For severe climatic conditions, a double-glass window with a massive wall must be used. 2) An air interlayer with a thickness of 29–35 cm is required to ensure maximum thermal efficiency of Trombe walls located in severe climatic conditions.	[37]
LR8	Shafigh et al.	2018	Malaysia	General	Optimizing thermal mass	1) Thermal mass materials enable 7–22% energy consumption reduction in buildings. 2) Concrete is one of the best thermal mass materials and the main parameters affecting the sensible heat storage capacity of it are moisture content, temperature, aggregate type, cementitious material type and the density of concrete.	[47]
LR9	Wong	2017	UK	General	Using natural daylighting	High initial costs, utilisation difficulties, and application limitations are the main challenge of using daylighting systems.	[48]
LR10	Sharifi et al.	2015	Japan	General	Using roof ponds	1) The most efficient roof pond cooling systems are roof ponds with wet gunny bags, shaded roof ponds, ventilated roof ponds, and roof ponds with movable insulation 2) The main factors affecting the performance of roof ponds are meteorological conditions, water depth, roof deck material, and thickness of the insulating panel.	[18]
LR11	Lin et al.	2021	China		1) Optimizing envelope of buildings 2) Optimizing ventilation systems in buildings 3) Using solar energy 4) Using Geothermal Energy	1) The design standards and certification systems for passive buildings in China are not developed. 2) Passive buildings cannot achieve maximum energy-saving as technologies for heat recovery and renewable energy utilisation are still under development in China.	[38]
LR12	Saber et al.	2021	UK		Application of various types of natural ventilation in buildings	1) An advanced control strategy such as fuzzy logic control coupled with an optimisation engine of neural network has the potential to enhance the performance of natural ventilation in UK buildings. 2) An automatic control of windows integrated with the control of heating and cooling systems is the best scenario for using natural ventilation in UK buildings.	[40]
LR13	Al Mohsen et al.	2020	Iraq		1) Using sunspaces 2) Using thermal storage walls 3) Direct gain system 4) Natural ventilation	Solar strategies are preferable in comparison to other passive strategies due to the existence of extreme weather during summer and winter in Iraq.	[41]
LR14	Amirifard et al.	2019	Canada		1) Improving thermal mass 2) Improving fenestration design 3) Improving insulation 4) Using natural daylighting 5) Using natural ventilation 6) Improving airtightness in buildings 7) Improving vapor tightness in buildings	Passive strategies need to be selected according to the geographical properties of buildings.	[39]
LR15	Bano and Sehgal	2018	India		1) Using shading devices 2) Considering the best	1) The most used variables for building envelope optimisation in India are walling, roofing, and glazing material.	[43]

(*continued on next page*)

Table 1 (*continued*)

Code	Author	Year	Location of the main author	Location covered	Passive strategies covered	Main findings	Ref
					orientation of buildings 3) Optimizing the envelope of buildings 4) Using direct gain system	2) The most used criteria for multi-objective optimisation of Indian buildings are energy-saving potential and cost.	
LR16	Wang et al.	2017	Germany		1) Improving airtightness of buildings 2) Improving insulation in buildings 3) Improving fenestration design of buildings 4) Using natural ventilation in buildings	1) Energy efficiency, as well as indoor air quality, is improved by pre-ventilation before classes. 2) Maximum daytime indoor temperature is decreased by applying night ventilation (passive cooling) in German school buildings.	[49]
LR17	Aflaki et al.	2015	Malaysia		Application of various types of natural ventilation in buildings	The major constraints for using natural ventilation in tropical areas are lack of temperature change between day and night, high humidity levels, and persistent cloud cover	[46]

techniques in building industry-related topics. The application of MCDA/MCDM methods in the sustainable selection of building insulation materials was reviewed by Siksnelyte-Butkiene et al. [58]. Aldhshan et al. utilized MCDA/MCDM techniques for assessing the efficiency of buildings' energy [59]. Tan et al. reviewed the application of MCDM techniques in Building Information Modelling (BIM). The application of MCDM techniques in the assessment of building-integrated green technologies was reviewed by Si et al. [60]. Stojcic et al. reviewed the usage of MCDM methods in building sustainability [61]. Zhu et al. [62] and Chen and Pan [63] also reviewed the application of MCDM techniques in construction management. However, to the best of the authors' knowledge, no paper has provided a holistic review regarding the application of MCDA/MCDM techniques in selecting the best passive energy consumption optimisation strategy in the building industry.

Based on the mentioned premises, the overarching aim of the current study is to logically generate a comprehensive document, through a systematic literature review (SLR), that clearly depicts the current state of passive energy consumption optimisation strategies in buildings, with particular emphasis on the selection criteria considered and the MCDA/MCDM techniques that aided such decisions. Consequently, the contributions provided by this SLR are three-fold: firstly, the trend of using MCDA/MCDM techniques for selecting the best passive energy consumption optimisation strategies in the building industry is identified based on the thorough investigation of all related articles from 6 very diverse research databases. Secondly, the SLR results provide a holistic knowledge regarding the previous applications of MCDM/MCDA techniques in the selection of passive strategies according to the selection criteria. Due to the myriads of passive energy consumption optimisation strategies, their associated selection criteria and applicable MCDM/MCDA techniques, most of the studies have mainly focused on a limited number of passive strategies using very few MCDA/MCDM techniques, thereby underrepresenting the potentials of other passive strategies, selection criteria and MCDM/MCDA techniques. Therefore, the third contribution of this study is highlighting potential pathways for further research regarding the three aforementioned elements of passive strategy selection challenges.

The remaining parts of this paper are structured as follows. The research methodology applied for this SLR is explained in detail within Section 2, with particular emphasis on the research questions and search protocols. The obtained results as well as their corresponding implications are presented in Section 3. Lastly, Section 4 concludes this SLR, identifies its limitations and suggests future research pathways. .

2. Review methodology

Systematic Literature Review (SLR) has recently become very popular among experts and researchers due to its logical and holistic approach [64]. In SLRs, all the existing literature relevant to a specific research question or topic area is logically identified, evaluated, and interpreted [65,66]. In this study, two methodologies called Procedure for Performing Systematic Reviews (PPSR) and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) developed by Kitchenham [67] and Sharma and Oremus [68], respectively, were used.

In the process of conducting an effective systematic literature review regarding a topic, the starting point is the formulation of a specific and representative main research question, which is then complemented by several sub-questions [69]. For this study, one main question and three sub-questions were formulated, and are presented as follows.

Main Question: "To what extent have Multiple Criteria Decision-Making (MCDM)/Multiple Criteria Decision Analysis (MCDA) techniques supported the determination of the best passive energy consumption optimisation strategies in buildings?"

Sub-question 1: "What passive energy consumption optimisation strategies have been investigated in the building industry?"

Sub-question 2: "What criteria have been used for selecting the best passive energy consumption optimisation strategy in the building industry?"

Sub-question 3: "What MCDM/MCDA techniques have been used for selecting the best passive energy consumption optimisation strategy in the building industry?"

In order to implement a robust systematic but all-encompassing search regime, six very popular databases including Compendex, GEOBASE, GeoRef, Inspec, Web of Science (WoS), and Scopus were considered and investigated in the current SLR. Additionally, the search employed a multidimensional approach to information extraction for all six databases. The main sources of information are journal articles, conference articles, conference proceedings, articles in press, book chapters, and dissertations. In order to implement a consistent search regime across all databases, carefully crafted keywords were used to query all databases in a similar manner [70]. The selection of keywords was guided by the combination of two well-known approaches called PICO (Population, Intervention, Comparison, Outcome) and SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research type) developed by Cooke et al. [71]. The formulated keywords are presented as follows:

"Building*" AND "Energy Consum*" OR "Energy Optimi*" OR "Energy Reduc*" AND "Passive" OR "Passive House" OR "Passive Strateg*" OR "Passive Measure*" AND "Multiple Criteria Decision Making" OR "Multi-Criteria Decision Making" OR "Multi-Criteria Decision-Making" OR "MCDM" OR "Multiple Criteria Decision Making" OR "Multi-Criteria Decision Analysis" OR "Multi-Criteria Decision-Analysis" OR "MCDA" OR "Rank*" OR "Prioriti*".

The next step in the current methodology was to filter the identified papers for further investigation. The main rationale behind the filtration is to identify and remove irrelevant articles that may have bypassed the keywords, owing to lack of and/or ambiguous definition of the original articles' keywords. Therefore, besides the formulated keywords, several inclusion criteria were formulated and defined at this stage and are presented as follows.

i. Language of the publication must be English;
ii. Research focus of the publication must be on building energy;
iii. Research focus of the publication must be on passive strategies;
iv. Full text of the publication must be available.

The applied research protocol of the current SLR is shown in Table 2.

The fourth and last step in the current study's methodology was to remove duplicates, triplicates, quadruplicates, and quintuplicates to obtain the final number of studies for further investigation. To do so, Mendeley reference management software was used to automatically identify and exclude articles that appear in more than one database. A complete illustration of the applied methodology for the current study is presented in Fig. 1, in which it is evident that a final total of 65 articles were considered for further investigation in this study.

3. Results and discussions

3.1. Overview of included articles and bibliometric analysis

Among the investigated articles, multiple interrelationships in terms of articles' database origin were observed and are illustrated in Fig. 2. The total number of research articles published per year is also depicted in Fig. 3. It was seen that the number of articles rose considerably after 2016 due to the introduction of the Sustainable Development Goals (SDGs) by the United Nations [72].

With respect to the country of publications, it was observed that China and Canada with 11 and 5 publications, respectively, had the highest number of publications in the included studies. The reasons for these considerable contributions by the mentioned countries are likely to be i) China is the most populated country in the world and this results in a massive amount of energy consumption in buildings every year [73]; ii) The temperature in Canada is very low during most of the months in a year, and therefore a large amount of energy is used for heating purposes in the building industry. Fig. 4 provides information about the distribution of publications with respect to the country.

It was observed that most of the included publications in this study were journal articles, with 54 publications. The number of conference proceedings, books, and dissertations was also 9, 1, and 1, respectively.

With respect to the journal of articles, it was seen that "Energy and Buildings", "Journal of Building Engineering", and "Building and Environment" were the top three journals in terms of the number of publications. Also, Elsevier was the main publisher of the included studies due to the existence of more relevant journals with respect to the topic of this SLR in comparison to other publishers. More details about the number of publications and distribution of publications with respect to the journal are provided in Fig. 5.

Table 2
Review protocol for the current SLR.

Item	Description
Keywords	Building* AND Energy Consum* OR Energy Optimi* OR Energy Reduc* AND Passive OR Passive House OR Passive Strateg* OR Passive Measure* AND Multiple Criteria Decision Making OR Multi-Criteria Decision Making OR Multi-Criteria Decision-Making OR MCDM OR Multiple Criteria Decision Making OR Multi-Criteria Decision Analysis OR Multi-Criteria Decision-Analysis OR MCDA OR Rank* OR Prioriti*
Search fields	All fields
Inclusion criteria	Written in English, focus on building energy; focus on passive strategies; available in full text of the publication
Publication type	Journal articles, conference articles, conference proceedings, articles in press, book chapters, dissertations
Time window	Unrestricted

Keyword co-occurrence analysis (KCA) is one of the most important elements of SLRs, as it enables the exploration of the structures of scientific/technical knowledge [74], via the thematic of the included articles [75]. In the current study, VOSviewer software was used to perform KCA, owing to its capability to generate visual network maps that quicken as well as simplify relationship analysis [76–80]. Keywords of the included publications were used and their distribution is illustrated in Fig. 6. The mentioned figure (Fig. 6) adequately depicts the main focal points of research within the investigated articles, which further makes understanding the areas of strength and underrepresentation easier. Moreover, the mentioned figure provides directions for future studies. According to the obtained map, 4 main clusters were identified in which "passive design", "thermal comfort and energy efficiency", "optimisation" and "building envelope" were the leaders of each category. In Fig. 6, the size of spheres indicates the frequency of keywords. In other words, larger clouds and fonts represent a higher appearance frequency.

According to Fig. 6, the following points can be obtained: firstly, "optimisation" is connected to all the other clusters, which suggests that it is the focal point of the process of selecting the best passive energy consumption optimisation strategies [81–83]. Secondly, within the blue cluster, where "passive design" is domiciled, the keyword "sensitivity analysis" is visible. However, "decision-making" is observed within the green cluster, without having any connection with "passive design". Also, a clear connection between "passive design" and "regression analysis" can be seen within the red cluster. Based on these network patterns, it can be concluded that previous studies have not effectively used decision-making tools for selecting passive strategies, and only relied on sensitivity and regression analysis techniques that mainly exist within simulation packages, which further buttresses the points related to the underrepresentation of social selection criteria within existing studies [84–86]. Thirdly, it can be seen that "building envelop" within the yellow cluster is only connected to the green cluster, where "optimisation" is the most influential keyword within the cluster. It is also visible that no connections exist between the yellow ("building envelope") and blue clusters ("passive design"). Based on the mentioned points, it is can be ascertained that most of the studies associated with building envelope neglected other passive strategies in their models, and only focused on optimizing the building envelope itself. Hence, no studies have simultaneously considered several passive strategies, which could signify lost opportunities thus far [87–89].

3.2. Identification of passive energy consumption optimisation strategies in the building industry

One of the main aims of this SLR was to identify passive energy consumption optimisation strategies that have been used and investigated in previous studies. According to the findings of the included articles, myriad passive strategies for optimizing energy consumption within the building industry were identified. Considering the fact that some of the passive strategies possess the same characteristics, the authors decided to categorize them into 12 groups with codes PSG1-PSG12. Table 3 provides information regarding the mentioned groups, the identified passive strategies, and corresponding references.

According to the obtained results, it was seen that research efforts have been significantly skewed towards certain passive energy consumption optimisation strategies over the years. More specifically, most of the studies were related to the determination of the optimum place and thickness of insulation layer (PSG1), using naturally ventilated envelope (PSG6), using sun shading devices (PSG8), and improving fenestration design of building (PSG9). On the other hand, the proficiency of other strategies such as reducing thermal bridge in buildings (PSG3), improving vapor tightness of building (PSG4), using natural daylighting (PSG7), reducing heat absorption in building's façade (PSG11), and using green envelope (PSG12) have been very limited.

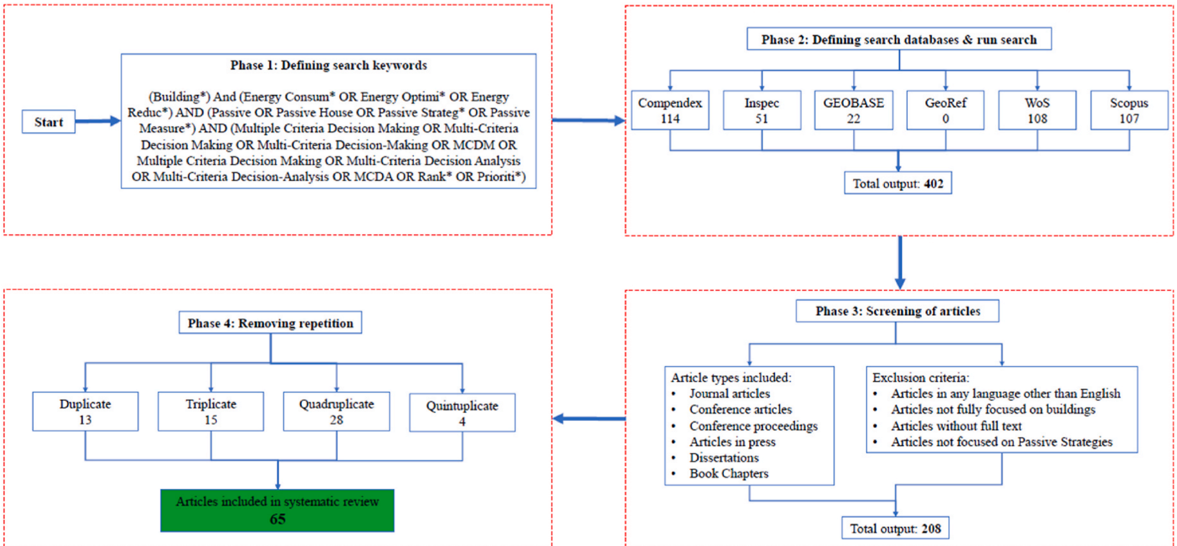

Fig. 1. Systematic literature review process flow diagram.

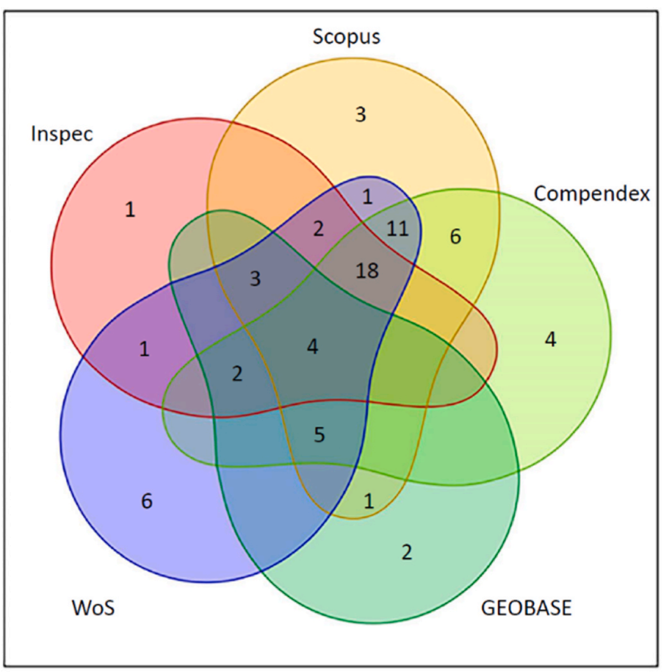

Fig. 2. Venn diagram of articles and their respective databases.

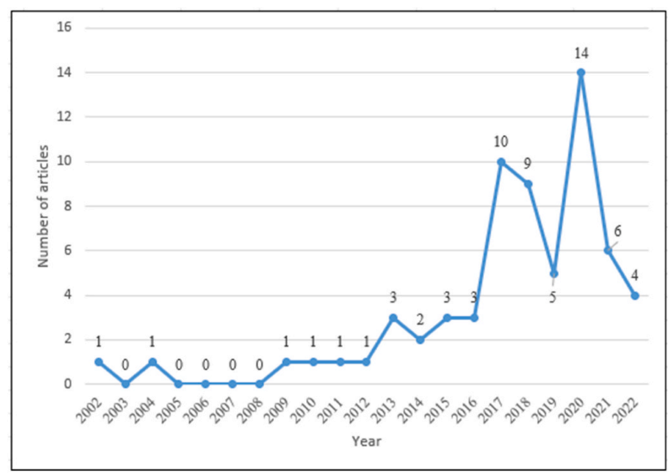

Fig. 3. Distribution of articles per year.

There are several considerations associated with the highlighted point. Firstly, the former passive strategies are more easily simulated in different types of energy software [157], while it is difficult to do so for the latter strategies [158]. However, recent studies have proven that the latter passive strategies have a great potential to optimize energy consumption in buildings [159–162]. Secondly, some of the latter passive strategies such as using green envelope [163] and reducing heat absorption in building's façade [164] are novel in comparison to the former passive strategies, and more efforts are required to further advocate their proficiencies within the building industry [165,166]. Thirdly, governments have not effectively provided financial incentives for applying the latter passive strategies on buildings, which further impedes their popularity among research and practice communities [167]. Therefore, conducting more studies on the latter passive strategies as well as advocating for more more financial incentives to the researchers and companies associated with them would definitely reduce the existing barriers to their adoption.

3.2.1. PSG1: determining the optimum place and thickness of insulation layer

One of the main purposes of energy consumption in buildings is to provide a comfortable atmosphere for occupants in which heating and cooling take place [168,169]. Insulation layers within a building's wall play a very significant role in the reduction of energy consumption [170]. Insulation performance of the buildings is a function of various factors including the place and thickness of the insulation layer [171]. Regarding the thickness of insulation layer, it is very challenging to realise a perfect trade-off between thickness and cost [172]. In other words, thicker layers of insulation can result in a better sealing of the building, thereby reducing cooling and heating loads; however, a rise in the expenses incurred is unavoidable. On the other hand, providing lighter layers of insulation will result in an increase in energy consumption and its associated cost [173]. Thus, finding the optimum place and thickness of the insulation layer is a crucial task that needs special attention. Fig. 7 illustrates the optimum insulation thickness point according to the energy, insulation and total costs. In order to come up with a prudent decision on an appropriate place of insulation, a careful

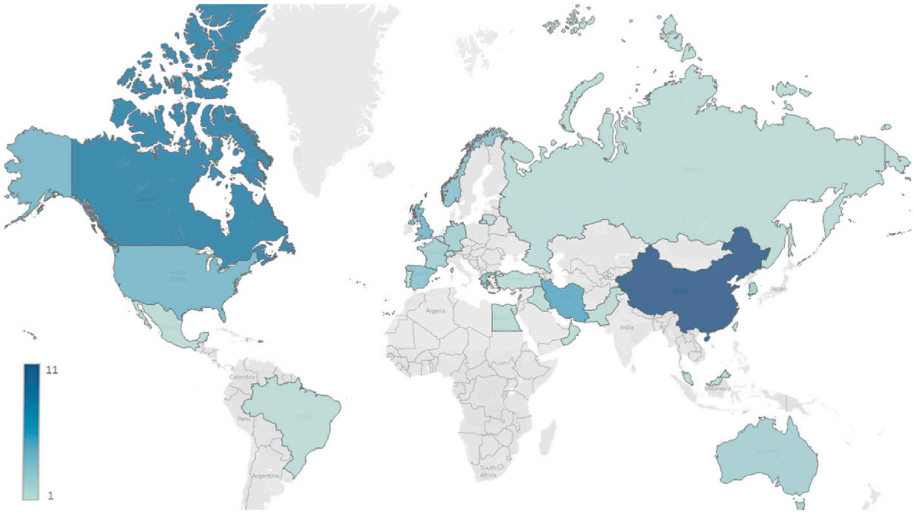

Fig. 4. Distribution of included articles with respect to countries of origin.

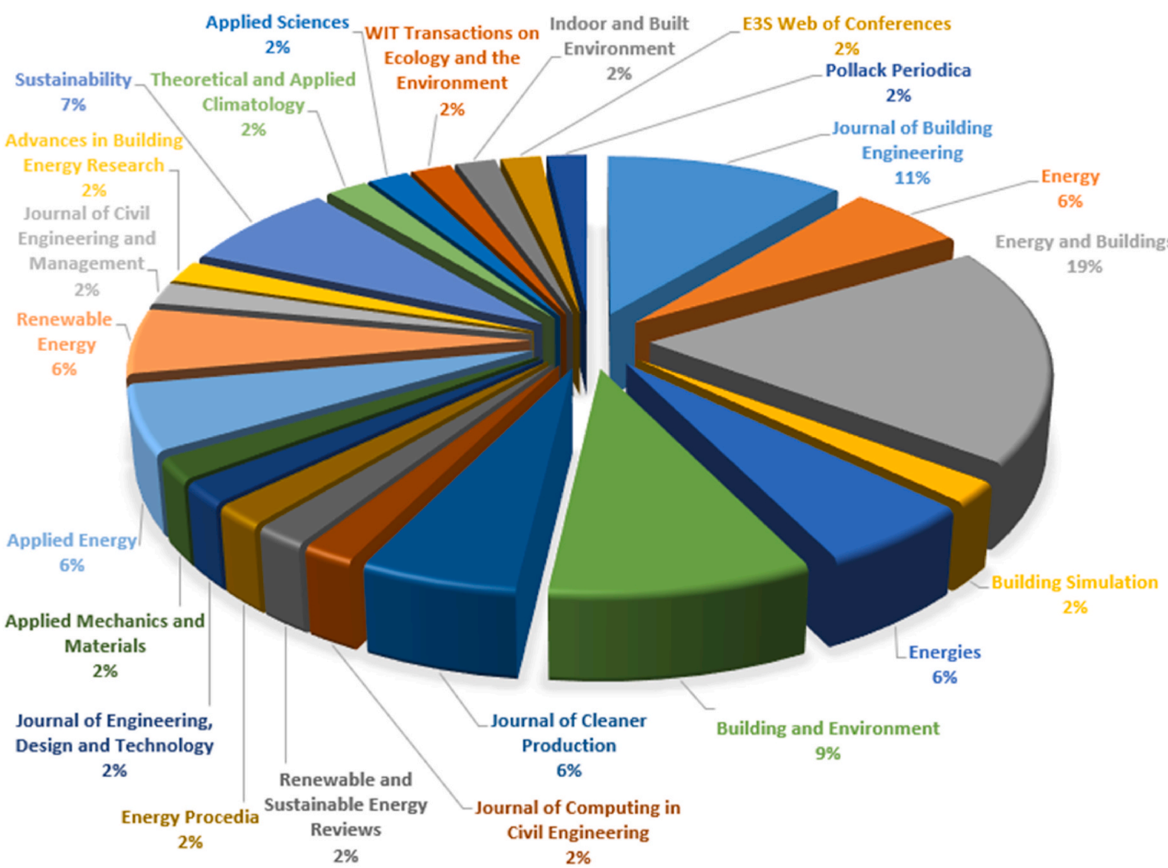

Fig. 5. Distribution of included articles with respect to publishing journals.

investigation into different possible scenarios of the location of the insulation layer needs to be taken into account [174]. Based on the mentioned premises, determining the optimum place and thickness of insulation layer is regarded as one of the passive energy consumption optimisation strategies in the building industry [39].

3.2.2. PSG2: increasing building's thermal mass

According to the existing literature, a material's ability to absorb, store and release heat is defined as thermal mass [175]. Possessing a high thermal mass feature is regarded as a valuable property for a building material, as heat is absorbed more in the day, and it is released during the night to warm the building up [176]. For instance, dense materials such as concrete and bricks are regarded as high thermal mass materials, while lightweight materials such as timber have low thermal mass properties [177].

One of the most famous groups of materials that possess high thermal mass and are widely used in the building industry are called Phase Changing Materials (PCMs). In comparison to traditional materials, a massive amount of heat is absorbed and released during the transition phase in buildings constructed with PCMs [178] which can be used for

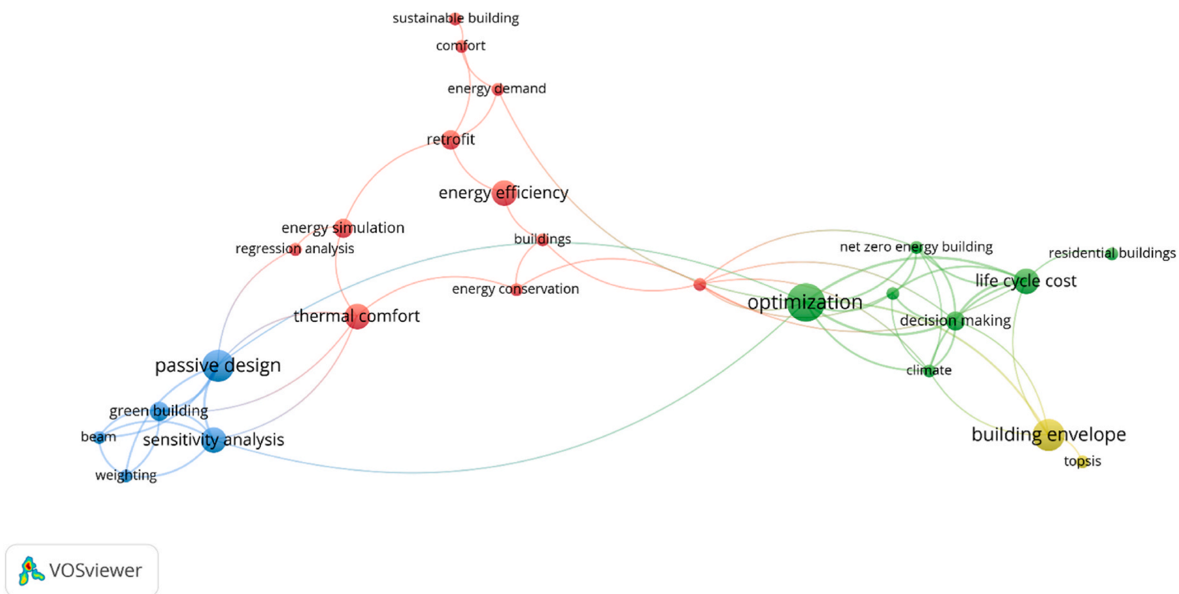

Fig. 6. Co-occurrence analysis map of the included articles.

providing a comfortable atmosphere for the residents [179]. Possessing higher heat capacity of PCMs is one of the reasons for their mentioned ability [180].

Another popular method used in the building industry is taking advantage of water walls [181], the concept of which emerged at the Massachusetts Institute of Technology (MIT) in 1947 [182]. Water walls possess almost the same features as PCMs, and they have become popular in the building industry, due to their lower costs in comparison to PCMs [183]. Water wall systems include an inner and an outer layer with a water layer in the middle, all standing on metal support frames. Concerns about potential leakage from the water layer and rusting of the frames have led to the adoption of corrosion-free materials (such as fibreglass) as mitigation measures in water wall systems [184]. Fig. 8 provides a schematic representation of the configuration of a typical water wall system for better visualisation.

3.2.3. PSG3: reducing thermal bridge in buildings

Thermal bridges in buildings are places where the thermal resistance of the incorporated materials is different, which often results from non-uniformities in their characteristics [185]. Thermal bridges have been regarded as the main reason for reducing thermal resistance of a building's roof and envelope [186], and corresponding heat leakage [187]. In order to tackle the mentioned issue, novel systems such as External Thermal Insulation Composite Systems (ETICS) have been introduced, which are able to reduce thermal bridges as much as possible [188]. A sample of ETICS is illustrated in Fig. 9.

3.2.4. PSG4: improving vapor tightness of building

One of the passive strategies which is underrepresented within existing literature is understanding how much improvements in the vapor tightness of buildings influence energy consumption patterns. Water vapor can penetrate the building by different mechanisms including diffusion and displacement by air movement [190]. This vapor may result in different discomforts for occupants such as the emergence of moulds in buildings [191]. Although most designers rely on HVAC appliances to avoid vapor penetration [192], passive strategies such as vapor retarders can also be used in buildings.

3.2.5. PSG5: improving air tightness of building

Numerous studies have investigated the devastating effect of air leakage on building's roof and façade. The mentioned harms can be attributed to increase in cooling/heating energy load, the increase in noise level, and the reduction of thermal comfort and condensation [193]. According to a study conducted by Urquhart et al. [194], 5–15% of energy demand in buildings is due to a lack of sufficient airtightness, while another complementary study by Straube and Burnett [195] similarly illustrated that 30–50% of the energy consumption in a well-insulated building is due to air leakage through the building's envelope. In order to prevent or at least minimize the mentioned losses, air retarders are apt passive solutions to be applied on buildings [196].

3.2.6. PSG6: using naturally ventilated envelope

This group of passive energy consumption optimisation strategies has been very popular among building experts, and many of the identified passive strategies are categorized within this group. Two passive strategies from this category are briefly explained as follows.

Building façade systems can generally be categorized into two groups called Single Skin Façades (SSFs) and Multi Skin Façades (MSFs) according to their structural systems [197]. Double Skin façades (DSFs) are well-known façades [197] in which natural convection, wind pressure, and sunlight are used [198]. DSFs consist of two different glazing materials in exterior and interior layers, and are separated using a channel including a ventilated air cavity [199]. The specific structure of a DSF varies according to the climate where the corresponding building is located. However, the general concept of DSF is based on the wind pressure and thermal buoyancy caused by the difference between the interior and exterior layers' temperatures [200]. For the sake of succinctness, readers are referred to Refs. [201–203] for more details.

Trombe walls are similar to DSFs, where a dark wall is used in the exterior instead of the glazing layer in a DSF. The mentioned wall needs to have a high thermal mass and is put in the south orientation of the building [204]. The wall absorbs some of the sunlight, where a portion of the absorbed heat is again absorbed by the cavity space. As a result, the mentioned heat can keep the building warm for some time [205]. In order to make Trombe walls suitable for multiple seasons (especially summer and winter times), a little change in the structure of the Trombe wall system is required [206]. Fig. 10 clearly illustrates the application of a Trombe wall system for multiple seasons applications. Solar chimneys [207], and sunspaces [208] also use the same concept with some modifications in their systems.

Table 3
Identified passive strategies and their categorisation.

Code	Passive Strategy	References
PSG1	Determining the optimum place and thickness of insulation layer	[7,39,90–129]
PSG2	Increasing building's thermal mass (e.g., using water walls, materials with higher thermal mass or Phase Changing Materials (PCMs))	[7,20,39,104,107–109,113,118,121,124,126,130–133],
PSG3	Reducing thermal bridge in buildings (e.g., using External Thermal Insulation Composite Systems (ETICS))	[7,20,39,108]
PSG4	Improving vapor tightness of building	[7,20,39,134,135]
PSG5	Improving airtightness of building (e.g., using air retarders)	[7,20,39,90,93,96,98,102,104,107,112–114,117,125,128,133,135–138]
PSG6	Using naturally ventilated envelope (e.g., using Trombe walls, solar chimneys, sunspaces (conservatories), multi skin facades like DSF (Double Skin Façade), Direct Gain (DG), Roof Pond, LPSHW (Lattice Passive Solar Heating Walls))	[39,94,97–99,99,103,106–108,112,117,127–129,133,135,139–147]
PSG7	Using natural daylighting (e.g., using light pipes, mirror systems, prismatic systems, lens systems, holographic diffracting systems, light shelves)	[39,99,114,118,135,148]
PSG8	Using sun shading devices (e.g., using Louvres, venetians blinds and curtains, projecting eaves)	[7,39,90,94,95,97–99,103,104,106,107,113,114,117,118,122,128,129,135,141,142,146,149–153]
PSG9	Improving fenestration design of building (e.g., using suitable glazing like tinted glazing, coated glazing, or laminated glazing for reducing heat loss by conduction, using daylight to offset daylighting needs, using the most efficient ratio for windows and walls, using the most efficient framing material for windows)	[7,39,90–97,99,100,102–104,106,109,112–114,117,119,121–125,128,129,134–137,149,150,154]
PSG10	Determining the optimum orientation of buildings	[39,95,98,100,103,107,113,114,118,124,129,135,149,153]
PSG11	Reducing heat absorption in building's façade (e.g., painting façade with light colours)	[100,101,104,110,113,138]
PSG12	Using green envelope (e.g., using green roof, garden roof and green façade)	[135,138,142,155,156]

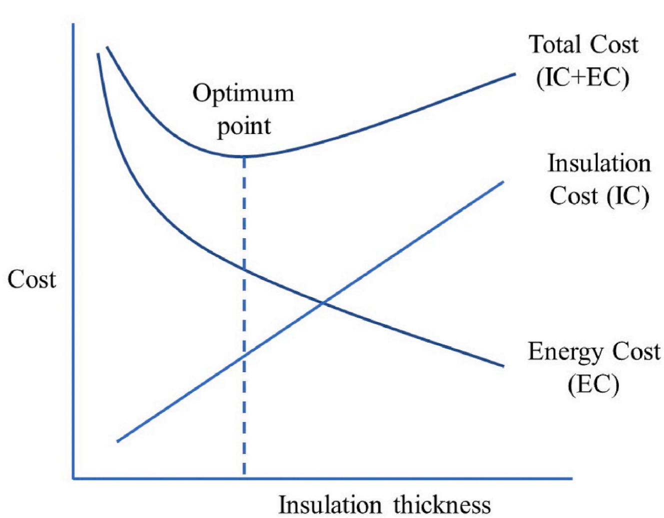

Fig. 7. Optimum insulation thickness [173].

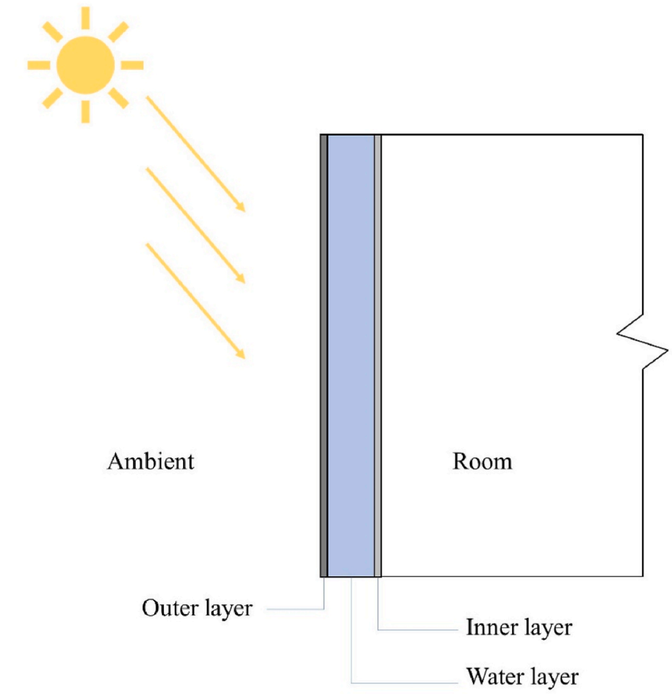

Fig. 8. A schematic depiction of typical water wall systems [182].

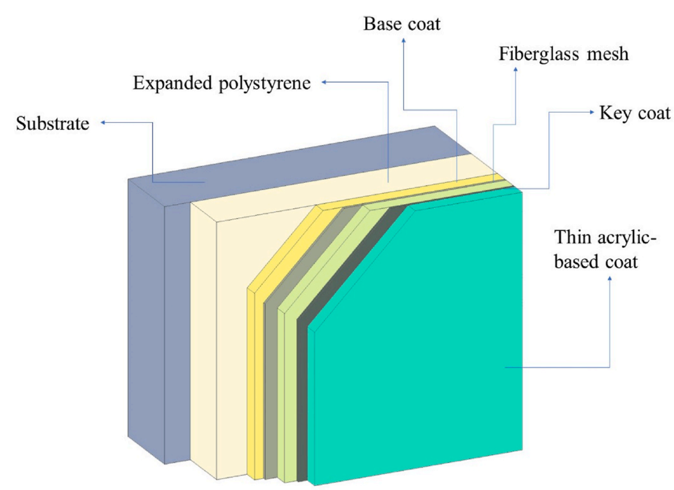

Fig. 9. ETICS sample [189].

3.2.7. PSG7: using natural daylighting

According to the existing literature, over 40% of a building's energy is expended on fulfilling lighting requirements through electricity [35,210]. However, studies have demonstrated that this energy consumption can be decreased by up to 75% by leveraging daylighting systems [211]. Moreover, the incorporation of daylighting into the building design stage has also been proven to have considerable benefits for occupants' mental health [212]. Different systems have been designed and used to take advantage of natural daylighting including light pipes [213], mirror systems [214], and light shelves [215]. Light pipes, for instance, are generally made of three parts called receiving part, reflecting tool, and diffuser. Light is absorbed using a hemispherical dome, transits through the tube, and reaches the indoor space using a diffuser [216]. Fig. 11 depicts a schematic illustration of a light pipe.

3.2.8. PSG8: using sun shading devices

Although sunlight can be very beneficial for buildings, it may also

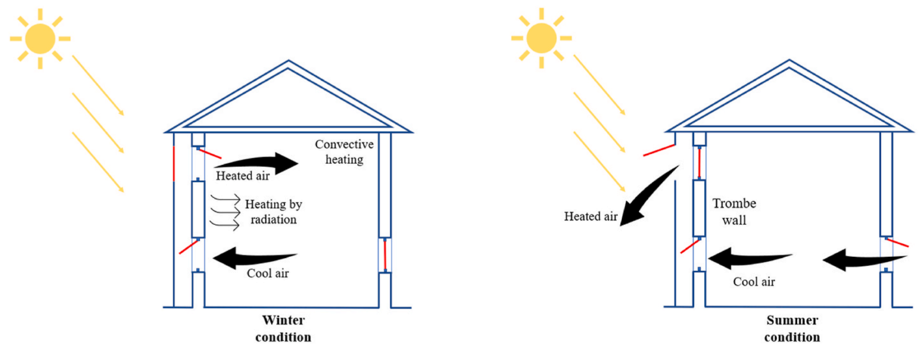

Fig. 10. An example of a naturally ventilated envelope (Trombe wall) and its function in winter and summer seasons [209].

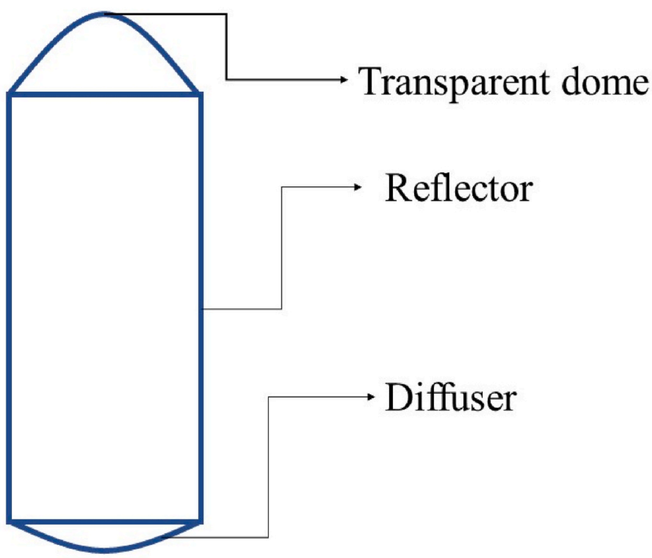

Fig. 11. Schematic illustration of light pipe [216].

lead to discomfort for residents stemming from increased heat circulating within the buildings [217]. Taking advantage of sun shading devices is a traditional and well-known strategy that has been used for many years [218]. The main aim of sun shading is to prevent the building from overheating in the summertime using suitable devices including curtains, blinds, and projecting eaves [22]. According to a case study by Ho [218], the cooling demand of a building can be decreased by approximately 23.2% by using blinds [218]. For further details on the fundamental principles and general applications of sun shading as passive energy strategies in buildings, it may be worthwhile consulting well-documented information within several earlier studies [219–221].

3.2.9. PSG9: improving fenestration design of building

This category of passive strategies is related to the fenestration design of the building, including suitable materials for window framing, suitable glazing, and the optimum ratio between wall and windows. Poor fenestration is responsible for a large amounts of energy losses in buildings. More specifically, studies have shown that 30–50% of the heat loss in buildings is due to poor fenestration [222]. Several studies have focused on passive strategies for improving the fenestration of buildings [223]. For instance, a German study illustrated that 20–24% energy saving can be accomplished based on the usage of a suitable window system [224]. Therefore, improving the fenestration design of building is a viable passive energy consumption optimisation strategy.

3.2.10. PSG10: determining the optimum orientation of buildings

Building orientation is another factor that needs to be considered in designing buildings. Due to the fact that the orientation of built structures cannot be changed, this parameter must be considered in the design stage of building construction projects [225]. Many studies have focused on finding the most suitable orientation in their studies. For instance, Odunfa et al. [226], Koranteng and Abaitey et al. [227], and Chan [228] conducted simulation studies in order to find the optimum orientation of their case studies, and observed a 4.87%, 16.02%, and 19.76% energy-saving potential in their case studies, respectively. Therefore, determining the optimum orientation of buildings is one of the passive strategies that can be used in designing buildings.

3.2.11. PSG11: reducing heat absorption in building's façade and PSG12: using green envelope

Owing to the similar characteristics of PSG11 and PSG12, these two groups are explained together in this section. Aside from focusing on the façade and roof properties themselves, there are other ways to increase the energy-saving potential of the mentioned parts of the building. One way to boost the energy-saving potential of facades is by taking advantage of light colours on the last layer of the exterior façade, so that less heat is absorbed and transmitted to the interior part of the building [229]. Also, covering the building's roof and façade with a green layer is another way to enhance its energy-saving potential [230]. A study conducted by Perez et al. [163] illustrated that covering the building's envelope using its optimum Leaf Area Index (LAI) is able to result in a 34% energy saving. Therefore, according to the preferences of the project's stakeholders, either light colours or green facades can be used as other suitable passive energy consumption optimisation strategies.

3.3. Identification of selection criteria for choosing passive energy consumption optimisation strategies in the building industry

Selection of the best passive energy consumption optimisation strategy, similar to other decision-making problems, is not possible without the identification and consideration of relevant selection criteria [231,232]. The mentioned stage has been regarded as one of the most crucial parts of solving a decision-making problem [233–235]. Once the appropriate and prudent set of influential criteria in a decision-making problem has been determined, accurate and reflective results will be produced [236].

According to the SLR process adopted for this study, 17 criteria were identified for selecting the best passive energy consumption optimisation strategy. For the sake of simplicity, the identified criteria have been coded as PSSC1-PSSC17. Table 4 illustrates the extracted selection criteria and their corresponding references.

Most of the identified studies only considered energy-saving potential and investment cost as their selection criteria. Although the criticality of the two aforementioned criteria is hardly contested, considerations should be given to the viability of other factors, if a truly holistic and robust assessment framework is to be developed. One of the reasons why other criteria were neglected may be that most of them are

Table 4
Identified selection criteria for choosing the passive energy consumption optimisation strategies.

Code	Selection criterion	Reference(s)
PSSC1	Compatibility with climate	[7,39,90,110,237]
PSSC2	Reduction of energy consumption	[7,39,90,92,95,96,99,101–108,110,112–114,117–119,121–123,125–129,131,133–136,138,139,142,146,238–243]
PSSC3	Reduction of GHGs emission	[7,39,90,119,133,136,139,141,237]
PSSC4	Improvement of indoor environmental quality	[7,39,96,101,110,118,136,139,147,237,242,244]
PSSC5	Job creation	[7,99,241]
PSSC6	Occupant wellbeing improvement	[7,39,96,101,110,128,136,139,147,237,242,244]
PSSC7	Reliability	[7,96,110,237]
PSSC8	Durability	[7,96,110,237,241]
PSSC9	Investment cost	[7,39,90,91,96,102,105,106,110,117,119,122,125,127,129,131,136,138,142,146,147,237,240,241,244]
PSSC10	O&M cost	[7,96,110,237,242]
PSSC11	Money Payback period	[7,90–92,136,237,241,244]
PSSC12	Installation time	[7,110,237,242]
PSSC13	Aesthetics	[110,136]
PSSC14	Being environmentally friend	[110,138,242,244]
PSSC15	Availability (being locally available)	[39,110,118]
PSSC16	Flammability	[39]
PSSC17	Feasibility (ease of application)	[39]

not able to be simulated theoretically. For instance, job creation (PSSC5) cannot be simulated in energy simulation software but is considered one of the most important social criteria according to the United Nations' Sustainable Development Goals [54]. Therefore, it is imperative for researchers to broaden their considerations of these criteria and embed experts' judgment as complementary data sources. Another reason for considering investment cost is due to the tendency of companies to minimize their costs in order to achieve the maximum benefit of their projects [245], which often motivates the researchers to focus on cost in their studies and neglect other criteria [246]. Hence, the previous suggestions on financial incentives to the companies may help mitigate against some of these barriers to the adoption of other strategies. Although other criteria may not seem to be financially viable to companies currently, their potential impacts have been illustrated within previous studies [247]. Low indoor environmental quality, for instance, can affect the productivity of staff in commercial buildings, which further reduces the profitability of the company in the long run [248]. Also, not considering the mentioned criterion in residential buildings can affect the occupants adversely, which has been identified as a reason for incessant accommodation changes [249].

3.4. Identification of MCDA/MCDM techniques in selecting passive energy consumption optimisation strategies in the building industry

The application of MCDA/MCDM techniques has been observed in structuring and resolving decision-making problems since 1970 [231,236]. These techniques were first made and used in operations research for supporting the subjective evaluation of experts in facilitating crucial decision-making processes [250]. The current SLR reveals that the eight main MCDA/MCDM techniques that dominate existing body of knowledge include Elimination and Choice Expressing Reality (ELECTRE), Analytical Hierarchy Process (AHP), Stepwise Weight Assessment Ratio Analysis (SWARA), Complex Proportional Assessment (COPRAS), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Best-Worst Method (BWM), Evaluation based on distance from average solution (EDAS) and Simple Additive Weighting (SAW). Just as was done for passive strategies selection criteria in the preceding section, the MCDA/MCDM techniques were also labelled as MCDM1-MCDM8 as presented in Table 5.

According to the obtained results, AHP (MCDM2) and ELECTRE (MCDM1) were the top two MCDA/MCDM techniques used in the included studies. On the other hand, it was observed that SWARA (MCDM3), BWM (MCDM6), EDAS (MCDM7), and SAW (MCDM8) were used the least in the included studies. A possible reason for such negligence could be intertwined with the fact that some MCDA/MCDM techniques are very novel in comparison to others. For instance, the ELECTRE method was introduced in 1966 [251], while EDAS was first used in 2015 [252]; thus, more efforts might be required to boost the popularity of the newer methods among researchers and industry professionals within the building energy optimisation discipline.

Also, it was observed that most of the studies were based on software simulations, whereas other techniques including the Pareto concept [253] are used in order to find the optimum values of parameters that can be simulated, and therefore no specific MCDA/MCDM technique is used. The problem with this kind of analysis is that only a limited number of criteria such as energy-saving potential and investment cost can be considered, while other crucial ones including some of those that are most important to the United Nation's global SDGs are dismissed. As previously mentioned in the introductory section, brief explanations of all the identified MCDA/MCDM techniques are also elucidated in this section to provide a better understating of each technique.

3.4.1. MCDM1: ELECTRE

ELECTRE technique is one of the MCDA-based methods which was first used by Benayoun et al., in 1966 as a part of a project operated by European Consultancy Company SEMA [251] and was presented for the first time in a journal article in 1968 [254]. This technique is able to deal with both qualitative [255] and quantitative [256] discrete criteria, and also orders the alternatives during the decision-making and/or problem-solving process [257]. During decision-making processes that are based on ELECTRE, a pairwise comparison matrix among alternatives is used [258]. Various versions of ELECTRE have been formulated and used according to the specific characteristics of the decision-making problems, including ELECTRE I [259], ELECTRE II [260], ELECTRE III [261], ELECTRE IV [262], and ELECTRE TRI [263].

3.4.2. MCDM2: AHP

AHP is one of the most popular MCDM techniques and was first introduced by Saaty in 1980 [264]. The most important components of a typical AHP process are the goal, criteria, and alternatives [265]. These components constitute the three-level hierarchical structure whereby the goal, criteria, and alternatives are placed at the top, middle, and bottom levels, respectively [266]. The hierarchical structuring is then followed by expert judgment and evaluation, whereby the pairwise comparisons of the different elements occur, while assuming the independency between them [267]. Finally, consistency of the judgments is verified, as AHP allows subjective judgments of the decision-makers. The threshold of the consistency rate is usually 0.1, and revisions are conducted if this rate is exceeded. Hence, results are considered reliable only if the consistency rate becomes less than 0.1 [268]. Due to the

Table 5
Identified MCDA/MCDM techniques for selecting passive energy consumption optimisation strategies.

Code	MCDA/MCDM	Reference(s)
MCDM1	ELECTRE	[91,92,147]
MCDM2	AHP	[92,110,134,242,244]
MCDM3	SWARA	[237]
MCDM4	COPRAS	[237,241]
MCDM5	TOPSIS	[138,241]
MCDM6	BWM	[7]
MCDM7	EDAS	[7]
MCDM8	SAW	[241]

simplicity of the AHP method, it has been widely used in many fields [269–271] including the construction [272–274] and building [275–278] industries.

3.4.3. MCDM3: SWARA

SWARA method is another MCDM technique which was first introduced by Keršuliene et al., in 2010 [279]. This method is generally used in decision-making problems to weigh selection criteria, which in turn forms the basis for ranking alternatives [280]. The procedures for implementing SWARA method are quite simple, which is perhaps the reason for its wide acceptability among researchers from different disciplines [281–283]. In the SWARA method, expert opinions have a significant role. Decision-makers use their expertise and knowledge to rank the criteria from top to bottom in terms of importance, after which each criterion is compared to the upper criterion and so on, until a comprehensive ranking order is generated [284].

3.4.4. MCDM4: COPRAS

Complex Proportional Assessment (COPRAS) method was first introduced by two colleagues of Vilnius Gediminas Technical University called Zavadskas and Kaklauskas in 1996 [285]. Considering both the negative and positive criteria in the decision-making process is one of the merits of this method [236]. It is necessary to mention that COPRAS is usually used besides other MCDA/MCDM techniques, as the weights of the criteria must be determined before using the COPRAS method [286]. This method has been widely used in many fields including the building industry [287–289].

3.4.5. MCDM5: TOPSIS

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was introduced by Hwang and Yoon for the first time in 1981 [290], aiming to select the alternatives having the furthest distance from the negative ideal solution and the shortest distance from the positive ideal solution simultaneously [291]. In other words, beneficial criteria are desired to be maximized while the cost criteria are desired to be minimized during the implementation of TOPSIS method [292]. This method has also been popular among researchers in many fields [293–295]. It is necessary to mention that vector normalisation may be required if the decision-making problem is multi-dimensional [296, 297].

3.4.6. MCDM6: BWM

Best-Worst Method (BWM) method is one of the novel MCDM techniques which was introduced by Rezaei in 2015 [298]. This method relies on conducting pairwise comparison [299]; however, fewer numbers of pairwise comparison is required due to the usage of systematic pairwise comparison as compared to traditional MCDM techniques such as AHP or ANP [300]. Also, studies have shown that the results obtained by BWM are more accurate and consistent in comparison to AHP [301]. Another feature of BWM is that it needs only integers, while other techniques like AHP require fractural numbers [302]. Although this method has been introduced for less than ten years, numerous studies have been conducted using this method [303–306].

3.4.7. MCDM7: EDAS

The Evaluation Based on Distance from average solution (EDAS) method is another novel technique which was introduced by Keshavarz Ghorabaee et al., in 2015 [252]. Other MCDM techniques such as AHP, ANP, and SWARA are required to determine the weights of criteria before using the EDAS method in solving an MCDM problem [307]. This method is especially useful when incompatible criteria are extant in the decision-making process [308]. In the procedure of applying the EDAS method to a decision-making problem, negative and positive distances from the average solution are calculated [309]. This method has become very popular since its introduction in 2015, and many researchers have used this method to solve decision-making problems [310–313] in the building industry [314,315].

3.4.8. MCDM8: SAW

The Simple Additive Weighting method is regarded as the oldest method in dealing with decision-making problems [316] which was first used by Churchman and Ackoff in 1945 [317]. In this method, each alternative is assessed based on predetermined criteria and is given a weight on each criterion assessment [318]. One of the advantages of this method is that the relative order of magnitude of the standardized scores remains equal due to the proportional linear transformation of the raw data in the SAW method.

In order to ease the identification of the pros and cons of each of the identified MCDA/MCDM techniques, Table 6 summarizes the main characteristics of each class, including the MCDA/MCDM techniques, year of introduction, advantages, and disadvantages.

In order to conduct a deeper investigation of the included articles, the relationships among passive strategies, selection criteria, and MCDA/MCDM techniques were extracted and presented in Table 7 simultaneously, so that a holistic view of the three items required for selecting the best passive energy consumption optimisation strategy can be obtained. Table 7 highlights that SWARA (MCDM3), COPRAS (MCDM4), BWM (MCDM6), and EDAS (MCDM7) were able to prioritize most of the passive energy consumption optimisation strategies. It is seen that reduction of energy consumption (PSSC2) and investment cost (PSSC9) were the most widely used selection criteria by previous studies, due to their ease of theoretical simulation, which further justifies the relationships observed in the co-occurrence map in Fig. 6 (e.g., considering PSSC2 and PSSC9 for simulating "envelope" in "optimisation" process).

Table 6
Advantages and disadvantages of the identified MCDA/MCDM techniques [231, 232,317,319–321].

Code	MCDA/ MCDM	Year	Advantage(s)	Disadvantage(s)
MCDM1	ELECTRE	1966	Providing solution even with missing data, ability to deal with both qualitative and quantitative discrete criteria	Difficulty in usage without software due to the complex evaluation procedures
MCDM2	AHP	1980	Simplicity, not requiring additional tool for weighing criteria	Getting sophisticated in the condition of increasing criteria and alternatives
MCDM3	SWARA	2010	capability and efficiency in handling uncertainty and simulating the human judgment's ambiguity	Not considering the reliability of experts' idea
MCDM4	COPRAS	1996	Considering both negative and positive criteria simultaneously	Instability in some circumstances due to data variation
MCDM5	TOPSIS	1981	Simplicity, ability to deal with large numbers of criteria and alternatives	Not considering the correlation between criteria, difficulty of vector normalisation if multiple dimensions exist
MCDM6	BWM	2015	Requiring fewer pairwise comparisons, high accuracy, and consistency	Not providing a global optimal solution which may result in the final result
MCDM7	EDAS	2015	Ability in situations where there are incompatible criteria	Inability to work when negative and zero elements exist in the average solution
MCDM8	SAW	1945	Simplicity	Accuracy decreases with large numbers of criteria and alternatives

Table 7
Relationships among passive strategies, selection criteria, and MCDA/MCDM techniques in selecting the best passive strategy.

	MCDM1	MCDM2	MCDM3	MCDM4	MCDM5	MCDM6	MCDM7	MCDM8
PSG1	[91]: PSSC9, 11; [92]: PSSC2, 11	[92]: PSSC2, 11; [110]: PSSC1, 2, 4, 6–10, 12-15	[99]: PSSC2, 5	[99]: PSSC2, 5	–	[7]: PSSC1-12	[7]: PSSC1-12	–
PSG2	–	–	[99]: PSSC2, 5	[99]: PSSC2, 5	[241]: PSSC2, 5, 8, 9, 11	[7]: PSSC1-12	[7]: PSSC1-12	[241]: PSSC2, 5, 8, 9, 11
PSG3	–	–	[99]: PSSC2, 5	[99]: PSSC2, 5	–	[7]: PSSC1-12	[7]: PSSC1-12	–
PSG4	–	[105]: PSSC2, 9	[99]: PSSC2, 5	[99]: PSSC2, 5	–	[7]: PSSC1-12	[7]: PSSC1-12	–
PSG5	–	–	[99]: PSSC2, 5	[99]: PSSC2, 5	[138]: PSSC2, 9, 14; [241]: PSSC2, 5, 8, 9, 11	[7]: PSSC1-12	[7]: PSSC1-12	[241]: PSSC2, 5, 8, 9, 11
PSG6	[147]: PSSC4, 6, 9	–	[99]: PSSC2, 5	[99]: PSSC2, 5	–	[7]: PSSC1-12	[7]: PSSC1-12	–
PSG7	–	–	[99]: PSSC2, 5	[99]: PSSC2, 5	–	[7]: PSSC1-12	[7]: PSSC1-12	–
PSG8	–	–	[99]: PSSC2, 5	[99]: PSSC2, 5	[241]: PSSC2, 5, 8, 9, 11	[7]: PSSC1-12	[7]: PSSC1-12	[241]: PSSC2, 5, 8, 9, 11
PSG9	[91]: PSSC9, 11; [92]: PSSC2, 11	[92]: PSSC2, 11 [105]: PSSC2, 9	[99]: PSSC2, 5	[99]: PSSC2, 5	[241]: PSSC2, 5, 8, 9, 11	[7]: PSSC1-12	[7]: PSSC1-12	[241]: PSSC2, 5, 8, 9, 11
PSG10	–	–	–	–	–	–	–	–
PSG11	–	[110]: PSSC1, 2, 4, 6–10, 12-15	–	–	[138]: PSSC2, 9, 14; [241]: PSSC2, 5, 8, 9, 11	–	–	[241]: PSSC2, 5, 8, 9, 11
PSG12	–	–	–	–	[138]: PSSC2, 9, 14;	–	–	–

4. Conclusion

Serious concerns regarding energy consumption in buildings exist due to the recent rising trends of population growth and its corresponding energy requirement. The problem of energy supply is further compounded by the fact that there is now high awareness on its sources, which has triggered global preferences for green and sustainable solutions. Based on these premises, passive energy consumption optimisation strategies are regarded as apt solutions. However, selecting the best passive strategy among all the existing ones makes it a challenging task for decision-makers. MCDA/MCDM techniques are useful tools to select the best passive strategy, however, to the best of authors' knowledge, no paper has reviewed the application of MCDA/MCDM techniques in selecting the best passive energy consumption optimisation strategies in the building industry. Also, the inclusion of articles into most of the existing literature reviews within this research discipline have been based on convenience sampling and not systematic, which significantly increases the risk of subjectivity and bias. Hence, this study provides a holistic systematic literature review regarding the application of MCDA/MCDM techniques in selecting the best passive energy consumption optimisation strategies and their corresponding selection criteria through PRISMA and PPSR methodologies. A range of popular discipline specific as well as multidisciplinary databases, including Compendex, GEOBASE, GeoRef, Inspec, Web of Science (WoS), and Scopus were queried based on meticulously constricted search strings. Following the implementation of several inclusion and exclusion criteria, 65 studies were finally selected and studied in this SLR. Further details on the findings of the SLR are elaborated thus:

- Several passive energy consumption optimisation strategies were identified and categorized into 12 groups (PSG1-PSG12). The mentioned groups were "Determining the optimum place and thickness of insulation layer (PSG1)", "Increasing building's thermal mass (PSG2)", "Reducing thermal bridge in buildings (PSG3)", "Improving vapor tightness of building (PSG4)", "Improving airtightness of building (PSG5)", "Using naturally ventilated envelope (PSG6)", "Using natural daylighting (PSG7)", "Using sun shading devices (PSG8)", "Improving fenestration design of building (PSG9)", "Determining the optimum orientation of buildings (PSG10)", "Reducing heat absorption in building's façade (PSG11)" and "Using green envelope (PSG12)". It was observed that most of the papers only considered a limited number of passive strategies such as determining the optimum place and thickness of insulation layer (PSG1), using naturally ventilated envelope (PSG6), using sun shading devices (PSG8) and improving fenestration design of building (PSG9). On the other hand, other passive strategies like reducing thermal bridge in buildings (PSG3) and improving vapor tightness of building (PSG4) were less considered in the including articles.
- This study also attempted to identify selection criteria for choosing the best passive energy consumption optimisation strategy, and 17 criteria were identified including "Compatibility with climate (PSSC1)", "Reduction of energy consumption (PSSC2)", "Reduction of GHGs emission (PSSC3)", "Improvement of indoor environmental quality (PSSC4)", "Job creation (PSSC5)", "Occupant wellbeing improvement (PSSC6)", "Reliability (PSSC7)", "Durability (PSSC8)", "Investment cost (PSSC9)", "O&M cost (PSSC10)", "Money Payback period (PSSC11)", "Installation time (PSSC12)", "Aesthetics (PSSC13)", "Being environmentally friend (PSSC14)", "Availability (being locally available) (PSSC15)", "Flammability (PSSC16)" and "Feasibility (PSSC17)". It was seen that most of the studies only considered energy-saving potential and investment cost and neglected other criteria.
- The relevant MCDA/MCDM techniques for selecting the best passive energy consumption optimisation strategy were also extracted from the included articles. The mentioned techniques were "ELECTRE (MCDM1)", "AHP (MCDM2)", "SWARA (MCDM3)", "COPRAS (MCDM4)", TOPSIS (MCDM5)", "BWM (MCDM6)", "EDAS (MCDM7)" and SAW (MCDM8). Among the identified techniques, AHP was the most popular technique.

Based on the aforementioned points, this SLR has successfully illustrated that most of the existing research efforts on passive energy consumption optimisation strategies have been geared towards very limited number of strategies, particularly insulation layer, using naturally ventilated envelope, and sun shading devices. Also, energy saving potential and financial aspects of the passive strategies were the core and often the only criteria considered. Therefore, besides the already elaborated benefits, this SLR provides a better representation of research trends through its incorporation of emerging MCDM/MCDA techniques which have been proven to be very useful under a wide range of complex scenarios, as well as lay the foundation for further investigations.

Some of the limitations of this SLR are related to the predefined inclusion/exclusion criteria that eventually governed the types and amounts of academic literature that were thoroughly discussed herein. Notwithstanding, the outcomes of this SLR reveal some opportunities for future studies, including i) investigating research studies that rely on novel MCDM/MCDA techniques for solving the problem of selecting the best passive energy consumption optimisation strategies; ii) research studies that consider more selection criteria (especially social criteria) besides energy-saving potential and cost, and use experts' judgment as complementary data; iii) research studies that focus on passive energy consumption optimisation strategies which have been given scarce attention using simulation and/or practical experiments; (iv) consultation of grey literature sources (such as practitioner reports, industrial standards, white papers, etc.) to complement the academic literature findings presented here.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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