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A review of Multi-criteria decision-making methods considering building performance

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Abstract
Multi-criteria decision-making (MCDM) is a branch of operational research that finds optimal results in complex scenarios, including various indicators, conflicting objectives, and criteria. MCDM analysis is a helpful tool to assist designers with this integration by generating the best solutions for achieving conflicting and multiple objectives. Recent studies have used MCDM methods and applications to resolve problems in the field of energy planning, environment, and sustainability. MCDM methods have been extensively used in management and optimization fields; however, their application to building performance is relatively recent. Building performance is an involved problem as it has to respond to multiple criteria. Assessment requires predictive models with numerous design and physical parameters as their inputs. Many MCDM methods are available, each with related benefits and drawbacks. Nevertheless, not all MCDM methods are appropriate for providing solutions for building performance. This paper aims to present an overview of the literature that include the most commonly used MCDM methods considering building performance design. Moreover, the paper highlightes the best practice implemented in each method that support decision making process. The outcomes of this work are to specifiy the most applicaple MCDM methods could be used in the field of building performance. In-addition, presenting how this methods can predicit the optimum design alternative.

Keywords: Multi-criteria decision making- MCDM-building performance- MCDM methods

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1-Introduction

In the past three decades, nearly all fields including engineering, science, humanities, business, psychology, law, and politics have paid particular attention to multi-criteria decision-making (MCDM). MCDM is a popular sequence of operations research models that addresses decision problems when various decision criteria are present (Pohekar & Ramachandran, 2004). MCDM can be regarded as both old and new, depending on one's frame of reference. MCDM methods are known for assistance in selecting appropriate solutions to design issues; and receiving increasing attention in sustainable design, daylight, or energy optimization problems (Zimmermann, 2011). Multi-Criteria Decision-Making (MCDM) techniques consider the design process holistically, as they include multi-disciplinary approaches and ensure that all the important aspects are taken into account. There are numerous methods that can result in a compromise solution, therefore many factors must be taken into account while choosing the best method. Criteria are often quantitative, focusing on the technical and economic aspects of these choice problems because the majority of the main performance indicators in building design problems are numerical (Kokaraki et al.,2019).

The building design is a decision-making process in which multiple criteria and professional disciplines exist. The final decision must consider the preferences of the interested parties that compose the design team and the chosen performance criteria (Moghtadernejad et al., 2019). The performance criteria are a common framework through which the design team will evaluate the potential design alternatives. The selection of an optimal alternative is the most essential step in design. This task is undertaken at the architectural preliminary design stage, where the designer defines the system's performance requirements concerning the project needs and provisions of the code and standards (Moghtadernejad et al., 2020). Subsequently, the designer selects a few alternatives that satisfy the performance requirements based on code and standards and chooses an alternative that preference with the clients (Prieto et., al. 2018). The stakeholders produce these alternatives and directly reflect their preferences. Therefore, there is a high connection between the alternatives and the selected criteria, as the latter directly involves the stakeholders' preferences. Several MCDM methods are available to the designers, which utilize single or hybrid approaches. However, applying Multi-criteria optimization and decision support tools in building performance is minimal and recent (Moghtadernejad et al., 2020).

Thus, the decision process is complex and needs to be as transparent as possible to allow professionals to achieve an integrated design approach (Kokaraki et al., 2019). Therefore, this paper aims to present an overview of the literature that include the most commonly used MCDM methods considering building performance design. Moreover, highlighted the best practice implementated of each method that support decision-making processThe methods are introduced along with their advantages and limitations.

Nomenclatures	
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
DEMATEL	Decision-Making Trial and Evaluation Laboratory
MCDM	Multi-Criteria Decision Making
MADM	Multi-Attribute Decision Making
MODM	Multi-ObjectiveDecision Making
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
VIKOR	Vlse Kriterijumska Optimizacija I Kompromisno Resenje Multicriteria Optimization and Compromise Solution, with pronunciation
WSM	The Weighted Sum Method
BWM	Best Worst Method
WASPAS	weighted aggregated sum product assessment

2- Methodology

In the field of building performance, the design procedure should not be only about selecting a design alternative that meets the performance requirements of the codes and standards and project expectations. The goal is to choose an alternative that maximizes all performance criteria.

This paper includes two parts; the first is an overview of Multi-criteria decision-making methods. The second part highlights the most applicable method in building performance.

3- Overview of Multi-Criteria Decision-Making Methods

MCDM is a potential tool for analyzing complex problems by judging different alternatives, like policy, scenario, strategy, weighting, etc., on

various criteria for selecting the best alternative using mathematical calculation (Bhole & Deshmukh, 2018). MCDM analysis is a valuable tool to assist designers with this integration by generating the best solutions for achieving conflicting and multiple objectives. MCDM can be broadly categorized into two categories; first Multi-Attribute Decision-Making (MADM) involves the selection of the best alternatives from prespecified alternatives described in terms of multi-attribute; however, very often, the terms MADM and MCDM are used to mean the same class of models. Second, Multi-Objective Decision Making (MODM) involves the design of alternatives that optimize multiple objectives of the decision-maker (Gavade, 2014) The decision-making process is perspective or normative, aimed at making the best decision without uncertainties (Hopfe et al., 2013). The decision-making process typically proceeds from top to bottom and returns to previous steps if new information is discovered later (Zardari et al., 2015). It consists of 8 steps; as shown in Figure 1.

- **Step 1:** Define the problem, limiting assumption, system and organizational boundaries and interfaces, and any experts' issues
- **Step 2:** Determine the requirements of a decision based on experts' judgments
- **Step 3:** Establish goals that may be conflicting, which are naturally concomitant with practical decision solutions.
- **Step 4:** Identify alternatives that best suit the goals selected by evaluating the different alternatives against a set of criteria.
- **Step 5:** Define criteria as objective measures of the goals to measure how well each alternative achieves the goals.
- **Step 6:** Select a decision-making tool that depends on the decision problem and the decision-maker's objectives.
- **Step 7:** evaluate the alternatives against the criteria, and the application of the tool to compare alternatives to the criteria.
- **Step 8**: validate solutions (alternatives) against the requirements and goals of the decision problem. (Zardari et al., 2015).

The ability of MCDM to reflect real-life problems become more important than ever, as these models can now be examined more with other measures (Munier, 2006). Various authors have presented some literature review surveys on MCDM methods. There are more than 100

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MCDM methods, each with distinct characteristics that can be used to support decision-making processes. Priority-based, outranking, distance-based, and hybrid approaches are also used for various problems.
There are four specific families of MCDM methods:
1. The outranking
2. Value and utility theory-based.

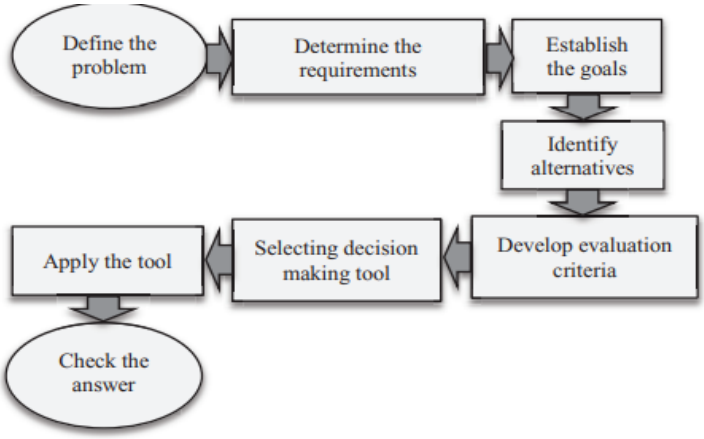

Fig.1. General decision-making process (Zardari et al., 2015).

3. The multiple objective programming
4. Group decision and theory-based negotiation methods (Zavadskas et al., 2010).
Even with the diversities in details of the methods, MCDM methods use various aggregation rules for criteria in comparing alternatives (Moghtadernejad et al., 2019). Some studies reviewed the applications and methodologies of the MCDM techniques and approaches, the others focused on MCDM techniques applied in specific areas, such as water management, sustainable energy planning, supplier evaluation and selection, bioenergy schemes, construction, municipal solid waste management, and green supplier evaluation and selection (Mardani et al., 2015). Kolios et al., (2016) have performed a Political, Economic, Social, Technological, Legal, and Environmental (PESTLE) study, employing Topsis and weighted sum method (WSM) methods for multi-criteria risk prioritization.
MCDM methods have many applications in architectural design, urban planning, and energy-efficient construction. Feyzi et al., (2019) used the ANP method for selecting a site for municipal solid waste incineration,

power plant construction, and renewable energy procedure. Ren et al., (2017) developed an MCDM framework for evaluating urban sewage sludge treatment technologies by integrating Best-Worst Method (BWM), Solid Waste Management (SWM), digraph, and Topsis. Khoshnava et al., (2018) employed DEMATEL and Fuzzy theory with ANP to select materials for green sustainability buildings for a construction company. Zavadskas et al., (2013) used WSM and Weighted Aggregated Sum Product Assessment (WASPAS) methods for ranking four alternatives in terms of twelve criteria for public or commercial building facades in selecting a proper façade system and found that sandwich panels are the most suitable for public or commercial buildings. Kabak et al., (2014) used hybrid MCDM methods based on Benfits, Opportunities, Costs and Risks (BOCR) and ANP to determine Turkey's energy status and prioritize alternative Renewable Energy (RE) sources.

The methods mentioned above are difficult to apply in practical engineering due to the time-consuming. In the early stage of the architectural design process, it does not make much sense to overly pursue simulation accuracy due to the uncertainty of scheme shape and the other design variable. In optimizing the multi-performance design of a building, selecting appropriate design variables for optimization based on each building's performance is also multi-criteria decision-making (Han et al., 2023).

Selecting one MCDM method depends on expert opinion and the type of decision problem. Some MCDM methods, due to their nature, can be appropriate and valuable in specific study fields (depending on the type and scale of the initial decision data (Haddad & Sanders, 2018).

4-Review of multi-criteria decision-making methods in the context of building performance

MCDM methods are known for assistance in selecting appropriate solutions to a design problem. these methods are receiving increasing in sustainable design, daylight, or energy optimization problems (Moghtadernejad et al., 2019).

This review includes previous scientific papers that investigated the suitability of the MCDM in the context of building performance. Extensive researches have been done on optimizing building performance concerning one or more facade design criteria. However, these studies mainly focus on passive design strategies, as stated by (Prieto et al.,2018).

Several researchers have compared the various methods and outlined the advantages and limitations of each MCDM method. Multiple studies

suggest that the analytic hierarchy process AHP is the most preferred method for multi-criteria decision analysis in building performance. Moghtadernejad et al., (2019) identified and compared several commonly used MCDM methods. Finding that, Choquet is the most appropriate MCDM method for façade design. The mean reason is that decision-makers need to define mutually independent criteria in other methods to avoid double counting.

Hopfe et al., (2013) presented a viable means of collaborative ranking complex design options based on stakeholders' preferences that involve a choice between two Heating, Ventilating and Air Conditioning (HAVC) systems design using AHP.

In energy, some MCDM methods are more widely used and more reliable than others. The AHP method is commonly employed in energy applications to evaluate power plants and prioritize development (Effatpanah et al.,2022). Han et al., (2023) stated that WSM, AHP, Choquet integral methods, and Topsis are the common MCDM methods in building performance. They compared nine MCDM methods and concluded that AHP, Choquet integral method and Topsis are the most applicable methods in building multi-objective optimization design.

Successful selection of the most appropriate multi-criteria methodology should consider arranging different perspectives to comprehend all sides of the problem and, when necessary, consider interconnections among the criteria. Thus, a theoretical review of commonly used MCDM methods that exist in engineering and building performance design are presented in this part.

To clarify the applications and effectiveness of the following seven methods; ANP, DEMETAL, TOPSIS, VIKOR, AHP, DELPHI, and CHOQUET INTEGRAL:

4.-1-ANYALTIC Network Process (ANP)

ANP has all the positive features of AHP, including simplicity, flexibility, simultaneous use of quantitative and qualitative criteria, and the ability to review consistency in judgment (Kheybari et al.,2020). It was used for project selection, product planning, strategic decision-making, and optimal planning. ANP is a robust MCDM method that converts to quantitative and standard data types. It is also interdependent and overcomes the problem of feedback between criteria (Sriram et al.,2022). Bohra et al., (2022) reviewed all possible applications of MCDM in renewable energy areas. And found that, AHP and ANP are the most popular, fuzzy sets are the second used impact analysis

INTERNATIONAL JOURNAL OF
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VOLUME 6, ISSUE 1, 2023, 274 – 305

assessment of generation technologies, and Topsis is the third acceptable method for policy and technology evaluation.

Introduced by Saaty (Saaty, 2006). It considers the interactions and allows for complex interrelationships between decision-making elements. It structures the problem as a network with connections among criteria, subcriteria, goals, and alternatives. The network structure elements are grouped into clusters, and every element may affect the others of any level i.e., Connections may exist among criteria, sub-criteria, and alternatives (Görener, 2012). The interaction between criteria and subcriteria shapes the network and can solve interdependency by finding the relative significance of different criteria.

- **The ANP method steps:**

It consists of 5 steps;

Step 1: Assess criteria, construct a network model, and structure the problem.
Step 2: Construct a pairwise comparison matrix and the relative weights.
Step 3: Consistency check.
Step 4: Form and solve the supermatrix.
Step 5: Compute the limited Matrix.
Step 6: Choose the best alternative based on weight values. The steps are shown in Figure (2), (Magableh & Mistarihi, 2022).

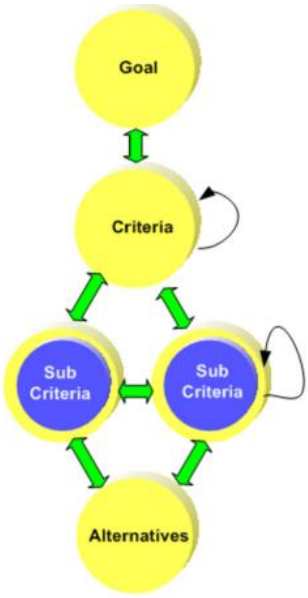

Fig 2: ANP methodology framework (Magableh & Mistarihi, 2022).

The ANP provides a way to input judgments and measurements to derive ratio scale priorities for the distribution of influence among the criterion and groups of criteria in the decision-making process (Chen et al.,2011). ANP presents the evolution of the analytical process AHP method, Which models the decision problem by a hierarchical structure when only the lower-level elements depend on the higher-level ones, and no dependence among the elements of the same level may exist (Asadabadi et al.,2019).

- **ANP Advantages**

  *Allowing the consistency degree of pairwise comparison matrixes to be evaluated.

  *Dealing with the dependence among criteria and alternatives.

  *Allowing decision-makers to analyze complex decision-making problems using a systematic approach that breaks down the mean problem into simpler and affordable subproblems.

  *The detailed analysis of priorities and interdependencies between cluster elements forces the decision maker to reflect on their project's priority to the decision-making problem itself, resulting in a better knowledge of the problem and a more reliable final decision (Kheybari et al., 2020).

- **ANP Disadvantages**

  *ANP needs a higher number of pairwise comparison matrixes.

  *ANP procedure becomes prohibitive if the number of network elements increases. This is why ANP needs to support proper software to avoid even more decision-maker efforts to understand the Method (Zhu et al.,2010).

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VOLUME 6, ISSUE 1, 2023, 274 – 305

- **ANP and building performance:**

Feng et al., (2018) proposed DEMATAL, ANP, and VIKOR as an environmentally friendly multi-critical decision-making model for reliability-based product optimization considering product life cycle creation. Gunduz & Khader, (2020), presented the MCDM model by using the ANP method to identify and prioritize potential risks in the construction sector, considering their interconnections and occurrence frequency. Based on the results from the model, recommendations to industry professionals are provided and presented. Xu & Chan, (2013) used the ANP method to develop a sustainable Building Energy-Efficiency Retrofit (BEER) model under the Energy Performance Constructing (EPC) mechanism, ANP was built on super decision software. Ozkaya & Erdin, (2020) employed ANP and TOPSIS to weigh and choose smart and sustainable City criteria as an evaluation framework to make cities smarter and more sustainable; the study converted 44 cities worldwide. According to the results, Tokyo, London, and New York are in the top three in the overall ranking. Chen et al., (2011) adopted ANP and DEMETA methods to establish a performance evaluation and relationship model for evaluating the performance of hot spring Hotels. To improve and develop a strategy map thatcan be used as a reference for the industry to overcome the increasing market competition.

4-2-Analytical Hierarchy Process (AHP)

AHP was developed by Saaty in 1980 and is extensively applied in problems involving multiple oven-conflicting criteria (Georgiou et al.,2015). The principal characteristic of the is that it is used comparisons, which are used both to compare the alternative concerning various criteria and to estimate criteria weight (Velasquez & Hester, 2013). Arroyo et al., (2015) revealed that cost-benefit analysis (CBA) is superior to AHP in every derived factor and criterion. AHP is a structured

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PRINT ISSN 2785-9665 ONLINE ISSN 2785-9673
VOLUME 6, ISSUE 1, 2023, 274 – 305

technique for organizing and analyzing complex decisions (Tan et al.,2021). The AHP system should be an accurate measure of the difference in attribute preferences For consumers, the results of this approach will be better than others (Sriram et al.,2022). Han et al., (2023) proposed an MCDM method based on sensitivity analysis and AHP for building performance optimization, which provides architects with a real-time interactive way to handle the building's sustainable design. The results showed that design efficiency increased by 211.5%.

AHP aims to define the optimum alternative and categorize the others, considering the criteria that describe them. To apply the original AHP method, four steps should be followed, as shown in Figure 3.

- **AHP method steps**

  It consists of 4 steps;

Step 1: The first step involves structuring the decision problem into a hierarchy structure. The aim is to be at the top of the hierarchy.
Step 2: The next step includes the criteria affecting the decision.
Step 3: The alternatives are placed at the bottom of the hierarchy. The weights for each creation should be obtained. The pairwise comparison Matrix and judgemental Matrix should have complied.
Step 4: Final performance for each alternative and ranking should be obtained (Siekelova et., al. 2021).

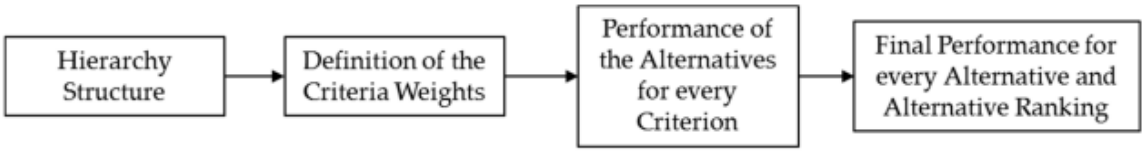

Fig 3: The process of AHP methodology (Siekelova et. al. 2021)

The AHP is particularly relevant when considering qualitative criteria, such as environmental and political impacts. It's widely employed for energy planning problems because of its ability to check consistency. Furthermore, throughout this method, the hierarchy is revealed after the breakdown of the problem, which enables the understanding and defining of the process itself (Kolios et al., 2016). it is also suitable for technological characteristics and future aspects that are not well-known (Georgiou et al.,2015).

INTERNATIONAL JOURNAL OF
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VOLUME 6, ISSUE 1, 2023, 274 – 305

- **Advantages**

*Relatively easy calculation algorithm
*Possibility of Performing calculations in regular spreadsheets.
*Possibility of assessing the consistency of comparison in pairs.
*Possibility of pairwise comparison by a group of experts (especially important when choosing the location variants for large-scale investments).
*Possibility of estimating both waiting of decision factors and the possibility of constructing the ranking of the Variant under consideration.
*Possibility of including the pair comparison procedure as a questionnaire.
*Possibility of integration with other methods.

*A considerable amount of software (oven available and accessible) supporting the calculation with the chosen method.

- **Disadvantages**

*Possible problem is maintaining the consistency of pairwise comparison when more elements are taken into consideration.

*AHP cannot directly be considered potential associations amongst many components, as it performs imperfectly when different levels are independent, which implies that the method is unsuccessful in representing the complicated connections among the components.

- **AHP and building performance**

  Leccese et al., (2020) proposed an original lighting quality assessment method for evaluating lighting in Educational rooms. The method is based on selecting lighting criteria, sub-criteria, and related indicators. Using AHPmethod to assign a weight to each criterion impacts the lighting quality differently. Han et al., (2023) proposed a multi-criteria decision-making method based on sensitivity analysis and AHP for building performance optimization, which provided architects with a real-time interactive way to handle the building's sustainable design, applied to a case study of office Building Design in China. Results showed that the optimal Solutions obtained with the help of the proposed method had better performance than those obtained without the method. Si et al.,(2016) evaluated the application of multi-criteria decision-making methods to select green technologies for retrofitting existing buildings, applying AHP to demonstrate

through a case study of a building part of a University estate. The finding showed that AHP could help to formulate the problem and facilitate the assessment and ranking of retrofitting measures when multiple criteria are jointly considered. Hopfe et al., (2013) presented a valuable means of collaborative ranking complex design options based on stakeholders' preferences and considering the uncertainty involved within the designs by using the AHP method to choose between two design approaches. Nadoushani et al., (2017) provided a systematic methodology for the selection of the Facade system for a building considering the social, economic, and environmental impacts on the decision. by using the Delphi technique to identify applicable sustainability criteria and their relative pairwise importance scores, while AHP is used to determine the Global alternative importance weights for different sustainability criteria and rank other alternative facade systems.

4-3-Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

It's a distance base method based on the selection of alternative that has the best value for all criteria, and has the shortest distance from the negative (Rahim et al., 2018). TOPSIS is an MCDM method that employed to find and prioritize the best solution from a set of alternative solutions using similarity. It is an evaluation tool used in decision-making to rank alternatives in different areas (Liu et al., 2018). TOPSIS considers the vagueness of decision-making and chooses the best alternative solution using interrelated relationship criteria derived from a limited set of decision solutions. It's widely employed because it is easy to implement and logical. The methods evaluate the alternatives regarding their distance to the scaled positive and negative ideal Solutions. Based on aggregation function representing closeness to the reference points. It has rational and comprehensible logic; the concept depicts in a mathematical form. Thanks to its easy application, it is considered one of the most popular MCDM techniques (Varatharajulu et., al., 2022).

- **The TOPSIS method steps**

  It consists of 6 steps;

Step 1: Normalization of the evaluation Matrix.
Step 2: Calculate weighted normalized decision metrics by multiplying the normalized evaluation Matrix with its associated weight.
Step 3: Identification of the positive and negative ideal Solutions.

INTERNATIONAL JOURNAL OF
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VOLUME 6, ISSUE 1, 2023, 274 – 305

Step 4: Calculation of separation measures.
Step 5: Calculate the relative proximity: the relative proximity.
Step 6: Alternatives are ranked according to descending (Kolios et al., 2016).

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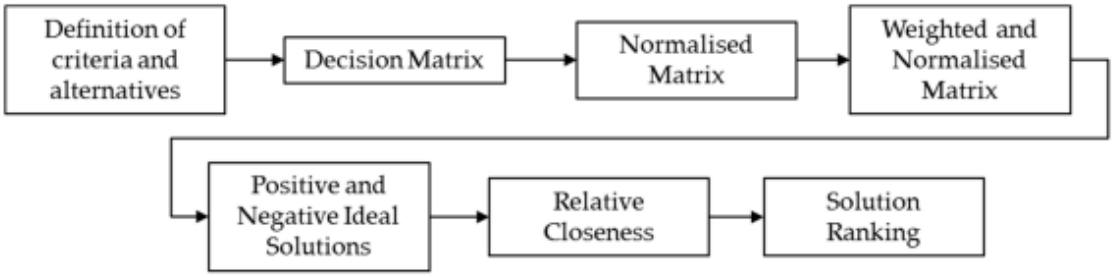

Fig4: The process of TOPSIS methodology (Kolios et al., 2016).

- **Advantages**

*It has a simple process, easy to use, programmable, and the number of steps remains the same regardless of the number of attributes (Kolios et al., 2016).

*Faster than other MCDM methods (Siksnelyte et al., 2018).
*Possibility of Performing calculations in a regular spreadsheet; it's based on quantitative data (Broniewicz & Ogrodnik, 2021).

- **Disadvantages**

*Need to weigh decision factors using other methods.

*Does not consider the correlation of attributes.

*Euclidean distance performance makes no distinction between positive and negative values in calculations in calculations.

*Interactions between criteria are not considered in this Method (Effatpanah et al., 2022).

- **TOPSIS and building performance**

Zhao et al., (2022) contracted a significant economy environment Energy (Performance evaluation index system) 3E for the complaint cooling,

heating, and power microgrid(CCHP) by designing an integrated MCDM methods framework based on anti-entropy, Grey-DEMATEL, TOPSIS, and DQGRA. The results showed that the benefits of system energy supply, equivalent emission reduction of pollutants, energy utilization, and equivalent energy saving are essential manifestations of CCHP-MG's 3E performance. Kokaraki et al., (2019) examined 4 MCDM methods(AHP,TOPSIS, ELECTRE, and PROMETHE) considering the design of a building, applied the decision makers' preferences and use of dynamic simulation of the potential building forms to a real-life case study. Results showed that all methods except TOPSIS showed agreement on the top 10 alternatives abroad. Furthermore, an investigation of four" what if" scenarios indicates that TOPSIS is the most sensitive method to the examined changes in subjective preferences. Keshtkar., (2017) presented a new technique for optimizing a counter-flow wet cooling Tower(CFWCT). First, evaluating thermal performance, then energy analysis. The optimum operating conditions were determined using the results officer Elementary step by considering some parameters controlled by the user and using TOPSIS methods. Results indicated improved (CFWCT) performance with a decision-making process.

4-4-Decision-Making Trial and Evaluation Laboratory (DEMETAL)

Developed in 1973, DEMATEL is an MCDM method that assesses both the influence degree among decision criteria and their relative importance. This method have the possibility to perform dependency analysis at the level of decision factors, making it possible to conduct a decision analysis in a new dimension (La Fata et al.,2023).

Generally, it allows for the analysis of cause-and-effect relationships at the level of the decision factors. The algorithm of the classic digital method is relatively simple and is based on comparing Factors in pairs using a point scale. DEMATEL method consists of three steps as the following process:

Step 1: Develop a matrix of Direct relations.
Step 2: The normalization of elements in the developed Matrix of Direct relations.
Step 3: The calculation of two key indicators is the so-called significance index and relations index (Broniewicz & Ogrodnik, 2021).

It is worth adding that the DEMATEL and AHP method's most common features have common features, including similar initial Matrix, namely the Matrix of comparison and matrixesDirect relations.

- **Advantage**

*DEMATEL requires only one pairwise comparison Matrix regarding the competitional complexity and is easier to implement.

*The DEMATEL method enables the analysis of dependencies (Direct and indirect) between decision factors. This should not be identified directly with the weights of these factors. Therefore, using DEMETAL help rank the elements in terms of mutual relations to identify those that have the most significant impact on others.

*The classic DEMATEL method facilitates ordering at the level of decision factors and their analysis regarding mutual interactions. Therefore, it can be an instrument supporting the selection of elements at the stage of the decomposition of the decision-making problems (Broniewicz & Ogrodnik., 2021).

*Possibility of analysis at the level of decision Factors in terms of mutual dependencies.

*relatively simple algorithm(compared to, e.g., the ANP method).

*Development of the methods for waiting factors.

INTERNATIONAL JOURNAL OF
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VOLUME 6, ISSUE 1, 2023, 274 – 305

*Possibility of group assessments, estimating the weighting.

*Ability to visualize the results in the form of a cause-and-effect diagram.

- **Disadvantages**

*DEMATEL neglects the consistency degree of pairwise comparison matrices to be evaluated.

*High subjectivism as the stage of the dependency assessment.

*A classic version of the method does not assume the weighting of the factors.

*The DEMATEL method is a support tool when selecting and analyzing decision factors. An analysis of dependencies can be successfully performed as part of export interviews to increase objectivity.

- **DEMATEL and building performance**

Wu et al., (2022) proposed DEMATEL and IES methods(interpretative structural modeling) are innovatively used to establish a barrier analysis framework for hydrogen energy storage(HES) applied in Multiple powers scenarios. The analytical framework is applied to identify the key barriers in each scenario and find out the interlinking relationship among the barriers prompted; comprehensive Solutions and policy suggestions to eliminate or reduce the barriers are presented. Gao et al., (2022) developed an MCDM hybrid method and Geographic information system(GIS) for site selection of wind photovoltaic shared energy storage projects. Authors suggested the DEMATEl approach to weight criteria, and then the improved gained and lost dominance score(GLDS) method was used to rank alternatives. The study aids in the layout of wind photovoltaics. Should energy storage projects broaden the application scopes of GIS and MCDMmethods Büyüközkan & Güleryüz, (2017) evaluated renewable energy resources(RER). The authors involve (DEMATEL, ANP, and TOPSIS) as investigated techniques to propose a practical and comprehensive evaluation model for a real industrial problem in Turkey. To improve the (RER) selection process. Gashniani, (2020) evaluated and weighted the factors affected by selecting appropriate and innovative delighting systems for building using integrated (Delphi, DEMATEL, and AHP) methods.

4-5-Choquet Integral

Choquet integral is an aggregation function defined concerning the fuzzy measure. A fuzzy measure is a set function acting on the domain of all possible combinations of a set of criteria. The body measures allow the Choquet integral to assign importance to all possible criteria groups, thus offering much greater aggregation flexibility. The imports and outputs are usually defined on the unit interval(0,1). However, other choices are also possible (Vu et al., 2014). A Choquet integral is a subadditive or super-additive integral created. by the French mathematician(Gustave Choquet,1953). It was initially used in statistical mechanics and potential theory, which found its way into decision theory in 1980, where it measures what is expected of an uncertain event. Wibowo & Grandhi, (2016) proposed an interval-valued intuitions fuzzy multi-criteria group-making approach for evaluating the sustainability performance of thermal power enterprises in a fuzzy environment, by using Choquet integral operator.

It can be regarded as a non-linear aggregation function. Choquet integral has a more complex structure since there is no requirement to provide the additivity (Ünver et al., 2022).

- **Advantages**

*The Choqeut aggregation function shares the same core as WSM and AHP, except the fuzzy measures account for the interaction among various criteria. These innovative features of Choquet Integral distinguish it from the other MCDM methods

*This feature makes it a very desirable method. Also, its application in several engineering is unprecedented.

*This method is unique among all multi-criteria decision-making models due to its ability to represent interactions between the criteria This method can be used for both single or multi-dimensional decision-making problems.

*Mathematically not demanding.

*Deals with uncertainty

*Can deal with qualitative and quantitative criteria.

*Can dynamically update value changes.

- **Disadvantages**

*The mean difficulty associated with this method is the complexity of determining the fuzzy measures, which depends on subjective input from a panel of experts.

*The difficulty of assessing weights depends on the input from a panel of experts.

*time-consuming when the number of criteria increases.

*The difficulty of the remaining interactions indexes, due to the lack of data and sometimes accuracies of using professionals' opinions, is the greatest holdback for this powerful aggregation method, which is why it is not widely used (Moghtadernejad et al., 2019).

- **Choquet integral and building performance**

Moghtadernejad et al., (2020) provided a new and simplified guideline for designers in achieving a high-performance facade system, with the help of multi-criteria decision-making MCDM methods by using AHP and Choquet to select the most suitable alternatives in preliminary facade design for a case study building. Abastante et al., (2018) proposed application of the basic idea of Architecture choice is that designing decisions supports the procedures for complex problems, with a Focus on the housing realm in the Piedmont region of Italy. Based on Choquet, AHP, and NAROR, creating decision guidelines related to building a model. Ozdemir & Ozdemir, (2018) evaluated residential heating system alternatives using the generalized Choquet integral. (Demirel, Demirel, & Kahraman, 2010) applied Choqeut integral to select the location of a warehouse in Turkey by using the Choquet integral to capture the values of the qualitative criteria. Finding that, Choquet successfully selected a warehouse location, which was a big problem for the Turkish logistic firm.

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VOLUME 6, ISSUE 1, 2023, 274 – 305

4-6-Delphi technique

The Delphi technique is a method of gathering the collective opinion of a group of experts particular topic (De Villiers et al., 2005). It allows experts to communicate their opinions and knowledge anonymously about a complex problem or a topic of interest, to see how their evaluation of the issue aligns with others, and to change their opinion. If desired, after reviewing and consideration of the collective findings of the group's ideas (Kennedy, 2004). The Delphi survey is named concerning agric religion on oracle at Delphi. The Greeks sought from the legend, who used a network of expert informers (Thangaratinam & Redman, 2005). This legend was considered one of the most truthful, and the data derived from the network of expert informers contributed to this endeavor (Bond & Bond, 2004). Delphi surveys have been used in modern history for over 50 years (Beech, 1999).It has been employed for virus purposes. Nadoushani et al., (2017) suggested a systematic methodology for selecting the façade system for a building by accounting for the decision's social, ecocnomic, and environmental impacts by using a Delphi technique and AHP. This approach utilizes the principles of building consensus by generating a thesis, anthesis, and synthesis (Shariff, 2015). Deveci et al., (2020) investigated the degree of importance of criteria affecting the optimal site selection for offshore wind farms based Delphi method in achieving more renewable energy integration. Delphi surveys are all contacted over a series of iterative rounds, and expert panelists are expected to complete a series of questionnaires until a consensus is reached (Polit & Beck, 2008). while there are no strict guidelines on the right number of rounds to be undertaking, figure (5) shows Delphi rounds (Shariff, 2015).

Delphi Rounds:

Round 1: (Thesis stage) to generate ideas.

Round2: Review and re-evaluate ideas (antithesis stage). It is a group Summary.

Round3: Re-evaluate ideas and arrive at a consensus (synthesis stage) shown in Figure 4 (Shariff, 2015).

- **Advantages**

*It utilizes experts in the field and brings together the collective wisdom of expert panelists in a cost-effective manner

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VOLUME 6, ISSUE 1, 2023, 274 – 305

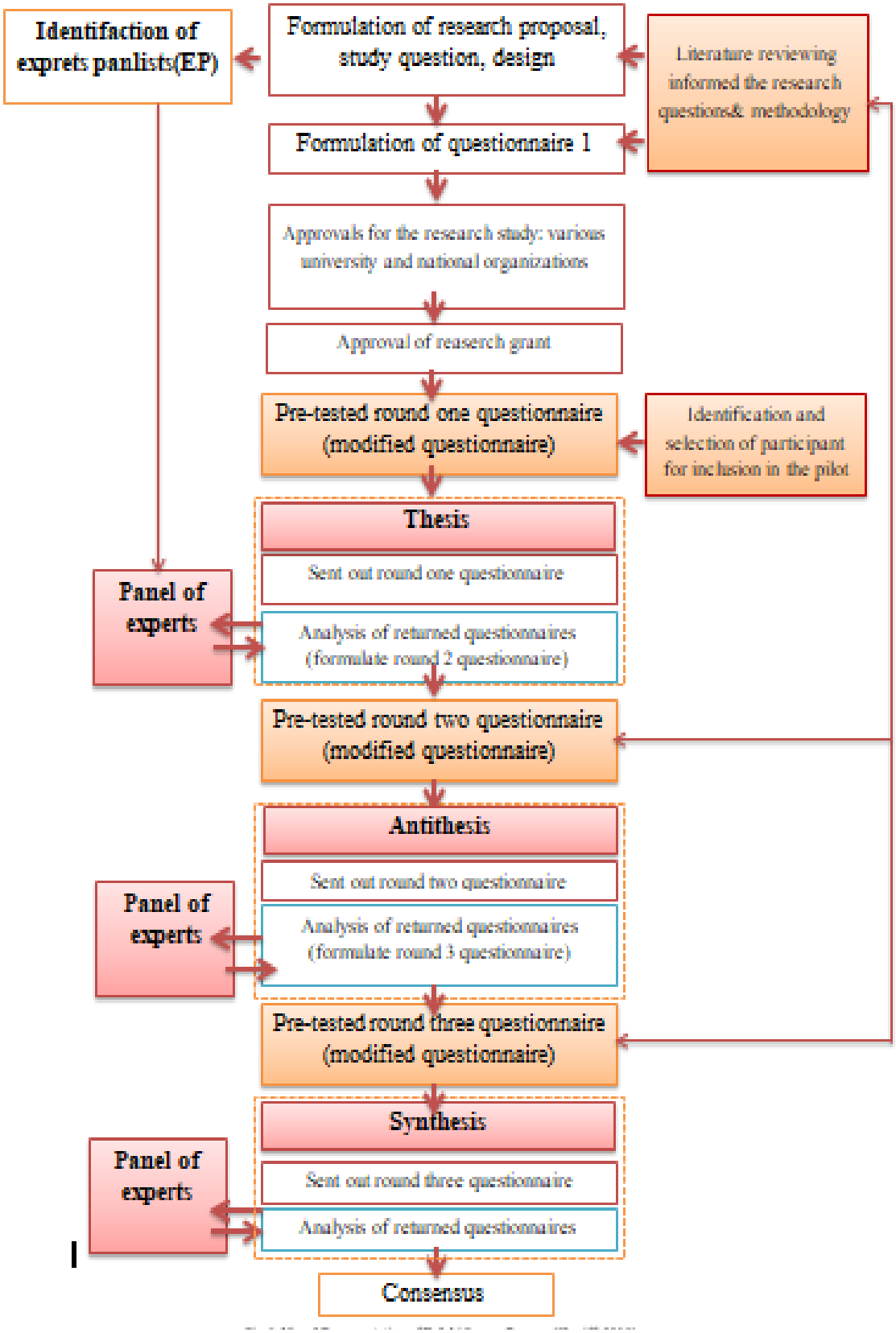

Fig 5: Visual Representation of Delphi Survey Process (Shariff, 2015)

*It facilitates group communication and cheating information among expert panelists anonymously and paradoxically, allowing independent thinking.

*It allows the expert panelists to focus on critical issues within the questionnaire, preventing them from getting sight tracked.

*content validity is assured by involving expert panelists and iterative roundsThe anonymity aspect encourages opinions, and multiple treaty rounds allow participants to re-evaluate the ideas leading to increased content validity.

*The questionnaire is self-reported and self-administered (Colton & Hatcher, 2004).

- **Disadvantages**

*Search services can be time-consuming due to their iterative nature, a

*expert bundle list may lose interest in the research study over time (Keeney, Hasson, & McKenna, 2006).

*There are nuclear guidelines suggesting definitions of experts, panel size, and sampling techniques (Hung, Altschuld, & Lee, 2008).

- **DELPHI method and building performance**

Vatandoost et al., (2019) applied the Delphi method to determine express choice in defining the proper architecture optimization problem in the extension and renovation of a Hospital. This method could achieve a reliable consensus among the selected expert panelist for a specific situation. Smarandache et al., (2020) evaluated research projects that are supported by neutroSophy in academic institutions. The framework offers the advantages of including uncertainty and indeterminacy in decision-making by using the Delphi technique. Results approved that how to use the method and demonstrate its usefulness. Sinha et al., (2018) reached a consensus through the Delphi method, recording the development of habitable quality indicators for multifamily residential buildings in India. After three rounds, a list of indicators appears suitable to form the basis for further search in this field. Nadoushani et al., (2017) presented a systematic methodology for the selection of the facade system for a building by accounting for the social, economic, and end environmental impacts of the decision. The Delphi method identifies applicable sustainability criteria, then AHP method ranks the alternative facade systems.

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VOLUME 6, ISSUE 1, 2023, 274 – 305

4-7-VIKOR (Vlse Kriterijumska Optimizacija I Kompromisno Resenje)

It is a based distance method. It was developed in 1990 and then disseminated thanks to the work of (opicovic and Tzeng). The VIKOR methods assess decision alternatives Based on the position to define reference points.

- **VIKOR method steps**

Step 1: Determination of best and worst varies

Step 2: The value of the comprehensive indicator is determined

Step 3: Comparing the ranking obtained in terms of acceptable advantages and acceptable decision stability.

VIKOR method was developed for the various upgrade of complex systems. It determines the weight stability intervals of the compromise ranking list, the compromise solution, and the optimal consistency solution obtained by the initial giving weights. VIKOR method is used to estimate the interval between compounds and alternatives. This method considered the complex decision-making of the often ambiguous process: inaccurate, indefinite, subjective, and vague data and information (Yazdani et al.,2016).

- **Advantages**

*possibility of Performing calculation irregular spreadsheet

*based on quantitative data

*Identification of patterns and anti-patterns

*possibility of integration with other methods

*possibility of defining a compromise solution, taking into account many conflicting criteria

*An effective way to begin system design when decision-making preferences are unclear. This method determines the stability intervals in the criteria weights (Effatpanah et al., 2022).

- **Disadvantages**

*Does not work well in conflicting situation and interaction between criteria.

*The ranking performed with different volume values of variables' weight.

- **VIKOR and building performance**

Lu et al., (2018) proposed a hybrid MCDM model to estimate the influences of International Airport performance concerning sustainability. Using DEMATAL, VIKOR method to select and improve the performance gap between the aspiration values and the current situation for the International Airport. The outcome indicated that social respective has the highest net influence. Miraj & Berawi, (2021) proposed an MCDM model to select the best alternative photovoltaic, alternative PV system in Tomi Island in Indonesia. To evaluate the effectiveness of MCDM approaches. The authors applied BWM and VIKOR. And found that, despite offering economic benefits, the non-renewable energy alternatives as the mean energy source or less preferred by decision-makers due to low power generation and insignificant carbon reduction. Kotb, et al., (2021) proposed a conceptual design model for sustainable hybrid renewable stand-alone in the resistance electricity demand of a more extensive skill reverse osmosis desalination plant in Baltim, Egypt. Based on fuzzy AHP and VIKOR. Tian et al., (2016) presented a framework by using the combination of AHP andVIKOR methods. To evaluate design alternatives based on Green indices in a subjective environment, considering the manufacturing industry. Results showed that, the proposed MCDM methods can significantly improve the objectivity in evaluating design alternatives in Hanes.

5-Discussion and Conclusion

Almost all decision making methods used in building performance are based on traditional approaches with noticeable trends of applying uncertainty theory, such as fuzzy, grey, rough, and neutrosophic theory. It can be said that the selection between existing MCDM methods is also a multi-criteria problem. Although, none of the MCMD methods could be considered superior method, each has its advantages and disadvantages, and it is not possible to claim that any technique is more suitable than the

others. Hence, the selection and applications of one MCDM method depend on expert opinion and the type of the decision problem (Han et., a. 2023).

Although this review suggested, AHP is the most suitable and commonly used method in building performance. In contrast, Moghtadernejad et al., (2020) stated that AHP does not reflect the most precise evaluation of alternatives' performance since it cannot account for the interaction among design criteria. In addition, they conducted Choquet integral as a decision method in façade preliminary design that can support designers in their decision-making activities. However, this method relies on fuzzy measures that, in practice, can be problematic; they also suggested creating a software program or a web service application. The DEMATAL technique is not used to confirm the interactions affecting the relationship between the factors but it is aimed at obtaining more accurate weights. Yitmen & Al-Musaed (2021) postulated that, ANP model accomplishes consequences for evaluation of high performance criteria in planning and designing phases of adaptive façade systems in complex commercial buildings. Celik. (2017) investigated DEMATEL method relationship model in disaster operations management, they found that, it is an effective tool for analysing structure and relations between few alternatives or system components. In contrary, (Gul et al., 2014), reported that, DEMATEL and ANP require less computational effort and allow for making use of the available information without any constraint on the sample size. They actually represent a structured, effortless, and replicable decision-aiding support tool (La Fata et al., 2023). VIKOR and TOPSIS used different normalizations and introduced different aggregation functions for ranking as shown in study of Opricovic and Tzeng, (2004). While Moghtadernejad et al., (2019) states that AHP and TOPSIS methods do not reflect the most precise evaluation of performance of the alterantives in real life design cases since they do not consider the interactions among various design criteria and consider them as independent. Chan, (2022) concluded that the Delphi consensus method is more significant in the validity of the gathered and reviewed data. This contributed to selecting and applying consensus methods in validating data, information, or criteria, especially in engineering fields. Choquet integral was assessed in the study of Jia and Wang, (2022) they conducted that, it is a very useful tool for aggregating decision information in decision problems, which can consider the importance of attributes and the association between attributes in decision problems. They added that, Choquet is the only decision making method capable of

considering such iteractions that are totally neglected in civil engineering. In addition, Choquet can be integrated with AHP to assign the most consistent preferences and deal with qualitative and quantitative information.

Generally, it should be noted that, one method outperforms the rest, as accuracy in prediction depends on the nature of the problem, as well as the data collection and processing in a way that best fits each individual method and application. Moreover, from previous review, it is observed that AHP is the most used method in energy performance projecta as well as TOPSIS method. While, Choquet are most used in building performance although some researchers exclude Topsis as it is time consuming. Most researchers concluded that, Delphi is the most used method in builing performance, and engineering fields.

For further research, in considering the significance of each method, more analysis considering more extended attributes can be conducted.

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