Research in Globalization 7 (2023) 100164

Contents lists available at ScienceDirect

Research in Globalization

journal homepage: www.sciencedirect.com/journal/research-in-globalization

Determination of priority criteria in green building transformation: An analysis on the service industry

Serkan Eti [a], Hasan Dinçer [b], Serhat Yüksel [b], Yeter Demir Uslu [b], Yaşar Gökalp [b], Hakan Kalkavan [c], Alexey Mikhaylov [d], Gabor Pinter [e,*]

[a] IMU Vocational School, İstanbul Medipol University, Turkey
[b] The School of Business, İstanbul Medipol University, Turkey
[c] Faculty of Political Sciences, Department of Economics, Istanbul Medeniyet University, Turkey
[d] Financial University under the Government of the Russian Federation, Moscow, Russian Federation
[e] Faculty of Engineering, Soós Ernő, Research and Development Center, Renewable Energy Research Group, University of Pannonia, Veszprém 8200, Hungary

ARTICLE INFO

Keywords:
Green Building
Clean Energy
Carbon Emission
Healthcare Industry
Fuzzy Decision-Making

ABSTRACT

The purpose of this study is to identify priority criteria in green (net zero energy) building transformation. For this purpose, an analysis has been conducted for hospitals by considering new methodology. In this scope, firstly, 10 different indicators are selected with the help of literature examination. After that, by using this new methodology, the weights of these items are computed. The main contribution of this study is that a priority evaluation is conducted so that more critical indicators of green building transformations can be identified. Because of this issue, for financial sustainability, companies should firstly focus on more significant factors. Another important novelty of this study is that a new decision-making technique is generated. With the help of this issue, both problems in methodology can be solved and methodological originality can be achieved. The findings show that renewable energy usage is the most critical factor.

Introduction

Green buildings are structures designed, built, and operated in line with the principles of sustainability. These buildings aim to be sustainable both environmentally, economically, and socially. It can be applied for many different building types such as green buildings, residences, schools, and hospitals (Ghalandari et al., 2023). The main purpose of these buildings is to protect natural resources and reduce environmental pollution. On the other hand, issues such as the protection of human health and energy saving can be taken into consideration in this regard. It is possible to talk about the importance of green buildings in many ways. First of all, green buildings can help prevent the depletion of natural resources by saving energy and water. On the other hand, green buildings contribute to the reduction of greenhouse gas emissions and environmental pollution (Rajarajeswari and Anbalagan, 2023). Furthermore, green buildings reduce energy consumption due to energy efficiency. Since this situation reduces operating costs, it contributes significantly to increasing profitability.

For buildings to be green buildings, certain actions must be implemented to increase environmental sustainability. In this context, some practices can be developed for the reduction, recycling, and reuse of waste. This situation is very important for achieving green building goals, as it can reduce environmental pollution (Huang et al., 2023). In addition, water conservation in green buildings should be achieved effectively. This will help to use natural resources effectively. Ensuring energy efficiency is another issue that can be taken into consideration in this process (Aibar-Guzmán et al., 2023). In this context, high efficiency equipment should be used for energy consuming systems such as heating, cooling, and lighting. Less energy consumption will help to minimize the damage to the environment. Thus, it will be much easier for buildings to reach green status.

Actions should be taken to reduce carbon emissions in green buildings. In this process, two different applications can be considered. Primarily, the use of clean energy sources helps to achieve this goal. Since fossil fuels are not used in these types of energy, carbon gas is not released in electricity production (Griffin et al., 2023). Secondly, thanks

* Corresponding author.
E-mail addresses: seti@medipol.edu.tr (S. Eti), hdincer@medipol.edu.tr (H. Dinçer), serhatyuksel@medipol.edu.tr (S. Yüksel), yuslu@medipol.edu.tr (Y.D. Uslu), ygokalp@medipol.edu.tr (Y. Gökalp), hakan.kalkavan@medeniyet.edu.tr (H. Kalkavan), alexeyfa@ya.ru (A. Mikhaylov), pinter.gabor@pen.uni-pannon.hu (G. Pinter).

https://doi.org/10.1016/j.resglo.2023.100164
Received 2 September 2023; Received in revised form 9 October 2023; Accepted 12 October 2023
Available online 13 October 2023

to carbon capture technology, it is possible to use fossil fuels without harming the environment. Thanks to this technology, carbon gas is destroyed without being released into the air. In addition, business processes in businesses need to be compatible with the environment (Chen et al., 2023). In this context, it is important to consider environmental issues in all activities such as purchasing and human resources.

There are many different aspects that need to be taken into consideration to achieve the green status of buildings. On the other hand, it is obvious that these improvements also increase the costs of the enterprises (Gan et al., 2023). In other words, the actions to be taken to have environmentally friendly buildings increase the costs of the enterprises. In this context, it is not financially possible for businesses to make many improvements to have new buildings. Therefore, businesses need to focus on issues that are more important. In this way, while the green building targets are achieved, the costs will not increase extraordinarily. In this context, there is a need for new studies in which priority analysis for these factors will be made.

In this study, it is aimed to make examination about the critical indicators that affect green building transformations. For this purpose, 10 different determinants are selected with the help of literature evaluation. After that, a new fuzzy decision-making model is generated to achieve this objective. In this proposed model, T-Spherical fuzzy sets are integrated into a new decision-making model named TOPSIS-based DEMATEL (TOP-DEMATEL). This methodology is taken into consideration to find the weights of these items for healthcare industry.

The main contributions of this study are underlined below.

(i) A priority evaluation is conducted so that more critical indicators of green building transformations can be identified. There are various influencing factors of these transformations. However, all improvements lead to cost increase. Because of this issue, for financial sustainability, companies should firstly focus on more significant factors. Hence, the analysis results of this study have a positive contribution to the effectiveness of the companies while taking necessary actions.

(ii) A criteria set is created for the companies to reach green building purposes. In this framework, many different quality studies in literature are reviewed and these factors are selected. The criteria set can be taken into consideration for the following studies regarding the evaluation of different industries, such as banking and healthcare.

(iii) The main methodological novelty of this study is the generation of a new decision-making technique by the name of TOP-DEMATEL. Classical DEMATEL technique has significant advantages, such as finding causal relationships between the factors. However, there are also lots of criticisms for this methodology. In this context, DEMATEL approach gives the same weights incorrectly in case of symmetrical evaluations. For the solutions of this problem, two steps of TOPSIS technique are integrated in the process of DEMATEL so that TOP-DEMATEL methodology is proposed. With the help of this issue, both problems in DEMATEL can be solved and methodological originality can be achieved.

(iv) Using Spherical fuzzy sets also increases the quality of the proposed model. A wider space is taken into consideration in these sets. This situation provides to work with a more detailed dataset. Due to this condition, uncertainty problems in this process can be managed in a more effective manner. As a result, the accuracy of the proposed model can be improved.

(v) By using T-Spherical fuzzy sets, the analysis results are computed for different t values. In other words, the findings are computed for various conditions. This condition mainly helps to measure the validity and consistency of the results of the proposed model.

The second section consists of literature review. The third section gives details for the methodology. The fourth section shows the analysis results. Discussions, policy implications and conclusions take place in the final sections.

Literature review

Green buildings, also known as sustainable buildings, mean that a building is compatible with the environment throughout its life cycle and that natural resources are used efficiently. Hospitals, on the other hand, are buildings that must provide 24/7 service. Since it is a building that produces continuous service, it is also important that the hospital provides green status (Shaabani et al., 2020). However, there are many criteria for the evaluation of hospitals with green building status. One of these criteria is the effective execution of waste management. Yoon et al. (2022) and Abanyie et al. (2021) stated that many wastes are generated in the health service delivery process and in cases where waste is not managed effectively, it can cause health problems for both employees and the environment. Bamakan, Malekinejad, and Ziaeian (2022) conducted a study on a blockchain-based waste management system. According to the results of the study, it is identified that waste management processes in hospitals within the scope of green buildings should be carried out effectively. Another important criterion is minimizing carbon emissions. Lu et al. (2019) and Rizan et al. (2021) concluded that hospitals have an important share in carbon production as they are institutions that provide 24/7 service. Therefore, minimizing carbon emissions is important for hospitals to be considered as green buildings. According to Khahro et al. (2021) carried out a study on reducing costs and carbon emissions in hospitals with building information modeling. In the study, it is determined that carbon emission is an important problem for the whole world. For this reason, high carbon emissions will inevitably bring problems such, as climate change and global warming.

The Carbon Capture Technologies are divided into the following two groups:

1) Physical methods are: Physical absorption is based on different solubility of carbon emissions in polar solvents. During physical absorption, the absorption process is not accompanied by a chemical reaction; adsorption is based on the absorption of carbon dioxide by various solid absorbers (carbonates, zeolites, solid amines); membrane extraction is based on the different ability of gases to pass through a semipermeable partition; electrochemical extraction is based on the reduction reaction of CO2 in CO.

2) Chemical methods are chemical absorption is based on the chemical interaction of carbon emissions with alkaline compounds; catalytic hydrogenation is based on the methanation reaction in the presence of metals; enzymatic extraction is based on the use of organic substances of a protein nature (Wilberforce et al., 2021; Wang et al., 2022).

In 1990, in Darmstadt, Germany, the construction of the first net zero energy house was completed, laying the beginning of the development of a new technology for the construction of energy-efficient buildings. The experience has been so successful that in order to carry out further research development of a set of net zero energy building in 1996, Dr. Feist founded the Institute passive house, which has become the main platform for the development of passive house ideas and practical developments around the world. Net zero energy buildings are most in demand in Germany and Austria, where the largest number of houses of this concept. Space-planning and design solutions have a significant impact on building energy consumption (Lund et al., 2011; Lund et al., 2022; Lund et al., 2016). The choice of the optimal form of the building, its orientation, location, assignment of areas of light openings, control of filtration processes allow to reduce the negative heat and energy impact of the outdoor climate on the heat balance of the building. When designing individual energy-efficient buildings with the same building volume should strive for buildings of a spherical (cubic) shape with maximum use passive solar exposure during the heating period due to the southern orientation of light openings, including number of glazed loggias and balconies. The efficiency of using the outdoor climate

increases with the creation of energy-active elements of the Net zero energy building, namely passive and active solar receivers, thermosyphon enclosing structures, heat accumulators, heat pump absorbers (Lund et al., 2017; Magyari et al., 2022; Jacobson et al., 2023).

Creating new values to meet the needs of today without compromising the needs of future generations is called green innovation. While ensuring the continuity of health services, it is necessary not to compromise on the needs of future generations. Bygstad and Øvrelid (2020) examined the relationship between process innovation and the harmony of the hospital's architect. Accordingly, it is argued that innovation processes in hospitals should be carried out effectively. Moslehian et al. (2022) conducted a study on the factors affecting innovation in hospital design. This study highlights the need for interdisciplinary training to address complex building design problems. Apart from this, another important criterion for the evaluation of hospitals in green building status is energy efficiency It is known that hospitals have high energy consumption (Nourdine and Saad, 2020). At the same time, the energy consumption levels of hospitals are quite high due to the continuous provision of health services. In this context, it is also important to keep the energy consumption levels of hospitals under control and to prevent unnecessary use. Accordingly, Montiel-Santiago, Hermoso-Orzáez, and Terrados-Cepeda (2020) examined the hospital's ability to benefit from lighting and daylight using building information modeling. It is concluded that energy efficiency should be provided to transform hospitals into more sustainable areas. Dulce-Chamorro and Martinez-de-Pison (2021) and Psillaki et al. (2023) carried out a study on the provision of health services by saving energy without sacrificing quality. In these studies, in which many methods are proposed to save energy, the importance of providing energy efficiency is also emphasized.

Apart from these, occupational safety is a multidisciplinary field that deals with the safety, health, and quality of life of people. The aim is to promote a safe and healthy work environment. As in all sectors, it is important to ensure the occupational safety of the personnel working in hospitals. Ullah et al. (2021) conducted a study examining the effect of occupational safety on sustainability in a public hospital in Pakistan. A structural equation model was applied to the data obtained from 431 experts. Accordingly, occupational safety practices are one of the main factors affecting sustainability. Adamopoulos et al. (2022) and Dewi and Wardani (2022) made a study on occupational safety practices and their effects on processes in hospitals. These studies using different methods emphasize that occupational health processes are important to maintain the service provided in hospitals. In addition, another important criterion in hospitals is noise pollution. The absence of noise pollution is also important in terms of the efficiency and quality of health services. For this reason, hospitals with green building status need to minimize noise. Mahdi et al. (2022), Tang, Ding, and Lin (2020), and Forsman and Svensson, (2019) conducted studies examining the continuity of health services and noise in the environment. These studies underlined the importance of noise management not to make a vital mistake at the time-of-service delivery.

According to studies in the literature, one of the necessary factors for hospitals to be evaluated in green status is the use of renewable energy. Renewable energy is a type of energy that constantly renews itself and is not likely to be exhausted in nature. The dimensions of energy consumption in hospitals are quite high. Accordingly, Alharthi, Hanif, and Alamoudi (2022) examined the role of renewable energy and environmental pollution on health and household income status in the Middle East and North African (MENA) countries. It is stated that the use of renewable energy is necessary for a better environment and health. Pata (2021) examined the relationship between renewable energy and health expenditures in the USA and Japan. It is concluded that renewable energy and health expenditures increase environmental quality. Accordingly, it has been suggested that the Japanese and American governments should promote green growth and diversify renewable energy sources. Jahangir et al. (2021) aimed to provide energy efficiency in hospitals in Iran. The results of the study show that by utilizing the grid-connected scenario, the amount of energy cost and net current cost will be reduced by 44.2 % and 50.2 %. Apart from this, the inclusion of criteria such as green human resources and green finance in business processes is necessary for buildings to be evaluated for green status. Shah (2019) and Zhang and Dong (2020) separately discussed green purchasing and green human resources processes in their studies. It is identified that they are necessary for environmental contribution. Perkumienė et al. (2020) researched the effect of green logistics practices on the tourism sector and the clean environment process. It is defined that green practices such as bicycle tourism and smart transportation are important for sustainable tourism.

Moreover, water efficiency and transportation issues are of great importance for the buildings to be evaluated for green status. The main reason is that the use of motor vehicles brings air pollution and other problems. Accordingly, it is estimated that there will be water problems in the world with climate change and global warming. In this context, Cheng et al. (2016) conducted a study on the evaluation of the water efficiency of a building in Taiwan. According to the study, the average water-saving rate from 2000 to 2013 for 1320 green building-certified buildings was investigated. Accordingly, it has been determined that for all green buildings, an average of 37.6 % savings is achieved according to the basic water use rate. Strade, Kalnina, and Kulczycka (2020) and Abd Rahman et al. (2021) carried out studies separately in the hospital and pharmaceutical sectors. They underlined that energy efficiency is an important issue for the green status of buildings. Towne et al. (2021) made a study on access to health services in China, despite the wide coverage of insurance. The study identified that easy access to the hospital is important for benefiting from health services. Saidi et al. (2022) and Safin et al. (2021) conducted a study examining the transportation to the hospital and the access possibilities within the hospital. They underlined that the quality of health services is related to both the transportation within the hospital and the ease of access to the hospital.

As a result of the literature review, the following conclusions are reached.

(i) The buildings need to operate in green status, both for humanity and for future generations.

(ii) It is also important for hospitals to be in green hospital status as they provide 24/7 service.

(iii) There are many criteria for hospitals to be evaluated in green status, such as water efficiency, renewable energy usage, and innovative production.

(iv) However, hospital administrations may not have the manpower and financial power to intervene in all these criteria at the same time.

(v) Hence, there is a need for a new evaluation that focuses on the priority analysis for these indicators, but in the literature, there are limited studies about this subject.

Therefore, in this study, it is aimed to develop effective strategies for hospital managers by weighting the criteria so that hospitals can be evaluated in green status. With these strategies, what needs to be done in the transition roads of hospitals to green status will be prioritized. In this way, it will be a guide for hospitals that want to get green building status.

Methodology

In this study, it is aimed to determine priority criteria in green building transformation. Within this context, an analysis has been conducted for hospitals by considering T-Spherical fuzzy TOP-DEMATEL methodology. Firstly, 10 different indicators are selected with the help of literature evaluation. After that, by using this new methodology, the weights of these items are computed. The ranking results are quite similar for different t values. With respect to the conditions of "t = 1" and "t = 2", renewable energy usage is the most critical factor. However, regarding the use of T-Spherical fuzzy TOP-DEMATEL (t = 3), the minimizing carbon emissions becomes the most significant factor

whereas renewable energy usage is the third most essential indicator. To achieve green building transformations, it has been determined that investments should be made primarily in renewable energy projects. In the long term, technological investments should be focused on solving the high-cost problem of these projects. On the other hand, it is very important to provide financial support from the states to solve this problem in the short term (Debrah et al., 2022; Mikhaylov, 2023; Metaxas et al., 2023; Srbová et al., 2023).

DEMATEL method is used to prioritize the factors in the decision-making process. In other words, it helps in calculating the importance weights of the factors affecting an issue (Bhuiyan et al., 2022). On the other hand, it is possible to determine the interactive relations in the decision-making process with the DEMATEL technique (Sun et al., 2022). In this way, it is used to analyze complex problems. Also, the DEMATEL method analyzes the relationships between factors in a decision-making process. In addition, it is possible to show these relationships visually, thanks to DEMATEL. However, there are some criticisms towards this method. Although the DEMATEL method tries to determine the interactive relationships between the factors in the decision-making process, it may not fully reflect all the interactive relationships in some cases. Within this framework, when experts make symmetrical evaluations about the factors, DEMATEL compute the weights of these factors equal although the experts do not give such an opinion. Therefore, to overcome this incorrect calculation, a new technique is generated by the name of TOP-DEMATEL (Özdemirci et al., 2023). In this new approach, some steps of TOPSIS are integrated into the process of DEMATEL so that this incorrect weight calculation problem can be solved (Eti et al., 2023a,b). In this proposed model, this new methodology is considered with T-Spherical fuzzy sets. Equation (1) gives information about these fuzzy sets where membership, non-membership and hesitancy are demonstrated with *s, d* and *u*.

$$0 \le s^t + u^t + d^t \le 1 \tag{1}$$

In this equation, different fuzzy sets can be generated by using some conditions, such as Spherical fuzzy sets (t = 2), picture fuzzy set (t = 1), q-ROFSs (u = 0), Pythagorean fuzzy set (t = 2 and u = 0) and Intuitionistic fuzzy set (t = 1 and u = 0). In the first stage of T-Spherical fuzzy TOP-DEMATEL, the evaluations of the experts are obtained and converted into the fuzzy sets with the values in Table 1.

With the help of Equation (2), Zi matrix is constructed.

$$Z^i = \begin{bmatrix} 0 & \cdots & \left(s^i_{1n}, u^i_{1n}, d^i_{1n}\right) \\ \vdots & \ddots & \vdots \\ \left(s^i_{n1}, u^i_{n1}, d^i_{n1}\right) & \cdots & 0 \end{bmatrix} \tag{2}$$

Equations (3) and (4) are used for the creation of the decision matrix.

$$TSFWAM_W\left(\widetilde{A}_{S1}, \widetilde{A}_{S1}, \cdots \widetilde{A}_{Sn}\right) = \left\{ \left[1 - \prod_{i=1}^{n}\left(1 - s^t_{\widetilde{A}_{Si}}\right)^{w_i}\right]^{\frac{1}{t}}, \prod_{i=1}^{n} u^{w_i}_{\widetilde{A}_{Si}}, \prod_{i=1}^{n} d^{w_i}_{\widetilde{A}_{Si}} \right\} \tag{3}$$

$$Z = \begin{bmatrix} 0 & \cdots & \left(s^d_{1n}, u^d_{1n}, d^d_{1n}\right) \\ \vdots & \ddots & \vdots \\ \left(s^d_{n1}, u^d_{n1}, d^d_{n1}\right) & \cdots & 0 \end{bmatrix} \tag{4}$$

Equations (5)-(7) give information about the submatrices.

$$X = sZ \tag{5}$$

$$s = \min\left[\frac{1}{\max_i \sum_{j=1}^{n} |z_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n} |z_{ij}|}\right] \tag{6}$$

Table 1
Fuzzy Sets.

Scales	U={x_1,… x_n}	S(A) = Supp(A) = $A^{>0}$={x ∈ U| m(x) > 0}	D*={α,β,γ ∈ [0,1]^3: α + β + γ = 1}
4	0.15	0.85	0.45
3	0.2	0.6	0.35
2	0.25	0.35	0.25
1	0.3	0	0.15
0	0	0	0

$$X^s = \begin{bmatrix} 0 & \cdots & s_{1n} \\ \vdots & \ddots & \vdots \\ s_{n1} & \cdots & 0 \end{bmatrix} X^u = \begin{bmatrix} 0 & \cdots & u_{1n} \\ \vdots & \ddots & \vdots \\ u_{n1} & \cdots & 0 \end{bmatrix} X^d = \begin{bmatrix} 0 & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} & \cdots & 0 \end{bmatrix} \tag{7}$$

Equation (8) is considered to generate total relation matrix.

$$T = \begin{bmatrix} 0 & \cdots & \left(\mu^T_{1n}, \eta^T_{1n}, \nu^T_{1n}\right) \\ \vdots & \ddots & \vdots \\ \left(\mu^T_{n1}, \eta^T_{n1}, \nu^T_{n1}\right) & \cdots & 0 \end{bmatrix} \tag{8}$$

Equation (9) is used for defuzzification.

$$Score = \mu^t - \eta^t - \nu^t \tag{9}$$

In the calculation of the weights, Equations (10)-(16) are taken into consideration.

$$C^*_j = \sqrt{\sum_{i=1}^{n}\left(t_i - \max_j t_i\right)^2}\ j = 1, 2, ..n \tag{10}$$

$$C^-_j = \sqrt{\sum_{i=1}^{n}\left(t_i - \min_j t_i\right)^2}\ j = 1, 2, ..n \tag{11}$$

$$R^*_i = \sqrt{\sum_{j=1}^{n}\left(t_j - \max_i t_j\right)^2}\ i = 1, 2, ..n \tag{12}$$

$$R^-_i = \sqrt{\sum_{j=1}^{n}\left(t_j - \max_i t_j\right)^2}\ i = 1, 2, ..n \tag{13}$$

$$S^*_i = C^*_i + R^*_i \tag{14}$$

$$S^-_i = C^-_i + R^-_i \tag{15}$$

$$W_i = \frac{S^-_i}{S^-_i + S^*_i} \tag{16}$$

Analysis results

In this study, it is aimed to determine the most important factors for buildings to have green status for healthcare industry. To achieve this aim, an analysis is carried out with the newly developed model. In this

Table 2
The List of Indicators.

Indicators	Supported Literature
Effective waste management (WMGMT)	(Ghalandari et al., 2023)
Minimizing carbon emissions (CRBEM)	(Wu et al., 2023)
Innovative production and design (IPDSG)	(Griffin et al., 2023)
Energy efficiency (EREFF)	(Rajarajeswari and Anbalagan, 2023)
Occupational safety (OCSTY)	(Azis, 2023)
Sound insulation (SNSLT)	(Huang et al., 2023)
Renewable energy usage (RWSGE)	(Chen et al., 2023)
Green business processes (GBSRC)	(Akcay, 2023)
Sustainable water management (SWTMG)	(Aibar-Guzmán et al., 2023)
Transportation (TNPTO)	(Gan et al., 2023)

context, firstly, the list of criteria is determined. Table 2 gives information about the details of the selected criteria.

Effective waste management is extremely important in terms of protecting natural resources, preventing environmental pollution, and creating a healthy living environment. Green buildings are defined as more environmentally friendly, energy efficient and sustainable structures. Minimizing carbon emissions is extremely important for green buildings. Therefore, minimizing carbon emissions during the design and operation of green buildings is important for a sustainable future. The carbon footprint of green buildings is lowered by designing buildings designed to reduce environmental damage by reducing energy use and minimizing carbon dioxide emissions.

Innovative production and design are of great importance for green buildings. For green buildings to play an important role for a sustainable future, they need to be more environmentally friendly and energy efficient using innovative manufacturing and design techniques. Energy efficiency is very important for green buildings because energy efficient buildings consume less energy and are environmentally friendly. While green buildings reduce their environmental impact with low energy consumption, they reduce costs with energy bills saved. Energy efficient green buildings reduce the amount of greenhouse gases released into the atmosphere thanks to their low energy consumption, and thus they cause less harm to the environment.

Occupational safety is an important issue for green buildings because the health and safety of workers must be ensured during construction, maintenance, and operation. Green buildings are environmentally friendly in terms of construction materials and technologies, but the safety of workers during the construction process needs to be ensured.

Sound insulation is an important issue for green buildings. Therefore, sound insulation is an important factor for improving the indoor quality and comfort of green buildings. Good sound insulation reduces the noise level inside the building, allowing employees or residents to have a more comfortable working or living environment. Sound insulation also helps to save energy. Good sound insulation makes heating and cooling systems work more efficiently. Renewable energy sources can be used endlessly in our world where natural resources are limited. Therefore, green buildings need to focus on solutions based on renewable energy sources to reduce their energy consumption and minimize their carbon footprint. These resources, unlike fossil fuels, are unlimited and reduce greenhouse gas emissions during energy production (Candila et al., 2021; Saqib et al., 2021).

By evaluating these 10 criteria, the opinions of three decision makers are taken into consideration. This expert team consists of academicians and people who work as top managers in international energy companies. They conducted lots of projects related to green building, strategic management, and energy efficiency (Table 3).

It is concluded that renewable energy usage has the greatest weight (,1327). Additionally, innovative production and design is also another significant factor with the weight of “,1304”. On the other hand, occupational safety and green business processes have lower significance by comparing with the other indicators. The results are also computed for different t values. Comparative weighting results are demonstrated in Table 4.

Table 3
Weights.

Criteria	C*	C-	R*	R-	S*	S-	Weights
WMGMT	,0413	,0372	,2605	,2820	,3018	,3192	,1289
CRBEM	,0462	,0367	,2203	,2318	,2664	,2685	,1259
IPDSG	,0333	,0314	,2182	,2410	,2514	,2724	,1304
EREFF	,0486	,0516	,2284	,2217	,2770	,2733	,1246
OCSTY	,0826	,0801	,2141	,1828	,2966	,2629	,1179
SNSLT	,0902	,0922	,2131	,1984	,3032	,2907	,1228
RWSGE	,0581	,0688	,2272	,2516	,2852	,3204	,1327
GBSRC	,0297	,0196	,2463	,2209	,2760	,2406	,1168
SWTMG	,0765	,0684	,2316	,2438	,3081	,3122	,1263
TNPTO	,0824	,0818	,2346	,2162	,3170	,2980	,1215

Table 4
Comparative Weighting Results.

Criteria	t = 1	t = 2	t = 3
WMGMT	,1289	,1304	,1322
CRBEM	,1259	,1307	,1338
IPDSG	,1304	,1267	,1220
EREFF	,1246	,1297	,1303
OCSTY	,1179	,1171	,1167
SNSLT	,1228	,1199	,1189
RWSGE	,1327	,1309	,1319
GBSRC	,1168	,1146	,1140
SWTMG	,1263	,1223	,1206
TNPTO	,1215	,1263	,1261

Based on the weights given in Table 4, the ranking of the criteria based on their importance is illustrated in Fig. 1.

Fig. 1 demonstrates that the ranking results are quite similar for different t values. With respect to the conditions of “t = 1” and “t = 2”, renewable energy usage is the most critical factor. However, regarding the use of T-Spherical fuzzy TOP-DEMATEL (t = 3), the minimizing carbon emissions becomes the most significant factor whereas renewable energy usage is the third most essential indicator. As can be understood from this situation, as the uncertainty in the content of the renewable energy use criterion increases, the importance of this criterion decreases. In this context, necessary measures should be taken to reduce the uncertainties contained in this criterion.

Discussions

Green building energy efficiency is vital for environmental sustainability, both during the construction and operation of the building. When multi-dimensional studies are examined by focusing on the concept of green building, it is observed that energy-efficient designs and integrated advanced technologies are used by applying renewable energy sources on-site to reduce energy demand and consumption (GhaffarianHoseini et al., 2013). According to Kyriakarakos and Dounis (2020) the appropriate implementation of renewable energy sources in buildings is a fundamental criterion for the energy efficiency of green buildings, as specifically solar energy systems have always played a significant role in development of green buildings. Moreover, in a study that assumes a combined optimized design model between an emergency generator (EG) and a photovoltaic (PV) in a large hospital, Mizuno et al. (2019) remarked that while it is difficult for EG to respond to power outages lasting more than three days due to a natural disaster or network problem, PV enables for more extended hospital service in the use of renewable energy (Barhoush et al., 2022, Giebel et al., 2020).

In this regard, in a study conducted across India, Tarkar (2022) emphasized the positive role of green hospitals in environmental protection and energy saving. Likewise, analyzing the energy requirement of a green hospital in Neom (S. Arabia), Alotaibi et al. (2019) used a simulation method, comparing renewable energy and conventional energy. The research finding is that the most optimal hybrid solution (biogas, diesel, and photovoltaic solar cells) can reduce carbon emissions and diesel usage by around 80 %. Furthermore, in a study investigating end-user concerns for green hospital designs, Wood et al. (2016) and Kalkavan (2021) surveyed public and private hospital customers in Malaysia. Accordingly, they also found that the materials used in the green hospital should be environmentally friendly and non-toxic.

Policy implications

To achieve green building transformations, it has been determined that investments should be made primarily in renewable energy projects. In this framework, it would be appropriate for businesses to meet

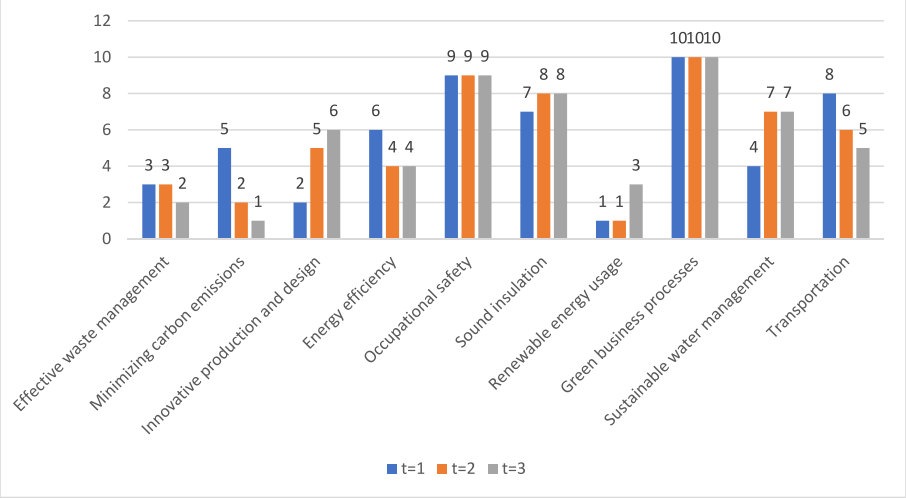

Fig. 1. Comparative ranking results of the indicators.

their electricity needs with clean energy, especially with small-scale solar panels and wind turbines. To increase these investments, it is necessary to provide a cost advantage. In the long term, technological investments should be focused on solving this problem. Thanks to these investments, it will be possible to reduce the costs of the projects. On the other hand, it is very important to provide financial support from the states to solve this problem in the short term.

Conclusions

The main contribution of this study is that a priority evaluation is conducted so that more critical indicators of green building transformations can be identified. Because of this issue, for financial sustainability, companies should firstly focus on more significant factors. Another important novelty of this study is that a new decision-making technique by the name of TOP-DEMATEL is generated. With the help of this issue, both problems in DEMATEL can be solved and methodological originality can be achieved. However, the main limitation of this study is that an evaluation is made for only healthcare industry. The results can be changed for different sectors, such as banking or textile. Thus, for future studies, these industries can be taken into consideration in the analysis process. Furthermore, in the following studies, some improvements can also be made to the proposed methodology.

The relevance of this study consists in hesitancy problems of the experts while making evaluations so that it can be possible to increase the accuracy of the findings. The scientific and practical application of the contribution is in new decision-making technique by the name of TOP-DEMATEL is generated. With the help of this issue, both problems in DEMATEL can be solved and methodological originality can be achieved. The facial expressions of the experts can be considered in the analysis process.

CRediT authorship contribution statement

Serkan Eti: Conceptualization. **Hasan Dinçer:** Methodology, Writing – original draft. **Serhat Yüksel:** Data curation. **Yeter Demir Uslu:** Formal analysis. **Yaşar Gökalp:** Validation. **Hakan Kalkavan:** Visualization, Investigation, Methodology. **Alexey Mikhaylov:** Writing – original draft. **Gabor Pinter:** Resources, Software, Supervision.

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.

References

Abanyie, S. K., Amuah, E. E. Y., Douti, N. B., Amadu, C. C., & Bayorbor, M. (2021). Healthcare waste management in the Tamale Central Hospital, northern Ghana. An assessment before the emergence of the COVID-19 pandemic in Ghana. Environmental. *Challenges, 5*, Article 100320.

Abd Rahman, N. M., Lim, C. H., & Fazlizan, A. (2021). Optimizing the energy saving potential of public hospital through a systematic approach for green building certification in Malaysia. *Journal of Building Engineering, 43*, Article 103088.

Adamopoulos, I., Lamnisos, D., Syrou, N., & Boustras, G. (2022). Public health and work safety pilot study: Inspection of job risks, burn out syndrome and job satisfaction of public health inspectors in Greece. *Safety Science, 147*, Article 105592.

Aibar-Guzmán, B., Aibar-Guzmán, C., Piñeiro-Chousa, J. R., Hussain, N., & García-Sánchez, I. M. (2023). The benefits of climate tech: Do institutional investors affect these impacts? *Technological Forecasting and Social Change, 192*, Article 122536.

Akcay, E. C. (2023). Barriers to Undertaking Green Building Projects in Developing Countries: A Turkish Perspective. *Buildings, 13*(4), 841.

Alharthi, M., Hanif, I., & Alamoudi, H. (2022). Impact of environmental pollution on human health and financial status of households in MENA countries: Future of using renewable energy to eliminate the environmental pollution. *Renewable Energy, 190*, 338–346.

Alotaibi, D. M., Akrami, M., Dibaj, M., & Javadi, A. A. (2019). Smart energy solution for an optimised sustainable hospital in the green city of NEOM. *Sustainable Energy Technologies and Assessments, 35*, 32–40. https://doi.org/10.1016/j.seta.2019.05.017

Azis, S. S. A. (2023). Implementation of Vegetated Green Urban Infrastructure: Is It Cost-Effective?. In *A Sustainable Green Future* (pp. 311–328). Cham: Springer.

Bamakan, S. M. H., Malekinejad, P., & Ziaeian, M. (2022). Towards blockchain-based hospital waste management systems; applications and future trends. *Journal of Cleaner Production, 131440*.

Barhoush, M., Hallawa, A., Peine, A., Martin, L., & Schmeink, A. (2022). Localization-Driven Speech Enhancement in Noisy Multi-Speaker Hospital Environments Using Deep Learning and Meta Learning. *IEEE/ACM Transactions on Audio, Speech, and Language Processing, 31*, 670–683.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., … Stepanova, D. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Bygstad, B., & Øvrelid, E. (2020). Architectural alignment of process innovation and digital infrastructure in a high-tech hospital. *European Journal of Information Systems, 29*(3), 220–237.

Candila, V., Maximov, D., Mikhaylov, A., Moiseev, N., Senjyu, T., & Tryndina, N. (2021). On the Relationship between Oil and Exchange Rates of Oil-Exporting and Oil-Importing Countries: From the Great Recession Period to the COVID-19 Era. *Energies, 14*, 8046. https://doi.org/10.3390/en14238046

Chen, Y., Li, Z., Xu, J., Liu, Y., & Meng, Q. (2023). How Does the Government Policy Combination Prevents Greenwashing in Green Building Projects? An Evolutionary Game Perspective. *Buildings, 13*(4), 917.

Cheng, C. L., Peng, J. J., Ho, M. C., Liao, W. J., & Chern, S. J. (2016). Evaluation of water efficiency in green building in Taiwan. *Water, 8*(6), 236.

Debrah, C., Chan, A. P. C., & Darko, A. (2022). Green finance gap in green buildings: A scoping review and future research needs. *Building and Environment, 207*, Article 108443.

Dewi, A. I., & Wardani, E. (2022). Occupational health and safety management system and work-related accidents among hospital nurses. *Enfermería Clínica, 32*, S6–S10.

Dulce-Chamorro, E., & Martinez-de-Pison, F. J. (2021). An advanced methodology to enhance energy efficiency in a hospital cooling-water system. *Journal of Building Engineering, 43*, Article 102839.

Eti, S., Dinçer, H., Gökalp, Y., Yüksel, S., & Kararoğlu, D. (2023). Identifying Key Issues to Handle the Inflation Problem in the Healthcare Industry Caused by Energy Prices: An Evaluation With Decision-Making Models. *Managing Inflation and Supply Chain Disruptions in the Global Economy*, 162–178.

Eti, S., Dinçer, H., Yüksel, S., & Gökalp, Y. (2023). Analysis of the suitability of the solar panels for hospitals: A new fuzzy decision-making model proposal with the T-Spherical TOP-DEMATEL method. Preprint *Journal of Intelligent & Fuzzy Systems*, 1–13.

Forsman, B., & Svensson, A. (2019). Frail older persons' experiences of information and participation in hospital care. *International journal of environmental research and public health, 16*(16), 2829.

Gan, X., Yan, K., Xie, K., & Tan, Y. (2023). The policy trajectory of green building development in China: A sequential and network analysis. *Sustainable Development.*

GhaffarianHoseini, A., Dahlan, N. D., Berardi, U., GhaffarianHoseini, A., Makaremi, N., & GhaffarianHoseini, M. (2013). Sustainable energy performances of green buildings: A review of current theories, implementations and challenges. *Renewable and Sustainable Energy Reviews, 25*, 1–17. https://doi.org/10.1016/j.rser.2013.01.010

Ghalandari, M., Mukhtar, A., Yasir, A. S. H. M., Alkhabbaz, A., Alviz-Meza, A., Cárdenas-Escrocia, Y., & Le, B. N. (2023). Thermal conductivity improvement in a green building with Nano insulations using machine learning methods. *Energy Reports, 9*, 4781–4788.

Giebel, C., Harvey, D., Akpan, A., & Chamberlain, P. (2020). Reducing hospital admissions in older care home residents: A 4-year evaluation of the care home innovation Programme (CHIP). *BMC Health Services Research, 20*(1), 1–7.

Griffin, S. C., Scanlon, M. M., & Reynolds, K. A. (2023). Managing Building Water Disruptions in a Post-COVID World: Water Quality and Safety Risk Assessment Tool for Academic Institutions and School Settings. *Buildings, 13*(4), 921.

Huang, H., Long, R., Chen, H., Sun, K., Sun, Q., & Li, Q. (2023). Why don't more people engage in green practices in China? A policy-oriented approach to promoting green transformation in five consumption areas. *Environmental Impact Assessment Review, 101*, Article 107099.

Jacobson, M. Z., von Krauland, A. K., Song, K., & Krull, A. N. (2023). Impacts of green hydrogen for steel, ammonia, and long-distance transport on the cost of meeting electricity, heat, cold, and hydrogen demand in 145 countries running on 100% wind-water-solar. Smart. *Energy, 100106*.

Jahangir, M. H., Eslamnezhad, S., Mousavi, S. A., & Askari, M. (2021). Multi-year sensitivity evaluation to supply prime and deferrable loads for hospital application using hybrid renewable energy systems. *Journal of Building Engineering, 40*, Article 102733.

Kalkavan, H. (2021). Discussing Business Innovation and Moral Basis of Redistribution Regarding Economic Equality. In H. Dinçer, & S. Yüksel (Eds.), *Financial Strategies in Competitive Markets: Multidimensional Approaches to Financial Policies for Local Companies* (pp. 341–354). Springer International Publishing. https://doi.org/10.1007/978-3-030-68612-3_24.

Khahro, S. H., Kumar, D., Siddiqui, F. H., Ali, T. H., Raza, M. S., & Khoso, A. R. (2021). Optimizing energy use, cost and carbon emission through building information modelling and a sustainability approach: A case-study of a hospital building. *Sustainability, 13*(7), 3675.

Kyriakarakos, G., & Dounis, A. (2020). Intelligent Management of Distributed Energy Resources for Increased Resilience and Environmental Sustainability of Hospitals. *Sustainability, 12*(18). https://doi.org/10.3390/su12187379

Lu, K., Jiang, X., Tam, V. W., Li, M., Wang, H., Xia, B., & Chen, Q. (2019). Development of a carbon emissions analysis framework using building information modeling and life cycle assessment for the construction of hospital projects. *Sustainability, 11*(22), 6274.

Lund, A., Marszal, A., & Heiselberg, P. (2011). Zero energy buildings and mismatch compensation factors. *Energy and Buildings, 43*(7), 1646–1654. https://doi.org/10.1016/j.enbuild.2011.03.006

Lund, H., Østergaard, P. A., Connolly, D., & Mathiesen, B. V. (2017). Smart energy and smart energy systems. *Energy, 137*, 556–565.

Lund, H., Østergaard, P. A., Connolly, D., Ridjan, I., Mathiesen, B. V., Hvelplund, F., … Sorknæs, P. (2016). Energy storage and smart energy systems. *International Journal of Sustainable Energy Planning and Management, 11*, 3–14.

Lund, H., Thellufsen, J. Z., Sorknæs, P., Mathiesen, B. V., Chang, M., Madsen, P. T., Kany, M. S., & Skov, I. R. (2022). Smart energy Denmark. A consistent and detailed strategy for a fully decarbonized society. *Renewable and Sustainable Energy Reviews, 168*, Article 112777. https://doi.org/10.1016/j.rser.2022.112777

Magyari, J., Zavarkó, M., & Csedő, Z. (2022). Smart knowledge management driving green transformation: A comparative case study. *Smart Energy, 7*, Article 100085.

Metaxas, T., Gallego, J. S., & Juarez, L. (2023). Sustainable urban development and the role of mega-projects: Experts' view about Madrid Nuevo Norte Project. *Journal of Infrastructure, Policy and Development, 7*(2), 2161. https://doi.org/10.24294/jipd.v7i2.2161

Mikhaylov, A. (2023). Understanding the Risks Associated with Wallets, Depository Services, Trading, Lending, and Borrowing in the Crypto Space. *Journal of Infrastructure, Policy and Development, 7*, 2.

Montiel-Santiago, F. J., Hermoso-Orzáez, M. J., & Terrados-Cepeda, J. (2020). Sustainability and energy efficiency: BIM 6D. Study of the BIM methodology applied to hospital buildings. Value of interior lighting and daylight in energy simulation. *Sustainability, 12*(14), 5731.

Moslehian, A. S., Tucker, R., Kocaturk, T., & Andrews, F. (2022). Analysis of factors historically affecting innovation in hospital building design. *HERD: Health Environments Research & Design Journal, 15*(4), 249–269.

Nourdine, B., & Saad, A. (2020, March). Energy consumption in hospitals. In 2020 International Conference on Electrical and Information Technologies (ICEIT) (pp. 1-6). IEEE.

Özdemirci, F., Yüksel, S., Dinçer, H., & Eti, S. (2023). An assessment of alternative social banking systems using T-Spherical fuzzy TOP-DEMATEL approach. *Decision Analytics Journal, 100184*.

Pata, U. K. (2021). Do renewable energy and health expenditures improve load capacity factor in the USA and Japan? A new approach to environmental issues. *The European Journal of Health Economics, 22*(9), 1427–1439.

Perkumienė, D., Pranskūnienė, R., Vienažindienė, M., & Grigienė, J. (2020). The right to a clean environment: Considering green logistics and sustainable tourism. *International Journal of Environmental Research and Public Health, 17*(9), 3254.

Psillaki, M., Apostolopoulos, N., Makris, I., Liargovas, P., Apostolopoulos, S., Dimitrakopoulos, P., & Sklias, G. (2023). Hospitals' Energy Efficiency in the Perspective of Saving Resources and Providing Quality Services through Technological Options: A Systematic Literature Review. *Energies, 16*(2), 755.

Rajarajeswari, C., & Anbalagan, C. (2023). Integration of the green and lean principles for more sustainable development: A case study. *Materials Today: Proceedings*.

Rizan, C., Bhutta, M. F., Reed, M., & Lillywhite, R. (2021). The carbon footprint of waste streams in a UK hospital. *Journal of Cleaner Production, 286*, Article 125446.

Safin, R., Lavrenov, R., Tsoy, T., Magid, E., Svinin, M., Roy, S. D., & Saha, S. K. (2021). Prioritizing Tasks Within a Robotic Transportation System for a Smart Hospital Environment. In Interactive Collaborative Robotics: 6th International Conference, ICR 2021, St. Petersburg, Russia, September 27–30, 2021, Proceedings 6 (pp. 182-193). Springer International Publishing.

Saidi, O., Masmoudi, M., Kobbold, K., Lizarazo, E., & Albert, P. (2022, February). Optimizing warehousing and transportation for a network of healthcare institutions: case of Territorial Hospital Group in France. In Supply Chain Forum: An International Journal (pp. 1-15). Taylor & Francis.

Saqib, A., Chan, T.-H., Mikhaylov, A., & Lean, H. H. (2021). Are the Responses of Sectoral Energy Imports Asymmetric to Exchange Rate Volatilities in Pakistan? Evidence From Recent Foreign Exchange Regime. *Frontiers in Energy Research, 9*, Article 614463. https://doi.org/10.3389/fenrg.2021.614463

Shaabani, Y., Vafaee Najar, A., Shafiee, M. N., Meraji, M., & Hooshmand, E. (2020). Designing a green hospital model: Iranian hospital. *International Journal of Healthcare Management, 13*(sup1), 427–433.

Shah, M. (2019). Green human resource management: Development of a valid measurement scale. *Business Strategy and the Environment, 28*(5), 771–785.

Srbová, P., Režňáková, M., & Tomášková, A. (2023). Socially responsible activities and the economic performance of family businesses. Journal of Infrastructure, Policy and Development, 1958. doi: 10.24294/jipd.v7i1.1958.

Strade, E., Kalnina, D., & Kulczycka, J. (2020). Water efficiency and safe re-use of different grades of water-Topical issues for the pharmaceutical industry. *Water resources and industry, 24*, Article 100132.

Sun, L., Peng, J., Dinçer, H., & Yüksel, S. (2022). Coalition-oriented strategic selection of renewable energy system alternatives using q-ROF DEMATEL with golden cut. *Energy, 256*, Article 124606.

Tang, H., Ding, J., & Lin, Z. (2020). On-site measurement of indoor environment quality in a Chinese healthcare facility with a semi-closed hospital street. *Building and Environment, 173*, Article 106637.

Tarkar, P. (2022). Role of green hospitals in sustainable construction: Benefits, rating systems and constraints. *Sustainable Materials and Practices for Built Environment, 60*, 247–252. https://doi.org/10.1016/j.matpr.2021.12.511

Towne, S. D., Jr, Liu, X., Li, R., Smith, M. L., Maddock, J. E., Tan, A., … Yuan, Z. (2021). Social and structural determinants of health inequities: Socioeconomic, transportation-related, and provincial-level indicators of cost-related forgone hospital care in China. *International journal of environmental research and public health, 18*(11), 6113.

Ullah, Z., Sulaiman, M. A. B. A., Ali, S. B., Ahmad, N., Scholz, M., & Han, H. (2021). The effect of work safety on organizational social sustainability improvement in the healthcare sector: The case of a public sector hospital in Pakistan. *International journal of environmental research and public health, 18*(12), 6672.

Wang, R., Wen, X., Wang, X., Fu, Y., & Zhang, Y. (2022). Low carbon optimal operation of integrated energy system based on carbon capture technology, LCA carbon emissions and ladder-type carbon trading. *Applied Energy, 311*, Article 118664.

Wilberforce, T., Olabi, A. G., Sayed, E. T., Elsaid, K., & Abdelkareem, M. A. (2021). Progress in carbon capture technologies. *Science of The Total Environment, 761*, Article 143203.

Wood, L. C., Wang, C., Abdul-Rahman, H., & Jamal Abdul-Nasir, N. S. (2016). Green hospital design: Integrating quality function deployment and end-user demands. *Journal of Cleaner Production, 112*, 903–913. https://doi.org/10.1016/j.jclepro.2015.08.101

Wu, X., Cao, Y., Liu, W., He, Y., Xu, G., Chen, Z. S., … Skibniewski, M. J. (2023). BIM-driven building greenness evaluation system: An integrated perspective drawn from model data and collective experts' judgments. *Journal of Cleaner Production, 136883*.

Mizuno, Y., Tanaka, Y., Kurokawa, F., & Matsui, N. (2019). Optimum Facility Design in Large Hospital using Renewable Energy. In *2019 8th International Conference on Renewable Energy Research and Applications (ICRERA)* (pp. 712–716). https://doi.org/10.1109/ICRERA47325.2019.8997023

Yoon, C. W., Kim, M. J., Park, Y. S., Jeon, T. W., & Lee, M. Y. (2022). A review of medical waste management systems in the Republic of Korea for hospital and medical waste generated from the COVID-19 pandemic. *Sustainability, 14*(6), 3678.

Zhang, X., & Dong, F. (2020). Why do consumers make green purchase decisions? Insights from a systematic review. *International journal of environmental research and public health, 17*(18), 6607.