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RESEARCH ARTICLE

COVID-19 safe campus evaluation for universities by a hybrid interval type-2 fuzzy decision-making model

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Abstract

The fight against the COVID-19 pandemic, which has affected the whole world in recent years and has had devastating effects on all segments of society, has been one of the most important priorities. The Turkish Standards Institution has determined a checklist to contribute to developing safe and clean environments in higher education institutions in Turkey and to follow-up on infection control measures. However, this study is only a checklist that makes it necessary for decision-makers to make a subjective evaluation during the evaluation process, while the need to develop a more effective, systematic framework that takes into account the importance levels of multiple criteria has emerged. Therefore, this study applies the best-worst method under interval type-2 fuzzy set concept (IT2F-BWM) to determine the importance levels of criteria affecting the "COVID-19 safe campus" evaluation of universities in the context of global pandemic. A three-level hierarchy consisting of three main criteria, 11 sub-criteria, and 58 sub-criteria has been created for this aim. Considering the hierarchy, the most important sub-criterion was determined as periodic disinfection. The high contribution of the interval-valued type-2 fuzzy sets in expressing the uncertainty in the decision-makers' evaluations and the fact that BWM provides criterion weights with a mathematical optimization model that produces less pairwise comparisons and higher consistency are the main factors in choosing this approach. Simple additive weighting (SAW) has also been injected into the IT2F-BWM to determine the safety level of any university campus regarding COVID-19. Thus, decision-makers will be better prepared for the devastating effects of the pandemic by first improving the factors that are relatively important in the fight against the pandemic. In addition, a threshold value will be determined by considering all criteria, and it will prepare the ground for a road map for campuses. A case study is employed to apply the proposed model, and a comparison study is also presented with the Bayesian BWM to validate the results of the criteria weights.

Keywords COVID-19 · Safe campus · Best-worst method · Interval type-2 fuzzy set

Introduction

The COVID-19 pandemic, which started in China's Wuhan province in 2020 and spread to the whole world and is named as "world-shattering epidemic," has created deep cracks in Turkey in many respects and continues to do so. It was officially declared as a "pandemic," that is, a "global outbreak," on March 11, 2020, in Turkey (Bostan et al. 2020). All countries worldwide have developed various arguments against this epidemic (Ciotti et al. 2020). Social practices such as "closing all schools," "flexible working," and "staying at home" have begun to reduce contact and mobility. These practices started in big cities such as Istanbul and Ankara, where the number of people affected by the epidemic was high; afterward, "use of masks" became one of the standard measures in the whole country (Demirbilek et al. 2020). In

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addition, awareness-raising activities for personal measures such as "personal hygiene" and "maintaining physical distance" were encouraged (Güner et al. 2020).

During the COVID-19 global epidemic period, a number of new applications have been put into effect for universities, which are the biggest pillars of higher education. Some of these applications include suspension of education, distance education, and partial face-to-face education, depending on the regional spread of the virus (Mahmut 2020). In 2021, due to the relative relief provided by the improvement of the vaccination rate, face-to-face education was resumed in universities. Many higher education institutions are environments where more than one unit and the students, academic, and administrative staff of these units come together in the campus environment and where individuals from the society interact. In addition to educational activities, academic research, various services, and administrative activities are also carried out on the campuses. Therefore, in controlling the COVID-19 epidemic by higher education institutions, the risks should be determined in terms of education and their fields of activity, and measures should be taken accordingly (Greenhalgh et al. 2021). In this context, a checklist has been published by the Turkish Standards Institute in order to contribute to the development of the necessary infrastructure for the development of safe and clean environments in universities, to ensure hygienic conditions, to implement and follow infection control measures, and to determine general standards, within the scope of combating the global COVID-19 epidemic and infectious diseases. It started the application of the "Safety Campus" document. Universities that have completed the specified criteria have been qualified for this document, and a step has been taken toward ensuring that students and staff continue their activities more safely.

However, in order to transform this checklist into a more systematic and useful structure, a hierarchy of criteria to be used in the assessment of the "COVID-19 safe campus" has been created in this study, and the importance levels of the main criteria, sub-criteria, and sub-sub-criteria within this three-level hierarchy have been determined. The purpose of doing this is to develop a more apparent decision-making mechanism for the universities. In this context, an improved version of the best-worst method (BWM) from multi-criteria decision-making (MCDM) methods is used. The main reason for choosing this method is that it can obtain more reliable and consistent results, is easy to apply, and requires less comparison data (Rezaei 2015). In addition, the weights obtained with BWM can be used independently and with other MCDM methods (Rezaei 2016). Traditional BWM uses only crisp values when comparing (Rezaei 2015). It is inevitable that developing BWM in a fuzzy environment will be beneficial both theoretically and instrumentally (Wu et al. 2019). When fuzzy sets are evaluated, type 2 fuzzy sets (T2FSs) can express uncertainty better than type 1 fuzzy sets (T1FSs) (Mendel and Wu 2007). The SAW method, one of the easiest multiple-attribute decision-making (MADM) methods, allows combining attribute values. For these reasons, type-2 fuzzy BWM was chosen for criterion weighting, and SAW method was chosen for calculating the safe campus score of universities.

The answers to the following two research questions (RQs) are sought as a result of the optimization models solved by the integrated interval type-2 fuzzy BWM.

RQ1: What are the criteria used in the COVID-19 safe campus assessment, the most important criteria, and what are the global weights of these?
RQ2: How to evaluate a university in terms of a COVID-19 safe campus, how is it decided whether it has a safe campus based on the weighted criteria and how to make a comparative analysis on the validity of the numerical results produced by the proposed methodology?

In order to find the answers to these RQs, the present study has the following research objectives.

RO1: To frame the criteria for COVID-19 safe campus assessment in a three-level hierarchical framework, obtain the weights of the main criteria with type-2 fuzzy BWM, and calculate the global weight values of the sub-sub-criteria by multiplying the local weights of the main criteria and the local weights of the sub-criteria obtained with type-2 fuzzy BWM.
RO2: To obtain the safe campus score of any university with SAW and perform a comparative study with Bayesian BWM to test the solidity of the criteria weight results produced by the proposed IT2F-BWM model.

In this context, the research organization is divided into the following sections: "Literature review," "Materials and methods," "Application results of the methodology," "Discussion," and "Conclusion."

Literature review

While looking at the studies on the safe campus evaluation of universities, it is useful to consider the issue from two perspectives. The first is the review of the literature on how ready the university campuses, which is the subject's focal point, are in the context of COVID-19 and determining which criteria will be taken as a basis when evaluating in this context. The second is an in-depth analysis of previous studies of the interval type-2 fuzzy best-worst method (IT2F-BWM), which constitutes the study's methodology.

Thus, the gap analysis of the study will be made, and the main contributions will be revealed.

Issues in safe campus evaluation of universities

One of the areas affected by the COVID-19 epidemic was universities, and the increase in the number of cases brought the closure of campuses. It was decided to reopen with the pharmacological and non-pharmacological measures taken. When pharmacological studies were examined, studies evaluating the use of vaccines were conducted (Coccia 2022c). Coccia (2022a) proposed an index that minimizes mortality and measures countries' ability to assess vaccine use, effective policy responses, and/or prevent new pandemic threats. The COVID-19 virus can spread tens of thousands of SARS-CoV-2 virions per minute via droplets and aerosols when people talk, sing, or even breathe (Chen et al. 2021). When non-pharmacological COVID-19 methods are examined, many studies evaluate the use of masks (Wang et al. 2020b). In his study, which evaluated the impact of non-pharmaceutical interventions on the incidence of COVID-19, Askitas et al. (2021) identified the most effective interventions as those aimed at reducing contacts in large groups, canceling public events, or reducing contacts in places where there may be high frequency, such as school and workplace closures. In addition, another study evaluating non-drug interventions recommended case-based measures, promotion of social distancing, and national quarantine. (Flaxman et al. 2020). Other interventions aim to prevent chains of epidemics associated with monitoring cases of infection, isolating infected individuals, and treating patients in a timely manner (Coccia 2022a).

Universities faced many challenges with the decision to offer face-to-face education during the COVID-19 pandemic. When the studies on the creation of a safe campus in the literature are examined, it is seen that studies have focused on effective measures to make face-to-face education safer during the COVID-19 pandemic (Cardonha et al. 2022; Greenhalgh et al. 2021; Muller and Muller 2021; Gillespie et al. 2021). Wilson et al. (2020), while studying the reliability of the measures taken at university A in North Carolina and the reasons for the increase in cases, Rafiq et al. (2021), on the other hand, conducted a study to determine the service models, strategies, and role of university libraries during the COVID-19 epidemic. In addition to the existing measures to reduce the effects of COVID-19 in universities and workplaces, a study was conducted to conduct screening tests (Poole et al. 2021; Paltiel et al. 2020).

Steimle et al. 2022 determined in their study that most students would like to continue face-to-face education if adequate safety precautions were taken. Almekhlafy (2020), in his study at Saudi Universities during COVID-19, revealed that students' perceptions of online learning were not positive. In another study conducted at the same university, besides the positive aspects of online education, slow internet connection, lack of computers of students, unreliable internet, etc. It has been stated that there are also negative aspects (Aljuaid 2021). According to Fatonia et al. (2020), advantages, disadvantages, and solutions of online learning for university students were investigated. Hekmati et al. (2021) examined the risk of contagion with the classroom arrangement in the environment where face-to-face lectures are held on university campuses. On the other hand, Fischetti et al. (2021) examined the effect of table, armchair, etc., placement on the risk of infection. Silva et al. (2021), Life Cycle Assessment (LCA) of face-to-face and distance learning classes was carried out in a higher education institution in the context of COVID-19. Betancourt and others (2021) provided early warning detection in COVID-19 by clinical tests for positive detection of virus RNA in the wastewater of students in 13 dormitories at the University of Arizona. Scott et al. (2021) conducted a COVID-19 detection study with university wastewater surveillance.

Cohen et al. (2021) tried to determine how university students manage their behaviors and risks in the context of COVID-19. In another study (Martínez-Lorca et al. 2020), their fear level was determined. Ihm et al. (2021) evaluated the effects of COVID-19 on students' physical and mental health.

Malomet and Harber (2021), with the concern of COVID-19, presented a new health services website approach within the scope of occupational health and safety of employees in higher education institutions. As a result of the survey conducted with 65 universities from 9 countries, it has been determined that 47% of the participating universities do not have a defined emergency management plan, and 33% of the universities that have plans are not for biological hazards and pandemics (Izumi et al. 2020). Again, Carnegie et al. (2021) conducted to document and content analysis of annual reports in some universities to determine the disclosure of COVID-19 risk effects.

Ambatipudi et al. (2021) developed a model that measures the risk of airborne COVID-19 spread in a university setting, Sousan et al. (2021), on the other hand, successfully detected COVID with air samples taken to detect SARS-CoV-2 on campuses and dormitories. Shen et al. (2021) presented a comprehensive literature analysis on the airborne transmission of COVID-19 infection in confined spaces. This study emphasized the importance of social distance, wearing masks, and ventilation systems to prevent the spread of COVID-19 on university campuses.

Byrne et al. (2020) presented a series of measures by the COVID-19 Health Services Coalition to enable face-to-face education on campus. In another similar study, Lordan et al. (2021) examined the approaches and practices that should be considered for the continuity of face-to-face education.

On the other hand, Brooks et al. (2022) evaluated the pandemic's impact on teachers' health status in another study.

Simulation studies have been carried out following the spread of the disease, isolation, and monitoring processes with different methods during the COVID-19 epidemic (Li and Yin 2021; McGee et al. 2021; Gressman and Peck 2020; Sherby et al. 2022; Junge et al. 2021; D'Orazio et al. 2021). Memari et al. (2021) studied easier coordination and case management thanks to a nerve center established within the university. Lu et al. (2021) created a COVID-19 prediction platform at the university. Kobayashi et al. (2020) proposed a social distance monitoring system model based on microcomputer modules to prevent the spread of the COVID-19 pandemic on university campuses.

Apart from these abovementioned researches, various studies such as the readiness against COVID-19, analysis of strategic prevention factors against COVID-19, comparative analysis of different periods in the COVID-19 pandemic, analysis of the impacts of partial/full lockdowns, and vaccination have been performed (Coccia 2021a, b, c, 2022a, b, c).

Studies on interval type-2 fuzzy BWM in the literature

BWM was first proposed by Rezaei (2015). The most crucial difference distinguishing this method from other methods is that it allows a more consistent evaluation using fewer comparisons (Rezaei 2016). BWM has been applied in many different areas and combined with other methods (Mi et al. 2019). One of the classic BWM limitations is the use of integers when evaluating. In order to prevent this situation, Guo and Zhao (2017) proposed fuzzy BWM, allowing evaluation by using triangular fuzzy numbers. There are many studies that develop the BWM under type-2 fuzzy environment. These studies are summarized in Table 1. Many articles in the literature offer novelty with IT2F-BWM in terms of practice and methodological aspects. IT2F-BWM was initially proposed by Wu et al. (2019) and applied to the green supplement selection problem. In supplier selection problems, Celik et al. (2019) found the most suitable supplier IT2F-BWM and TODIM. Hoseini et al. (2021) used BWM in combination with TOPSIS. IT2F-BWM has been widely used in solving risk assessment problems. Komatina et al. (2021) proposed two new parameters to PFMEA, and their weights were calculated with type-2 fuzzy BWM. Gölcük (2020) IT2F-BWM with perceptual reasoning by Tang et al. (2021) TODIM and Celik and Gul (2021) integrated with MARCOS and Gölcük (2021) with WASPAS. In addition to risk assessment, type-2 BWM was used in particular areas. Pishdar et al. (2019) integrated the IT2F-BWM and MACBECT methods to find a solution to the hub airport determination problem in the aviation industry. Qin and Liu (2019) used IT2F-BWM together with MULTICOMARA for the movie industry. Chen et al. (2022) implemented the DEA−IT2F-BWM integration to solve the health industry problem. Gong et al. (2021) implemented the IT2F-BWM−MARCOS integration in the renewable energy field. Wan et al. (2021) suggested the integration of IT2F-BWM with VIKOR to be compatible with multi-criteria group decisions. The studies that contribute to BWM methodologically are as follows. Liu et al. (2019) proposed the type-2 BWM sort method, motivated by the AHP sort method. The effectiveness of the proposed model is demonstrated through an example. Norouzia and Hajiagha (2021) developed BWM around hesitant and interval type-2 fuzzy sets and demonstrated the effectiveness of its application with a numerical example.

Contributions of the current study

As a result of the detailed literature review in the above two sections regarding the problems related to the safe campus evaluation of universities and the studies using IT2F-BWM, the contributions of the current study are revealed as follows.

First, a comprehensive hierarchy of criteria has been developed for the first time in the literature on whether a university is safe in the context of COVID-19. For the university campus to be evaluated with this hierarchy, 3-11-58 criteria/sub-criteria/sub-sub-criteria have been determined under this structure. In creating this structure, mostly the literature and expert opinions were used for some criteria.

Secondly, the weights of the criteria in this hierarchy were determined by using the extended version of BWM with interval type-2 fuzzy numbers. This section is the focus of the article.

Third, SAW was used to determine a safety score for any university. Here, the weight values obtained from IT2F-BWM were used in the analysis with SAW.

Finally, a comparison analysis was performed with Bayesian BWM, another extension of BWM, to test the robustness of the determined weight values.

Materials and methods

It would be helpful to present this section in three sub-sections. These are (1) "Sample and data," (2) "Variable measures," and (3) "Simulation model, software, and analysis procedure." A two-stage decision-making approach is proposed for the last sub-section, the "Simulation model, software, and analysis procedure." Although we state that the methodology followed in this research is two-stage, we can say that determining the weights of the criteria hierarchy used in the COVID-19 safe campus evaluation is the first stage, with IT2F-BWM, is the

Table 1 Previous studies regarding IT2F-BWM

Study	Application area/case	Combined methods/approach	Novelty (case-based or method-based?)
Wu et al. (2019)	Green supplier selection	VIKOR	To better reflect the ambiguity, BWM has been extended using IT2FS
Pishdar et al. (2019)	Aviation industry	Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH)	A key performance list was determined, and weighted with IT2F-BWM. Nineteen airports were listed in the scope of the hub with the MACBETH method
Qin and Liu (2019)	Movie industry	MULTICOMORA	The IT2FBWM-MULTICOMORA approach, aimed to verify the effectiveness of personalized movie recommendations
Liu et al. (2019)	Numerical example	NA	Inspired by the AHP sort and BWM methods, the BWM sort method has been proposed in the type-2 fuzzy sets environment to cluster the alternatives, and the effectiveness of the proposed method is shown in an example
Gölcük (2020)	Risk assessment	Perceptual reasoning	IT2FBWM and perceptual reasoning were used to evaluate the risks in digital transformation projects
Wan et al. (2021)	Multi-criteria group decision	VIKOR	Pairwise comparisons were carried out with a type-2 interval fuzzy set. BWM, proposed by Rezaei (2015), was developed in the type-2 environment
Gölcük (2021)	Risk assessment	Fuzzy inference system, Aggregated sum product assessment (WASPAS)	To avoid the limitations of classical FMEA, type-2 fuzzy BWM-WASPAS and fuzzy inference system are used together
Gong et al. (2021)	Renewable energy	Attribute system, MARCOS	The attribute system was designed, the weights of the attributes were determined with the IT2FBWM, and the rankings were determined in light of the MARCOS method
Tang et al. (2021)	Risk assessment	TODIM	Risk parameters for ballast tank maintenance are weighted with type-2 fuzzy BWM. Then the hazards were prioritized with the TODIM method
Celik et al. (2021)	Supplier selection	TODIM	The GSS problem is structured as an MCDM problem. The importance of the parameters affecting the supply selection was determined by type-2 fuzzy BWM. The best supplier was determined under these conditions with type-2 fuzzy TODIM
Komatina et al. (2021)	Risk assessment	NA	Process failure mode and effect analysis (PFMEA) extends with quality and cost criteria. Verbal expressions evaluating risk factors were modeled with the help of type-2 fuzzy numbers. The priorities of failures were determined with IT2FBWM
Hoseini et al. (2021)	Supplier selection	TOPSIS	For the evaluation of potential suppliers in Iranian construction industry, criterion weights were determined with IT2FBWM and supplier evaluation with type-2 fuzzy TOPSIS
Norouzia and Hajiagha (2021)	Numerical example	NA	The method is proposed by combining BWM hesitant and interval type-2 fuzzy sets. A numerical example is given to demonstrate the effectiveness of the proposed method
Celik and Gul (2021)	Risk assessment	MARCOS	Risk weights are weighted with IT2FBWM and hazards are prioritized with MARCOS
Chen et al. (2022)	Hospital selection	Data envelopment analysis (DEA)	This study was carried out in the TrIT2F environment, which will combine BWM and DEA, and select the reasonable sites of makeshift hospitals

main focus of the study. The second stage is determining a safe campus score for universities using a simple additive weighting (SAW) using the weight values obtained in the first step.

Sample and data

In order to provide input to the IT2F-BWM model, eight experts, mostly academics working at the university, who carry out the Safety Campus certification processes in the occupational health and safety department of their universities and who are experienced in their fields, were contacted. The questionnaire form was designed to be evaluated and added to this article as a "Supplementary file" and was forwarded to these experts. The qualifications of the experts who answered the questionnaires promptly are as follows. The first expert has been a manager in one of the leading universities in Turkey for many years, specializes in health management, and has many studies in this field. The second expert is an academician and practitioner in medicine and disaster management. The third and fourth expert is an academician with many studies in the health sector, disaster management, and multi-criteria decision-making. The fifth expert is a professional in the field of business and management and has many studies in this field. The sixth expert holds a doctorate in emergency aid and disaster management. By including different disciplines in the selection of experts, it was possible to deal with the subject from different perspectives. Before filling out the questionnaire, information was presented step-by-step on how to fill in a questionnaire for BWM. Pop-up windows were used in the word program to prevent information not suitable for the questionnaire from entering into the form. Since all of the experts had used multi-criteria decision-making methods before, no further training was needed in methodological terms. The evaluations of 6 experts who provided correct and timely feedback were accepted and the data were taken from the questionnaire forms and entered into the software.

Variable measures

In order to carry out this study, a hierarchy of criteria used in the evaluation was created as a result of a detailed field research and literature review. This, of course, is an innovation that the study adds to the literature. Because the creation of such a comprehensive hierarchy in revealing this issue has not been handled in the literature. This is the only study that deals with the safety assessment of university campuses in the context of COVID-19 using MCDM. Based on the "Safety Campus" document published by the Turkish Standards Institute to determine general standards within the scope of combating the global COVID-19 epidemic and infectious diseases and the literature, three main criteria have been determined in order to evaluate the reliability of campuses within the scope of the COVID-19 pandemic. These are infection control, planning, and occupational health and safety. Figure 1 shows the hierarchy of criteria used in the evaluation.

The COVID-19 agent is a virus of zoonotic origin. It is transmitted from person to person by droplet, contact, and in some cases, aerosol. Therefore, standard droplet and contact isolation precautions should be applied to cases suspected to have COVID-19. The "infection and control" criterion covers preventing or reducing the spread, performing good case management, reducing social-physical contact, and performing purification procedures following the rules (Poole et al. 2021; Shen et al. 2021; Betancourt et al. 2021; Paltiel et al. 2020). On the other hand, the "planning" criterion refers to the strategies that will ensure that the current situation can be evaluated and the actions and applications to be made can be kept under control, and that the desired goals can be achieved by collecting and evaluating the data correctly (Byrne et al. 2020; Lordan et al. 2021). Finally "occupational health and safety" criterion identifies risks in the COVID-19 pandemic, their prevention or reduction to an acceptable level, taking and monitoring protective measures, conducting training activities, and reinforcing them with control mechanisms (Brooks et al. 2022; Betancourt et al. 2021). Under the infection and control dimension, there are four sub-criteria: case management, decontamination, touch reduction, and social distance; under the planning, there are four sub-criteria named training, emergency action, infection-control, and cleaning plans. Under the occupational health and safety criteria, there are three sub-criteria: risk assessment, audit and organization, and waste management. Under these sub-criteria, there are 58 sub-sub-criteria in total. At this point, the literature sources of the criteria in this hierarchy are presented in Table 2.

Simulation model, software, and analysis procedure

An optimization modeling software named Lingo for linear, nonlinear, and integer programming is used in modeling. Each model (considering that there are 15 different evaluations in a survey and six expert evaluations are taken into account, a total of 15*6=90 models were solved) was solved with the mathematical models coded in Lingo, and the weight values, as well as the consistency ratios of each expert, were obtained. The analysis procedure of the study consists of two stages, "IT2F-BWM" and "SAW."

The following stages provide details on the followed analysis procedure.

- Stage 1: Determining importance weights by interval type-2 fuzzy BWM

Before explaining the algorithm of the IT2F-BWM, which is the first method of the hybrid research methodology

followed in this study, the concept of the interval type-2 fuzzy set, which is used to express its uncertain linguistic approximation, is expressed simply below. Uncertainties arise from lack of knowledge as a result of not having full knowledge of natural situations and processes. Statistical uncertainties arise from the characteristics of the methodologies used. There are many sources of uncertainty in the calculation and evaluation processes (Castillo et al. 2007). Zadeh (1975) developed type-2 fuzzy sets as an extended version of classical fuzzy sets (Karnik and Mendel 2001; Mendel 2007). Type-2 fuzzy sets can express ambiguities better than type-1, since their membership functions are fuzzy. Membership functions of type-1 fuzzy sets are two-dimensional, whereas membership functions of type2 fuzzy sets are three-dimensional (Kilic and Kaya 2015). This fuzzy set concept reflects uncertainty more robustly and accurately (Mendel et al. 2006). This fuzzy set extension has been applied to many multi-criteria decision-making (MCDM) problems due to ease of calculation, the necessity of reflecting the uncertain environment in decision-making, and difficulties in obtaining precise data (Celik et al. 2019). Celik et al.'s (2015) study can be seen in a detailed literature review. Some basic definitions and notations about interval type-2 fuzzy sets can be found in Mendel et al. (2006) and Chen and Lee (2010).

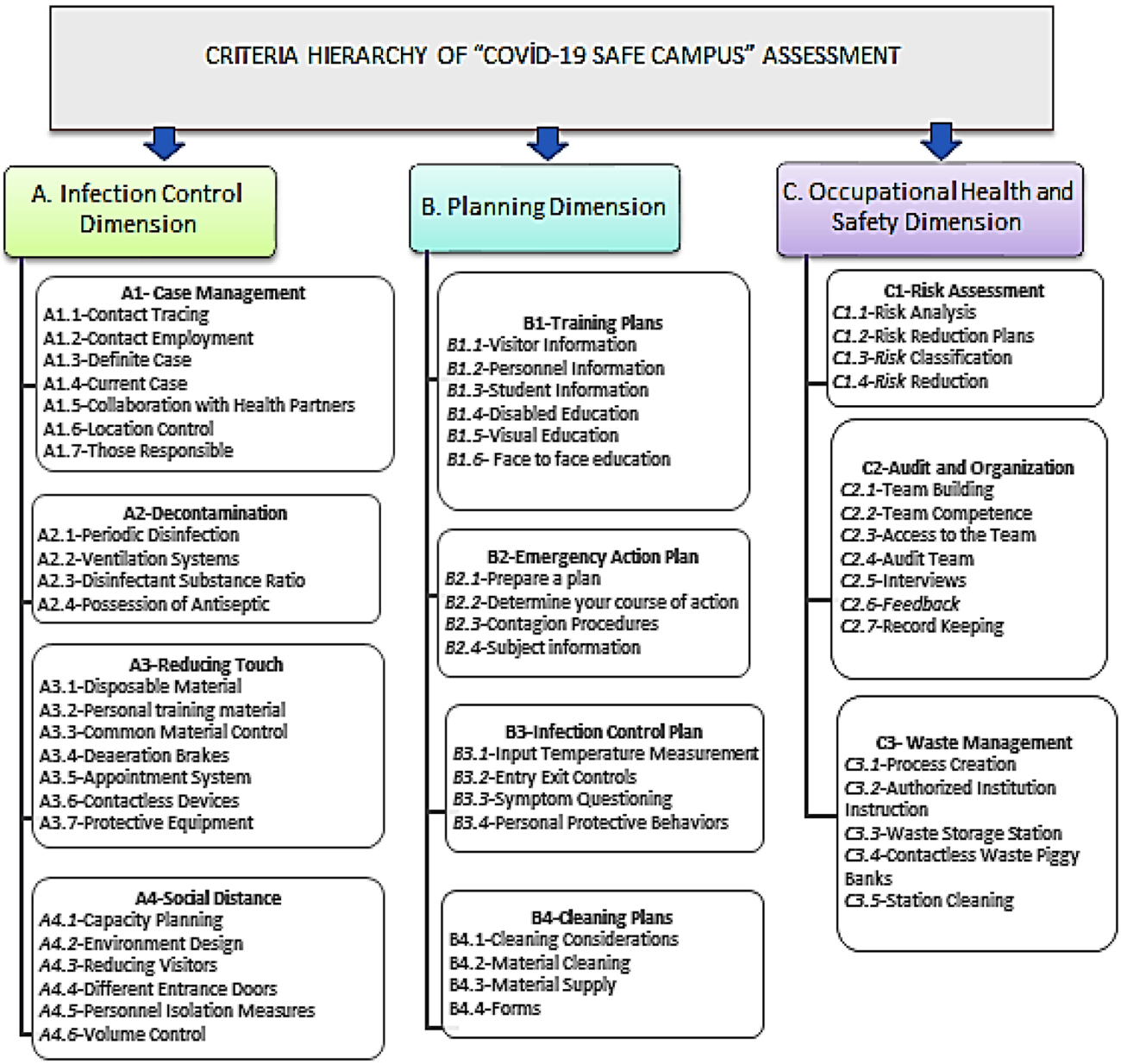


Fig. 1 Criteria hierarchy of "COVID-19 safe campus" assessment

Table 2 Main and sub-criteria descriptions with their sources

Main criteria	Sub-criteria	Explanation	References
Infection and control	Case management	Case management is the prevention of the spread of the disease and the rapid detection and isolation of definitive cases	Poole et al. (2021), Betancourt et al. (2021), Paltiel et al. (2020), Okoye et al. (2021), Greenhalgh et al. (2021), Gressman and Peck (2020), Sherby et al. (2022)
	Decontamination	It includes all the processes (cleaning, disinfection, and sterilization) performed to make an object, surface, or area free of microorganisms and safe	Greenhalgh et al. (2021). Sousan et al. (2021), Dhama et al. (2021)
	Reducing touch	It means limiting the use of common materials, preventing contact as much as possible to reduce the virus's spread, and ensuring the disinfection of common materials at frequent intervals. It also includes measures to reduce the number of people in the environment and to use personal protective equipment	McGee et al. (2021), Esmaeilzadeh (2022), World Health Organization (2020a)
	Social distance	In order to prevent the spread of the disease, it means taking measures such as keeping the number of patients at a level that will not force the health system, making capacity plans, restricting mobility, providing different entrance and exit doors, and not speaking loudly in the environment	Poole et al. (2021), D'Orazio et al. (2021), Kobayashi et al. (2020), Shen et al. (2021), Byrne et al. (2020), McGee et al. (2021), Wilson et al. (2020), Mossa-Basha et al. (2020), Greenhalgh et al. (2021), Fischetti et al. (2021), Bartolucci et al. (2022), Ugail et al. (2021)
Planning	Training plans	It covers the education plans for the personnel of higher education institutions, students, and visitors	Lordan et al. (2021), Wilson et al. (2020), Chisita et al. (2022)
	Emergency action plan	It covers the plans made to be able to organize immediately, intervene regularly, ensure that the institution remains operational, and minimize the damages that may arise in case of a diagnosis and/or suspicion of contagious disease among staff and students	Izumi et al. (2020)
	Infection and control plans	It covers the necessary arrangements and plans to minimize the risk of people encountering the virus	Poole et al. (2021), Shen et al. (2021), Wilson et al. (2020), Esmaeilzadeh (2022), Cohen et al. (2021)
	Cleaning plans	It covers the correct use of cleaning materials and the creation of cleaning and disinfection plans. This plan includes plans for the determination of all kinds of measures to minimize the harmful effects of biocidal and other related products to be used for cleaning and disinfection on humans, nature, and other living things, the usage characteristics of the products, the hazard classes, and the correct usage methods	Chen and O'Keeffe (2020), Curryer et al. (2021), CDC (2020)

Table 2 (continued)

Main criteria	Sub-criteria	Explanation	References
Occupational health and safety	Risk assessment	Risk assessment refers to the work that needs to be done in order to identify the hazards that exist in the workplace, analyze and rank the factors that cause these hazards to turn into risks, and decide on control measures	Lordan et al. (2021), Malomet and Harber (2021), Ambatipudi et al. (2021), Wang et al. (2020a), Lu et al. (2021)
	Audit and organization	It is necessary to monitor and control whether the occupational health and safety measures taken in the workplace are followed and to ensure that nonconformities are eliminated. For this purpose, it covers the process of forming teams, determining their duties, and supporting them with feedback and recording mechanisms	Byrne et al. (2020), Brooks et al. (2022), Carnegie et al. (2021), Malomet and Harber (2021)
	Waste management	It refers to ensuring management without harming the environment and health during the collection and disposal of waste	Betancourt et al. (2021), Sarkodie and Owusu (2021), Scott et al. (2021), Silva et al. (2021)

On the other side, the BWM is an MCDM method developed by Rezaei (2015) for the first time and used in solving MCDM problems. This method is used to determine the importance weights of the criteria by considering the pairwise comparison. An important advantage of the method is that the number of pairwise comparisons required for calculation is less than other pairwise comparison methods such as AHP (While AHP needed $n(n-1)/2$ comparisons, the BWM needed only $2n-3$ comparison). This advantage is provided by the existence of two vectors used in the evaluations. These vectors are best-to-others and others-to-worst (Rezaei 2016; Rezaei et al. 2016). Many extensions have been developed since its originated version. These extensions have emerged with the development of concepts such as fuzzy sets (e.g., triangular fuzzy sets, trapezoidal fuzzy sets, interval type-2 fuzzy sets, intuitionistic fuzzy sets, hesitant fuzzy sets), *Z* numbers, neutrosophic sets, and rough sets (Guo and Zhao 2017; Hafezalkotob and Hafezalkotob 2017; Mou et al. 2016; Aboutorab et al. 2018; Omrani et al. 2018; Li et al. 2019; Wu et al. 2019; Mi et al. 2019; Mohammadi and Rezaei 2020; Torkayesh et al. 2021; Yucesan and Gul 2021; Celik and Gul 2021; Yamagishi et al. 2022; Celik et al. 2021). The implementation steps of IT2FBWM are given in the Supplementary file, which is an important component of the research methodology of this study. While evaluating the decision criteria, an IT2F linguistic scale is needed to proceed. IT2F pairwise comparisons on the *n* criteria are performed considering the linguistic variables of decision-makers. The linguistic terms are as follows (Celik et al. 2015): equally important (EI), moderately more important (MMI), strongly more important (SMI), very strong more important (VSMI), extremely more important (EMI), and intermediate value (IV) for all linguistic terms. The scale is provided in Table 3. The optimization model is built and solved, as explained in Wu et al. (2019).

The consistency index (CI), as shown in Table 4, is used to calculate the consistency ratio (CR). The same process in Rezaei (2015) and Wu et al. (2019) is applied here to find the decision-maker's evaluation CR. The bigger the δ^*, the higher the CR.

Table 3 The IT2F linguistic scale

Linguistic variable	Corresponding IT2F numbers
EMI	((8;9;9;10;1;1), (8.5;9;9;9.5;0.9;0.9))
IV between EMI and VSMI	((7;8;8;9;1;1), (7.5;8;8;8.5;0.9;0.9))
VSMI	((6;7;7;8;1;1), (6.5;7;7;7.5;0.9;0.9))
IV between VSMI and SMI	((5;6;6;7;1;1), (5.5;6;6;6.5;0.9;0.9))
SMI	((4;5;5;6;1;1), (4.5;5;5;5.5;0.9;0.9))
IV between SMI and MMI	((3;4;4;5;1;1), (3.5;4;4;4.5;0.9;0.9))
MMI	((2;3;3;4;1;1), (2.5;3;3;3.5;0.9;0.9))
IV between MMI and EI	((1;2;2;3;1;1), (1.5;2;2;2.5;0.9;0.9))
EI	((1;1;1;1;1;1), (1;1;1;1;0.9;0.9))

Table 4 CI values in terms of linguistic term

Linguistic term	Defuzzified value of the linguistic term	CI
EI	0.975	2.9582
IV between MMI and EI	1.95	4.4872
MMI	2.925	5.8948
IV between SMI and MMI	3.9	7.2373
SMI	4.875	8.5373
IV between VSMI and SMI	5.85	9.8069
VSMI	6.825	11.0533
IV between EMI and VSMI	7.8	12.2812
EMI	8.775	13.494

- Stage 2: Determining university safe campus score by SAW

The university campuses are evaluated in the second phase of our methodology, a score is given on a 1–5 Likert scale (1—worst, 2—bad, 3—average, 4—good, 5—very Good) according to the above mentioned 58 sub-sub-criteria. And then, by multiplying these scores with the weights obtained from IT2F-BWM, the final campus safety score is determined. This method is called SAW for short and was first developed by Churchman et al. (1957). It is a well-known MCDM method (Churchman and Ackoff 1954).

Case study demonstration

A field study was conducted to demonstrate the applicability of the proposed methodology in this study. As stated in the "Introduction" of the article, the main objectives are as follows: (1) to determine the main criteria, sub-criteria, and sub-sub-criteria required for the assessment of the COVID-19 safe campus in a three-level hierarchical framework; (2) IT2F-BWM and COVID-19 obtaining the weights of the main criteria, sub-criteria, and sub-sub-criteria required for the Safe Campus assessment locally and globally; (3) in the model created, a secure campus score of any three universities was obtained with the SAW method; (4) the weights of the COVID-19 safe campus criteria and sub-criteria are discussed by comparing them with the literature.

Application results of the methodology

As a result of solving the IT2F-BWM models, the local and global weight values of each expert's main criteria, sub-criteria, and sub-sub-criteria in the entire hierarchy were obtained and given in Table 5 in detail. Accordingly, the importance weights of the main criteria were calculated as 0.5218, 0.2885, and 0.1897 for A, B, and C, respectively. From this point of view, it is seen that the main criterion of infection and control has more importance than the total weight of the other two main components in the safe campus evaluation of a university campus. It has been concluded that university campuses are the most important determinant of being prepared for the COVID-19 outbreak, with an importance percentage of approximately 52%. This main component is followed by planning with approximately 29% and occupational health and safety with 19%. When a similar analysis is made for the sub-criteria under the main criteria A, B, and C, it is seen that the most important sub-criteria are A1 (Case management), B3 (Infection-control plans), and C1 (Risk analysis) for each group, respectively. When the main criterion A is examined, the sub-criteria (A1, A2, A3, A4) have an average significance weight of 0.3396, 0.1791, 0.3003, and 0.1810, respectively. Case management was the most important sub-criteria with an importance percentage of approximately 34%, while decontamination was the least important sub-criteria with approximately 18%. When the B main criterion is examined, it is seen that the importance weights take the values of 0.1111, 0.2071, 0.4436, and 0.2383 for each sub-criterion (B1, B2, B3, B4), respectively. The infection-control plans sub-criterion was the most important sub-criterion with a high percentage (nearly 44%), while the training plans sub-criterion was the least important sub-criterion with 11%.

For the C main criterion, the following fundamental results were obtained: While the risk assessment (C1) and audit and organization (C2) sub-criteria have a close percentage of importance, waste management (C3) has a relatively lower percentage of importance. The calculated average weight values were 0.4475, 0.4058, and 0.1467, respectively.

Obtaining the local weights of the criteria and sub-criteria at the 1st and 2nd levels of the hierarchy, the global weights of the 58 sub-criteria at the last 3rd level were calculated and plotted in detail in Fig. 2. The first five sub-criteria with the highest importance weight of 58 sub-criteria are respectively; it was found that A2.1 with a value of 0.0498, A1.1 with a value of 0.0477, A1.3 with a value of 0.0461, B3.3 with a value of 0.0445, and B3.4 with a value of 0.0439. These are periodic disinfection, contact follow-up, definitive case, symptom questioning, and personal protective behaviors. The five least important criteria among the sub-criteria are as follows: it was C3.3 with a value of 0.0025, C3.2 with a value of 0.0025, B1.1 with a value of 0.0033, B1.4 with a value of 0.0037, and C3.4 with a value of 0.0039. These are the criteria of waste storage station, authorized institution instruction, visitor information, student information, and contactless waste piggy banks.

Table 5 Local and global weights of main, sub-, and sub-sub-criteria in the hierarchy

Expert #1-Local weights						Global weight	Expert #2-Local weights						Global weight	Expert #3-Local weights						Global weight	Expert #4-Local weights						Global weight	Expert #5-Local weights						Global weight	Expert #6-Local weights						Global weight
A	0.6984				A1.1	0.3834	0.1652	A	0.7778				A1.1	0.1017	0.0440	A	0.6125				A1.1	0.3957	0.0257	A	0.5750				A1.1	0.3374	0.0354	A	0.2766				A1.1	0.1293	0.0030	A	0.1905				A1.1	0.1344	0.0126
					A1.2	0.1239	0.0534						A1.2	0.1017	0.0440					A1.2	0.0699	0.0045					A1.2	0.1183	0.0124					A1.2	0.0842	0.0020					A1.2	0.1075	0.0101
					A1.3	0.0992	0.0427						A1.3	0.4104	0.1777					A1.3	0.0798	0.0052					A1.3	0.1183	0.0124					A1.3	0.1293	0.0030					A1.3	0.3818	0.0357
		A1	0.6172	A1.4	0.0992	0.0427			A1	0.5567	A1.4	0.2033	0.0880			A1	0.1062	A1.4	0.1863	0.0121			A1	0.1825	A1.4	0.0947	0.0099			A1	8E-02	A1.4	0.1003	0.0023			A1	0.4908	A1.4	0.1792	0.0168
					A1.5	0.1239	0.0534						A1.5	0.0762	0.0330					A1.5	0.1397	0.0091					A1.5	0.0552	0.0058					A1.5	0.1724	0.0040					A1.5	0.0670	0.0063
					A1.6	0.1239	0.0534						A1.6	0.0762	0.0330					A1.6	0.0931	0.0061					A1.6	0.1578	0.0166					A1.6	0.3552	0.0083					A1.6	0.0896	0.0084
					A1.7	0.0465	0.0200						A1.7	0.0305	0.0132					A1.7	0.0355	0.0023					A1.7	0.1183	0.0124					A1.7	0.0294	0.0007					A1.7	0.0403	0.0038
					A2.1	0.6298	0.0598						A2.1	0.6000	0.0962					A2.1	0.5800	0.0806					A2.1	0.4912	0.0238					A2.1	0.5251	0.0265					A2.1	0.2542	0.0115
		A2	0.1360	A2.2	0.1603	0.0152			A2	0.2062	A2.2	0.2000	0.0321			A2	0.2269	A2.2	0.2000	0.0278			A2	0.0842	A2.2	0.2338	0.0113			A2	2E-01	A2.2	0.2418	0.0122			A2	0.2386	A2.2	0.1305	0.0059
					A2.3	0.0763	0.0072						A2.3	0.0667	0.0107					A2.3	0.0600	0.0083					A2.3	0.1780	0.0086					A2.3	0.0518	0.0026					A2.3	0.4276	0.0194
					A2.4	0.1336	0.0127						A2.4	0.1333	0.0214					A2.4	0.1600	0.0222					A2.4	0.0971	0.0047					A2.4	0.1813	0.0092					A2.4	0.1877	0.0085
					A3.1	0.3432	0.0201						A3.1	0.1032	0.0058					A3.1	0.1382	0.0412					A3.1	0.2963	0.0835					A3.1	0.3205	0.0434					A3.1	0.1331	0.0045
					A3.2	0.1188	0.0069						A3.2	0.1290	0.0072					A3.2	0.1843	0.0550					A3.2	0.1441	0.0406					A3.2	0.1477	0.0200					A3.2	0.0761	0.0026
					A3.3	0.1584	0.0093						A3.3	0.3642	0.0204					A3.3	0.3992	0.1191					A3.3	0.1441	0.0406					A3.3	0.1477	0.0200					A3.3	0.0888	0.0030
		A3	0.0837	A3.4	0.0950	0.0056			A3	0.0722	A3.4	0.1290	0.0072			A3	0.4872	A3.4	0.0388	0.0116			A3	0.4900	A3.4	0.1441	0.0406			A3	5E-01	A3.4	0.0369	0.0050			A3	0.1789	A3.4	0.0399	0.0014
					A3.5	0.1584	0.0093						A3.5	0.1032	0.0058					A3.5	0.0921	0.0275					A3.5	0.1080	0.0304					A3.5	0.0886	0.0120					A3.5	0.1065	0.0036
					A3.6	0.0787	0.0046						A3.6	0.0425	0.0024					A3.6	0.0788	0.0235					A3.6	0.0554	0.0156					A3.6	0.1477	0.0200					A3.6	0.1775	0.0060
					A3.7	0.0475	0.0028						A3.7	0.1290	0.0072					A3.7	0.0685	0.0205					A3.7	0.1080	0.0304					A3.7	0.1108	0.0150					A3.7	0.3781	0.0129
					A4.1	0.4290	0.0489						A4.1	0.4065	0.0521					A4.1	0.4336	0.0477					A4.1	0.3194	0.0447					A4.1	0.4194	0.0282					A4.1	0.4048	0.0071
					A4.2	0.1949	0.0222						A4.2	0.1896	0.0243					A4.2	0.2068	0.0228					A4.2	0.1552	0.0217					A4.2	0.1926	0.0129					A4.2	0.0503	0.0009
		A4	0.1632	A4.3	0.1155	0.0132			A4	0.1649	A4.3	0.1422	0.0182			A4	0.1797	A4.3	0.1241	0.0137			A4	0.2433	A4.3	0.1552	0.0217			A4	2E-01	A4.3	0.0419	0.0028			A4	0.0918	A4.3	0.1912	0.0033
					A4.4	0.0945	0.0108						A4.4	0.0948	0.0122					A4.4	0.1034	0.0114					A4.4	0.1552	0.0217					A4.4	0.0714	0.0048					A4.4	0.1147	0.0020
					A4.5	0.1155	0.0132						A4.5	0.1138	0.0146					A4.5	0.0886	0.0098					A4.5	0.1552	0.0217					A4.5	0.1926	0.0129					A4.5	0.1434	0.0025
					A4.6	0.0505	0.0058						A4.6	0.0531	0.0068					A4.6	0.0434	0.0048					A4.6	0.0597	0.0084					A4.6	0.0821	0.0055					A4.6	0.0956	0.0017
B	0.1905				B1.1	0.1261	0.0018	B	0.1597				B1.1	0.1667	0.0033	B	0.2855				B1.1	0.1090	0.0020	B	0.3000				B1.1	0.1730	0.0048	B	0.1287				B1.1	0.0391	0.0004	B	0.6667				B1.1	0.0503	0.0080
					B1.2	0.1656	0.0023						B1.2	0.1667	0.0033					B1.2	0.1362	0.0025					B1.2	0.1730	0.0048					B1.2	0.3959	0.0037					B1.2	0.1147	0.0182
					B1.3	0.1656	0.0023						B1.3	0.3125	0.0062					B1.3	0.1816	0.0034					B1.3	0.3381	0.0093					B1.3	0.1367	0.0013					B1.3	0.1434	0.0228
		B1	0.0730	B1.4	0.0688	0.0010			B1	0.1248	B1.4	0.0625	0.0012			B1	0.0655	B1.4	0.0568	0.0011			B1	0.0918	B1.4	0.1038	0.0029			B1	7E-02	B1.4	0.1367	0.0013			B1	0.2386	B1.4	0.0956	0.0152
					B1.5	0.3479	0.0048						B1.5	0.1250	0.0025					B1.5	0.3802	0.0071					B1.5	0.1730	0.0048					B1.5	0.1823	0.0017					B1.5	0.1912	0.0304
					B1.6	0.1261	0.0018						B1.6	0.1667	0.0033					B1.6	0.1362	0.0025					B1.6	0.0393	0.0011					B1.6	0.1094	0.0010					B1.6	0.4048	0.0644
					B2.1	0.5455	0.0202						B2.1	0.4423	0.0154					B2.1	0.5556	0.0282					B2.1	0.2308	0.0165					B2.1	0.1780	0.0054					B2.1	0.2386	0.0285
					B2.2	0.1818	0.0067						B2.2	0.2308	0.0081					B2.2	0.0694	0.0035					B2.2	0.0962	0.0069					B2.2	0.4912	0.0148					B2.2	0.1789	0.0213
		B2	0.1948	B2.3	0.1818	0.0067			B2	0.2185	B2.3	0.2308	0.0081			B2	0.1778	B2.3	0.1667	0.0085			B2	0.2386	B2.3	0.4423	0.0317			B2	2E-01	B2.3	0.2338	0.0070			B2	0.1789	B2.3	0.4908	0.0585
					B2.4	0.0909	0.0034						B2.4	0.0962	0.0034					B2.4	0.2083	0.0106					B2.4	0.2308	0.0165					B2.4	0.0971	0.0029					B2.4	0.0918	0.0109
					B3.1	0.1728	0.0198						B3.1	0.5155	0.0500					B3.1	0.0761	0.0132					B3.1	0.2308	0.0124					B3.1	0.1892	0.0042					B3.1	0.1789	0.0585
					B3.2	0.2338	0.0268						B3.2	0.0779	0.0076					B3.2	0.1624	0.0282					B3.2	0.0962	0.0052					B3.2	0.0541	0.0012					B3.2	0.0918	0.0300
		B3	0.6024	B3.3	0.5155	0.0591			B3	0.6079	B3.3	0.1728	0.0168			B3	0.6084	B3.3	0.5584	0.0970			B3	0.1789	B3.3	0.2308	0.0124			B3	2E-01	B3.3	0.1892	0.0042			B3	0.4908	B3.3	0.2386	0.0781
					B3.4	0.0779	0.0089						B3.4	0.2338	0.0227					B3.4	0.2030	0.0353					B3.4	0.4423	0.0237					B3.4	0.5676	0.0127					B3.4	0.4908	0.1606
					B4.1	0.1883	0.0047						B4.1	0.4423	0.0035					B4.1	0.5844	0.0247					B4.1	0.5017	0.0739					B4.1	0.1784	0.0119					B4.1	0.1789	0.0109
					B4.2	0.0819	0.0020						B4.2	0.2308	0.0018					B4.2	0.1399	0.0059					B4.2	0.2458	0.0362					B4.2	0.2379	0.0159					B4.2	0.2386	0.0146
		B4	0.1298	B4.3	0.5776	0.0143			B4	0.0488	B4.3	0.2308	0.0018			B4	0.1482	B4.3	0.2099	0.0089			B4	0.4908	B4.3	0.1843	0.0271			B4	5E-01	B4.3	0.5138	0.0344			B4	0.0918	B4.3	0.4908	0.0300
					B4.4	0.1521	0.0038						B4.4	0.0962	0.0008					B4.4	0.0658	0.0028					B4.4	0.0683	0.0101					B4.4	0.0700	0.0047					B4.4	0.0918	0.0056
C	0.1111111				C1.1	0.4444	0.0141	C	0.0625				C1.1	0.4423	0.0188	C	0.1020				C1.1	0.5584	0.0163	C	0.1250				C1.1	0.4912	0.0351	C	0.5947				C1.1	0.1558	0.0268	C	0.1429				C1.1	0.0918	0.0075
					C1.2	0.2222	0.0071						C1.2	0.2308	0.0098					C1.2	0.2030	0.0059					C1.2	0.2338	0.0167					C1.2	0.1948	0.0335					C1.2	0.4908	0.0401
		C1	0.2857	C1.3	0.1111	0.0035			C1	0.6818	C1.3	0.0962	0.0041			C1	0.2857	C1.3	0.1624	0.0047			C1	0.5714	C1.3	0.1780	0.0127			C1	3E-01	C1.3	0.0649	0.0112			C1	0.5714	C1.3	0.2386	0.0195
					C1.4	0.2222	0.0071						C1.4	0.2308	0.0098					C1.4	0.0761	0.0022					C1.4	0.0971	0.0069					C1.4	0.5844	0.1004					C1.4	0.1789	0.0146
					C2.1	0.4346	0.0276						C2.1	0.3446	0.0049					C2.1	0.1286	0.0075					C2.1	0.1462	0.0052					C2.1	0.1355	0.0513					C2.1	0.1773	0.0036
					C2.2	0.1377	0.0087						C2.2	0.1605	0.0023					C2.2	0.1029	0.0060					C2.2	0.2556	0.0091					C2.2	0.3925	0.1485					C2.2	0.3785	0.0077
					C2.3	0.1095	0.0070						C2.3	0.1605	0.0023					C2.3	0.1029	0.0060					C2.3	0.1462	0.0052					C2.3	0.1084	0.0410					C2.3	0.1064	0.0022
		C2	0.5714	C2.4	0.0918	0.0058			C2	0.2273	C2.4	0.1204	0.0017			C2	0.5714	C2.4	0.3632	0.0212			C2	0.2857	C2.4	0.1065	0.0038			C2	6E-01	C2.4	0.1807	0.0684			C2	0.1429	C2.4	0.1330	0.0027
					C2.5	0.1095	0.0070						C2.5	0.0803	0.0011					C2.5	0.0858	0.0050					C2.5	0.0532	0.0019					C2.5	0.0671	0.0254					C2.5	0.0760	0.0016
					C2.6	0.0486	0.0031						C2.6	0.0963	0.0014					C2.6	0.1715	0.0100					C2.6	0.1462	0.0052					C2.6	0.0771	0.0292					C2.6	0.0886	0.0018
					C2.7	0.0683	0.0043						C2.7	0.0375	0.0005					C2.7	0.0451	0.0026					C2.7	0.1462	0.0052					C2.7	0.0387	0.0146					C2.7	0.0403	0.0008
					C3.1	0.4762	0.0076						C3.1	0.4490	0.0026					C3.1	0.5055	0.0074					C3.1	0.3594	0.0064					C3.1	0.4844	0.0216					C3.1	0.2103	0.0086
					C3.2	0.1587	0.0025						C3.2	0.1633	0.0009					C3.2	0.1403	0.0020					C3.2	0.0781	0.0014					C3.2	0.1335	0.0059					C3.2	0.0657	0.0027
		C3	0.1429	C3.3	0.1270	0.0020			C3	0.0909	C3.3	0.1633	0.0009			C3	0.1429	C3.3	0.1169	0.0017			C3	0.1429	C3.3	0.1875	0.0033			C3	7E-02	C3.3	0.0484	0.0022			C3	0.2857	C3.3	0.1262	0.0051
					C3.4	0.0794	0.0013						C3.4	0.0612	0.0003					C3.4	0.1754	0.0026					C3.4	0.1875	0.0033					C3.4	0.2225	0.0099					C3.4	0.1577	0.0064
					C3.5	0.1587	0.0025						C3.5	0.1633	0.0009					C3.5	0.0619	0.0009					C3.5	0.1875	0.0033					C3.5	0.1111	0.0050					C3.5	0.4401	0.0180

One of the most important steps of the IT2F-BWM phase is the consistency analysis part. Within the scope of the study, CR values were calculated separately for all matrices of 6 experts. The results are presented in Table 6. Accordingly, all values were obtained as less than 6.6%. This shows that all decision-making expert jewelry members make a consistent dual evaluation. Because there is no value even close to the threshold value of 0.1 in AHP.

By SAW method, a score for each assessed university campus is determined by multiplying importance weights of the 58 criteria (from the third level in the hierarchy) and scores given to the alternatives to the criteria (by the aid of 5-point Likert type linguistic variables), within the scope of the study, the safe campus score of three universities has been computed as the follow-up study of the case. The real-life applicability of the study was evaluated by comparing

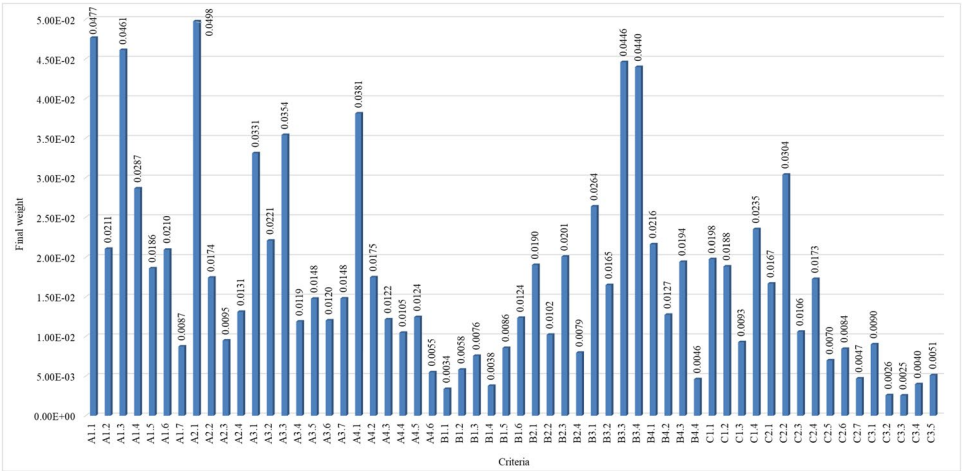


Fig. 2 Final weights of criteria (averaged and globalized). *Note: Please refer to* Fig. 1 *for criteria definitions*

Table 6 CR (consistency ratio) values of all evaluation matrices in the study

Matrix on *criteria*	CR value					
	Expert #1	Expert #2	Expert #3	Expert #4	Expert #5	Expert #6
A–B–C	0.0172	0.0232	0.0147	0.0348	0.0146	0.0663
A1–A4	0.0120	0.0235	0.0414	0.0219	0.0219	0.0182
B1–B4	0.0090	0.0181	0.0225	0.0182	0.0057	0.0182
C1–C3	0.0249	0.0143	0.0249	0.0202	0.0076	0.0249
A1.1–A1.7	0.0058	0.0114	0.0100	0.0085	0.0074	0.0100
A2.1–A2.4	0.0089	0.0124	0.0148	0.0160	0.0108	0.0355
A3.1–A3.7	0.0075	0.0114	0.0085	0.0110	0.0069	0.0099
A4.1–A4.6	0.0051	0.0103	0.0127	0.0118	0.0084	0.0116
B1.1–B1.6	0.0114	0.0217	0.0123	0.0201	0.0082	0.0116
B2.1–B2.4	0.0109	0.0268	0.0250	0.0268	0.0160	0.0182
B3.1–B3.4	0.0081	0.0081	0.0213	0.0268	0.0113	0.0182
B4.1–B4.4	0.0098	0.0268	0.0198	0.0197	0.0117	0.0182
C1.1–C1.4	0.0193	0.0268	0.0077	0.0160	0.0121	0.0182
C2.1–C2.7	0.0047	0.0084	0.0104	0.0151	0.0081	0.0097
C3.1–C3.5	0.0095	0.0172	0.0140	0.0217	0.0097	0.0142

the safe campus scores of the universities. In this context, the following steps were applied sequentially. Initially, three universities were determined as hypothetical. These universities are as follows: university A takes measures against COVID-19 with 2000 students, university B has 5000 students and does not apply measures against COVID-19, university C has 8000 students and is taking precautions against COVID-19 but has been identified as an inadequate university. Based on these explanations, the expert group created the decision matrix. Then, the normalization results are multiplied by the criterion importance weights, all values are summed, and the ranking results are given in Fig. 3.

It has been reached that the results of the analysis made with the SAW method of the importance weights obtained with the IT2F-BWM support the determined assumption. In this context, it has been found that the criterion importance weights obtained with IT2F-BWM are applicable in real life.

Discussion

The importance of the criteria for creating safe campuses within the scope of the COVID-19 pandemic was evaluated with IT2F-BWM. Evaluation of 3 main criteria in order of importance is as follows: infection control, planning, and OHS. Infection control criteria include preventing human-to-human transmission by droplet, contact, and, in some cases, aerosol in the fight against COVID-19. Poole et al. (2021)

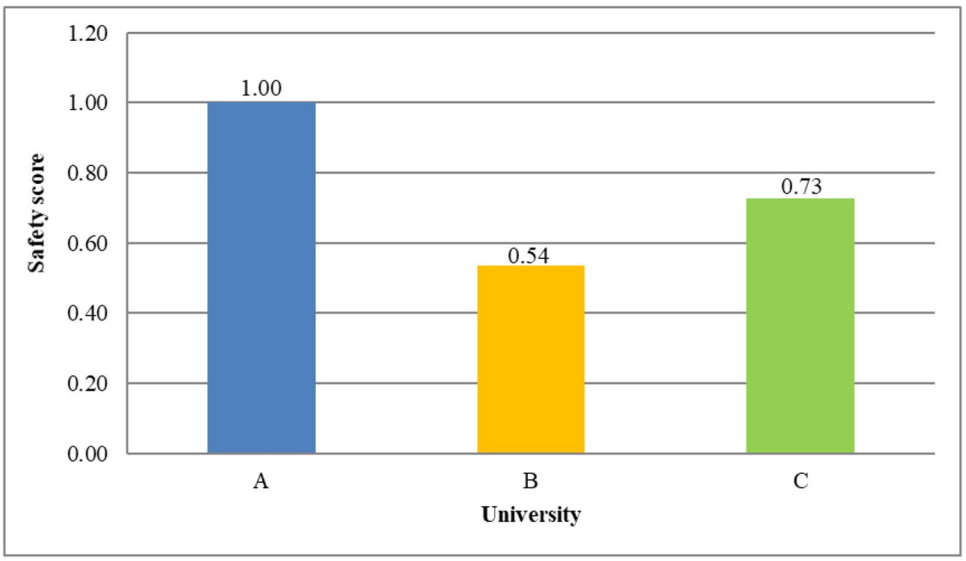


Fig. 3 COVID-19 safe campus scores of three universities

tried to provide infection control with non-pharmaceutical interventions with the community workplace model proposal to reduce COVID-19 transmission in workplaces and universities. Another similar study, Greenhalgh et al. (2021), suggested basic control methods for a safe return to campus against the pandemic. Hsu et al. (2021) in a study they conducted with Bayesian BWM to prevent epidemics on campuses, extensive disinfection of the environment, isolation of contacts, and ventilation are among the most important criteria. Similarly, Chen and O'Keeffe (2020) in Taiwan state that it is necessary to pay attention to factors such as hygiene, contact tracing, social distance, and ventilation in order for universities to open safely. Izumi et al. (2020) mentioned the importance of planning, another important criterion for managing and responding to pandemics in higher education institutions. The criterion with the lowest degree of importance is determined as occupational health and safety criteria. In the literature review, studies that include direct measures for occupational health and safety in the fight against COVID-19 are limited. Studies on the risk assessment sub-criterion, which is the subtitle of this criterion, are mentioned more frequently than the main title. For example, Ambatipudi et al. (2021) evaluated the risk of university reopening to combat COVID-19.

There are four sub-criteria under the infection control main criterion. These criteria are in order of importance. The most important sub-criterion of case management is contact tracing. The most important criterion for reducing contact is the reduction of common materials. The most important sub-criterion of social distance is capacity planning. When these four main sub-criteria are evaluated within themselves, the most important sub-criterion for the infection control dimension in the fight against the pandemic in universities has been determined as periodic disinfection. In a similar study, Dhama et al. (2021) stated that one of the most effective methods of ensuring the population's safety in the fight against the COVID-19 pandemic is the implementation of disinfection procedures. Melnick and Darling-Hammond (2020) mentioned the necessity of periodically disinfecting the common areas (toilet, gym, laboratory, etc.) and classrooms to reopen schools. The next most important sub-criterion has been identified as reducing contact. The importance of social distance in the fight against COVID-19 is indisputable (Poole et al. 2021). For this reason, reducing the risk of transmission by reducing contact, even when social distance does not prevent it, explains the importance of this criterion. Contact follow-up sub-criteria were determined as the third most important sub-criterion. The first two lowest criteria (periodic disinfection and contact reduction) are for contamination risk management. However, while risk management is indisputable in an epidemic that surrounds the whole world, it is also important to carry out crisis management (contact follow-up) immediately after contamination occurs.

When evaluating the sub-criteria of the planning dimension, the most important sub-criteria of the training plans were face-to-face training, the most important sub-criteria of the emergency action plan were transmission procedures, the most important infection control was symptom inquiry, and the most important was cleaning considerations. In many places, measures have been taken at the regional and local levels to reduce the risk of COVID-19 transmission, especially in indoor environments (Chen and O'Keeffe 2020). These measures were carried out within the framework of a certain program. Gillespie et al. (2021) stated that the risk of transmission would decrease significantly with the mitigation measures to be taken during face-to-face training. At the same time, in order to develop a disaster-resistant education system, procedures and plans should be developed to reduce the risk of transmission during education, especially for events such as ceremonies (Izumi et al. 2020). Questioning symptoms using the Center for Disease Control and Prevention's COVID-19 symptom list is also seen as a preventable method for transmission (Cohen et al. 2021; CDC 2020). In addition, measures such as the frequency of cleaning, disinfectants to be used, and personal protective measures to be followed during use are other factors that reduce contamination (World Health Organization 2020b; Curryer et al. 2021).

When the sub-criteria of occupational health and safety dimension are evaluated, it is seen that the most important sub-criterion of risk assessment is determined as risk reduction, the most important sub-criteria of audit and organization are team competence, and the most important sub-criteria of waste management are process creation. Considering that prevention is superior to treatment, the primary goal of risk planning and classification processes is to eliminate the risk and bring it to an acceptable level if this cannot be done. In this context, there is a need for evaluations that take into account risk reduction strategies in order to make informed and safe decisions for reopened universities (Ambatipudi et al. 2021). It has been stated that the risk of contamination can be minimized by combining risk reduction strategies (Lordan et al. 2021) and sustainable risk management in the epidemic control-prevention war. Along with the risk reduction studies to be carried out, the competence of the teams to be formed within the institution, the communication, the harmony, and the training of the team members with each other are also important (Talu and Nazarov 2020). Therefore, by determining common goals through teamwork, success is achieved within the framework of team spirit. Another issue to be considered in terms of occupational health and safety is ensuring waste safety. In some waste management studies, it is seen that the COVID-19 virus is also found in institutional waste (Sousan et al. 2021; Shen et al. 2021; Scott et al. 2021). In addition, proper collection and disposal

of waste such as masks and personal protective equipment are important in minimizing the risk of contamination.

In order to test the robustness of the results of the proposed IT2F-BWM model for this problem, a comparison study was conducted with another BWM version "Bayesian BWM." Bayesian BWM was first proposed by Mohammadi and Rezaei (2020) and included some new features that improve the existing classical BWM. One is that it considers evaluations of multiple decision-makers on a probabilistic basis without losing information, providing a more consistent evaluation. Yet another is that it contributes to the interpretation of the weight values by evaluating the superiority of the criteria to each other on the axis of a reliability value, thanks to the credal ranking, a new feature it contains. In this study, calculations were made with Bayesian BWM for all criteria included in the hierarchy of criteria whose weights were determined for COVID-19 safe campus evaluation. By taking the same pairwise comparisons made by the evaluators, only the mathematical models in the Bayesian BWM algorithm were solved with Matlab, and the results were obtained.

According to the results obtained by Bayesian BWM, the importance weights of the main criteria were calculated as 0.5360, 0.2723, and 0.1917 for A, B, and C, respectively. When the results are compared with the IT2F-BWM, there seems to be a slight difference. While there was a 2% change only in A and B, the percentage rate of C did not change. In the COVID-19 safe campus evaluation of a university campus, the main criterion of infection and control seems to be more important than the total weight of the other two main criteria. This main criterion is followed by planning with 27% and occupational health and safety with 19%. When the main criterion A is examined with Bayesian BWM, it is seen that the sub-criteria (A1, A2, A3, A4) have an average significance weight of 0.2521, 0.2268, 0.2562, and 0.2649, respectively. When this result is compared with IT2F-BWM, it is seen that the variability increases considerably and the values of the three sub-criteria weights are very close to each other. This is an important detail. Considering that the superiority of the criteria to each other can be determined more precisely with Bayesian BWM (shown in Fig. 4, in the creedal ranking graphs), case management (A1), reducing contact (A3), and social distance (A4) are of relative importance; unlike these, it is seen that decontamination is the least important sub-criterion (A3) as in the proposed approach. When the B main criterion is examined, it is seen that the importance weights take the values of 0.1564, 0.2573, 0.3713, and 0.2150 for each sub-criterion (B1, B2, B3, B4), respectively. The infection control plans sub-criterion was determined as the most important sub-criterion with a high percentage (approximately 37%), while the education plans sub-criterion was determined as the least important sub-criterion with 16%. Although the trend here is the same as in IT2F-BWM, the weight values have changed considerably. The following key results were obtained with Bayesian BWM for main criterion C: sub-criteria of risk assessment (C1) and audit and organization (C2) are of relative importance, while waste management (C3) has a relatively lower percentage of importance. The calculated average weight values were 0.4242, 0.4019, and 0.1739, respectively. This result is close to that obtained from IT2F-BWM with great similarity. An important feature of Bayesian BWM was credal ranking. The credal ranking results for the main and sub-criteria (criteria at level 2) are presented in Fig. 4. The values in the credal ranking indicate the confidence interval at which one criterion is superior to the other criterion. For example, criterion A is higher than criterion B with 99% confidence level. The B criterion is higher than the C criterion at the 87% confidence level. Finally, criterion A is 100% confidence level. It is interpreted in the same way in other graphs. Other results are attached to the Supplementary file due to space limitations.

As a result of the comparative study between the proposed IT2F-BWM and Bayesian BWM outputs, the global weights in Fig. 5 were obtained for the 56 criteria at the lowest level of the hierarchy. When the correlation between the weight values obtained from both models is examined, it is seen that the Pearson correlation coefficient is 82.94%. This is a very high value. It can be said that the results of the two models are highly correlated. Moreover, in this case, it also proves the applicability of IT2F-BWM to this problem. Although some features are better with Bayesian BWM, we can say that the proposed model is also extremely successful in solving the problem and producing solid results.

The part of the comparison study so far was about how the criterion weights, the first stage of the proposed hybrid model, yield results with both methods. Another stage that needs to be compared is the second stage, which is the stage for the analysis of the result obtained by testing the safe campus scores of the universities with an MCDM method other than SAW. In this case, as stated in Table 7, 3 different models are tested apart from the current model. Table 7 also shows which MCDM method each hybrid model used in the first and second stages. It presents the safety score and rankings of university campuses obtained with each model.

When we look at the studies on COVID-19 in the context of the universities, in general, issues such as the reliability of the measures taken, the reasons for the increase in cases, the examination of the course of the epidemic, simulation studies, risk management, and the effect on the physical and mental health of the students are emphasized. Hsu et al. (2021), using the Bayesian BWM method, which is similar to our study, created a questionnaire with five main and 36 sub-criteria in the light of the expert opinion. Then, this questionnaire was filled out by experts, and the final results were obtained. In our study, which was carried out

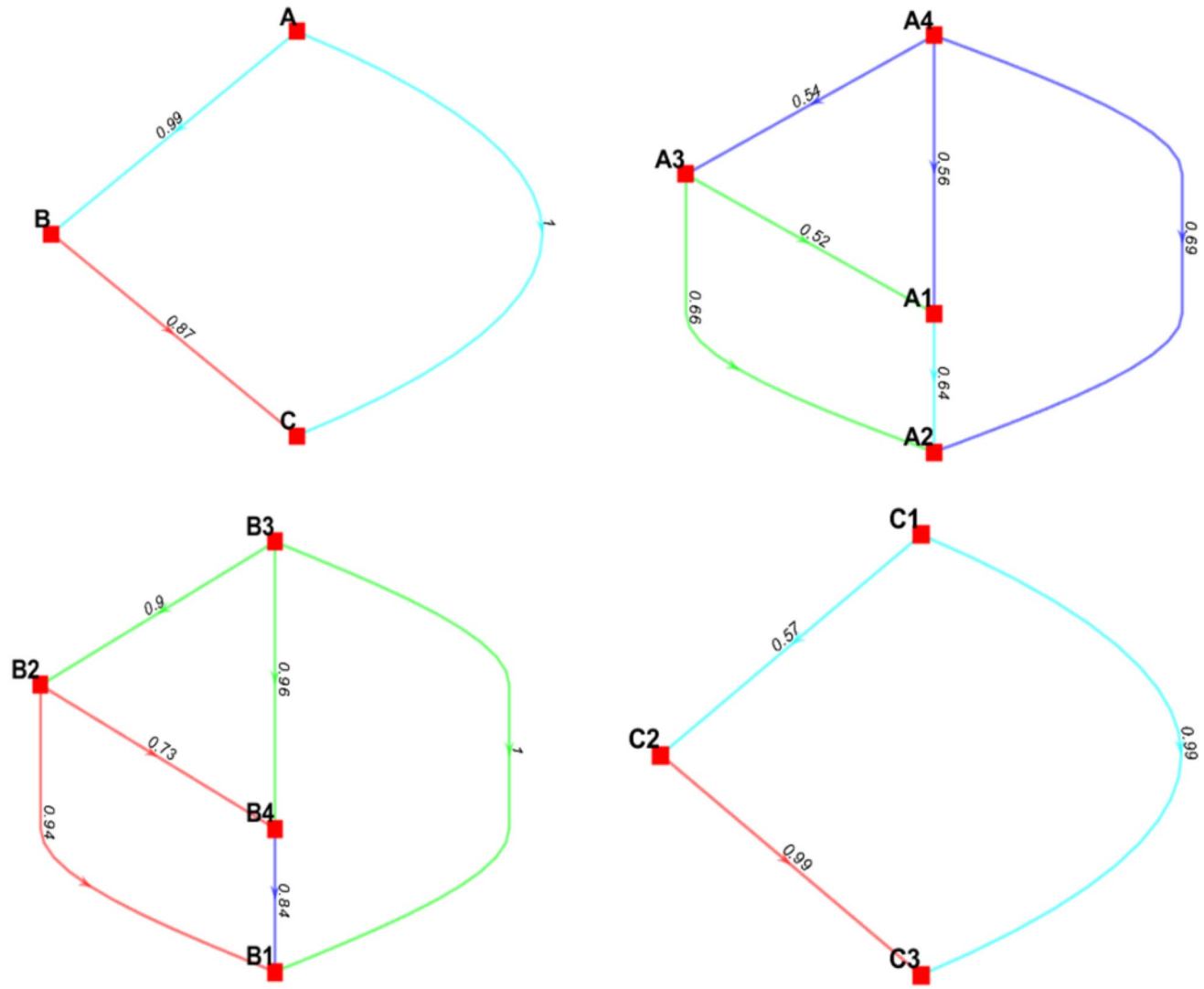


Fig. 4 Credal ranking graphs of main and sub-criteria

to contribute to the development of the necessary infrastructure to develop safe and clean environments in universities, provide hygienic conditions, implement and follow infection control measures, and contribute to the determination of general standards, a comprehensive criteria hierarchy was created in the light of the literature and expert opinion. Since the number of criteria is higher, more effective results can be obtained. BWM with interval type-2 fuzzy numbers is used, which eliminates the use of integers, which is one of the limitations of the classical BWM and is supported by SAW. In addition, comparative studies were made to strengthen the obtained results. As in any research, this research also has limitations. Entering or removing different criteria and sub-criteria, the analysis may cause changes in the results. More effective results can be obtained by increasing the number of experts. In addition, the results can be compared with each other using different methods.

Conclusion

The COVID-19 pandemic, which the world has faced for the last few years, has affected all industry dynamics. In the fight against the COVID-19 pandemic, it has become important for decision-makers to identify countries' vulnerabilities and learn how to deal with similar crises in the future. In this context, producing policies, minimizing response times, and strengthening decision-making mechanisms have become strategic goals for policymakers to develop the power to combat the pandemic.

Universities, the most important components of the education sector, have struggled in this pandemic by taking into account many precautions, restrictions, and the new education systems (face-to-face or distance education). However, the importance of evaluating many issues that this pandemic has affected the safety of university campus areas, and in this

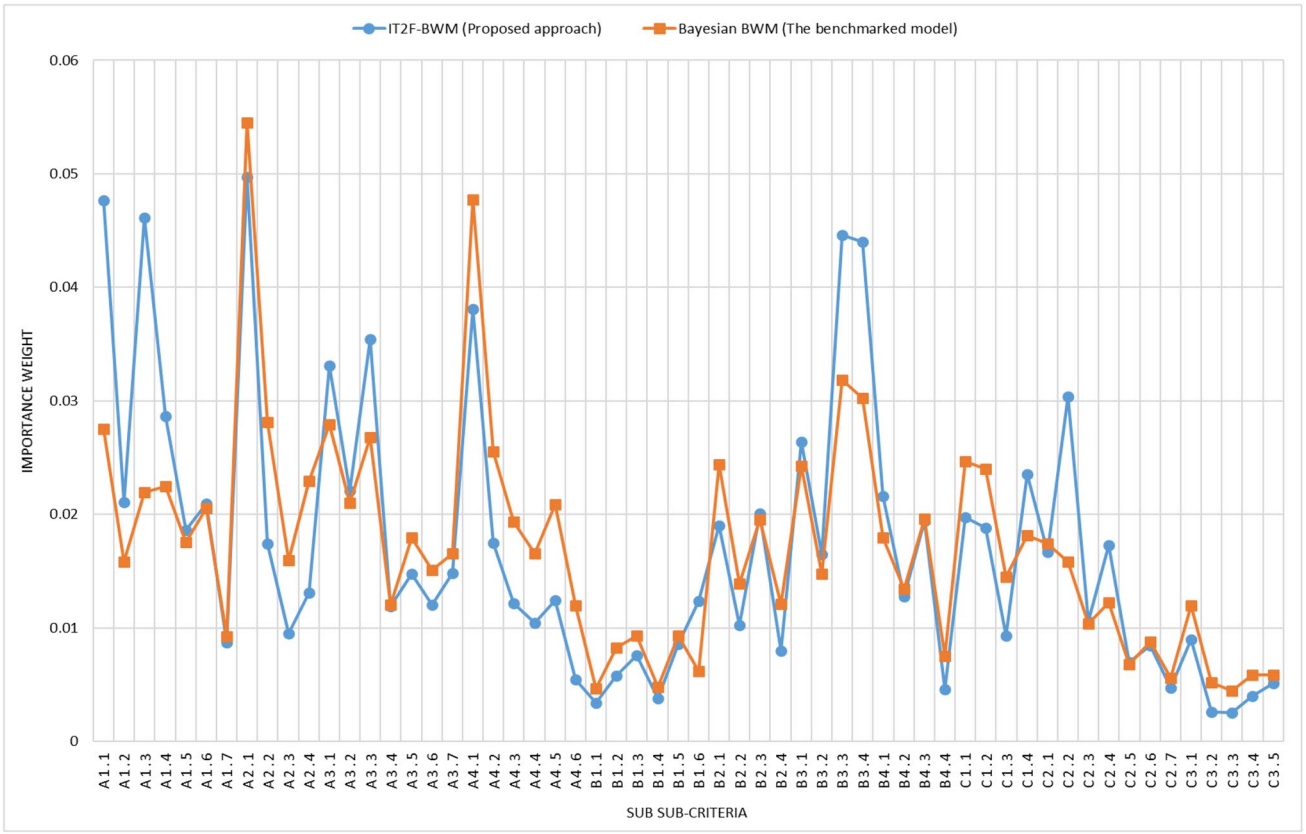


Fig. 5 Comparison of the results of IT2F-BWM and Bayesian BWM

context, the certification of campus areas has emerged in terms of the preferences of the stakeholders and their ability to continue their education activities comfortably. In order to combat the pandemic, a checklist has been determined by the Turkish Standards Institute to contribute to developing safe and clean environments in higher education institutions in Turkey. This list is a recommendation and does not contain information about which items are important. In addition, a hierarchical relationship was not established between the items. In this case, knowing which substances should be improved first is impossible to respond quickly to the pandemic.

Therefore, this study developed a methodology used to evaluate the COVID-19 safe campus of universities. This methodology is an approach where interval type-2 fuzzy BWM and SAW methods are hybridized. While IT2F-BWM was used to determine the weights of the criteria to be used in the evaluation, the weights of SAW universities were determined and used to determine the security scores according to these criteria. Here, the main focus of the approach is the IT2F-BWM model, and a comparison study with Bayesian BWM was conducted to test the robustness of the numerical results obtained from this model. When the results of the compared model and the currently proposed IT2F-BWM model are considered simultaneously, the numerical results show that the most important main criterion is infection control. However, it was seen that

Table 7 Results of the comparative study performed with different hybrid models

Hybrid model #	The used method in the hybrid model		Safety score (rank)		
	1st stage	2nd stage	University A	University B	University C
Current model	IT2F-BWM	SAW	1.00 (1)	0.54 (3)	0.73 (2)
Model 1	Bayesian BWM	SAW	1.00 (1)	0.54 (3)	0.74 (2)
Model 2	IT2F-BWM	TOPSIS	1.00 (1)	0.12 (3)	0.44 (2)
Model 3	Bayesian BWM	TOPSIS	1.00 (1)	0.10 (3)	0.44 (2)

Stage 1: Determining importance weights of criteria; stage 2: Determining university safe campus score

the most important sub-criteria were "case management" under the main infection-control criteria, "infection control plans" under the main criteria of planning, and "risk analysis" under the main criteria of occupational health and safety. When the results are examined in the context of the global weights of the 58 sub-criteria, it is seen that the most important sub-sub-criterion is "periodic disinfection" and the least important sub-sub-criterion is the "waste storage station." In addition, as a hypothetical example, the safety score was calculated for three universities by using the weights obtained with SAW and the scores made for each university with a 5-point Likert scale. With this proposed methodology, the fight against COVID-19 performance of universities can be measured. In addition, policymakers will be able to identify the strengths and threats of universities and develop new strategies in the fight against COVID-19. By the way, the pandemic preparedness status of universities can be compared.

Although this study allows the analysis of the current situation of a university in order to respond to the pandemic quickly and effectively, it has some shortcomings. It has not been taken into account that the degree of impact of the criteria determined in the study may change with factors such as age, gender, and chronic illness. It cannot be determined how the risk will change due to the interaction of the criteria (the risk factors increase due to the interaction of risk factors together). It has been ignored that the importance of the determined criteria may change at the stages of the pandemic. The validation of the determined criteria importance could not be performed due to the lack of sufficient time to make the necessary observations and the inability to determine exactly from which mechanism the contagion spread. Limitations noted in future studies should be considered.

Moreover, future studies are planned to improve the hypothetical SAW model and to determine the safety scores of all national universities against such an epidemic. With such a model, a classification can be made by determining the safe campus levels of all public and private universities nationwide. Thus, in this context, it will be possible for decision-makers to take action for university campuses that have low or insufficient safety or are likely to be directly in non-safe classes.

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Data availability Not applicable.

Declarations

Ethical approval Ethics committee approval is not required.

Consent to participate Not applicable.

Consent to publish The authors confirm that the final version of the manuscript has been reviewed, approved, and consented for publication by all authors.

Competing interests The authors declare no competing interests.

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