

University of Bahrain

College of Science



Environmental and Sustainable  
Development program

# **Developing Environmental Sustainability Performance Index for Higher Education Institutions**

A Thesis submitted in partial fulfillment of the requirements for the degree of  
Ph.D. in Environment and Sustainable Development

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**June 2023**

# Abstract

This dissertation presents a new environmentally performance index for higher education institutions, named the University of Bahrain Environmental Sustainability Higher Education Institutions Ranking System (UoBESHEIRS). The Environmental Sustainability Higher Education Institutions Ranking Systems (ESHEIRSs) aim to evaluate the advancement of universities towards environmental sustainability. This work critically examines the existing ESHEIRSs, highlighting their limitations in evaluating universities based on predetermined targets and indicators in accordance with the Berlin Principles. However, these ranking systems adopt a uniform approach that does not account for the climate-related factors specific to the country in which a university is located. As such, they rely on a universal methodology that may not be suitable for all universities. UoBESHEIRS is a dynamic system, leveraging artificial intelligence and machine learning techniques to propose different weights for each indicator annually, based on the universities' data from the preceding year. In addition to commonly included targets such as climate change impact, energy consumption, waste management, water consumption, transportation, and education on environmental sustainability, UoBESHEIRS introduces biodiversity as a distinct target. This work investigates the influence of climate elements on universities' performance, discovering a significant correlation between the average annual temperature and university performance.

UoBESHEIRS considers the climate factors specific to the country in which a university is situated and establishes indicator weights based on the aggregated university data. This approach ensures an equitable and unbiased assessment of HEIs' progress in terms of environmental sustainability, education, research, and services. It can function as an independent ranking system or be integrated into another existing ranking system or can be incorporated into any ranking system within both ranking groups (education and environmental), enabling the customization of indicator weight assignments based on specific areas of interest in the ranking (not exclusively limited to environmental

sustainability). UoBESHEIRS presents a comprehensive and automated approach to evaluating the performance of higher education institutions (HEIs).

## **Keywords**

Environmental sustainability, Higher education institutions performance index, Ranking System, Climate parameters, Machine learning, Goal programming.

## **Publications**

Buzaboon, A., Alnaser, W., Alboflasa, H., Shatnawia, S., Albinalia, K. & Aljowder, T. (2020). Evaluation of Environmental Sustainability Higher in Education Ranking Systems: Towards a Flat Intraranking System. Arab Gulf Journal of Scientific Research AGJSR (Vol. 38)., 11–28. Retrieved from <https://doi.org/10.51758/AGJSR-01-2020-0002>.

A. Buzaboon, H. Alboflasa, W. Alnaser, S. Shatnawi and K. Albinali (2021). Automated Mapping of Environmental Higher Education Ranking Systems Indicators to SDGs Indicators using Natural Language Processing and Document Similarity. Date of Conference: 29-30 September 2021. Published in: 2021 International Conference on Innovation and Intelligence for Informatics, Computing, and Technologies (3ICT). Date Added to IEEE Xplore: 04 November 2021. INSPEC Accession Number: 21415163. DOI: 10.1109/3ICT53449.2021.9581693. Publisher: IEEE. Conference Location: Zallaq, Bahrain.

Buzaboon, A., Alnaser, W., Shatnawi, S., Albinali, K., Alboflasa, H., & Almohsin, E. (n.d.). Temperature-dependency of Environmental Higher Education Ranking Systems. Published in: 2021 Third International Sustainability and Resilience Conference: Climate Change. Date of Conference: 15-16 November 2021. Date Added to IEEE Xplore: 13 January 2022. ISBN Information: INSPEC Accession Number: 21571735. DOI: 10.1109/IEEECONF53624.2021.9667995. Publisher: IEEE. Conference Location: Sakheer, Bahrain.

# Dedication

I dedicate my thesis work to my family and friends. Special gratitude to my parents, (Abdulla Buzaboon and Fatima Buhiji), whose encouragement for persistence rings in my ears. My husband (Ghazi Ajlan), my sisters (Amina and Muneera), my brothers (Mohammed and Nawaf), and my children (Fatima, Faisal, and Abdulla), who never left my side and are very special. The thesis is also dedicated to my many friends and family who have supported me during my study, like my friends (Amal Alansari, Khawla Albinali, Sawsan Alhamar, Khulood Aldoseri, Ghadnana Alsada, Marwa Algallaf, Fatima Janahi and Amna Alamer).

I appreciate all who have provided scientific assistance and advice, especially Mrs. Khawla Albinali, Mrs. Thajba Aljawder, Dr. Basma Alnajar, Mrs. Eman Khalil, and Mr. Hussain Abdulrasool, for helping me develop my technology skills. Special appreciation is to Dr. Safwan Shatnawi for the many hours of proofreading and for helping me master the leader dots.

I want to dedicate my work to whoever supported me during the treatment I followed for my autistic son (Abdulla). Special appreciation to Dr. Reema, the founder of the Andalosya Autism Program. Special thanks to Dr. Kamelia Alborshaid, the founder of Alcamelia special needs Center, for her continuous support, to my husband, my other two children and my assistant (Rowena Contessa) for always supporting me psychologically and positively during the treatment program, to Dr. Badria Buzaboon, founder of Almanal center, for her continuous support in taking care of (Abdulla) and for supporting me throughout his treatment.

# Acknowledgements

I wish to thank my supervisor, (Prof. Dr. Waheeb Alnaser, and my co-supervisor, Dr. Hanan Albuflasa), for their continuous support and assistance in conducting my research. Special thanks go to the Dean of the College of Science, (Prof. Dr. Mohammed Elhilo), and the Ph.D. program committee members for their continued support. Thanks to my classmates, teachers, mentor teachers, and administrators who assisted me with this thesis; their excitement and willingness to provide feedback made completing this research an enjoyable experience.

I also thank my first conference contribution colleagues (Ms. Thajba Aljawder and Dr. Abdulla Abulshook). The conference was in Morocco; with lots of quality time with the Kingdom of Bahrain participants who contributed to the first research paper published for this thesis and other participants from different Arab countries. Many thanks to the following HEI Quality Assurance Directors for their assistance with this research: Dr. Bassam Al Hamad, Quality Assurance Director and Assistant Professor in the Department of Chemical Engineering, College of Engineering, University of Bahrain; Dr. Rabab Asghar Abbas, Assistant Professor, Chairperson of the Integrated Sciences Department, and Quality Assurance Director at the College of Health and Sports Sciences, University of Bahrain; Mrs. Eman Khalil, Quality Assurance Coordinator for Applied Studies for 2018/2019 at the University of Bahrain; Dr. Basma Alnajjar, team member of the University of Bahrain Ranking Committee; Dr. Abdulla Aboulshouk, Quality Assurance Director in the Ministry of Interior's Academy. Lastly, I thank whoever gave me any information that built my overall knowledge, skills, and personality.

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# Glossary

**Sustainability** - In the charter for the University of California Los Angeles Sustainability Committee, sustainability is defined as follows (UCLA-Sustainability-Charter, n.d., (p. 2)): The integration of environmental health, social equity, and economic vitality to create thriving, healthy, diverse, and resilient communities for this generation and generations to come. The practice of sustainability recognizes how these issues are interconnected and require a systems approach and an acknowledgement of complexity.

**Environmental Sustainability** - Environmental sustainability is responsible for conserving natural resources and protecting global ecosystems to support health and wellbeing (Khan et al., 2022).

**International Ranking Expert Group** - (in short: IREG Observatory) is an international institutional non-profit organization of ranking associations, universities and other groups interested in HEIs rankings and academic excellence. Its objective is strengthening public awareness and awareness of a range of issues related to university rankings and academic excellence. The practice acquired by a group of rankers and ranking analysts, who met first in 2002, led to the establishment of an International Ranking Expert Group (IREG). In 2009 this informal group was transformed into IREG Observatory as a non-profit organization. It is registered in Brussels, Belgium, and its Secretariat is in Warsaw, Poland. (IREG, n.d.)

**Berlin Principles** - It is a framework developed by IREG for the evaluation of ranking systems.

**Machine Learning** - This term was coined by Arthur Samuel, a computer scientist at IBM and a pioneer in AI and computer gaming. Samuel designed a computer program for playing checkers. The more the program played, the more it learned from experience, using algorithms to make predictions.

**Document Similarity** - Document similarity (or distance between documents) is one of the central themes in information retrieval. How do humans usually determine when documents are similar? Usually, documents are treated as similar if they are semantically close and describe similar concepts.

**Artificial Intelligence** - The ability of a digital computer or computer-controlled robot to perform tasks is commonly associated with intelligent beings.

**Climate Classification** - Formalising systems that recognise, clarify, and simplify climatic similarities and differences between geographic areas enhances the scientific understanding of climates.

**Location Intelligence** - It is the methodology of deriving insights from location data to answer spatial questions. It goes beyond simple data visualisation on maps to analysing location data as an integral part of a business or societal problem.

**Goal Programming** - It is a branch of multiobjective optimisation, which is a branch of multicriteria decision analysis. It can be considered an extension or generalisation of linear programming to handle multiple, usually conflicting, objective measures.

# Abbreviations

|                   |                                                                                                    |
|-------------------|----------------------------------------------------------------------------------------------------|
| <b>ARWU</b>       | Academic Ranking of World Universities                                                             |
| <b>ACC</b>        | Accuracy                                                                                           |
| <b>AASHE</b>      | Association for the Progression of Sustainability in Higher Education                              |
| <b>AI</b>         | Artificial Intelligence                                                                            |
| <b>AAT</b>        | Average Annual Temperature                                                                         |
| <b>BPs</b>        | Berlin Principles                                                                                  |
| <b>ESD</b>        | Environmental Sustainable Development                                                              |
| <b>ESDGs</b>      | Environmentally Sustainable Developments Goals                                                     |
| <b>ESHEIRS</b>    | Environmental Sustainability Higher Education Institutions Ranking System                          |
| <b>FSSD</b>       | Framework for Strategic Sustainability Development                                                 |
| <b>GRI</b>        | Global Report Initiative                                                                           |
| <b>HEI</b>        | Higher Education Institution                                                                       |
| <b>HEIRS</b>      | Higher Education Institutions Ranking Systems                                                      |
| <b>ISCN</b>       | International Sustainable Campus Network                                                           |
| <b>KG</b>         | Köppen-Geiger                                                                                      |
| <b>ML</b>         | Machine Learning                                                                                   |
| <b>NLP</b>        | Natural Language processing                                                                        |
| <b>PRISMA</b>     | Preferred Reporting Items for Systematic Reviews and Meta-Analyses                                 |
| <b>QS</b>         | Quacquarelli Symonds                                                                               |
| <b>SAT</b>        | sustainability assessment tools                                                                    |
| <b>SD</b>         | Sustainable Development                                                                            |
| <b>STARS</b>      | Sustainability Tracking and Assessment Rating System                                               |
| <b>SDGs</b>       | Sustainable Development Goals                                                                      |
| <b>TBL</b>        | Triple Bottom Line                                                                                 |
| <b>THEUIR</b>     | Times Higher Education University Impact Rankings                                                  |
| <b>UoBESHEIRS</b> | University of Bahrain Environmental Sustainability Higher Education<br>Institutions Ranking System |
| <b>UIGM</b>       | University of Indonesia GreenMetric                                                                |

# **Chapter 1**

## **Introduction to the Study**

Sustainability is an essential concept in today's world, It focuses on preserving resources, protecting the environment, and finding ways to reduce the amount of waste and consumption. In particular, it addresses the need for people to be mindful of their actions and decisions' impacts on the environment and how to minimize those impacts. Sustainability involves many aspects, such as renewable energy, minimizing waste and pollution, and conserving resources. Understanding that sustainable development is more than just finding ways to reduce our negative environmental impact. It is also about creating a balanced relationship between humans, the environment, and the economy (UCLA-Sustainability-Charter, n.d., (p. 2)).

Environmental, social, and economic sustainability are the three main pillars of sustainability. Giving people what they want without compromising life quality and lowering the financial burden of doing morally are two examples of economic sustainability. Social sustainability, on the other hand, involves maintaining access to necessary natural resources without sacrificing the quality of life while also being aware of and legally protecting human health from pollution and hazardous business and organization activities. The main topics of the third sustainability pillar, the environment, are energy, water, waste, biodiversity, ecosystems preservation and using technology to promote a greener future (Khan et al., 2022).

Sustainable Development (SD) is the development of the sustainability in those pillars to meet the Sustainable Development Goals (SDGs). SDGs were born during the United Nations Conference on SD, Rio+20. SDGs are a set of universal goals that meet the urgent environmental, political, and economic challenges facing the globe. The SDGs are unique in that they cover issues that affect people and reaffirm international commitment to end poverty, permanently, everywhere. SDGs involve us all (government, civil society, and citizen) to build a more sustainable, safer, more prosperous planet for all humanity (SDG, 2015).

One important part of the SDGs is the Environmental Sustainable Development (ESD). It is crucial to protect resources like clean air, water, and wildlife for future generations. With the evolution of the SD, there are many nouns being attached to the word “sustainable”. For example, sustainable education, sustainable manufacturing, sustainable organization, sustainable school, sustainable university, and more. In higher education, sustainable universities play a crucial role in sustainable development by establishing innovative new practices, occupying a prominent societal position, and educating the next generation.

On the other hand, ranking systems became a standard feature in the higher education field. Nowadays, more institutions participate in these ranking systems. The university ranking systems originated in the 1970s, when social scientists began to gain an interest in the methods and value of ranking higher education institutions (Wilbers & Brankovic, 2021). In 2004, the QS rankings were released, in collaboration with THE, and were referred to as the THE-QS World University Rankings, where both had made SDGs adoption ranking for universities. University rankings got to be common in the 1980s, when entire countries and continents started using several indicators, such as academic reputation (usually based on subjective, peer-reviewed surveys), admission selections, and academic output and financial resources, to reflect and rank the quality of education providers (Insider Guides, 2023). In 2003, the Academic Ranking of World Universities (ARWU) was the first to start benchmarking ‘world-class universities’ and evaluated universities on their research performance. Regarding “ranking” the ranking systems, International Ranking Expert Group (IREG) published and set of well-defined lists of targets and indicators to rank and assess the ranking systems. The set of targets and indicators are the so-called Berlin Principles (BPs). Once a ranking system passes the BPs assessment, it will have the right to use the “IREG Approved” label.

The environmental pillar of the Triple Bottom Line (TBL), the ESD, includes environmental issues-related laws, regulations, and other policy frameworks. These concerns include preserving biodiversity, conserving natural resources, wildlife, and threatened and endangered species, air and water pollution, solid waste management, ecosystem management, and solid waste disposal. This will encourage HEIs to

improve the quality of the air and water by lowering greenhouse gas emissions and reducing consumption of waste.

The Environment pillar has a direct relation and effect on the climate. Sustainable development, in turn, depends on maintaining environmental quality. Since climate change impedes development and sustainable development is essential to building skills for mitigation and adaptation, there is a connection between the two. In developing nations, greenhouse gas emissions like CO<sub>2</sub> worsen the effects of climate change and global warming. Reducing CO<sub>2</sub> emissions can be accomplished by using innovative technology and increasing the usage of renewable energy sources. The Planning for adaptation to climatic change should identify populations or sectors at risk, provide the essential environmental management actions or tools for the public to adapt, and examine possibilities to build resilience. One environmental management tool is Environmental Sustainability Higher Education Institutions Ranking Systems (ESHEIRSs).

ESHEIRSs assess the environmental sustainability of HEIs. In the upcoming chapter, different ranking systems will be reviewed to find to what extent they support environmentally sustainable practices within universities and reflect the local and unique conditions. The following chapters includes whether the current ESHEIRSs support environment-related aspects like weather, geographical aspects, vegetation/ climate classification, etc. The challenges, limitations, and advantages of the current HEI ranking systems, and to what extent are these ranking systems aligned to the BPs. The support of Artificial Intelligence (AI) and Machine Learning (ML) of the development of a new ESHEIRS. And the development of a customised ranking methodology based on the climate class of the specific HEI's country of residence.

## **1.1 Research problem**

HEIs' assessment methods have two main categories in performance indicator classification. The first group (A) focuses on the progress toward research, education, and services, such as Quacquarelli Symonds World University Ranking (QS) and THE ranking. Instead, the second group (B) focuses on research, education, and the environment, such as University of Indonesia GreenMetric (UIGM), Times Higher

Education University Impact Rankings (THEUIR), and Green Report Card. Group (B) mainly considers water, energy, climate change, waste, transportation, education, and research in their assessments. However, to a certain extent, current ESHEIRSs do not customize their methodology, calculations, and equations based on the climate classification category of the country of a specific university. As an example, UIGM view the ranking results based on climate class, but they don't use different methodology for each climate class. This gap has significant implications for that university's ranking; for example, arid areas will use more electric power than tropical regions, but both are treated and assessed using the same criteria as all ESHEIRSs. But why using the same ESHEIRS for all HEIs is a problem?

Let us consider Energy as an example of a specific HEI located in a particular area with temperate and mild weather, where the temperature fluctuates between 23 °C, 25 °C, and 28 °C, that is, within an acceptable range. They use natural ventilation most of the time; there is little energy usage, limited to energy-efficient appliances or lighting (i.e., air conditions or heating appliances are likely not used). On the other hand, there are universities located in a specific hard or harsh climate and depend heavily on cooling to maintain the air quality inside the building. Therefore, using the same criteria for both scenarios is not fair. This is only one example that can also be considered valid for natural water availability and consumption, a method of transportation, etc.

Furthermore, HEIRS indicators weights setting methods are primarily subjective and set by experts. Automating the weights setting method process may positively impact the process and support setting objective weights rather than human-based decisions. To decide upon the weights of the indicators using ML, AI may help. AI will help eliminate the interference of HEIs in ranking; they provide information that helps them only, such as a QS contact list, without data cleansing or validation. Machine Learning, data mining, and statistics support the implementation of AI in the weight-setting methods in the application of the recommendation system.

## 1.2 Research Questions

In this research, the aim is to develop a new ranking system for universities by exploring the following questions:

1. What are the challenges, limitations, and advantages of the current HEI ranking systems, and to what extent are these ranking systems aligned to the BPs?
2. How can AI and ML support the development of a new environmentally oriented ranking system?
3. How to develop a customised ranking methodology based on the climate class of the specific HEI's country of residence?

The author sets the research objectives after identifying the research questions. The research objectives are in the coming section.

## 1.3 Research Objectives

The objective of this research is to develop a system capable of ranking HEIs based on their performance in ESD and environmental sustainability using different ranking methodologies, according to the climate class of the country of residence for the HEI, and to automate the ranking system by leveraging AI and ML tools, aligned to the BPs, and adaptable to the overall universities performance.

In detail, the research objectives are as follows:

- Identify the challenges, limitations and advantages of the current ESHEIRS by assessing current ESHEIRSs using the BPs.
- Assess current ESHEIRSs using AI and ML techniques.
- Identify the limitations of current ESHEIRSs.
- Develop a new ESHEIRS using AI and ML attempting to solve some of the limitations of current ESHEIRSs.
- Apply mathematics and AI to the new ESHEIRS.
- Customise the methodology based on the HEI's climate class.

Stating the research objectives and meeting them could enhance the research importance. The following section points out the significance of the research.

## 1.4 Research Significance

There is a need to identify and establish indicators relevant to the regional and societal context of the HEIs in different regions and customize them based on the climate class of the HEI's country of origin. These indicators and the method measure will lead to long-term monitoring of climate change and its effects on the environment over time, which would help HEIs achieve similar goals and scalable success strategies and practices (Sonetti et al., 2016).

External and internal factors, such as a campus's institutional, social, and environmental characteristics, provide scope for developing targeted and sustainable strategies for various parameters, which can expand the scale of SD in HEIs (Washington-Ottombre & Bigalke, 2018).

Universities are in the business of educating students, so they must be focused on providing a quality learning experience and ensuring that students succeed academically. Universities must be able to demonstrate that they are providing a return on investment for students by helping them to secure meaningful employment opportunities after graduation. As such, universities must remain attentive to their core customers—the students—to maintain their success. Students are the main clients of universities and HEIs. They have a variety of primary needs on the campus. Water availability for example, is essential, as the students need to use it for drinking, washing, and much more. Also, universities and HEIs must ensure a healthy environment, free of toxic waste, which affects students' lives negatively. Other secondary, but important, needs for students at the campus are:

1. Creating a new generation concerned with sustainability by providing education sources and enhancing research.
2. Energy consumption and climate action.
3. Creating more space for green outdoor spaces to live in the fresh air.
4. Providing smart on campus transportation to move quickly between campus buildings, especially in the “hot” summer and “cold” winter.

In addition, an environmentally sustainable university will encourage national and international collaborations and provide research grants in this area.

This will help to design a sustainable framework and assess the HEIs progress besides education and research (Wals, 2014). Generally, HEIs need a customisable ranking methodology depending on the area's environmental characteristics and

climate class. It is necessary to overcome some of the current ESHEIRSs' limitations and map ESHEIRSs to SDGs using manual and automated methods. Furthermore, the assessment of current ESHEIRSs using the BPs and the application of AI and ML to the ranking process are key.

To fulfill the research objectives, the researcher used certain computer applications and many supported tools in setting the study requirements. The following section describes the study setting.

## **1.5 The Study's Setting**

To evaluate the ESHEIRSs and determine their efficiency in measuring environmental sustainability, the following points were considered:

1. Natural language processing (NLP) techniques allowed to classify the ESHEIRSs' indicators to the SDGs' indicators. This study make use of the query expansion technique to make the NLP techniques more effective. It utilizes document similarity to identify the correlation between each set of corpus documents. Different similarity measures were employed in order to discover the likeness between the forms.
2. The required setting included a group of experts who manually map the ESHEIRSs' indicators to the SDGs' indicators.
3. The researcher used a voting system to map the ESHEIRSs' indicators to the SDGs.

To review the limitations of current ESHEIRSs, this study evaluated one of these environmental factors, the AAT, and its impact on the ranking of universities. The author collected data from the overall university scores of 2020 ranking for two ESHEIRSs (UIGM and THEUIR) and the AAT values for countries hosting these universities. The researcher used the linear regression technique and residual plot to determine the relationships between AAT and university ranking scores.

The development of the new ESHEIRS required many settings, such as the revision of one of the climate classification system. The climate classification systems are either qualitative or quantitative. The latest quantitative climate classification system is the Köppen-Geiger climate classification system. This system will be considered for this study, the climate change map of the Köppen-Geiger climate classification system is

in Figure 1 with classes and subclasses and their changing distribution around the globe.

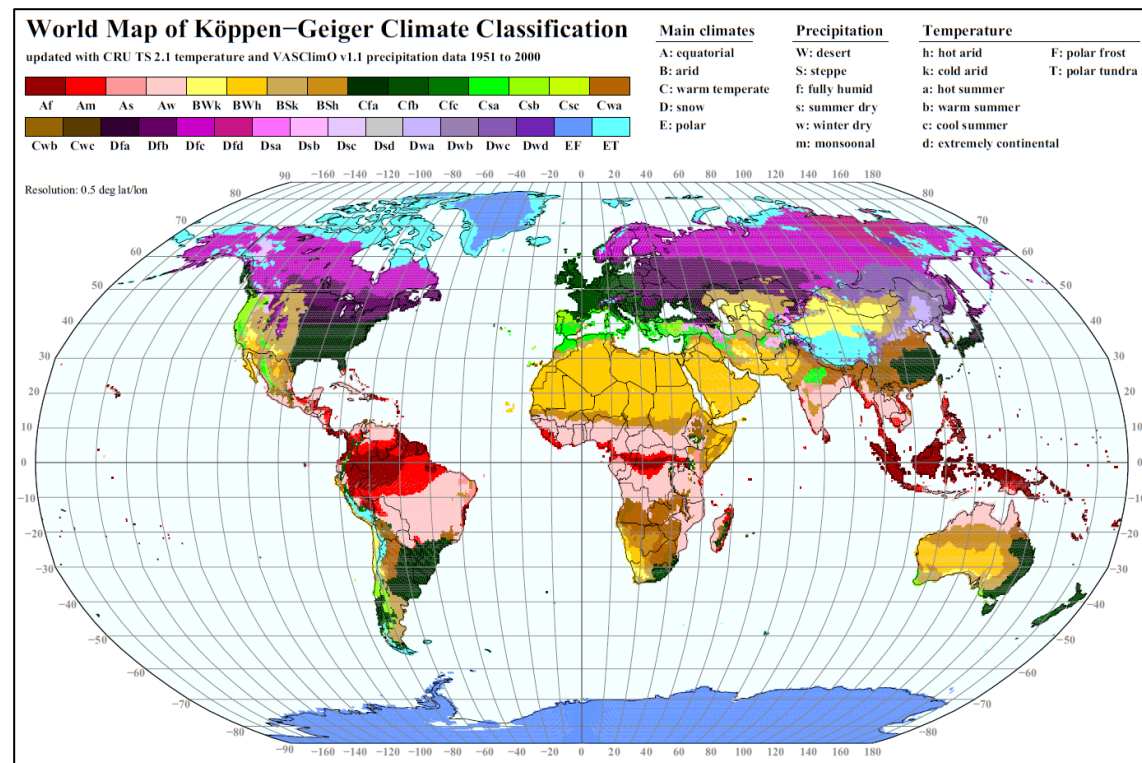


**Figure 1** The updated Köppen–Geiger climate classification published by Kottke et al. (2006), Rubel and Kottke (2010) and Rubel et al. (2017).

In this part of the study, multicriteria goal programming model was used to set the weights of the ESHEIRS's indicators. In addition to this mathematical approach. Then, AI techniques was applied on the model automatically set the weights of the indicators, instead of actual experts. Then, the results were analyzed by statistical methods and tests. R studio and Python programming language were used to run and test our approach.

The setting of the new ESHEIRS's web hosting process included Web hosting techniques (e.g., Google Cloud), website development tools (e.g, Bootstrap), and images editing applications (e.g., Pixlr X).

HEIRSs and ESHEIRSs were reviewed, then manually assessment of ESHEIRSs using the BPs were conducted. The consideration of ESHEIRSs integrated with AI and ML techniques to explore the possibility of automating the process of ranking universities and of using the multicriteria goal programming model. The

findings derived the characterisation and methodology of the new proposed ranking system. Finally, the work set environmental sustainability indicators that are compatible with each main class (i.e., A, B, C, D, and E) of the KG climate classification system.

The next chapter is systematic review. An executive summary follows the systematic review summarizing the most important publications considered in the study at later stages. Next, benefits from previous studies and how they affect and enrich the entire work were clarify stated.

## **Chapter 2 Theoretical Framework and Literature Review**

### **2.1 Systematic Review**

Despite implementing and subscribing to the 2030 Program and its SDGs, public sector organisations, notably HEIs, have faced increased quantities of accountability. HEIs are supposed to guide diverse stakeholders on this topic and execute this agenda and the SDGs at respective organizations. Even though such organisations' functions have been acknowledged, the disciplines and concerns HEIs must handle along the journey to sustainability and SD remain unknown. A comprehensive assessment of the sustainability performance indices for HEIs was carried out to determine the essential ideas and primary study subjects that reflect sustainability and SD in HEIs and guide future investigation. The review provides a comprehensive understanding of how environmental sustainability and SD can be integrated into higher education institutions. Furthermore, the review examines ranking indicators weights setting methods, as well as the potential usage of AI and ML in the setting of indicators. It also examines the relationship between the ranking method and the climate parameters of the originating country.

#### **2.1.1 Introduction**

The use of ranking systems in higher education has become commonplace, to better account for the different perspectives and needs of all stakeholders. This approach is designed to ensure that everyone's viewpoint is taken into consideration, as well as the collective viewpoint of the group as a whole. Through this method, the ranking system aims to be more comprehensive and efficient in meeting all the requirements of all involved. Periodically, current rating systems are developed by various agencies on both the national and international stages, and HEIs begin participating in these rankings. A few rankings, like those established by QS and Times Higher Education (THE), place importance on the excellence of education and research. On the contrary, many ranking schemes, including the UIGM ranking, emphasise the environmental implications of HEIs. THEUIR, also concentrated on long-term

advancement. It was based primarily on the United Nations' SDGs, which also encompass the TBL components, climate, and culture as part of the 2030 Agenda for SD. The United Nations established these goals in 2015, and almost every one of the 17 SDGs is connected to academic achievement (Buzaboon et al., 2020).

HEIs would play an essential role in accomplishing the SDGs by teaching the next generation the abilities and information required to comprehend and respond to sustainability's obstacles and opportunities and by conducting experiments that enhance the action plan for ESD. HEIs also may act as a model by influencing stakeholders to embrace and model more excellent environmentally responsible practices by leveraging their knowledge, skills, and management. The SDGs are a crucial mechanism for integrating sustainable marketing strategies; judgement call approaches and practices into university operations, as well as for strengthening accountability to various stakeholders (Mori et al., Fien, & Horne, 2019a). Added pressure is being put on universities to maintain their relevance and sustainability in the face of changing industrial trends, disruptive technologies, budgetary constraints, and alterations in socioeconomic environments. In order to accomplish this goal, educational institutions such as academic institutions need to comprehend the local, national, and international settings wherein organizations function and exert impact. Ranking systems for universities are employed for marketing goals, quality assurance, and as a method for democratic oversight (Thakur, 2007). Nevertheless, rankings are neither capable of assuring institutions' excellence nor ensuring that institutions will continue to exist in the future, as there is no universal agreement on what constitutes excellence in higher education (Thakur, 2007).

HEIs have got begun to monitor and statement on overall performance toward meeting respective SD objectives (Gamage & Sciulli, 2017). To assist HEIs in this attempt, a growing range of sustainability assessment tools have indeed been created (Bullock & Wilder, 2016). In the broader context, sustainability assessment tools offer HEIs with an organized set of processes and techniques for measuring, auditing, benchmarking, and communicating respective SD efforts (Gilbert, 2011), including financial, environmental, societal, and interlinking concerns across the HEI approach. The concept of these sustainability assessment tools and the experience of HEIs that have used one another, and their shortcomings have indeed been recorded in (Berzosa et al., 2017). Studies indicate that

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the most extensively used sustainability assessment tools have primarily concentrated on policies and actions taken within the company, including measures to conserve energy or improve students' sustainability literacy in educational programmes (Fischer et al., 2015a). Insufficient attention has indeed been put on the external implications of HEIs on the community, the natural habitat, and the economics, such as contributions to the mitigation of environment shift (Vaughter et al., 2013). Impact evaluation on SD is complicated since consequences manifest through multiple channels, notably investigation and training (Koehn & Uitto, 2014). Because HEIs are frequently detached in time and place from such effects and impacted stakeholder companies, they depend on proper tools to back up their evaluation methodologies.

Furthermore, there is currently no commonly accepted meaning of "impact of HEIs" in the literature or practice. Nevertheless, published research agrees on several critical aspects of the word. HEIs are fundamental to improving community development and sustainability. HEIs have an impact that reaches far beyond the campuses, and the effects can be both direct and indirect (Lebeau & Cochrane, 2015). Regarding the direct Consequences, one of the most direct consequences of an HEI on the community is the development of the local economy. The presence of an HEI usually brings more jobs and businesses to the area and increases research funding. This can lead to more significant business growth, higher salaries, and increased investment in the area. HEIs also provide opportunities for the community, such as better educational opportunities and access to health services. They also offer cultural and recreational activities that benefit students and the community. By providing educational opportunities, increasing investment, and creating networks, HEIs can help promote sustainable community development. They emerge from several activities within the fundamental pillars of HEIs, most notably education, investigation, campus administration, marketing, and campus experiences (Gupta et al., 2017).

On the other hand, HEIs can have indirect effects on the community as well. For example, they can provide fresh ideas and new perspectives. The presence of an HEI often encourages the development of new ideas and initiatives, which can positively affect the local economy, culture, and environment. HEIs can also help to build networks between the local community and the outside world. The presence of an HEI can help people become more aware of global issues and provide a platform for international collaboration and exchange. Over the recent decade, there has been a greater focus on the consequences of SD between

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participants such as community and private donors, policymakers, accrediting organisations, students, and staff. The indicators that evaluate the consequences of SD are then evaluated to determine whether the targeted SD consequence influence regions. Ultimately, the degree to which these indicators can represent the complicated routes from HEI activities to particular SD outcomes is investigated, i.e., if they can represent both indirect and direct effects (Bonaccorsi et al., 2010).

Earth's surface was examined using AI-based techniques which revealed the strongest indication of SD impact. ML methods were utilized to confirm this. (Efremova et al., 2019) suggested and highly recommend further research on an AI-based infrastructure to evaluate SDG solutions and how AI could be more effectively used in the future. In addition, university ranking systems are often used to measure HEIs' quality and its educational offerings. So, assessing the methodology of such ranking systems is essential to ensure that accurate results are produced. This evaluation should include assessing the data sources used for the rankings, the weight given to each data source, and the criteria used to determine the rankings. Additionally, it is essential to consider the impact of potential biases or limitations in the methodology and any potential benefits or drawbacks of using the ranking system. This evaluation of the methodology will help to ensure that the rankings produced accurately represent the university's quality. IREG published their BPs and are being used to assess the ranking systems methodology through set of weighted targets and indicators.

Higher education institutions use rankings to measure the quality of their programs, assess the performance of their faculty and staff, and compare their institutions to their peers. Science and mathematics can support higher education institutions' ranking systems. For example, mathematics can be used to develop algorithms to determine an institution's rankings. These algorithms can incorporate data from multiple sources, such as student performance, faculty research, and external reviews, in order to calculate an institution's ranking. Mathematical optimization techniques would be supportive in the HEIs assessment. Goal programming is a mathematical optimization technique that can optimize decisions in which multiple objectives must be balanced. It is often used in ranking systems by setting weights for each goal or objective and then finding a combination of those weights to maximize the overall ranking system performance. By setting the weights for each goal, goal programming provides a way to customize the ranking system to fit the specific situation and to prioritize objectives over others.

Thus, the study aims to develop a new ranking system to address the shortcomings of existing systems. The development includes exploring the HEIRSs and ESHEIRSs and using BPs to score the ESHEIRS manually, additionally, automating university ranking using AL and ML and setting ranking indicators weights using goal programming.

### 2.1.2 Method

**Study design:** The present study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Liberati et al., 2009).

**Search strategy:** Specific keywords were included and linked using the Boolean search to maximize the search sensitivity: “Sustainability” OR “Sustainable” OR “Sustainable development” OR “University Sustainable development” AND “Universities Higher education” AND “Higher education institution” AND “Environmental sustainability” AND “Artificial intelligence” AND “climate parameters” AND “Machine learning” AND “performance” AND “ranking” AND “index.”

**Source electronic database:** Multiple databases were selected to identify the relevant published literature. This includes PubMed, ScienceDirect, Scopus, MEDLINE Complete, CINAHL Complete, and EMBASE.

**Time frame:** For each dataset, papers in English published between 2006 and 2022 were searched using specific keywords.

### 2.1.3 Results

The search of the relevant literature resulted in the discovery of 16,700 publications from a wide range of databases such as PubMed, Science Direct, and Google Scholar. The inclusion criteria are to include the articles with the titles that are directly related to the keywords. Initially, 15,900 of these were disregarded owing to the presence of redundant information or lack of relevance. The inclusion criteria here is the abstract of the research has to be related to the keywords. After evaluating the titles and abstracts of the articles, a total of 704 were removed from the 800 as they were irrelevant. A total of 96 publications that had a chance of being relevant were chosen for full-text reviews, however 64 of those articles were ultimately excluded for several reasons first of all, the research they described did not fulfil the requirements for inclusion specially after considering the research papers’ methodologies and results they do Not support the topic of the review. In the end, this study included a total

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of 32 research studies since those studies satisfied the selection criteria outlined in Figure 2 which demonstrate the PRISMA flow chart followed in the review.

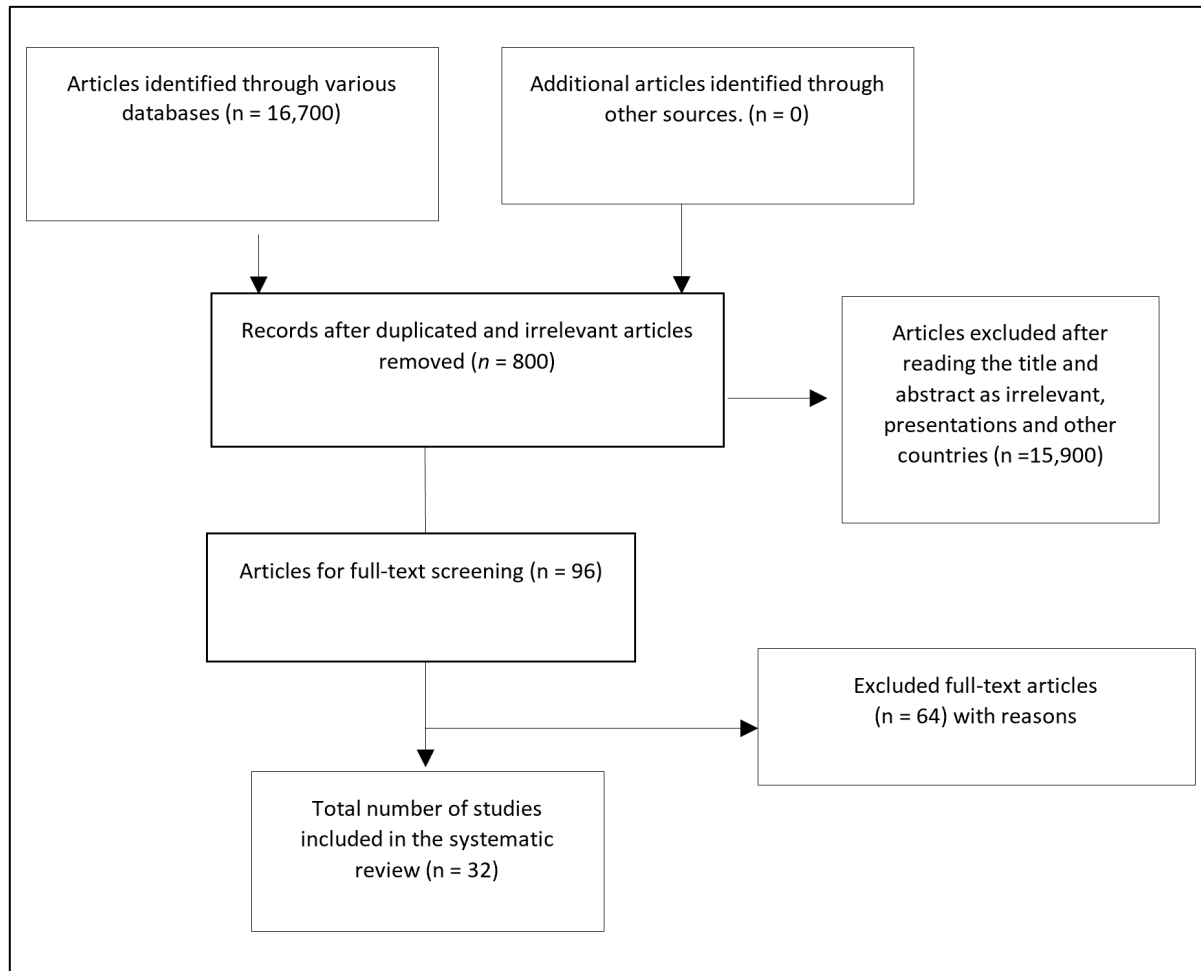


**Figure 2 PRISMA Flow chart**

Most studies were published on sustainability, Environmental Education Research, and Higher Education. Considering the regional context, the majority of papers targeted HEIs in Porto, Portugal, Kenya, Regional (Chile), JAPAN, Netherlands, US, Amsterdam, United Kingdom, Cambridge, Indonesia, Brazil/for Global Universities, Switzerland, Philadelphia, Nigeria, Canada, Mexico, Spain, Slovenia, Czech Republic, Indonesia and Saudi Arabia.

Previous studies (Awuzie & Abuzeinab, 2019; Barth, 2013) have explored budgeting and SD (sustainable development) implementations in higher education institutions (HEIs).

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Barth (2013) revealed the barriers that can be encountered when introducing changes to a particular HEI to promote SD. Awuzie and Abuzeinab (2019) identified the main motivations and obstacles connected to the initiation and development of programs. Research has also discussed the potential for HEI administration to take a “top-down” or “dispersed” management approach. Blanco-Portela et al. (2017) used interpretive structural modeling (ISM) to examine the relationship between various organisational characteristics and SD adoption in HEIs. Godemann et al. (2014) sought to study the incentives and impediments to organisational transformation for sustainability in HEIs and businesses, noting that further research is needed. Huge et al. (2018) explored the power of responsibility and stakeholder involvement in creating SD transformation, calling for further study on the influence of these. Hoover and Harder (2015) investigated the organisational and relational mechanisms that influenced organisational SD transformation in HEIs. Lastly, Leal Filho et al. (2017) used the social justice issue maturity framework to analyse shifts in technical HEIs to understand better the processes promoting sustainability.

Further studies on the situational interpretation of sustainability, in addition to methods to detect and resolve theoretically highly disputed interested players, were proposed by researchers. Lozano and von Haartman (2018) identified and assessed the significant barriers to adopting SD at HEIs, recommending more studies to determine people's views of every barrier, calculate related implications, and find and verify solutions to address specific barriers. These researchers added more details concerning difficulties in public and private HEIs to distinguish their distinctions. Veiga Avila et al. (2019) examined the relevance of sustainable sources in three kinds of organisations (businesses, civil society, and government agencies), highlighting the significance of every factor, rating the variables, and examining the relationships among them to classify each one. Researchers also evaluated category linkages and advised that each kind of organisation determine these essential factors and the impact these have on business to boost sustainability. Additional research has been requested to find firms that are less involved in sustainability, determine underlying factors, and investigate the causes of impacts on SD transformation. According to the researchers, studies must learn how obstacles impact SD and how significant these factors are in all types of businesses.

On the other hand, the literature review highlighted a need for additional investigation of government entities. For example, Blanco-Portela et al. (2018) conducted a comparative

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study by continents to determine and evaluate hurdles to sustainability practices at HEIs, recommending that additional in-depth research on obstacles to innovation and sustainability was required. Such studies would have to consider the investment in development and sustainability, its organisation's lifespan, the kind of HEI (private versus public), and the purpose or lack thereof to meet the SDGs. Lastly, the participation of HEIs from various locations and the portrayal of initiatives established to fulfil the SDGs via entrepreneurship have been promoted.

In terms of sustainability related concepts, sustainable procurement is a concept that has recently become popular in the business world. It involves making decisions about purchasing goods and services that consider sustainability factors such as environmental, social, and economic impacts. Sustainable procurement is a way to ensure that businesses are protecting the environment and their long-term interests by sourcing goods and services from responsible suppliers. It also enables businesses to meet their goals of reducing the environmental impact of their operations, as well as ensuring that those supplying the goods and services have fair working conditions and a living wage. Sustainable procurement is essential in creating a more sustainable and responsible business. Bauer et al. (2018) found a discrepancy across policy and practice in sustainable procurement after surveying drivers and impediments. These researchers recommended further detailed discussions and case studies to supplement this study. (Casarejos et al., 2017; Dyer et al., 2017; Horan et al., 2019) delivered domination and management in HEI sustainability. Dyer and Dyer (2017) developed the empirical "governing equaliser" methodology from leadership literature to find activities, tools, and approaches that enhance SD in HEIs (i.e., to analyse sustainability governance in HEIs). The professional interview might confirm the "administration equaliser," while criterion development is a field that should disclose whether characteristics are used in practice.

In addition, management effectiveness and strategic planning can help to conserve HEIs long-term sustainability. Horan et al. (2019) conducted a research study on the effectiveness of management in helping to conserve HEI, as well as a framework for strategic sustainability planning. In this study, the Framework for Strategic Sustainability Development (FSSD), was conducted using a qualitative approach, examining both quantitative and qualitative data. The results of the study showed that effective management is essential for the conservation of HEIs. The research proposed several strategies that should

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be employed to ensure that the sustainability of HEIs is maintained. These strategies included initiatives such as integrating sustainability into an HEI's curriculum and research, promoting sustainable practices, and implementing an effective governance system. The research concluded that the FSSD could provide a valuable framework for conserving HEIs. Furthermore, the researchers suggested that further research should be undertaken to understand how such a framework could be implemented in practice. In addition, Casarejos et al. (2017) proposed using an integrative view, "Higher Education Advancing Progression for Sustainability" (HEADS), to assess the academic sector's contribution to the nationwide conservation transition process more towards a reduced culture and, quite remarkably, in photovoltaic solar speciality advancement.

The rankings of universities have evolved into a phenomenon that is seen all around the world over course of the last generations. In 2010, Universitas Indonesia launched an online world university ranking with the goal of providing a representation of the current conditions and procedures regarding green campuses and sustainable development in universities. Specifically, the ranking directed to accept a depiction of the Indonesian universities. The UIGM ranking system is a tool used to assess whether certain specifications are followed and how efficiently they are executed. The climate change and energy criteria is the most prevalent standard that several educational institutions have reached (about 2500 of 2800 maximum score). The BPs are adhered to by the vast majority of the indicators that are included in UIGM. The UIGM rating gives every university the opportunity to evaluate the areas in which they excel and where they need improvement in their efforts to promote green universities and environmental sustainability. The UIGM ranking system will progress in response to more suggestions as well as good feedback from the colleges who are participating (Suwartha & Sari, 2013a).

Sustainability assessment tools are becoming increasingly important for universities due to the rising awareness of environmental degradation. Universities need to be able to assess their environmental impact and show they are committed to ESD. One such example is the Sustainability Assessment Tool (SAT). SAT is a comprehensive tool designed to assess a university's sustainability in four key areas: energy, water, waste, and transport. This tool was developed by the Australian National University and is widely used by universities in Australia and New Zealand (Bullock & Wilder 2016). The tool is divided into three sections: baseline, performance, and potential. The baseline section provides an initial assessment of a

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university's current environmental performance. The potential section outlines the potential improvements that could be made in each of the four key areas. The performance section provides feedback on the university's current performance and identifies areas that need improvement. This data is used to create an overall sustainability score, which can then be compared across universities to identify best practices. The SAT is a powerful tool for universities to demonstrate their commitment to sustainability. It can also be used to identify areas for improvement and develop strategies to reduce the university's environmental footprint. By using the SAT, universities can work towards a future of environmental sustainability. Bullock and Wilder (2016) examined 12 sustainability assessment tools. Bersosa (2017) instead tried implementing the SAT content and indicators in a particular HEI to establish their breadth. Findler et al. (2018) assessed sustainability assessment tools validity using comprehensiveness. Urbanski & Filho (2015) examined whether sustainability assessment tools might evaluate HEI effects on SD. Fischer et al. (2015a) showed the dominance and marginalisation of HEI evaluation areas in the sustainability assessment tools, while de AraÚjo Goes and Magrini (2016) published sustainability assessment tools HEI data. These publications indicated that HEI sustainability progress is unmeasurable despite multiple sustainability assessment tools.

HEIs have been essential suppliers to sustainability initiatives for about 20 years. The United Nations gave more significance to HEIs and universities when they launched the SDGs on the 25<sup>th</sup> of September 2015. HEIs and industries are more alarmed by the Environmentally Sustainable Developments Goals (ESDGs), which are nine, as a part of the SDGs. These ESDGs are: Good Health and Well-Being (Goal 3), Quality Education (Goal 4), Clean Water and Sanitation (Goal 6), Affordable and Clean Energy (Goal 7), Industry, Innovation, and Infrastructure (Goal 9), Sustainable Cities and Communities (Goal 11), Climate Action (Goal 13), Life below Water (Goal 14), Life on Land (Goal 15) (Hamzah & Alnaser, 2018).

Universities partially took initiatives toward sustainability with more focus on the environmental side, rather than on the TBL elements (Najafian and Karamidehkordi, 2018). However, sustainable practices are neither systematic nor comprehensive, but also slow rate of progress is achieved due to the lack of top-level management support, the resistance to change, and the lack of sustainability knowledge in universities (Jorge et al ,2015 ; Parvez and Agrawal, 2019; Utama et al., 2018). University ranking systems such as QS, THE, and

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ARWU do not promote, clearly, sustainable practices in universities. Moreover, in some cases, they encourage unethical misconduct and promote quantity over quality and lack of professionalism while processing the data. Universities implemented some practices only to improve their position in these ranking tables (Mussard & James, 2018). The UIGM ranking system is not entirely compatible with the BPs and has critical lacks. However, the UIGM can form a base to build a more scientific and strict method to plan suitable sustainability policies (Ragazzi & Ghidini, 2017). Central HEIs' stakeholders have general knowledge about sustainability. Still, they are unfamiliar with HEIs' sustainability (Sepasi et al., 2019). The system presented in this research aims to bridge this gap by spreading the culture of sustainability in HEIs and weaving sustainable practices into academic practices with more focus on collaboration and partnership, which is an essential element in SDGs. However, financial funding remains the main factor affecting sustainability, and new financial resources must be incorporated for more relevant and sustainable universities.

Generally, League tables are designed to simplify and quantify the work of educational institutions into a single, comparable number. This comparison process consists of three steps: collecting data on certain indicators, scoring the data of each indicator, and cumulatively weighting and combining the scores. The number of indicators used in a ranking system may greatly differ, ranging from five (e.g. Times Higher Education) to as many as dozens (e.g. La Repubblica or Wuhan). Specific areas of institutional activity or types of institutional output can therefore be compared across institutions in much the same manner as with performance indicators.

While it is true that the choice of indicators and the weight given to each indicator can drastically change the final output, it is important to remember that the indicators chosen do not necessarily dictate the "best" institutions. Every ranking system will have its own criteria for what makes an institution "the best". As a result, it is important to recognize that each system is creating a subjective definition of "quality" when they decide which indicators and weightings to use. It is also important to remember that the choice of indicators and weightings should be tailored to the individual or group who will be making use of the data. In this way, the definition of "quality" can be adapted to best suit the needs of the individual or group. In terms of the focus of their targets, there are two distinct types of HEIRS, Groups A and B, both focus on higher education institutions ranking systems. Group A focuses on Education, Research, and Services, while Group B is focused on Education, Research, and

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Environment. Group A's ranking system is centered around Education, emphasizing teaching quality, faculty, and student resources. Research is also highly regarded, with research output being considered when assigning rankings. Lastly, student and alums services, library facilities, and technology infrastructure are also considered. Group B's ranking system is primarily focused on Education, with a focus on teaching quality and student resources, but also emphasizes research output and the environment. Environmental factors such as carbon footprint, sustainability, and energy efficiency are considered when assigning rankings. They also consider student and alums services, library facilities, and technology infrastructure. Overall, both Group A and Group B rank HEIs based on their criteria, with Group A focusing more on traditional academic metrics and Group B considering the environment. Table 1 shows the categories of HEIs ranking systems along with examples of ranking systems for each group.

**Table 1 Categories of HEI Ranking Systems and Examples**

| <b>Group A</b><br><b>Focus on Education, Research, and Services</b> | <b>Group B</b><br><b>Focus on Education, Research, and Environment</b>                                                                       |
|---------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| ARWU                                                                | National Wildlife Federation's State of the Campus Environment                                                                               |
| QS World University Ranking                                         | Self-Assessment Questionnaire (SAQ)                                                                                                          |
| THE                                                                 | Assessment Instrument for Sustainability in Higher Education (AISHE)                                                                         |
| Rankings of Universities in the United Kingdom                      | THEUIR                                                                                                                                       |
| National Institutional Ranking Framework                            | Environmental Workbook and Report                                                                                                            |
| CWTSLR                                                              | Greening Campuses                                                                                                                            |
| University Performance                                              | Campus Ecology                                                                                                                               |
| Faculty Scholarly Productivity Index                                | Environmental Performance Survey                                                                                                             |
| Swiss Quality Label for Further Education                           | Indicators Snapshot/Guide                                                                                                                    |
| Norrington Table                                                    | Grey Pinstripes with Green Ties                                                                                                              |
| Tom Perkins Table                                                   | Emergency medical systems self assessment                                                                                                    |
| University Compress                                                 | UNI-Metrics                                                                                                                                  |
| University Ranking by Academic Performance (URAP)                   | Global Reporting Initiative (GRI)                                                                                                            |
| US News & World Report's Best Global Universities Rankings          | GASU                                                                                                                                         |
| Webometrics                                                         | GREENS (developed by GBCI and NGO)                                                                                                           |
| Wuhan University                                                    | Sustainability Tracking, Assessment & Rating System (STARS) by Association for the Advancement of Sustainability in Higher Education (AASHE) |
| QS's Asian University Rankings                                      | The College Sustainability Report Card (Green Report Card)                                                                                   |
| THE Asia University Rankings                                        | UIGM                                                                                                                                         |
| BCUR by Shanghai Jiao Tong University                               | People & Planet University League                                                                                                            |

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| <b>Group A</b><br><b>Focus on Education, Research, and Services</b>                      | <b>Group B</b><br><b>Focus on Education, Research, and Environment</b> |
|------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Wu Shulman, published in the name of the Chinese Academy of Management Science (payment) | International Sustainable Campus Network (ISCN)                        |
| University Ranking by Academic Performance (URAP)                                        | Campus Score (Hajrasouliha, 2017)                                      |

Alghamdi, den Heijer, and de Jonge (2017) applied a desk study approach with quantitative and qualitative elements, including a review of research articles, academic books, network platforms, graduate theses, and websites for 12 SATs, including the UIGM. These tools can be categorized into management, academia, Environment, engagement, and innovation, all of which have similar criteria and indicators. Among the tools, environmental indicators are the most prevalent. Table 2 points out the strengths and weaknesses of selected ESHEIRSs.

**Table 2 Strengths and Weaknesses of Selected ESHEIRSs (Buzaboon et al, 2021)**

| <b>ESHEIRSs</b>                   | <b>Strength</b>                                                                                                                                                                                                  | <b>Weaknesses</b>                                                                                                                                                                                                                              |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UIGM                              | <ul style="list-style-type: none"> <li>Continuously improved based on user feedback.</li> <li>Significant diffusion.</li> <li>Comprehensive.</li> <li>Easy to consult.</li> <li>Excellent assistance.</li> </ul> | <ul style="list-style-type: none"> <li>The use of generic quantitative indicators does not support economic dimensions.</li> <li>Lack of social aspect.</li> <li>Lack of evaluation of urban morphology in terms of sustainability.</li> </ul> |
| People & Planet University League | <ul style="list-style-type: none"> <li>Emphasis on environmental policy.</li> <li>Bottom-up approach (developed and monitored by students).</li> </ul>                                                           | <ul style="list-style-type: none"> <li>UK-related.</li> <li>The questionnaire changes every year, making comparison studies difficult.</li> </ul>                                                                                              |
| ISCN                              | <ul style="list-style-type: none"> <li>Joined by top-tier universities.</li> <li>Provides a global forum to support university sustainability.</li> </ul>                                                        | <ul style="list-style-type: none"> <li>The report does not assure the agreed SCN/GULF. Sustainable Campus.</li> </ul>                                                                                                                          |
| Campus Score                      | <ul style="list-style-type: none"> <li>Evaluation of urban morphology and green aspects.</li> <li>Evaluation of the relationship between urban morphology and academic graduation time.</li> </ul>               | <ul style="list-style-type: none"> <li>USA-related..</li> <li>Not specific for sustainability issues.</li> <li>Difficult to find data.</li> </ul>                                                                                              |

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The following text will outline briefly the concept of some of the ESHEIRSs. It will provide a concise overview of them, highlighting the key points and ideas associated with them and will allow readers to gain a better understanding of ESHEIRSs and their associated ideas.

People & Planet is a ranking system that covers the following indicators: Policy and strategy, staff, environmental and management systems, ethical investment and banking, managing carbon, workers' rights, sustainable food, staff, student engagement, education for SD, energy sources, and waste (company, 2023). People & Planet takes 50% of its data from information made public on the university website and the other 50% from information published within the higher education statistics agency, estate management record, and another independent agency.

ISCN is a ranking system that allows the contributing HEIs to have membership under the requirements of building the following three principles: Buildings and their sustainability impacts; campus-wide planning and target settings; integration of research, teaching facilities, and outreach (Network, 2023). The member institutions are expected to meet the obligation specified in the charter: Fulfil the conditions of the three principles, set measurable targets under each of the three principles, produce annual reports that comply with the guidelines, and pay early fees. Any institution may apply for an ISCN Sustainable Campus Excellence Award. Winners are selected and receive the prize at the ISCN award ceremony that takes the place of the annual conference. ISCN offers three types of awards: Partnership for Progress, Cultural Change for Sustainability, and Whole Systems Approach. The candidate institutions must choose one of these three categories in their application.

The UIGM ranking has based its instruments on a broad philosophy encompassing the "three Es:" Environment, economics, and equity (Indonesia, 2023). Universities concerned with sustainability generally consider the UIGM's selected criteria essential. These include The university's size and zoning profile, whether urban, suburban, or rural; electricity consumption, because of its link to the carbon footprint; transportation; water usage; waste management; setting and infrastructure; energy and climate change; education and research. Beyond these indicators, the UIGM aims to understand how the university responds to sustainability issues through policies, actions, and communications. Scoring for each item is numeric, so the data can be treated statistically. The amount of universities taking part in the UIGM has grown considerably in the last decade. In 2010, only 95 universities from 35

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countries were involved. By 2014, this had increased to 360 universities from 65 countries. That number then rose to 516 universities from 65 countries in 2016, and then again to 619 universities from 75 countries in 2017. This drastic increase illustrates the success of the UIGM and its increasing popularity around the world.

Campus Score ranks the HEIs depending on the urban, green, live, and campus scores. Each has several indicators and is scored using an identified score. Campus Score includes urban morphology strategy, but it is only published research that has not yet been implemented because of data availability limitations (Hajrasouliha, 2017).

The College Sustainability Report Card assesses environmental sustainability efforts at 322 United States and Canadian schools (Institute, 2023). It employs three surveys to gather information about sustainability in campus operations, campus survey covering the Administration, Climate Change & Energy, Green Building, and Transportation categories; a dining services survey covering the Food & Recycling category; and an endowment survey covering the Endowment Transparency, Investment Priorities, and Shareholder Engagement categories. The research process includes sending surveys to administrators and students at all 322 institutes. Researchers also collect information from publicly available sources. This ranking calculates a school's overall grade from the grades received in nine equally weighted groups. The system uses 52 indicators to evaluate presentation within the groups.

GREENSHIP is a rating tool containing a series of aspects for assessment ((GSF), 2023). Each group has criteria that hold a specific value (credit point). The rating tools in green buildings assess building levels that achieve a sustainable concept.

STARS is a commitment process developed in 2006 by extensive HEIs stakeholder commitment to measure their sustainability performance. It has since been adopted by more than 900 colleges and universities around the world, providing a range of benefits to those who take part. These include: gaining international recognition for sustainability efforts; generating new ideas; engaging with the community; creating a starting point for continuous improvement; informing strategic planning and budgeting; integrate sustainability into the curriculum; making real progress towards sustainability; being part of a global public of STARS institutions. The institution can earn points toward a STARS Bronze, Silver, Gold, or Platinum Rating or make the STARS Reporter designation by participating in STARS. Each seal represents significant sustainability leadership. STARS is an international assessment tool, but it has the following drawbacks: the information about the target group and its impact

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is available, but not identifying the reasons; for education concerns, it focuses only on research and curriculum; Not all scores of data are used; the methodology does not allow recalculation of the results.

The GRI Sustainability Reporting Standards are the first adopted global standards for sustainability reporting. Since GRI's inception in 1997, the founders have altered it from a niche practice to one now taken by the growing popularity of organisations (GRI, 2023). Most (93%) of the world's largest 250 establishments report on their sustainability performance. Disclosing sustainability information inspires accountability, helps identify and manage risks, and enables organisations to seize new opportunities. Communicating with the GRI Standards, supports public and private firms to protect the Environment and recover society while prospering economically by improving governance and stakeholder relations, enhancing reputations, and building trust. GRI works with the largest businesses in the world as a force for positive change. As a result, the impact of their work on societal well-being through better jobs, less environmental injury, and access to clean water.

The SAQ for colleges and universities is a qualitative questionnaire aimed to help these institutions assess the extent to which they are sustainable in seven critical areas of HE (ULSF, 2023): curriculum; research and scholarship; operations; faculty and staff development and rewards; outreach and service; student opportunities; institutional mission; structure, and planning. The SAQ aims to: raise awareness and encourage debate about what sustainability means for HE, almost and philosophically; give a snapshot of the state of sustainability on the campus; promote discussion on the next steps for the institution. The scoring of SAQ is based on the questionnaire itself. The survey has the above target, each with an assertion and specific rubrics for evaluation.

The THEUIR is a new ranking system based on SDGs published in 2019 (THE, 2023). It evaluates university performance on 11 SDGs in the first edition of the ranking and offers the only global presentation tables that measure universities against the UN SDGs. They use sensibly calibrated indicators to provide complete and balanced contrasts crossways three broad areas: research, outreach, and stewardship (THE, 2023). The first edition included more than 450 universities from 76 countries. The metrics were developed in partnership with Vertigo Ventures. The list is led by New Zealand's University of Auckland, while Canada's McMaster University, British Columbia, and the UK's University of Manchester complete

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the top three. Japan is the most-represented nation on the table with 41 organisations, trailed by the US with 31 and Russia with 30.

Quacquarelli Symonds Sustainability University Rankings QSSUR evaluates HEIs annually based on the 12 key pillars of what makes a world-class university (QS, 2023): Research, Teaching, Academic Development, Employability, Internationalization, Facilities, Online/Distance Learning, Social Responsibility, Innovation, Arts & Culture, Inclusiveness, and Specialist Criteria. In 2013, the Institute of Knowledge Societies, Financing and Deregulation in Higher Education (QS, 2023) stated that the authors of the QSSUR pointed out that, despite the growing interest in university rankings, HEIs show the need for assessment, which would be based solely on their merits/properties, rather than on their comparison with other HEIs. The QS World University Rankings Sustainability 2023 was released in 2023, featuring 700 universities from around the world. The methodology used for the rankings is comprised of indicators designed to measure an institution's ability to tackle the world's greatest environmental, social, and governance (ESG) challenges. Indicators are split into environmental sustainability measures – including sustainable institutions, sustainable education and sustainable research – and social impact measures, which includes equality, knowledge exchange, educational impact, employability and opportunities, and quality of life.

To summarize, there are several common ESHEIRSs used today to measure the environmental sustainability performance of various HEIs. Each system has its own advantages and disadvantages, but all provide an effective means of comparing performance and making decisions based on that information. Ultimately, the choice of ranking system will depend on the specifics of the situation, but all offer a useful way to measure relative performance. The literature review conducted by Marrone et al. (2018) revealed that the Total Higher Education and Universities Impact Rating (THEUIR) is based on evaluating HEIs' progress towards the SDGs. The study found that the UIGM was the most effective tool for assessing sustainability among the different SATs. UIGM was considered effective due to its comprehensive nature and ability to measure both environmental and social factors. The authors concluded that UIGM was the most suitable tool for assessing the environmental and social performance of HEIs.

Regarding the ESHERIRs review, ESHEIRSs for this study were considered from particular types of institutions or only a single field of study. Further ESHEIRSs were

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excluded that were discontinued before 2003. Furthermore, data about the ESHEIRSs were collected from the following sources of information: the online portal of particular ESHEIRSs and publications is presenting an ESHEIRS.

Focusing on another aspect of ESHEIRSs, ranking systems and league tables generally evaluate the progress of HEIs based on a set of targets and indicators. Establishing the indicators and the weights of the indicators can be achieved by utilizing one of the conventional methods or developing a new approach. The traditional methods involve gathering the list and values of indicators from experts. On the other hand, an indicator weight setting model can also be either created or developed existing one, for example, using the goal programming model.

To better understand and address any issues related to calculating indicators and specifically SDGs indicators using goal programming, García and Guijarro (2021) developed a goal programming technique that combined arithmetic and geometric averages. This approach allowed them to create composite indices that accurately reflected the SDGs, and helped to ensure that discrepancies between the various goals were taken into consideration.

Another use of the goal programming is to manage water consumption in areas with low water resources. Musa (2021) defined water sources as groundwater, surface water, desalinated water, and treated wastewater, along with the consumption sectors (i.e., domestic, agricultural, and industrial sectors). In this study, Musa used the goal programming model to control water quality and satisfy water demands, with the high allocation of water resources, less extraction of groundwater, and less over production and overall cost. This study proposed different possible setups to fulfil high water demands from limited resources in Saudi Arabia and help build new strategies for sustainable water.

The need to prepare for digital transformation is a recurrent theme in the recent public and academic debate. AI has the potential to reduce operational costs, increase efficiency, and improve customer experience (la Torre et al., 2021). Thus, it is crucial to forming project teams in an organisation in such a way that they will welcome AI in the decision-making process. ML technologies support the use of AI, ML techniques passed through many improvements. In 2006, reviewed synthetic datasets were applied in recommendation systems (Tso & Schmidt-Thieme, 2006) and presented their synthetic data generation methodology that considers attributes. They also conducted empirical evaluations on existing hybrid recommendation algorithms and other state-of-the-art algorithms using these synthetic

variable data and observed their behavior as data characteristics vary. They introduce the use of entropy to control the randomness of the generated data.

Researchers are improving AI and ML technologies every day. They focus particularly on applications related to the SDGs, including agriculture (food security), forests (life on land), and water (water quality) (Holloway et al., 2018). Holloway et al. reviewed practical statistical ML methods, how they work in a remote sensing context, and examples of their application to these data types in the literature. Rather than prescribing particular ways for specific applications, they guided the small sensing practitioner and applied statistician.

The current technological revolution demands a rapid pace of change for companies and has increased the attention to the role of teams in fostering innovation adoption. The exact requirement could be employed in the higher education sector, specifically in implementing the AI and goal programming model for supporting higher education assessment tool creation.

#### **2.1.4 Discussion**

The concept of a sustainability institution outlines a comprehensive approach to achieving sustainability goals in research universities. It is designed to be flexible and straightforward so that academics can effectively implement and manage initiatives, regulations, methodologies, guidelines, and measurements. As such, the concept provides a framework for universities to strategically prioritize sustainability efforts, identify areas of improvement, and track progress over time. Additionally, the concept provides a framework for universities to evaluate and measure their sustainability initiatives' effectiveness while remaining open to new ideas and approaches. Ultimately, the concept of a sustainability institution is an essential tool for research universities to ensure that they take the necessary steps to become more sustainable and remain accountable for their efforts (Nations, 2008).

The concept of sustainability universities is a highly important one, and must be implemented in stages. There is no doubt that the process of continuously improving ecological, societal, and economic strength is a long and arduous journey, and it must be completed in small, manageable steps. This is echoed by Lozano, who suggests that universities must develop capacity to maintain sustainability in tiny increments. Doing so will ensure that the sustainability university concept is firmly established, and that the institution and its students will benefit from it (Lozano, 2006). Sustainability is becoming an

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increasingly important consideration within the university environment, with many institutions working hard to create a sustainable institution model. Such a model will require the investment of funds, resources and time in order to be successful. Sustainability is becoming an increasingly important consideration within the university environment, with many institutions working hard to create a sustainable institution model. Such a model will require the investment of funds, resources, and time to succeed. Many universities have already taken steps towards this goal, such as revising their vision and mission statements to include environmental impact considerations, developing environmental policies, and providing sustainability training. However, more effort is needed to create a genuinely sustainable institution. It is important to remember that sustainability is not a one-size-fits-all solution, and each university must identify unique ways to integrate sustainability into its operations. This may include engaging in communication, investigation, and SD initiatives to promote sustainability and ensure that the institution's mission and goals reflect its commitment to sustainability. Sustainability efforts within universities will likely continue to become more widespread as the importance of sustainable practices is increasingly understood. Institutions of higher education have an essential part to play in making a more sustainable future, and it is up to them to take the necessary steps to ensure this goal is achieved (Parr, 2022).

On the contrary, no guarantee that is simply writing academic papers will guarantee any improvement in their academic performance. Developing cultural awareness is often a key component in encouraging environmental initiatives. This holds unless the problem of a total lack of sustainability initiatives or implementing policies leading to the complete deregulation of certain universities is no longer an issue (Unesco, 2020). Despite many university members' good intentions and hard work worldwide, society has not yet achieved sustainability. It can be challenging to measure the positive effects of these efforts; progress has been made in terms of new information, a better understanding of the damages caused by unsustainable practices, and a shift in values. In the past few decades, universities have prioritized sustainability in their activities, taking steps to reduce their carbon footprints and promote eco-friendly practices. These results are felt on and off campuses, with universities leading the way in environmental awareness and positively contributing to society. Despite the progress made in this regard, there is more to be done to ensure a more sustainable future. This includes increased education, research, and advocacy to ensure that the lessons learned

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are applied more widely and that new solutions are found to our challenges. Ultimately, it is in the hand of everyone to make the world more sustainable, and HEIs are uniquely positioned to lead the way. With their commitment and dedication, there is no doubt that our society will continue to make progress toward a more sustainable future (Nations, 2016).

In regard to the dedication of academic institutions toward the reducing emissions and promoting sustainability initiatives, the UIGM evaluation was established. This dedication was taken into consideration with respect to all 3 main dimensions: research, educational, and environmental. The UIGM presents opportunity for every institution to take specific initiatives in order to collect good outcomes and, as a consequence, gain a higher rating in the review that will take place the following year. The UIGM may serve as both a framework and a conventional protocol for the construction of a green university, and it can thus assist universities in greening their operations more generally. It is obvious that comprises of following and receive reinforcement from the relevant to this study would then result in significant advancements in the UIGM ratings model, which will in turn stimulate Universitas Indonesia's involvement in the overall advancement of environmentally sustainable practices (Suwartha & Sari, 2013a).

Climate change is one of the biggest global issues and taking steps to address it in the educational system is a great way to start. The ESHEIRSs should take into account the AAT, annual rainfall, and average wind speed for the given location. Customizing an ESHEIRS to consider the climate parameters of a given country where the university is based is a great idea. This information can be obtained from public weather data sources. Additionally, the ranking system should incorporate other environmental sustainability factors, such as the university's energy sources (e.g., renewable energy sources), recycling rate, and waste management.

Published work shows the relation between climate parameters and green space ratio, which is a part of ESHEIRSs indicators. The green space ratio and land surface temperature show a strong negative correlation (Amani-Beni et al., 2019). Majid Amani et al. (2019) reported that the land surface temperature decreases by 0.4 °C for every 10% increase in the green space ratio. The land surface temperature is also affected by the distance between the surface and the green space or waterbodies. As the length decreases by one kilometer, the land surface temperature decreases by 0.15 °C. Thus, increasing the green room and planning its distribution in urban land is essential to enhance the cooling effect.

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Additionally, Hossain (2010) suggested that the structure of a city has a direct effect on its microclimate. To maintain a sustainable environment, the pattern, orientation, shape, and density are all critical factors in planning the structure of a city and organizing its streets, green space, and buildings. The morphological character of a town, which affects its microclimate, also affects its electrical energy consumption. Thus, planning a city's structure significantly reduces energy consumption.

An in-depth study had analysed the significant factors in sustainable neighborhood design using specialised computer software packages. It has become clear that improvement can be implemented to enhance environmental sustainability levels in existing communities (Shareef, 2021). The changes can be implemented by adopting specific suggested scenarios. It is essential to highlight the effect of energy consumption and its direct relation to global warming and human welfare.

Huang, Yang, and Chen (2015) investigated the relationship between temperature and mortality by factors at both community and individual levels. It results in a significant effect of high-low temperature changes on mortality in China. The research focused on related community factors (annual temperature, population density, sex ratio, percentage of older population, health access, household income, and latitude) and individual-related factors (age, sex, education level, and cause of death). According to this study, special attention must be given to individuals/communities at risk to minimize the harmful effect of life-threatening temperatures.

Furthermore, other studies (Anderson et al., 2011) reported a relation between the rapid global warming and its ability to increase the rate of violent behavior. The researchers suggested that uncomfortably warm temperatures significantly affect irritability, aggression, and violence. It can also influence the factors that put children and youths at risk for developing into violence-prone adults, indirectly affecting economic and political stability. There is a need for technological and lifestyle changes to reduce greenhouse emissions in developed and developing countries.

As to HEIs, several actions have been taken by the UniTo to improve energy effectiveness (Baricco et al., 2018). They adopted a new energy plan to reduce energy consumption, enhance buildings' efficiency, and embrace renewable energy production resources. Several arrangements were implemented relevant to the UIGM, some of which covered the replacement of older chiller and shifting to LED. Furthermore, efforts were made

toward the implementation of green buildings. Finally, in 2017, an action plan was announced by the university related to five sustainability fields: Energy, Food, Green Public Procurement, Mobility, and Waste.

The systematic review suggests that environmental sustainability can be effectively integrated into higher education. However, further research is required to realize the efficacy of these programs and initiatives. Additionally, the collaboration between different aspects of science is necessary to develop and enhance the reach of sustainability. With the right strategies and commitment, higher education can become a major driver of environmental sustainability worldwide.

### **2.1.5 Conclusion**

This review of the literature on environmental sustainability in HEIs uncovered a need for more research in case studies, projects, methodologies, and techniques that can help identify best practices. Additionally, studying examples of less effective implementations can provide valuable insights. This comprehensive review provides a thorough understanding of SD and ESD in Higher Education Institutions. Limitations noted in the review can be used to inform a future research agenda. The importance of goal programming and AI in developing ESHEIRSs is highlighted along with the importance of considering climate parameters of the country of origin. Further research is necessary to strengthen this field of study to identify the most effective strategies for driving E SD in HEIs.

The research hypothesis: HEIs will perform better when developing an environmental sustainability performance index for HEIs with a customised methodology based on the climate class of the country of residence of the HEI. The new ESHEIRS will have more impact when facilitating arithmetic, automation, and climate classification.

## Chapter 3 Methods

In this study, a combination of qualitative and simulation methods was employed to achieve the objectives of proposing indicators for a new environmental ranking system and assigning weights to these indicators based on the climate group of a country for universities. Specifically, qualitative data was collected through conducting an analysis and focus group discussions to propose indicators for the new ranking system. Then, system simulation was used to assign weights to these indicators, including the development of a new software solution based on dummy data IN Appendix L to generate weights for the proposed indicators for each environmental group. This methodology allowed for a thorough examination of the proposed ranking system and the determination of its validity and reliability. The new proposed ESHEIRS achieved by the following points:

1. Reviewing existing Higher Education Institutions Ranking Systems (HERSs) and criteria for assessing them.
2. Examining existing ESHEIRSs and assessing their consideration of environmental elements.
3. Conducting an analysis and focus group discussions to propose indicators for a new ESHEIRS.
4. Exploring the possibility of automating the assessment of ESHEIRSs using AI and ML techniques.
5. Using experimental analysis (simulations) to assign weights to the indicators based on the climate group of a country of origin of universities, including developing a new software solution based on dummy data to generate weights for the proposed indicators for each environmental group.

A multi-step process was employed to achieve the research objectives. First, an investigation was conducted on various HEIRSs to analyze their respective methodologies, data collection methods, and target universities. Next, a systematic assessment of the ESHEIRSs was conducted using a well-defined set of targets and indicators from the IREG Observatory. To

ensure the correctness of these assessments, mapping ranking indicators to SDGs indicators was conducted. Finally, an analysis of the ESHEIRS methodologies was conducted to identify the limitations of the top ESHEIRSs. The analysis concluded that the same method was used for all universities, limiting the accuracy of the rankings. To address this limitation, the emphasis of the importance of climate change in ESD was introduced and a more specific methodology was developed for universities of different climate classes.

### **3.1 Research Tools**

A simulation research strategy was employed to suggest a novel ESHEIRS. Quantitative and qualitative methodology was employed under a deductive research approach to verify hypotheses. Data was gathered over an extended time frame, with multiple ranking systems evaluated from the past three decades. Three publications have resulted from the thesis - a journal paper and two conference papers (presented in Appendix B to D). Two more journal papers, outlined in Appendix E and F, are in the process of being published. This process of publishing research has enabled the author to progress to the subsequent stage. The subsequent section describes the data collection and the procedures taken.

### **3.2 Data Collection**

Document analysis, a qualitative research method, was used as a data collection tool. This method involves analyzing written materials such as reports and browsing websites to gather information about ranking systems. The advantage of this method is that it allows for the examination of a wide range of sources, including official reports and grey literature, to understand the ranking systems from different perspectives. Additionally, document analysis is less time-consuming and less expensive than other methods such as interviews or surveys. However, the limitations of this method include the potential for bias in the selection of sources, as well as the possibility that the information found may not be up-to-date or accurate. Additionally, the interpretation of the data can be subjective, as it relies on the researcher's own understanding and perspective. To mitigate the limitations, BPs was used to score the indicators. The BPs are a set of guidelines for benchmarking higher education institutions. It provides a comprehensive framework for comparing universities and colleges in terms of their academic excellence, research performance, and overall contributions to society.

Furthermore, using simulation data as a data collection method involved conducting experiments or simulations to generate data for analysis. This method is often used in scientific research to test hypotheses or evaluate the performance of a system or approach. In the context of this research, simulation data was used to test the AI and NLP tools that were developed for automating the assessment of ESHEIRSs. As a result, an evaluation of the effectiveness and efficiency of the proposed solution was done along with further adjustments before applying it in real-world situations. The advantage of using simulation data is that it allows for controlled and repeatable testing, which can lead to more accurate and reliable results. However, one limitation of this method is that the results may not always be generalizable to real-world situations due to the controlled nature of the simulation. Additionally, collecting and preparing simulation data can be time-consuming and costly.

### **3.2.1 Reviewing existing HERSs and criteria for assessing ranking systems**

To achieve the first objective of the research, various HEIRSs were reviewed and benchmarked. Higher education institutions ranking systems websites were used for the analysis and gathered information like the methodology used, the number of targets and indicators, data collection method, result calculation, target universities, and country of origin. Initially, difficulties were encountered in achieving the first objective, but later on the review of all the required information from the official ranking websites and scholarly articles was helpful. The analysis in this stage used the HEIRSs website and published work, considering the ranking systems methodology. This information was important to gain a better understanding of the different ranking systems available and to be able to compare them effectively.

The full review is available in this study's literature review section, which includes a description and related research studies of standard ranking systems that assess research, education, and services of the universities, along with other research studies focusing on research, education, and environment. The general review ends up focusing more on the ESHEIRSs, due to the importance of assessing the environmental sustainability progress of the university to help in the fulfillment of the 2030 plan of the SDGs.

### 3.2.2 Examining existing ESHEIRS and assessing their consideration of environmental elements.

To achieve the second objective of examining existing ESHEIRS (Energy, Social, Health, Economic, Infrastructure and Resilience Systems) and assessing their consideration of environmental elements, the following steps was taken:

- Identify existing ESHEIRS that have been implemented in various regions or cities.
- Analyze the environmental elements that are considered in each of the identified ESHEIRS. This can include factors such as energy efficiency, renewable energy sources, water management, and waste management.
- Assess the level of consideration given to environmental elements in each of the identified ESHEIRS. This can include looking at the overall proportion of the ESHEIR that is devoted to environmental elements and the specific policies or measures that are implemented to address environmental concerns.
- Evaluate the effectiveness of the environmental elements in each of the identified ESHEIRS. This can include looking at the outcomes that have been achieved, such as reductions in greenhouse gas emissions or improvements in air or water quality.
- Examining the use of custom indicator weights based on climate groups, One can identify the climate group of the region for which the ESHEIRS is being implemented. This can be done using climate classification systems such as the KG climate classification system.
- Based on the identified climate group, assign custom indicator weights to the various environmental elements considered in the ESHEIRS. This can be done based on the specific challenges and opportunities presented by the climate group in question.
- Re-evaluate the effectiveness of the ESHEIRS using the custom indicator weights to determine if they are better suited to the specific climate group in question.

Table 3 presents a review of 15 different ESHEIRSs and their respective characteristics. The table includes information such as the name of the system, the country of origin, whether the system considers Standardized Aptitude Tests, the sustainability pillar that the system focuses on, the methodology used, the number of dimensions and indicators considered in the system, and the names of the dimensions.

The systems vary in their focus and methodology, with some placing more emphasis on the environmental component of sustainability and others focusing on general sustainability assessment. Some systems use a questionnaire or research paper approach, while others use a more hands-on approach such as the Deming cycle. The number of dimensions and indicators considered also varies between systems, with some having as few as 2 dimensions and 20 indicators and others having as many as 8 dimensions and 126 indicators.

It's worth noting that all systems are country specific and focus on different aspects of sustainability and have different methodologies. Some systems are more environmental focused, while others are more general, and some systems are self-assessment with questions to calculate indicators for benchmark and dialogue.

**Table 3 Comparison of College and University Ranking Systems for Sustainability Across Different Countries and Methodologies**

|          | <b>College and University Ranking System</b>                                                                                                                                                               | <b>Country</b>  | <b>Sustainability Ranking Focus</b> | <b>Methodology</b>                                                                       | <b>Number of Dimensions</b> | <b>Indicators</b> | <b>Dimensions</b>                                                 |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------------------|------------------------------------------------------------------------------------------|-----------------------------|-------------------|-------------------------------------------------------------------|
| <b>1</b> | AISHE 2.0<br>(Auditing Instrument for Sustainability in Higher Education, n.d.)                                                                                                                            | The Netherlands | General sustainability assessment   | Deming cycle approach                                                                    | 5                           | 30                | Operations, education, research, society, identity.               |
| <b>2</b> | AMAS Adaptable Model for Assessing Sustainability in Higher Education<br>(Rencoret, 2015)                                                                                                                  | Chile           | General sustainability assessment   | Research paper                                                                           | 3                           | 25                | Institutional commitment, leadership, advanced sustainability.    |
| <b>3</b> | ASSCAssessment System for Sustainable Campus<br>(Sustainable Campus Index Table of Contents STARS of Data Accuracy, 2020)                                                                                  | Japan           | Environment                         | Questionnaire                                                                            | 4                           | 26                | Management, education and research, environment, local community. |
| <b>4</b> | AUSPEvaluación de las Políticas Universitarias de Sostenibilidad Como Facilitadoras Para el Desarrollo de los Campus de Excelencia Internacional<br>(AUSPEvaluación de Las Políticas Universitarias, n.d.) | Spain           | Environment                         | Data collection by questionnaire and interviews.                                         | 4                           | 176               | Organisation, teaching, research, environmental management.       |
| <b>5</b> | BIQ-AUAAAlternative University Appraisal<br>(Abdul Razak et al.,                                                                                                                                           | Asian-Pacific   | General sustainability assessment   | Self-assessment with questions to calculate indicators for benchmark (BIQ) and dialogue. | 4                           | 30                | Governance, education, research and communication.                |

| College and University Ranking System |                                                                        |  | Country                | Sustainability Ranking Focus      | Methodology                                                                                                                                                            | Number of Dimensions | Indicators | Dimensions                                                                                                                           |
|---------------------------------------|------------------------------------------------------------------------|--|------------------------|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------|--------------------------------------------------------------------------------------------------------------------------------------|
| 2013)                                 |                                                                        |  |                        |                                   |                                                                                                                                                                        |                      |            |                                                                                                                                      |
| 6                                     | CITE AMB Red de Ciencia, Tecnología, Innovación Ambiental Iberoamérica |  | Colombia               | General sustainability assessment | Questionnaire with 27 yes/no questions.                                                                                                                                | 4                    | 27         | Management, research, education, community.                                                                                          |
| 7                                     | DUK German Commission for UNESCO AG HS                                 |  | Germany                | General sustainability assessment | The tool operates as moderator in the whole-school approach. It contains 10 action fields and each one offers five stages of implementation, allowing the HEIs option. | 4                    | 50         | Operations, research, education, community.                                                                                          |
| 8                                     | ESDGC Education for Sustainable Development and Global Citizenship     |  | Wales / United Kingdom | General sustainability assessment | Adaptation of a maturity model and training usually applied to companies and the industrial sector; results with a semaphore system.                                   | 5                    |            | Commitment and leadership, teaching and learning, institutional management, partnerships, research and monitoring.                   |
| 9                                     | GASU unirank (Abdul Razak et al., 2013)                                |  | UK                     | Environment                       | Based on GRI report with adaptations to HEIs.                                                                                                                          | 8                    | 126        | Direct economic impact, environment, labor practices and decent work, human rights, society, product liability, curricula, research. |

|    | College and University Ranking System                        | Country   | Sustainability Ranking Focus      | Methodology                                                                                                                                                                                                   | Number of Dimensions | Indicators | Dimensions                                                                                                        |
|----|--------------------------------------------------------------|-----------|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------|-------------------------------------------------------------------------------------------------------------------|
| 10 | GC Good Sustainable Toolkit<br>Company's Pathways            | USA       | General sustainability assessment | The purpose is to aid decision support/management and benchmarking; developed by a US company (Good company) and without support to key experts.                                                              |                      | 30         | Campus operations without the involvement of research and stakeholder involvement.                                |
| 11 | GM Green Metrics University Ranking (Suwartha & Sari, 2013b) | Indonesia | Environment                       | Wide world application across the universities.                                                                                                                                                               | 6                    | 33         | Scenario and infrastructure, energy and climate change, waste, water, transport, education & research             |
| 12 | GMID Graz Model for Integrative Development                  | Austria   | General sustainability assessment | Applicable, but not specific to HEIs; applied to the RCE, an international network of formal, non-formal, and informal education organisations, mobilized to provide ESD to the local and regional community. | 5                    |            | leadership, social networks, participation, education and learning, research.                                     |
| 13 | GP Green Plan and the Label DD&RS<br>Plan Vert ou            | France    | Environment                       | Audited and certified by internal and external stakeholders concerning the ISO 26000; the purpose is assisting in the elaboration of sustainability plans/policies.                                           | 5                    | 44         | Strategy governance, education and training research, environmental management, social policy, regional presence. |

|    | College and University Ranking System                                                                                                | Country | Sustainability Ranking Focus      | Methodology                                                                                                                                                                                                                         | Number of Dimensions                   | Indicators | Dimensions                                                                                   |
|----|--------------------------------------------------------------------------------------------------------------------------------------|---------|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|------------|----------------------------------------------------------------------------------------------|
| 14 | HE 21 Higher Education 21' Sustainability Indicators or HEPS Higher Education Partnership for Sustainability (Yarime & Tanaka, 2012) | UK      | General sustainability assessment | Focusing mainly on parameters of organisational management change; less emphasis on social indicators and does not encompass in a balanced way all the dimensions of ESD in HEIs (more emphasis on governance).                     | 2                                      | 20         | Twelve key indicators and eight strategic management indicators.                             |
| 15 | PSIR Penn State Indicator Report (Fischer et al., 2015b)                                                                             | USA     | Environment                       | Results of each indicator reported in four levels of implementation and with proposals for improvement; less emphasis on social indicators and without teaching and curriculum components.                                          | 5                                      | 33         | Environmental dimensions of the campus, transport, decision support, research and community. |
| 16 | P&P People & Planet University League (People & Planet, n.d.)                                                                        | UK      | Environment                       | Graphical presentation of results; in operation for several years allowing the annual comparison and an annual ranking; data collection is carried out in the universities' webpages and the UK Higher Education Statistics Agency. | Indicators not divided into dimensions | 13         | Greater focus on environmental operations and less on community.                             |

|    | College and University Ranking System                                                                                                 | Country | Sustainability Ranking Focus      | Methodology                                                                                                                                                           | Number of Dimensions | Indicators | Dimensions                                                                                                                        |
|----|---------------------------------------------------------------------------------------------------------------------------------------|---------|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------|
| 17 | SAQ (Sustainability et al., 2009)                                                                                                     | Taiwan  | Environment                       | Greater emphasis on campus operations; presented through a questionnaire addressed to various internal stakeholders.                                                  | 8                    | 35         | Curriculum, research and scholarship, operations, faculty, services, student opportunities, administration, mission and planning. |
| 18 | SRCSustainability Report Card (Sustainable Endowments Institute, 2023)                                                                | USA     | Environment                       | More focus on energy saving and less emphasis on education; presented through a questionnaire with a final grade from A to D.                                         | 5                    | 52         | Campus operations, meal service, donation investment, transportation, involvement of key stakeholders.                            |
| 19 | STARS, Sustainability Tracking, Assessment, & Rating System (Sustainable Campus Index Table of Contents STARS of Data Accuracy, 2020) | USA     | General sustainability assessment | Five levels of final classification, allowing the ranking (reporter, bronze, silver, gold, platinum); one of the most used tools internationally; updated every year. | 5                    | 74         | Academic, involvement of key actors, operations, planning and administration, innovation and leadership.                          |

|    | College and University Ranking System                                  | Country | Sustainability Ranking Focus      | Methodology                                                                                                                                                                                                                                                                                                                            | Number of Dimensions | Indicators | Dimensions                                                                 |
|----|------------------------------------------------------------------------|---------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------|----------------------------------------------------------------------------|
| 20 | SUMSustainable University Model (López Martínez & Candel Torres, 2015) | Mexico  | General sustainability assessment | Divided in four phases (vision development, mission, sustainable committee, audit of sustainability strategies) incorporating the Deming cycle approach; tested at various world universities.                                                                                                                                         | 4                    | 23         | Education, research, dissemination and partnership, campus sustainability. |
| 21 | SLSSustainability Leadership Scorecard (Fischer et al., 2015b)         | Ireland | Environment                       | Self-assessment developed specifically for colleges and universities to improve social responsibility and environmental performance through a whole-school approach; final scores with a range 0–4; no weights in the indicators and final result in a dashboard index; adapted from the Green Scorecard and linked to ODSs standards. | 4                    |            | Leadership and governance, learning, teaching and research, operations.    |

|    | College and University Ranking System                                     | Country | Sustainability Ranking Focus      | Methodology                                                                                                                                                                                                                                                                                                              | Number of Dimensions | Indicators | Dimensions                                                                                                                                                                                  |
|----|---------------------------------------------------------------------------|---------|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 22 | SustainTool Program Sustainable Assessment Tool (Fischer et al., 2015b)   | USA     | General sustainability assessment | Presented in 40 multiple-choice questions in a self-assessment questionnaire, with answers being given individually or in a group; allows the communication, review, and development of an action plan; available for several years with updates especially directed to the health area.                                 | 8                    |            | Environmental support, funding stability, partnership, organisational capacity, program, evaluation, program adaptation, communications, strategic planning.                                |
| 23 | THE, Times Higher Education Impact University Ranking (Poza et al., 2021) |         | Environment                       | Based on the evaluation of the implementation of the ODS in HEIs. It has 11 ODSs (3, 4, 5, 8, 9, 10, 11, 12, 13, 16, and 17); each ODS has a small number of indicators associated with it; each ODS has equal weight. The first version is available for seven ODS, but still in development (1st version, April 2019). | 11                   |            | Each ODS has a small number of indicators associated with it; equal weight is given to each ODS; first version available for seven ODS, but still in development (1st version, April 2019). |

|    | College and University Ranking System          | Country      | Sustainability Ranking Focus | Methodology                                                                                                                                                                                                                                                                                                                                                                                                   | Number of Dimensions | Indicators | Dimensions                                                                                               |
|----|------------------------------------------------|--------------|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------|----------------------------------------------------------------------------------------------------------|
| 24 | TUR<br>Three-Dimensional University Ranking    | Europe       | Environment                  | Based on indicators: 15 indicators, weighted based on a participatory process and analytical hierarchical process (AHP); three dimensions (research, education, and environment); less holistic approach; graphical presentation of results; allows ranking based on rankings of world universities, simplified sustainability only in five indicators; tested in the best universities, but without updates. | 3                    | 15         | Research, education, environment.                                                                        |
| 25 | UEMSUniversity Environmental Management System | Saudi Arabia | Environment                  | Based on EMAS/ISO 14001 with a social responsibility component and indicators: 27 indicators, three dimensions (university EMS, public participation and social responsibility, and teaching and research in sustainability); greater focus on the environment and campus areas.                                                                                                                              | 3                    | 27         | University EMS, public participation and social responsibility, teaching and research in sustainability. |

|    | College and University Ranking System                                            | Country        | Sustainability Ranking Focus | Methodology                                                                                                                                                                                                                                                                                                                                     | Number of Dimensions | Indicators | Dimensions                                                                                                              |
|----|----------------------------------------------------------------------------------|----------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------|-------------------------------------------------------------------------------------------------------------------------|
| 26 | USAT Unit-Based SustainabilityAssessment Tool                                    | United Nations | Environment                  | Score of one to four indicators; adapted from SAQ, AISHE, and GASU; can be used in the department, college, or HE unit; without updates; Developed by the United Nations Environment Program (UNEP) for the African context.                                                                                                                    | 4                    | 75         | Teaching, research and community services, operation and management, student involvement, written policy and statement. |
| 27 | uD-SiM ModelUncertainty-Based Quantitative Assessment of Sustainability for HEIs | Canada         | Environment                  | Based on indicators and the models of pressure, exposure, Action (DPSEEA) and a multicriteria decision process (applying fuzzy logic);aggregate score in a final index that integrates the non-linear of the indicators, with differerent weights and normalized indicators. Indicators based on the GASU model. Calculation method is complex. | 4                    |            | Environmental, economic, social and education.                                                                          |
|    |                                                                                  |                |                              |                                                                                                                                                                                                                                                                                                                                                 |                      |            |                                                                                                                         |
|    |                                                                                  |                |                              |                                                                                                                                                                                                                                                                                                                                                 |                      |            |                                                                                                                         |
|    |                                                                                  |                |                              |                                                                                                                                                                                                                                                                                                                                                 |                      |            |                                                                                                                         |
|    |                                                                                  |                |                              |                                                                                                                                                                                                                                                                                                                                                 |                      |            |                                                                                                                         |

### **3.2.3 Conducting an analysis and focus group discussions to propose indicators for a new environmental ranking system.**

This part of the research aimed to support the objective of creating new ESHEIRS. An evaluation and a review of the existing ESHEIRSs in terms of methodology, consumer friendliness, transparency, and support of sustainable practices was analysed. ten ESHEIRSs were being benchmarked and assessed, with a focus on three international ones, and identifies their strengths and weaknesses. Based on these findings, The objectives are fivefold: 1) to assess the selected ESHERSs using the BP scale, 2) to identify the weaknesses of the best-performing ESHERS, 3) to propose a general methodology for the future design of a new ESHEIRS, 4) to suggest several indicators for inclusion in the new system, and 5) to identify the requirement for sustainability related tools for assessing ranking systems other than the BPs. The criteria for the inclusion/exclusion of ranking systems were the availability and accessibility of comprehensive data about each ranking system. The three ESHEIRSs was selected for evaluation based on this criterion. The use of BPs to evaluate the systems reduced potential bias in the assessment process. The authors recruited Six HEIs quality assurance directors and HEIs workflow experts to score the ranking systems based on the BPs, with scores ranging from 1 to 5. Statistical analysis was used to interpret the findings of the experts. The purpose of the study was to assess the selected ESHEIRSs, identify their weaknesses, propose a new methodology and indicators for a ranking system, and identify alternative tools for ranking systems assessment.

The results of the scoring process are presented in Table 5 in the results chapter. The ESHERSs were evaluated based on separate sub-scores for methodology, consumer friendliness, and transparency, with a final score calculated. The ESHERSs are ranked from highest to lowest scores in Table 5, with UIGM receiving the highest score of 3.8, followed by THEUIR at 3.7, and STARS at 3.3. The results of the benchmarking process for the ESHERSs based on the BPs are shown in chapter 4. UIGM received the highest score for methodology, with an average score of 3.8. Meanwhile, THEUIR scored highest in terms of transparency and consumer friendliness, with scores of 3.8 and 3.7, respectively.

Based on these results, it can be concluded that UIGM provides the best assessment of environmental sustainability in higher education institutions based on all its targets and

indicators. However, both THEUIR and STARS are popular and offer professional methodologies, making them attractive to consider in further research.

### **3.2.4 Exploring the possibility of automating the assessment of environmental HE systems using AI and ML techniques**

To achieve the objective of exploring the possibility of automating the assessment of ESHEIRSs using AI and ML techniques, simulation data collection methods was employed. Specifically, the utilization of NLP and text similarity methods to test AI and Information Technology solutions for assessing ESHEIRSs. These methods allow for the analysis and comparison of large amounts of unstructured data, such as reports and websites, in an automated and efficient manner.

Hypothesis: The hypothesis of this research HEIs will perform better when developing an environmental sustainability performance index for HEIs with a customised methodology based on the climate class of the country of residence of the HEI. The new ESHEIRS will have more impact when facilitating arithmetic, automation, and climate classification. And in another words, is that using the BPs and mapping ESHEIRSs' indicators to SDGs' indicators using artificial intelligence and machine learning techniques will lead to a more effective and efficient ranking system for HEIs in terms of measuring and promoting environmentally sustainable practices and supporting home countries in achieving the SDGs.

A research study aimed to explore the possibility of automating the assessment of environmental HE systems using AI and ML techniques was conducted (Anwaar Buzaboon et al., n.d.). The focus was on the assessment of ESHEIRSs using the BPs as indicators.

Advanced machine learning tools such as Latent Dirichlet Allocation, Latent Semantic Analysis, Support Vector Machines, or Neural Network methods were not used in this research since these methods require big data for both training and testing the system. Big data training and testing did not exist for this research because they require significant time to develop. Also, these methods are complex and were outside of the scope of this research. Instead, the used of NLP and text similarity methods were used to support the automation of the assessment approach. This approach was used because the focus of the research was not on computer science, but rather on the use of AI and NLP tools to support the automation of the assessment of ESHEIRSs. These methods were considered more appropriate for the specific objectives and research questions of the study.

The following procedure was used to automate the mapping of selected ESHEIRS indicators to the SDGs indicators:

- Each ranking indicator and its description stored as a separate document.
- Each SDG indicator is stored as a separate document.
- Created a corpus of all documents obtained from the first two steps.
- The Jaccard technique was used to calculate the similarity between each pair of documents in the corpus.
- Identified the maximum similarity between the ranking indicator document and the SDG indicators documents and mapped the ranking indicators to that SDG indicator.
- The following pseudo code outlines the steps that the model used to automate the mapping of the ranking system indicators to the United Nations SDGs indicators:
  - Initialized the similarity matrix and mapping matrix to null.
  - Defined a threshold value ( $\Theta$ ) to determine the level of similarity between indicators.
  - Converted the ranking system indicators and the SDG indicators into a document term matrix (DTM) using n-gram analysis.
  - Extracted the most frequent terms from the DTM using the Tf-Idf weighting scheme.
  - Each ranking system indicator ( $k$ ), was compared with all the other ranking system indicators ( $j$ ) that have a lower index than  $k$ .
  - Calculate the similarity between the two indicators using the Jaccard similarity coefficient.
  - If the similarity between the two indicators is greater than the threshold value ( $\Theta$ ), the mapping matrix was marked as true for the corresponding indices ( $k, j$ ).
  - Repeat the process for all pairs of ranking system indicators.

---

**Algorithm 1: Find Document Similarity**

```

procedure FINDSIMILARITY(corpus)
    similarityMatrix     $\leftarrow$     null
    mapMatrix           $\leftarrow$     null
    threshold           $\leftarrow$     0
    n                    $\leftarrow$     3
    DTM                 $\leftarrow$     document terms matrix(corpus,ngram=n)
    Terms               $\leftarrow$     freq terms(DTM,Tf-Idf)
    for (k = 0, k < corpus.length, k++) do
        for (j = 0, j < k, j++) do
            similarity[k,j]  $\leftarrow$  jaccard(DTM[dk],DTM[dj])
            if similarityMatrix[k,j] >  $\theta$  then
                Map[k,j] = True
            end if
        end for
    end for
end procedure

```

---

This algorithm uses a text-based approach to automatically map the ranking system indicators to the SDG indicators by comparing the text descriptions of the indicators. The algorithm identifies the indicators that are most similar to each other based on their text descriptions and maps them accordingly. The result of the algorithm is a mapping matrix that shows the relationship between the ranking system indicators and the SDGs indicators. The data used for the implementation of the algorithm was obtained by gathering indicators and their descriptions for the STARS, THEUIR, and UIGM ranking systems from the official websites of these ranking systems. Additionally, they collected information on all the SDGs, their indicators, and descriptions were gathered from the SDGs website and reports to compile the corpus for their proposed method.

To generate the golden truth data set that was used to evaluate the accuracy and performance of the model. Three experts were recruited to manually map the three ranking systems indicators to the SDG indicators, the result of their work serves as a benchmark for evaluating the results of the model experimental results.

Recall and precision was used as evaluation metrics to assess the performance of the automated mapping of ranking system indicators to SDG indicators. The recall measured the ability of the system to identify all relevant results and the precision measures the ability of the system to avoid false positives and only identified relevant results. By comparing the results of the automated mapping to the benchmark data (golden truth), these measures were used to evaluate the accuracy and performance of the proposed system.

Recall and precision are two widely used evaluation metrics in information retrieval and machine learning that are used to assess the performance of a model in identifying relevant results. Recall (True Positive Rate or Sensitivity): Recall is the proportion of relevant instances that are correctly retrieved by the model. It measures the ability of the model to identify all relevant results. The formula for recall is given by:

$$\text{Recall} = \text{True Positives} / (\text{True Positives} + \text{False Negatives})$$

where True Positives are the instances that are correctly identified as relevant by the model and False Negatives are the instances that are relevant but not identified as such by the model. Precision (Positive Predictive Value): Precision is the proportion of retrieved instances that are relevant. It measures the ability of the model to avoid false positives and only identify relevant results. The formula for precision is given by:

$$\text{Precision} = \text{True Positives} / (\text{True Positives} + \text{False Positives})$$

where False Positives are the instances that are incorrectly identified as relevant by the model. In general, a model that has high recall will retrieve many relevant instances but may also retrieve many irrelevant instances. A model that has high precision will retrieve fewer instances but most of them will be relevant. The trade-off between recall and precision can be balanced using metrics such as the F1 score, which is the harmonic mean of recall and precision. Finally, the goal of this research is to propose a general methodology for the future design of a new ESHEIRS and suggest several indicators for inclusion in the new proposed system. The aim is to demonstrate that the automated method can achieve similar results as the manual method and provide a more efficient and scalable solution for mapping indicators from different ranking systems to the SDG indicators.

### **3.2.5 Using simulation to assign weights to the indicators based on the climate group of a country for universities.**

Multi-Objective Programming and Goal Programming was used to avoid any biases in the assignment of weights to the proposed indicators for the new environmental ranking system. This methodology was chosen to ensure that the scores for each indicator were determined objectively and were not influenced by any subjective factors. Additionally, the development of a new software solution was done based on dummy data to generate weights for the proposed indicators for each environmental group, which further supported the objective and unbiased nature of the weight assignment process.

Multi-Objective Programming and Goal Programming are mathematical optimization techniques that are commonly used in decision-making problems involving multiple objectives. These methods are well suited for ranking systems because they allow for the simultaneous consideration of multiple criteria, such as environmental impact and economic cost. Multi-Objective Programming and Goal Programming can also handle trade-offs between conflicting objectives, which is important for ranking systems where there may be trade-offs between different indicators. Additionally, Multi-Objective Programming and Goal Programming can be used to incorporate subjective preferences, such as those of stakeholders or experts, into the ranking process. This can help ensuring that the final ranking is reflective of the priorities and values of the stakeholders. Overall, Multi-Objective Programming and Goal Programming are powerful tools for creating transparent and robust ranking systems that consider multiple objectives and stakeholders' preferences.

A systematic approach was used to assign weights to environmental oriented indicators for universities. They based the indicators on the results of focus group discussions and aimed to map them to the SDGs indicators. The environmental group of the country a university exists in was also considered in this process.

To accomplish this objective, a software solution was created and proposed. This software solution helped to automate the mapping process between the ranking system indicators and the SDGs indicators. It also helped to assign weights to the proposed environmental oriented indicators based on the environmental group of the country.

This research makes a significant contribution to the field by offering a method to assign weights to environmental oriented indicators in a systematic and automated way, while

considering the environmental group of a country and mapping the indicators to the SDGs. The use of focus group discussions to propose the indicators adds to the validity of the results, ensuring that the indicators are relevant and meaningful for the purpose of ranking universities based on their environmental performance.

The mathematical models is:

$$\min \sum_{\{i=1\}}^n \sum_{\{j=1\}}^d (\alpha_j n_{ij} + \beta_j p_{ij}) \quad (1)$$

$$\text{s.t.} \quad \sum_j^d w_j ind_{ij} + n_{ik} - p_{ik} = ind_{ik} \quad i = 1..n, k = 1..d \quad (2)$$

$$\sum_{\{j=1\}}^d w_j = 1 \quad (3)$$

$$\sum_{\{j=1\}}^d w_j ind_{ij} = Perf_{Uni} \quad i = 1..n \quad (4)$$

$$\sum_{\{i=1\}}^n (n_{ij} + p_{ij}) = D_j \quad j = 1..d \quad (5)$$

$$\sum_{\{j=1\}}^d D_j = Z \quad (6)$$

The objective of the mathematical model given above is to reduce the discrepancy between the set goals and actual outcomes. However, some discrepancies can be desirable and have a positive impact, such as a university exceeding its target for reducing CO<sub>2</sub> emissions. To account for this, the model introduces two variables,  $\alpha$  and  $\beta$ , which can either be 0 or 1. If a positive deviation is desired,  $\alpha$  is set to 1 and  $\beta$  is set to 0, and vice versa, ensuring that the model only minimizes undesired deviations. The resulting weight ( $w_i$ ) for each indicator is calculated in a way that minimizes the sum of all undesired discrepancies.

The mathematical model employed in this research has a key objective to minimize deviations from the predetermined goals set for environmental sustainability. This allowed

the model to evaluate the performance of universities in various environmental indicators and provide a comprehensive ranking system. The model introduces the variables  $\alpha$  and  $\beta$ , which either have a value of 0 or 1, to determine whether positive deviations should be minimized or not. By setting  $\alpha$  1 if a positive deviation is desired and  $\beta$  to 0 if not, the model ensures that it only minimizes the unwanted deviations. This results in the calculation of weights,  $w_i$ , for each indicator in a way that guarantees the least sum of all unwanted deviations.

However, the model has a drawback in that it may not reward universities that exceeded the set goals in some indicators. To overcome this limitation, setting the objective goal scores higher than any individual university score was suggested so that the model can provide a fair and comprehensive ranking system.

Additionally, the model tends to assign high weights to indicators with the least deviation values, which can result in skewing the results towards a few indicators and leaving most indicators with insignificant weights. To address this, the model was adjusted to introducing minimum and maximum values for each indicator, ensuring a more balanced distribution of weights. Overall, the mathematical model provides a robust and efficient approach to ranking universities based on their environmental performance.

$$\sum_{j=1}^d w_j = 1 ; \min q \leq w_i \leq \max q \quad (7)$$

Additionally, the model may face difficulties in terms of computational efficiency as the number of indicators increases. The time and space complexity for the model grows exponentially with the number of indicators, becoming a challenging issue for larger datasets. The time complexity of the model is expressed as  $(nm)$  where  $n$  is the number of possible values (1...100) and  $m$  is the number of indicators. Although this computational challenge is beyond the scope of this research and the focus is only on assigning weights to indicators, it may present a new research opportunity for the computer science community to address. This highlights the importance of developing more efficient algorithms and methods to handle large datasets in the future.

This model's tendency to assign high weights for indicators that got the minor deviation values following the greedy algorithm approach skews the results toward a few individual

indicators and leaves most of the indicators with insignificant weights. Therefore, the adjustment to the model was to introduce min and max values for each indicator to get more balanced weights, as the following Equation shows:

$$\sum_{j=1}^d w_j = 1 ; \min q \leq w_i \leq \max q \quad (8)$$

Another limitation to this approach is the time and space complexity of the model, especially when the number of indicators is significant where the time complexity is  $n^m$ , where  $n$  is the number of possible values (1...100) and  $m$  is the number of indicators. Although the time and space complexity is out of this research scope, and the author only focused on assigning weights to indicators, this challenge may initiate a new research problem for the computer science community.

A software solution was developed for this task. The next algorithm envisions the system approach. It takes four inputs: a list of indicators (Indicators), a list of actual university performance data for each indicator (Uni\_Performance), a list of goal values for each indicator (Goals), and a list of deviation values for each indicator (Devs). The output is a list of deviations for each indicator.

The algorithm first loops through each goal in the list of Goals. For each goal, it loops through each university performance value in the list of Uni\_Performance. Finally, for each indicator in the list of Indicators, it checks if the difference between the university performance value and the goal is positive or negative. If the difference is positive, it adds the difference to the deviation value for that indicator. If the difference is negative, it subtracts the difference from the deviation value for that indicator. The algorithm continues to loop through each goal and each university performance value until all deviation values have been calculated.

---

**ALGORITHM 2** *Find\_Indicator\_Deviation(Indicators, Uni\_Performance, Goals, Devs)*

**INPUT:** Indicators is a list of the ranking system indicators

: Uni\_Performance is a list of actual university data for each indicator<sub>k</sub>  
 $\in$  Indicators

: Goals is a list of all object goal for each indicator<sub>i</sub>  $\in$  Indicators

**OUTPUT:** Devs list of deviation for each indicator<sub>i</sub>  $\in$  Indicators

**For Each** *goal*  $\in$  *Goals* **Do**

**For Each**  $P_i \in$  University\_Performance **Do**

**For Each** indicator<sub>k</sub>  $\in$  Indicators **Do**

**If**  $\alpha = 1$  and  $(P_i - \text{goal}) > 0$  **Then**

**Let**  $\text{Dev}_j \in \text{Deveation} = \text{Dev}_j + (P_i - \text{goal})$

**Elseif**  $\beta = 1$  &&  $(P_i - \text{goal}) < 0$  **Then**

$\text{Dev}_j = \text{Dev}_j + (p_i - \text{goal})$

**End if**

**Next** indicator

**Next**  $p_i$

**Next** goal

---

Then the system used another algorithm to find the weights for the indicators. Algorithm 2, to Find\_Solution\_Space is an algorithm that finds all possible solutions for the given Indicators within a specific weight range (Min and Max). The algorithm loops through each value of  $s$  in the range Min to Max and calculates the weight for each Indicator. If the sum of weights equals to 1, the solution is added to the list of solutions.

The algorithm, Find\_Best\_Solution is an algorithm that determines the best solution among the list of solutions generated by the Find\_Solution\_Space algorithm. The algorithm calculates the sum of deviations from the desired goals for each solution and stores it in the list "Solutions\_Devs". The solution with the minimum deviation is then selected as the best solution.

---

**ALGORITHM 3** Find\_Solution\_Space(Indicators, Min, Max, Solutions)

**INPUT:** Min is the minimum weight for indicator<sub>i</sub> ∈ Indicators

          : Max is the maximum weight for indicator<sub>i</sub> ∈ Indicators

**OUTPUT:** Solutions list of possible weights for each indicator<sub>i</sub>

$$\in \text{Indicators} ; \sum_i^k \text{weight}_i = 1$$

**FOR** s in Min .. Max **DO**

    Sum ← 0

    weight ←  $\phi$

**FOR** Each Indicator in Indicators **Do**

$\text{weight}_i \leftarrow s$

        Sum += s

**Next** indicator

**IF** sum = 1 **Then**

        Add(solutions, weight)

**End IF**

**Next s**

---

**ALGORITHM 4** Find\_Best\_Solution(Solutions, Indicators, Devs)**INPUT:** Solutions a list of all possible solutions

: Devs list of sum of all unwanted deviations from the object goals

: Indicators list of the ranking system indicators

**OUTPUT:** best\_solutionSolutions\_Devs  $\leftarrow \phi$ min\_devs =  $-\infty$ **FOR Each** solution  $\in$  Solutions **Do**sum\_devs  $\leftarrow 0$ **FOR Each** indicator  $\in$  Indicators **Do**

sum\_devs += indicator \* solution

**Next** indicator

Solutions\_Devs (solution) = sum\_devs

**IF** solutions\_Devs(solution) < min\_devs **Then** min\_devs = sum\_devs**Next** solution

best\_solution = Minimum(solutions\_Devs)

---

The system provides a way of evaluating the performance of a collection of universities based initially on a set of 9 environmental indicators. The output of the system as in the code of Appendix I is a weight assigned to each of the indicators, indicating the significance of each indicator in determining the overall performance of the universities. To test the system, dummy values were used to represent the performance of 15 universities against each of the 9 indicators. The system used two parameters, Alpha, and Beta as in the Appendix J and K which represents the computer program of the algorithm, and which were set to control the desired outcome as in Table 4. The output of the system is a list of weights assigned to each of the 9 indicators, based on the performance of the universities. These weights provide a way to compare the relative importance of each indicator in determining the overall

performance of the universities. By understanding the weight assigned to each indicator, the system provides valuable insights into which areas the universities need to focus on to improve their overall performance and meet the desired environmental goals.

**Table 4 The Computer Program Indicators Weights Finalization and the Minimization of the Indicators' Deviations**

| University          | Indicators |     |      |    |    |    |     |     |     |
|---------------------|------------|-----|------|----|----|----|-----|-----|-----|
|                     | 1          | 2   | 3    | 4  | 5  | 6  | 7   | 8   | 9   |
| Alpha               | 1          | 1   | 1    | 1  | 1  | 0  | 1   | 1   | 1   |
| Beta                | 0          | 0   | 0    | 0  | 0  | 1  | 0   | 0   | 0   |
| Object Value        | 20         | 100 | 1000 | 15 | 18 | 70 | 50  | 100 | 110 |
| Weight              |            |     |      |    |    |    |     |     |     |
| University 1        | 8          | 29  | 722  | 20 | 15 | 38 | 6   | 95  | 81  |
| University 2        | 8          | 7   | 262  | 15 | 11 | 59 | 51  | 30  | 113 |
| University 3        | 7          | 78  | 246  | 15 | 8  | 66 | 16  | 100 | 48  |
| University 4        | 18         | 11  | 757  | 15 | 9  | 32 | 22  | 50  | 60  |
| University 5        | 19         | 6   | 410  | 8  | 15 | 45 | 22  | 35  | 88  |
| University 6        | 9          | 10  | 825  | 8  | 11 | 53 | 52  | 102 | 82  |
| University 7        | 24         | 48  | 342  | 19 | 11 | 50 | 36  | 13  | 20  |
| University 8        | 13         | 50  | 640  | 7  | 12 | 43 | 8   | 62  | 87  |
| University 9        | 19         | 51  | 589  | 12 | 7  | 41 | 50  | 37  | 35  |
| University 10       | 13         | 19  | 697  | 20 | 14 | 41 | 38  | 68  | 63  |
| University 11       | 10         | 10  | 188  | 11 | 9  | 32 | 44  | 82  | 62  |
| University 12       | 23         | 85  | 421  | 12 | 23 | 72 | 43  | 63  | 78  |
| University 13       | 20         | 70  | 100  | 15 | 11 | 28 | 50  | 33  | 15  |
| University 14       | 18         | 27  | 1000 | 11 | 16 | 46 | 17  | 43  | 63  |
| University 15       | 25         | 23  | 104  | 10 | 12 | 37 | 10  | 94  | 56  |
|                     | 20         | 63  | 189  | 14 | 10 | 53 | 20  | 48  | 30  |
| Indicator Deviation | 0          | 0   | 0    | 59 | 23 | 72 | 103 | 102 | 113 |

To conclude, It was a challenge to identify an official source that evaluated ranking systems in terms of sustainability, but the IREG Observatory's published set of targets and indicators was used as the benchmark. The evaluation process was conducted and the SDGs indicators were mapped to the ranking indicators to ensure the correctness of the results. It was found that the top ranking systems have limitations, which this research focused on customizing the method rather than attempting to solve the particular limitations.

## Chapter 4 Results

To ensure a robust ESHEIRS for HEIs, The task has been split into multiple stages. The first stage involves reviewing various methodologies for assessing a HEI's environmental sustainability. The second phase is an assessment of existing ESHEIRSs by manually applying BPs and two other methods, as well as utilizing ML techniques. The third stage reviews the limitations of current ESHEIRSs. The fourth stage is the development of a new ESHEIRS that attempts to address some of these limitations through the application of mathematics and artificial intelligence (AI). Finally, the fifth stage customizes the methodology according to the HEI's climate class. Through these phases, robust ESHEIRS were proposed that can provide unbiased rankings.

The workflow in Figure 3 were followed in order to solve and answer the research questions.

After carrying out a detailed review of existing HERSs and the associated criteria and principles, setting out to develop a new ESHEIRS to determine the extent to which current ESHEIRSs consider environmental elements, as well as exploring the possibility of automating the assessment of these systems through the use AI and ML techniques. To further strengthening this research, a series of focus group discussions were conducted to propose indicators for a new environmental ranking system, after which an simulation was conducted to assign weights to the indicators based on the climate group of a country's residents. This simulation culminated in the development of a new software solution based on simulated data which was used to generate weights for the proposed indicators for each environmental group. Further elaborations on the results of this research can be found in the upcoming sections.

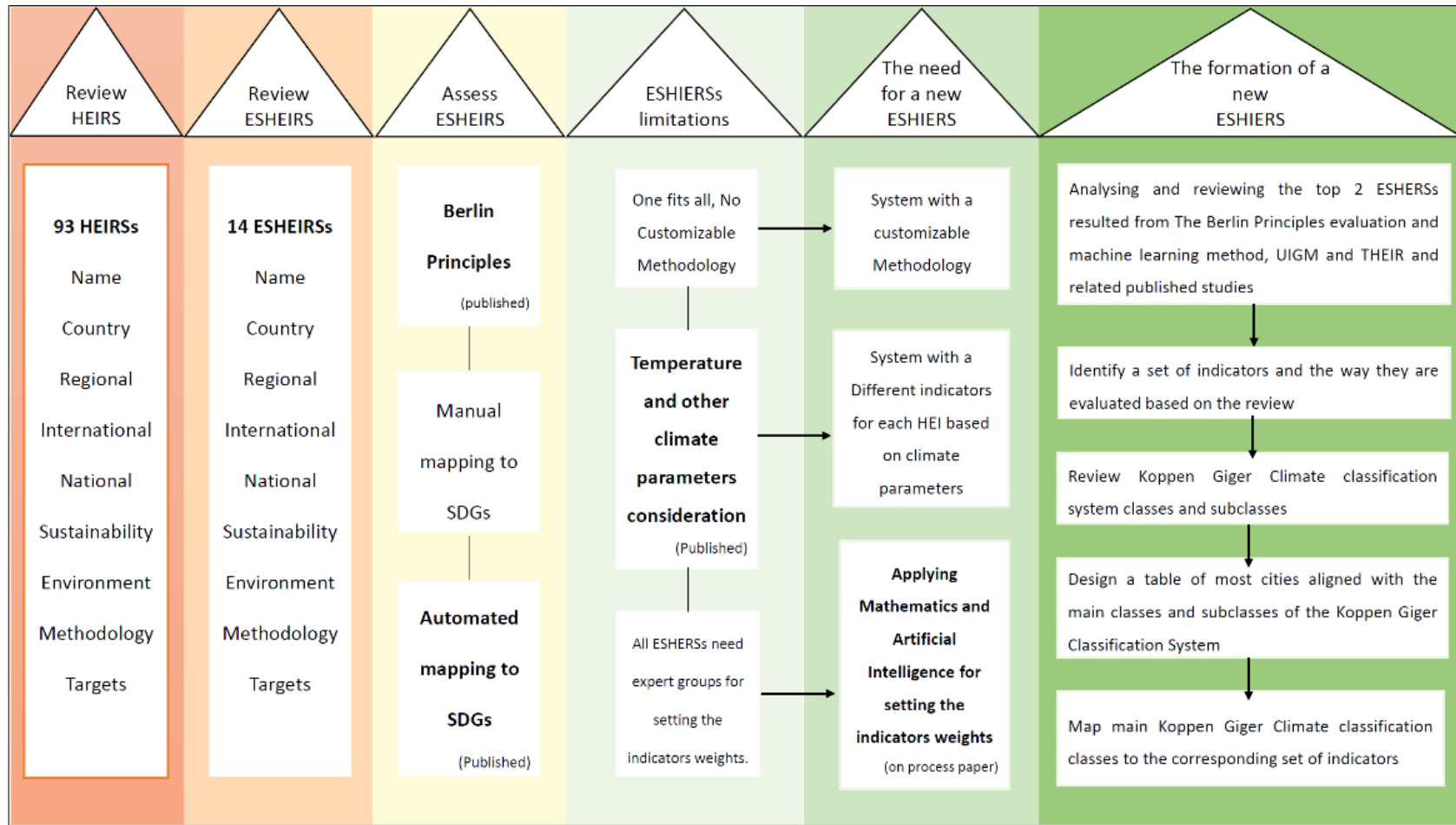


**Figure 3 The study's main flow**

## 4.1 Global Survey of Rankings and League Tables

To achieve the first objective of the study which is, to assess current ESHEIRSs using the BPs, existing HERSs and criteria were reviewed for assessing them and examined existing ESHEIRSs and assessed their consideration of environmental elements.

The first stage of the research focused on evaluating Higher Education Institution Ranking Systems (HEIRS) with a particular focus on their importance in the assessment process and potential benefits to the education system. a total of 93 ranking systems were reviewed, 66 of them focus on research, education, and services. Figure 4 shows the distribution of these ranking systems and their scope, where 26 ranking systems are national, 15 are international, and 22 are global. The SDGs and the 2030 agenda have shifted the focus towards sustainability; therefore, 27 ranking systems assess the sustainability of HEIs. Figure 5 shows the classification of the existing ranking systems in terms of inclusion/exclusion of sustainability in their indicators. Out of those 27, only 14 were considered ESHEIRSs as depicted in Figure 6. The research also revealed that the average number of targets in the reviewed HEIRSs was five. Figure 7 shows the number of indicators (targets) for each reviewed ranking system.

The findings also suggest that every ranking system follows a different methodology, but all use one method for all universities to evaluate their environmental sustainability. Furthermore, the review shows the importance of assessing the sustainability of universities, especially environmental sustainability, because there are only 14 systems with the addition of the new QS environmental sustainability rating system. The review of ESHEIRSs found that the review itself is insufficient, and it is necessary to compare or assess the current ESHEIRSs further.

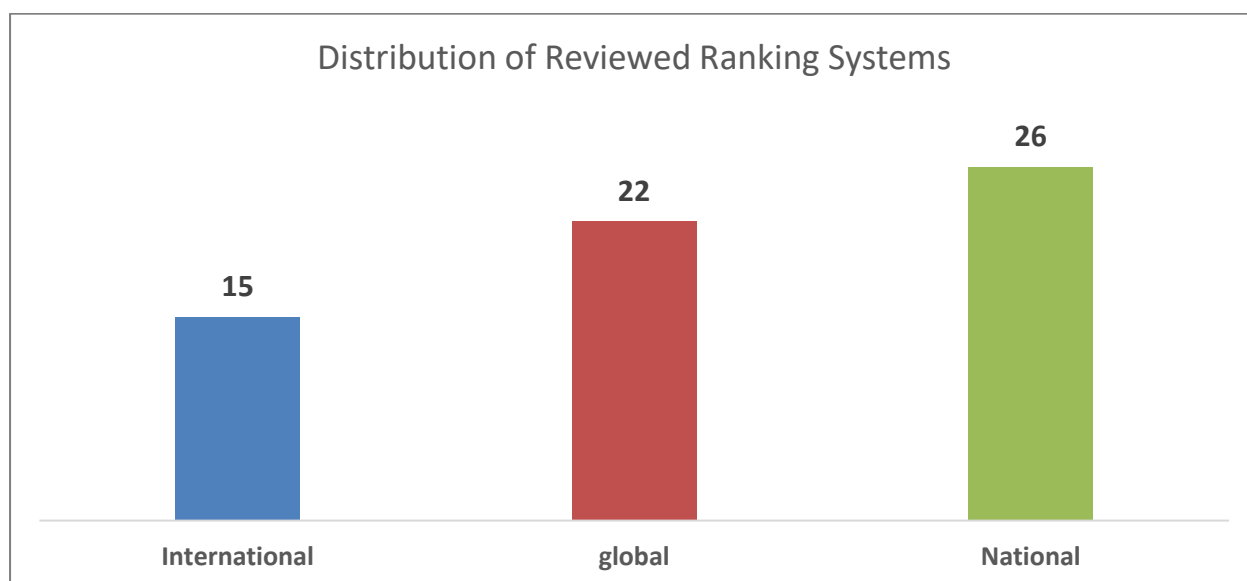


**Figure 4 Review of regional, national, and international HEIs' ranking systems**

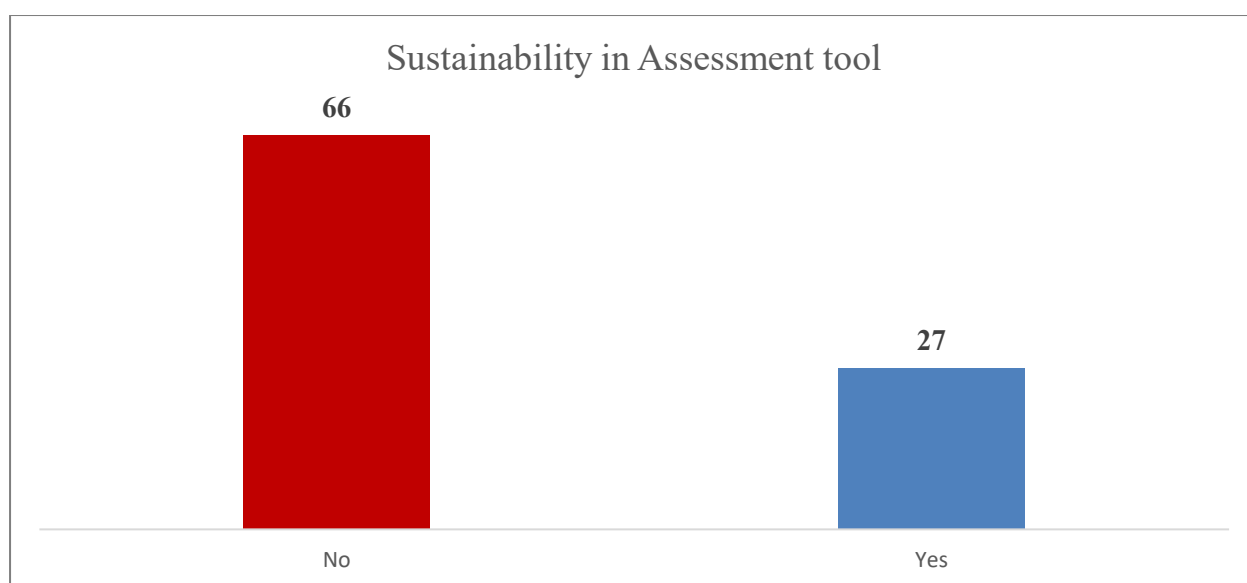


**Figure 5 Count of reviewed HEIs' Sustainability assessment tools**

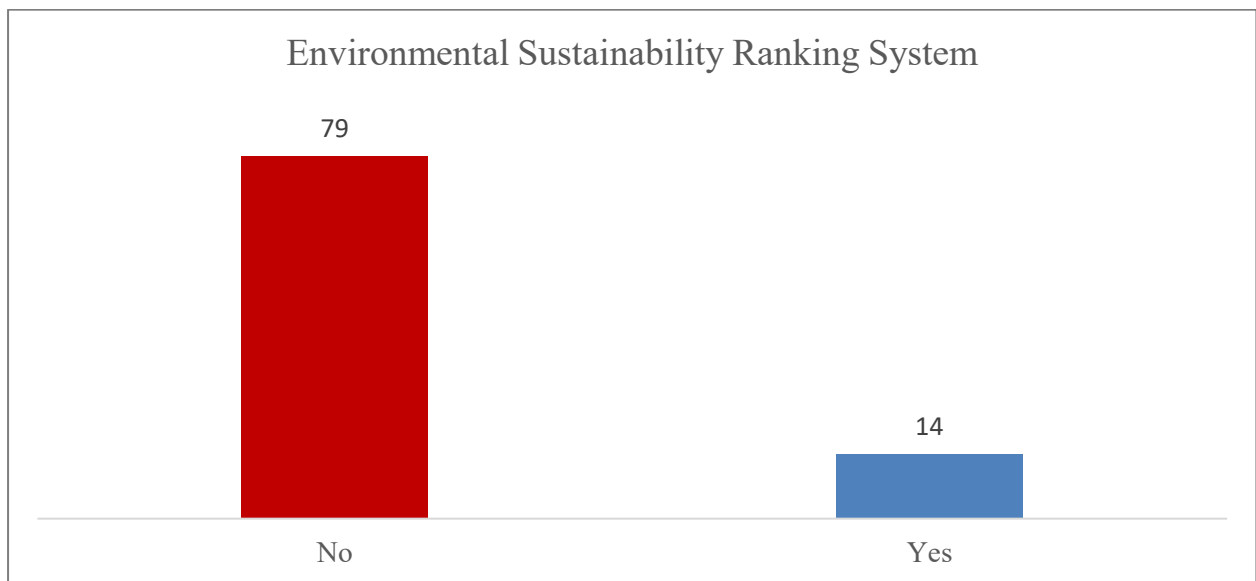


**Figure 6 Count of reviewed ESHEIRSs**

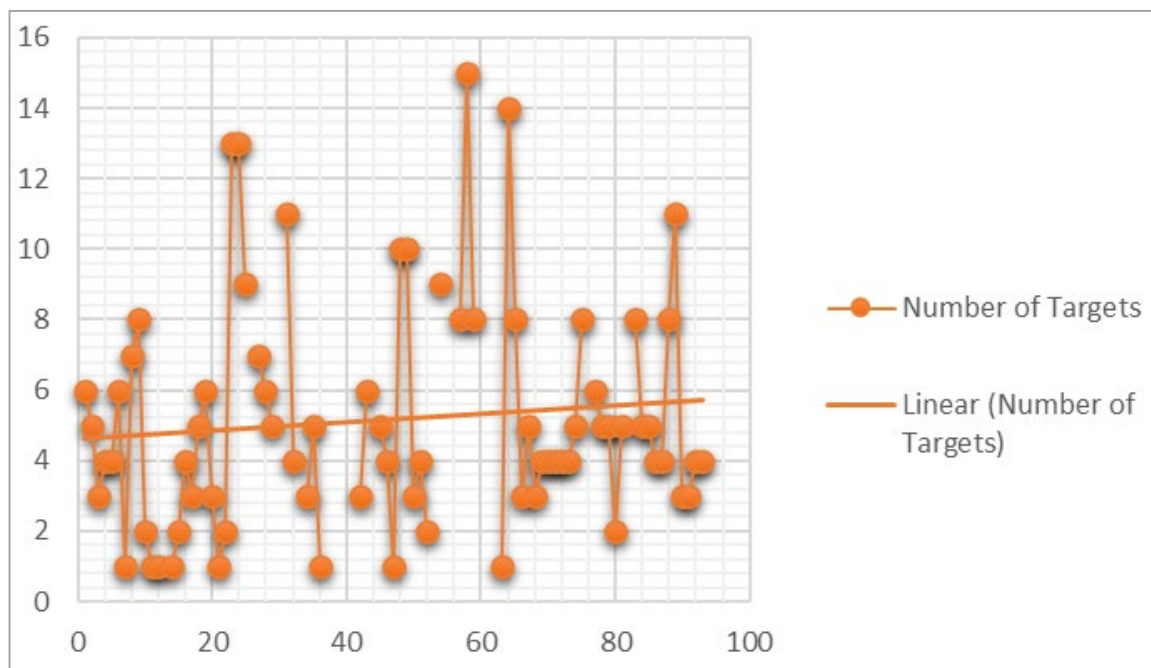


**Figure 7 The average number of targets for the reviewed HEIRSs**

Appendix A shows the methodology followed by each HEIRS of the 91 systems. Other information includes the HEIRS's name, targeted universities, the focus of the systems, the

number of contributed universities for the year 2021 and, number of targets and indicators for the HEIRS that focus on sustainability.

In summary, the results of this review highlight the importance of assessing the sustainability of universities, especially in terms of environmental sustainability. The study suggests that HEIRS need to include more indicators to evaluate the sustainability of universities and recommends further research to assess the current ESHEIRSs and identify best practices.

## **4.2 Assessments of current ESHERSs: Using BPs, Manually, and using ML techniques**

In this experiment, the aim is to explore the possibility of automating the assessment of ESHEIRSs using AI and ML techniques. First, BPs were used as a reference to assess the compliance of the ranking systems and to what extent these ranking systems adhere to the requirements listed in these principles. Therefore, five experts were recruited to assess three ranking systems which are UIGM, THE impact, and STARS. These systems were selected since they are global and include Environment/Sustainability indicators. The experts used the BPs rubric for assessing these ranking systems where they assessed their methodology, transparency, and consumer friendliness aspects. For each aspect, BPs contain sub indicators to evaluate ranking systems. Table 5 shows a summary of the scores recorded by the experts in each of the tested aspects and its sub indicators (modes). The table shows the results of the Methodology Score (M) assessment of the ESHEIRS across six modes (2B, 3, 4A, 7A, 8, and 11). The methodology score reflects how well the ESHEIRS identifies and assesses the sustainability and environmental performance of higher education institutions. The results show that the average Methodology Score (M) for ESHEIRS is relatively high, ranging from 3.1 to 4.3 across the modes evaluated. The highest score was obtained by UIGM in mode 2B, with a score of 4.3, while the lowest score was obtained by STARS in mode 3, with a score of 2.8.

Also, the Transparency Score (T) assessment for the ESHEIRS ranking systems across six modes (2A, 4B, 6A, 6B, 9A, and 12A,). The Transparency Score reflects the degree to which the ranking systems disclose information about their methodologies and data sources used in the ranking process, making it easier for stakeholders to understand and evaluate the

results. The average Transparency Score for ESHEIRS ranges from 2.8 to 4.7 across the different modes evaluated. The highest score was obtained by UIGM in mode 6A, with a score of 4.7, while the lowest score was obtained by STARS in mode 2A, with a score of 3.2.

Additionally, the table shows the results of the Consumer Friendliness Score (C) assessment for the ESHEIRS ranking systems across two modes (15A and 15B). The Consumer Friendliness Score reflects the ease with which stakeholders can access and understand the ranking information, making it more user-friendly and accessible. The average Consumer Friendliness Score for ESHEIRS ranges from 2.8 to 3.7 across the different modes evaluated. The highest score was obtained by THEUIR in mode 15A, with a score of 5, while the lowest score was obtained by STARS in mode 15B, with a score of 1.3.

Overall, these results suggest that the evaluated ESHEIRSSs are generally effective in identifying and assessing the sustainability and environmental performance of higher education institutions, but there may be some variability in performance across different modes and ranking systems. On the other hand, the transparency of ESHEIRS ranking systems is generally moderate to high. However, there is some variability in performance across different modes and ranking systems. Finally, the consumer friendliness of ESHEIRS ranking systems is moderate, with some variability in performance across different modes and ranking systems.

Another task for the experts is to map the ESHEIRS' indicators to the SDG indicators, this task aims to generate ground truth dataset that could be used in validating the automated mapping of the ESHIRS' indicators to the SDGs indicators using AI and machine learning methods. Each expert mapped the ESHEIRS' indicators to the SDGs indicators and then majority vote technique was used to determine the final ESHEIRS' indicators to the SDGs indicators mapping matrix.

The most recent and distinct SDGs indicators were accounted, which totaled 231 individual metrics. Although the actual number of SDG indicators is 243, twelve of these metrics are duplicated across multiple SDGs. The research included two tables to report the number of indicators per ranking system and the total number of manually and automatically mapped indicators to the SDGs. Table 6 shows the manually mapped ESHEIRSSs indicators

to SDGs indicators. Additionally, Table 7 to 10 display statistical data on the ranking systems indicators and the manual/automated mapping of these indicators to the SDGs .

In this stage the indicators and their descriptions were utilized developed by the ESHEIRS framework as the corpus to evaluate the automatic ESHEIRS indicators against the SDGs indicators and their corresponding descriptions. Each indicator, along with its respective description, was treated as a distinct document. To measure the similarity between documents in both corpuses, the document similarity method were employed , which relies on the TF/IDF (term frequency-inverse document frequency) measure. Algorithm 1 was used to guide the process of determining document similarity. The cosine similarity was used to measure which is often used to determine the similarity between two documents or text snippets in natural language processing (Buzabo et al.,2021). Then the accuracy of the system were assessed using the Accuracy, Precision, and F1 scores.

$$ACC = \frac{(TP + TN)}{(TP + TN + FP + FN)} \quad (1)$$

$$Precision = \frac{TP}{(TP + FP)} \quad (2)$$

$$F1 = 2 \times \frac{(Accuracy \times Precision)}{(Accuracy + Precision)} \quad (3)$$

The following are the variables were used in Equations 1, 2, and 3:

**Actual Condition:** This is the manual mapping of ESHEIRS to SDGs indicators.

**Predicted Condition:** This is the automated mapping of ESHEIRS to SDGs indicators.

**True Positive (TP):** The correct number of mappings done by the automated mapping matches the manual mapping.

**False Negative (FN):** The incorrect number of mappings done by the automated mapping unmatching the manual mapping.

**False Positive (FP):** The unmapped indicators by automated mapping are unmapped by manual mapping.

**True Negative (TN):** The unmapped indicators by automated mapping are mapped by manual mapping. Accuracy (ACC) is a mathematical scale of how good a binary classification correctly test identifies or removes a condition.

**Table 5 HEI Quality Assurance Directors' Assessments of Ranking Systems Based on Methodology, Consumer Friendliness, and Transparency**

| Name<br>of<br>ESHEIRS | Methodology Score (M) |     |     |     |     |     |     | Transparency Score (T) |     |     |     |     |     |     | Consumer Friendliness<br>Score (C) |     |     | Final<br>Score<br>(MTC) | Mode | STD | Median |
|-----------------------|-----------------------|-----|-----|-----|-----|-----|-----|------------------------|-----|-----|-----|-----|-----|-----|------------------------------------|-----|-----|-------------------------|------|-----|--------|
|                       | 2B                    | 3   | 4A  | 7A  | 8   | 11  | Avg | 2A                     | 4B  | 6A  | 6B  | 9A  | 12A | Avg | 15A                                | 15B | Avg |                         |      |     |        |
| <b>UIGM</b>           | 4.3                   | 3.2 | 4   | 3.3 | 4.7 | 3.2 | 3.8 | 4.2                    | 2.8 | 4.7 | 4.5 | 4.5 | 4.3 | 4.2 | 4.5                                | 2.7 | 3.6 | 3.8                     | 4.5  | 0.7 | 3.8    |
| <b>THEUIR</b>         | 4.2                   | 2.8 | 3.8 | 2.3 | 4.7 | 3.5 | 3.6 | 4                      | 3.7 | 2.2 | 4   | 5   | 4   | 3.8 | 5                                  | 2.3 | 3.7 | 3.7                     | 4    | 0.9 | 3.7    |
| <b>STARS</b>          | 3.1                   | 2.8 | 3.7 | 3.8 | 4.7 | 3   | 3.6 | 3.2                    | 3.3 | 2   | 3.7 | 4.3 | 4.3 | 3.5 | 4.2                                | 1.3 | 2.8 | 3.3                     | 3.7  | 0.9 | 3.3    |

**Table 6 Ranking Systems Indicators Mapping Statistics**

| <b>Ranking System</b> | <b>Number of Indicators</b> | <b>Number of Automated Mapped Indicators to SDGs Indicators</b> | <b>Number of Manually Mapped Indicators to SDGs Indicators</b> |
|-----------------------|-----------------------------|-----------------------------------------------------------------|----------------------------------------------------------------|
| <b>UIGM</b>           | 39                          | 10                                                              | 43                                                             |
| <b>STARS</b>          | 68                          | 1                                                               | 4                                                              |
| <b>THE Impact</b>     | 193                         | 32                                                              | 31                                                             |

**Table 7 The Confusion Matrix of Mapping UIGM Indicators to SDGs Indicators**

| <b>n=9533</b>            | <b>Predicted Map</b> | <b>Predicted Not Mapped</b> | <b>Total</b> |
|--------------------------|----------------------|-----------------------------|--------------|
| <b>Actual Mapped</b>     | 3                    | 7                           | 10           |
| <b>Actual Not Mapped</b> | 7                    | 9516                        | 9523         |
| <b>Total</b>             | 10                   | 9523                        | 9533         |

**Table 8 The Confusion Matrix of Mapping THEUIR Indicators to SDGs Indicators**

| <b>n=47151</b>           | <b>Predicted Map</b> | <b>Predicted Not Mapped</b> | <b>Total</b> |
|--------------------------|----------------------|-----------------------------|--------------|
| <b>Actual Mapped</b>     | 4                    | 27                          | 31           |
| <b>Actual Not Mapped</b> | 28                   | 47092                       | 47120        |
| <b>Total</b>             | 32                   | 47119                       | 47151        |

**Table 9 The Confusion Matrix of Mapping STARS Indicators to SDGs Indicators**

| <b>n=16596</b>           | <b>Predicted Map</b> | <b>Predicted Not Mapped</b> | <b>Total</b> |
|--------------------------|----------------------|-----------------------------|--------------|
| <b>Actual Mapped</b>     | 0                    | 2                           | 2            |
| <b>Actual Not Mapped</b> | 2                    | 16592                       | 16594        |
| <b>Total</b>             | 2                    | 16594                       | 16596        |

**Table 10 Results of Automatically Mapping ESHEIRS SDGs**

| ESHEIRS                   | Accuracy | Precision | F1     |
|---------------------------|----------|-----------|--------|
| <b>UI GreenMetric</b>     | 0.99853  | 0.3       | 0.4614 |
| <b>THE Impact ranking</b> | 0.99883  | 0.125     | 0.2222 |
| <b>STARS by AASHE</b>     | 0.99976  | 0         | 0      |

Using the automated system based on NLP and ML techniques to map indicators to SDGs has many advantages which are minimizing Bias since automating the mapping process reduces the potential for human bias, which can occur when manually setting indicators or weighting them. This can result in a more objective and fair assessment. Also, it's more efficient and faster than manual mapping, making it possible to analyze more ranking systems in a shorter amount of time. Additionally, it's objective, and the results are based solely on the data, eliminating the possibility of subjective interpretation. This can ensure that the assessment is unbiased and impartial. Moreover, it ensures consistency in mapping indicators to SDGs, reducing the potential for errors and discrepancies in the results. This can provide a more accurate and reliable assessment, which can be useful for decision-making purposes.

The proposed technique achieved high accuracy. However, the precision was relatively low due to the large number of possible indicators mapping options. The STARS was the worst case since this ranking scheme has few indicators mapped to the SDGs.

UIGM scores the highest. In the assessment using the BPs, it gets the highest score. Also, the manual mapping of its indicators to the environmental indicators gets the highest mapped indicators; in the automated mapping it gets the highest. This results in a requirement to study it further in terms of its strengths and weaknesses.

### 4.3 Impact of Climate Parameters on ESHEIRSs scores

After reviewing the existing ESHEIRSs, it is recommended that ranking systems adopt a more standardized methodology that is adapted to the environmental conditions of a given region when evaluating the sustainability of universities. These environmental conditions are identified by the main climate elements of Temperature, Precipitation, and Humidity, which significantly impact all environmental indicators. Nevertheless, current ESHEIRSs do not adequately consider the effects of these indicators on universities' sustainability performance, highlighting the need for a more tailored approach that takes into account regional environmental conditions.

To further investigate the impact of climate elements on ESHEIRSs scores, this experiment examines the correlation between university performance (Score) in the UGIM ranking system and the climate element of AAT of the country in which the university operates (Buzaboon, Alnaser, Shatnawi, et al., n.d.). The study employed a dataset comprising of overall university scores for the year 2020 ranking in the UGIM ranking system, along with corresponding AAT values for the countries hosting the universities. To identify any associations between AAT and university ranking scores, linear regression analysis was used.

Table 11 presents the results of a linear regression model fitted to a dataset of 1114 observations. The table reports the coefficient of multiple determination (multiple R), which measures the strength of the linear relationship between the independent variables and the dependent variable. The value of multiple R is 0.084568255, indicating a weak positive linear relationship between the variables. The coefficient of determination (R-squared) is 0.00715179, which suggests that a small proportion of the variance in the dependent variable can be explained by the independent variables. The adjusted R-squared is 0.006258941, indicating that the model has little explanatory power. The standard error of the estimate is 18.96527514, suggesting that the model's predictions are not very accurate.

Table 12 shows the results of an ANOVA test conducted on the same regression model. The ANOVA test aims to determine if there is a significant relationship between the predictor variable (Temp) and the response variable (UGIM Score). The table is divided into three parts: the Regression section, the Residual section, and the

Total section. The Regression section shows that the predictor variable is statistically significant, with a significance F-value of 0.0047355. The Residual section reports that the variance in the model not explained by the predictor variable is 359.6816611, while the Total section shows that the sum of squared differences between the actual values and the mean value is 402847.0848.

The coefficients, standard errors, t-values, p-values, and confidence intervals for the intercept and predictor variable (Temp) in the regression model are also provided. The intercept coefficient is statistically significant, with a p-value of 0. The Temp coefficient is -0.176043584, indicating that a one-unit increase in the predictor variable results in a decrease in the response variable by 0.176043584 units. The lower and upper 95% confidence intervals for the intercept coefficient are 58.9404591 and 63.05230326, respectively.

This experiment shows that the AAT has a negative impact on the UGIM scores and supports the argument in this thesis that ranking systems should adapt their indicators weights based on the climate elements.

**Table 11 Temperature Summary Output of Regression Statistics**

| <i>Regression Statistics</i> |          |
|------------------------------|----------|
| Multiple R                   | 0.084568 |
| R Square                     | 0.007152 |
| Adjusted R Square            | 0.006259 |
| Standard Error               | 18.96528 |
| Observations                 | 1114     |

**Table 12 Temperature ANOVA Test**

|            | <i>df</i> | <i>SS</i> | <i>MS</i> | <i>F</i> | <i>Significance F</i> |  |  |  |
|------------|-----------|-----------|-----------|----------|-----------------------|--|--|--|
| Regression | 1         | 2881.078  | 2881.078  | 8.010077 | 0.004735              |  |  |  |
| Residual   | 1112      | 399966    | 359.6817  |          |                       |  |  |  |
| Total      | 1113      | 402847.1  |           |          |                       |  |  |  |

|           | <i>Coefficients</i> | <i>Standard Error</i> | <i>t Stat</i> | <i>P-value</i> | <i>Lower 95%</i> | <i>Upper 95%</i> | <i>Lower 95.0%</i> | <i>Upper 95.0%</i> |
|-----------|---------------------|-----------------------|---------------|----------------|------------------|------------------|--------------------|--------------------|
| Intercept | 60.99638            | 1.047817              | 58.2128       | 0              | 58.94046         | 63.0523          | 58.94046           | 63.0523            |
| Temp      | -0.17604            | 0.062202              | -2.83021      | 0.004735       | -0.29809         | -0.054           | -0.29809           | -0.054             |

#### 4.4 The Development of a New ESHEIRS

The development of a new system includes the identification of the weights using AI and ML. The resulting weights for each climate group by the multicriteria goal programming technique were displayed in Table 13. It is important to note that the multicriteria goal programming technique tends to favor solutions that take a greedy approach. As a result, the indicator with the least deviation value was assigned the maximum weight, leaving the other indicators with the minimum possible weight of 1. However, to avoid such extreme values, the algorithm was modified to force minimum and maximum weights for each indicator.

**Table 13 Weights for the 30 indicators – generated by the multicriteria goal programming for each climate group**

| Indicators (1...30) |   |   |   |   |   |   |   |   |   |    |    |    |   |   |   |    |    |    |    |  |
|---------------------|---|---|---|---|---|---|---|---|---|----|----|----|---|---|---|----|----|----|----|--|
| Group               | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | . | . | . | 27 | 28 | 29 | 30 |  |
| A                   | 2 | 4 | 2 | 2 | 4 | 1 | 4 | 2 | 3 | 2  | 2  | 2  | . | . | . | 2  | 8  | 14 | 8  |  |
| B                   | 2 | 4 | 2 | 2 | 4 | 2 | 5 | 2 | 4 | 2  | 2  | 2  | . | . | . | 2  | 8  | 8  | 8  |  |
| C                   | 2 | 4 | 2 | 2 | 4 | 1 | 4 | 2 | 3 | 2  | 2  | 2  | . | . | . | 2  | 8  | 14 | 8  |  |
| D                   | 2 | 4 | 2 | 2 | 4 | 1 | 4 | 2 | 3 | 2  | 2  | 2  | . | . | . | 2  | 8  | 14 | 8  |  |
| E                   | 2 | 4 | 2 | 2 | 4 | 1 | 4 | 2 | 3 | 2  | 2  | 2  | . | . | . | 2  | 8  | 14 | 8  |  |

In order to evaluate the effectiveness of the proposed ranking system, a panel of 5 experts were engaged who had contributed to the preparation of data submissions for various ranking systems to assign weights to the proposed indicators. The resulting weights were then utilized to rank universities according to their scores, with each indicator being assigned a fixed weight regardless of the climate group to which the university belonged. The results obtained from this fixed-weight ranking system were then compared to those of the multicriteria goal programming method, with Table 14 providing the indicators used in the proposed ranking system along with the corresponding scores assigned to them based on the expert panel's agreement.

The comparison of the two ranking methods is presented in Table 15, while Figure 8 depicts the impact of applying the multicriteria goal programming method on the rankings of universities in each climate group. The results demonstrate that universities in Group B and Group E have a competitive advantage over other groups,

as the performance of universities in these groups is more heavily influenced by the AAT due to their specific climate characteristics. These findings suggest that the proposed ranking system is effective in accounting for climate variations and could provide a more accurate representation of university performance compared to other ranking systems that do not consider such factors.

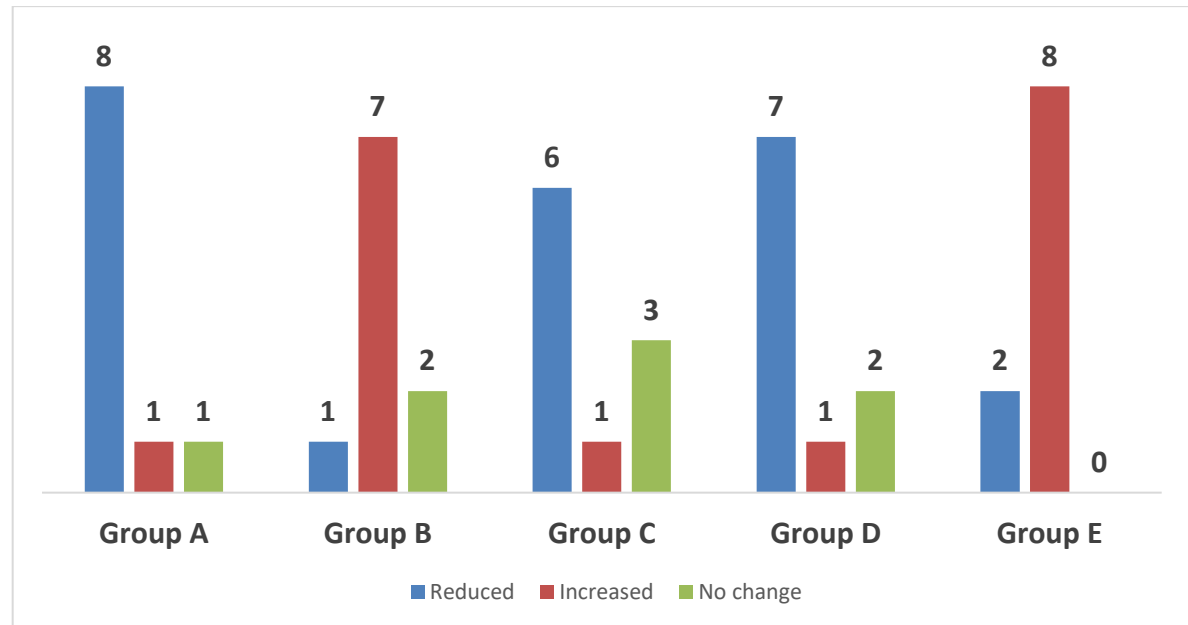


**Figure 8 Impact of Multicriteria Goal Programming on University Ranking Per Group**

For data collection and HEIs application to the system, they have to fill up a questionnaire Appendix H. The questionnaire has a mandatory requirement as in the following list:

- University Name
- Date of Establishment
- Address
- URL of the official website
- HEI's President Contact information
- Environmental Sustainability Coordinator contact information
- Partnerships on Environmental Sustainability
- Networks (Local, Regional, International)
- Partnerships (Government, Community, Education, Business, etc.)
- Public access to open spaces

- Open green spaces' details: Open Space Name, Total Area (m<sup>2</sup>), Duration (hours per week)
- Community services' details: Community Name, Number of Participants, Duration
- Type of higher education institution (Comprehensive, Specialized higher education institution)
- Climate ( Tropical wet, Tropical wet and dry, Semiarid, Arid, Mediterranean, Humid subtropical, Marine west coast / Oceanic Climate, Humid continental, Subarctic)
- Number of campus sites
- Campus setting ( Rural, Suburban , Urban, City center, High rise building area)
- Total campus area (m<sup>2</sup>)
- Total campus ground floor area of buildings (m<sup>2</sup>)
- Total campus buildings area (m<sup>2</sup>)
- Total number of regular students (part time and full time)
- Total number of online students (part time and full time)
- Total number of academic and administrative staff
- Estimated annual total population
- Total university budget (in US Dollars)
- University budget for sustainability effort (in US Dollars)
- Total carbon footprint (CO<sub>2</sub> emission in the last 12 months, in metric tons)
- Electricity usage per year (in kilowatt hours)
- Number of cars actively used and managed by university
- Number of cars entering the university daily
- Number of motorcycles entering the university daily
- Number of shuttles operated in the university
- Average number of passengers of each shuttle
- Total trips of each shuttle services each day
- Average number of Zero Emission Vehicles (e.g. bicycles, cano, snowboard, electric car, etc.) on campus per day
- Total campus' smart building area (m<sup>2</sup>)

- Renewable energy sources and it's capacity (in kilowatt hour)(Bio diesel, Clean biomass, Solar power, Geothermal, Wind power, Hydropower, Combine Heat and Power, or None)
- Total ground parking area (m2)
- Number of courses/subjects related to sustainability offered
- Total number of courses/subjects offered
- Total research funds dedicated to sustainability research (in US Dollars)
- Total research funds (in US Dollars)
- Sustainability website address (URL) if available
- Approximate daily travel distance of a vehicle inside your campus only (in Kilometers)

Evidence is required for all items as they will go through review and analysis process in the future.

**Table 14 University of Bahrain Higher Education Institutions Ranking System Indicators**

|                                    |                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                             | Class A                                                                                                                 | Class B | Class C | Class D | Class E | Class A                      |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|---------|---------|---------|---------|------------------------------|
| Indicator                          |                                                                                                                                                                                                                                                                                                                                                                | Measure                                                                                                                                                                                                                                                     | (The points are according to the first iteration of the program of the dummy university data for climate class A and B) |         |         |         |         | The fised indicators weights |
| Target 1: Impact on Climate Change |                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                             |                                                                                                                         |         |         |         |         |                              |
| 1.1                                | Carbon policy: is a proper carbon policy adopted? (yes/no)                                                                                                                                                                                                                                                                                                     | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                 | 2                                                                                                                       | 2       | 2       | 2       | 2       | 2                            |
| 1.2                                | Energy certifications: has the university obtained one or more energy certifications? (yes/no)                                                                                                                                                                                                                                                                 | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                 | 4                                                                                                                       | 4       | 4       | 4       | 4       | 5                            |
| 1.3                                | Greenhouse gases efficient inventory: are the CO2 emissions measured? (yes/no)                                                                                                                                                                                                                                                                                 | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                 | 2                                                                                                                       | 2       | 2       | 2       | 2       | 2                            |
| 1.4                                | Greenhouse emissions per capita: total CO2 emissions divided by the number of FTE students                                                                                                                                                                                                                                                                     | <input type="checkbox"/> >= 2.05 metric tons<br><input type="checkbox"/> < 2.05 - 1.11 metric tons<br><input type="checkbox"/> < 1.11 - 0.42 metric tons<br><input type="checkbox"/> < 0.42 - 0.10 metric ton<br><input type="checkbox"/> < 0.10 metric ton | 8                                                                                                                       | 8       | 8       | 8       | 8       | 2                            |
| Target 2: Energy Consumption       |                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                             |                                                                                                                         |         |         |         |         |                              |
| 2.1                                | Sustainable management of buildings: percentage of buildings (measured in cubic meters) managed in an energy sustainable way on the overall extension of the university buildings not subject to legal restrictions                                                                                                                                            | <input type="checkbox"/> < 1%<br><input type="checkbox"/> 1 - 25%<br><input type="checkbox"/> > 25 - 50%<br><input type="checkbox"/> > 50 - 75%<br><input type="checkbox"/> > 75%                                                                           | 2                                                                                                                       | 2       | 2       | 2       | 2       | 3                            |
| 2.2                                | Energy consumed per capita: total number of Kw/h per FTE student                                                                                                                                                                                                                                                                                               | <input type="checkbox"/> >= 2424 kWh<br><input type="checkbox"/> < 2424 - 1535 kWh<br><input type="checkbox"/> < 1535 - 633 kWh<br><input type="checkbox"/> < 633 - 279 kWh<br><input type="checkbox"/> < 279 kWh                                           | 14                                                                                                                      | 8       | 14      | 14      | 14      | 2                            |
| 2.3                                | Renewable energy: Heat gain for campus building(s), (BTUs/hour)<br><br>Heat gain $q = 1.10 \times \text{cfm} \times (t_o - t_i)$<br><br>Where,<br><br>$q$ = sensible heat gain from the outside air in Btu/h<br>$\text{cfm}$ = flow rate of outside air entering the building<br>$t_o$ = outside air temperature in °F<br>$t_i$ = inside air temperature in °F | <input type="checkbox"/> <15.000 Btu/h<br><input type="checkbox"/> 15.000 - 39.000 Btu/h<br><input type="checkbox"/> 40.000 - 200.000 Btu/h<br><input type="checkbox"/> 200.000-400.000 Btu/h<br><input type="checkbox"/> >400.000 Btu/h                    | 4                                                                                                                       | 4       | 4       | 4       | 4       | 2                            |
| 2.4                                | Are you purchasing electricity from green energy supplier (yes/No)<br>if Yes provide a copy of the contract agreement and the name of the energy supplier.                                                                                                                                                                                                     | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                 | 2                                                                                                                       | 2       | 2       | 2       | 2       | 1                            |

|                             |                                                                                                                                                 |                                                                                                                                                                                                                                                                                            | Class A                                                                                                                 | Class B | Class C | Class D | Class E | Class A                      |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|---------|---------|---------|---------|------------------------------|
| Indicator                   |                                                                                                                                                 | Measure                                                                                                                                                                                                                                                                                    | (The points are according to the first iteration of the program of the dummy university data for climate class A and B) |         |         |         |         | The fised indicators weights |
| Target 3: Waste Management  |                                                                                                                                                 |                                                                                                                                                                                                                                                                                            |                                                                                                                         |         |         |         |         |                              |
| 3.1                         | Waste production per capita: total weight of the waste produced, divided by the number of FTE students                                          | <input type="checkbox"/> > 0.0926 (kg/person/day)<br><input type="checkbox"/> 0.0700 - 0.0926 (kg/person/day)<br><input type="checkbox"/> 0.0400 - 0.0699 (kg/person/day)<br><input type="checkbox"/> 0.0003 - 0.0399 (kg/person/day)<br><input type="checkbox"/> < 0.0003 (kg/person/day) | 2                                                                                                                       | 2       | 2       | 2       | 2       | 2                            |
| 3.2                         | Unrecycled waste: per capita unrecycled waste produced in the university, divided by the per capita unrecycled waste recorded in the country    | <input type="checkbox"/> < 1%<br><input type="checkbox"/> 1 - 25%<br><input type="checkbox"/> > 25 - 50%<br><input type="checkbox"/> > 50 - 75%<br><input type="checkbox"/> > 75%                                                                                                          | 2                                                                                                                       | 2       | 2       | 2       | 2       | 2                            |
| 3.3                         | Internal waste recycle: percentage of waste recycled internally on the total waste produced                                                     | <input type="checkbox"/> Not managed<br><input type="checkbox"/> Partial (1 - 25% treated)<br><input type="checkbox"/> Partial (> 25 - 50% treated)<br><input type="checkbox"/> Partial (> 50 - 75% treated)<br><input type="checkbox"/> Extensive (> 75% treated)                         | 2                                                                                                                       | 2       | 2       | 2       | 2       | 3                            |
| 3.4                         | External waste recycle: percentage of waste recycled externally and internally through a proper separate collection on the total waste produced | <input type="checkbox"/> Not managed<br><input type="checkbox"/> Partial (1 - 25% treated)<br><input type="checkbox"/> Partial (> 25 - 50% treated)<br><input type="checkbox"/> Partial (> 50 - 75% treated)<br><input type="checkbox"/> Extensive (> 75% treated)                         | 2                                                                                                                       | 2       | 2       | 2       | 2       | 2                            |
| 3.5                         | Recycle of toxic waste: percentage of toxic waste which is properly treated on the overall toxic waste produced                                 | <input type="checkbox"/> Not managed<br><input type="checkbox"/> Partial (1 - 25% treated)<br><input type="checkbox"/> Partial (> 25 - 75% treated)<br><input type="checkbox"/> Extensive (> 75% treated)<br><input type="checkbox"/> 100% No toxic waste is produced                      | 2                                                                                                                       | 2       | 2       | 2       | 2       | 1                            |
| 3.6                         | Sewage disposal: percentage of sewage which is properly treated                                                                                 | <input type="checkbox"/> Not managed<br><input type="checkbox"/> Partial (1 - 25% treated)<br><input type="checkbox"/> Partial (> 25 - 75% treated)<br><input type="checkbox"/> Extensive (> 75% treated)<br><input type="checkbox"/> 100% No toxic waste is produced                      | 2                                                                                                                       | 2       | 2       | 2       | 2       | 4                            |
| 3.7                         | Plastic consumption: does the university implement a proper policy to reduce the consumption of plastic? (yes/no)                               | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                | 1                                                                                                                       | 1       | 1       | 1       | 1       | 2                            |
| 3.8                         | Paper consumption: does the university implement a proper policy to reduce the consumption of paper? (yes/no)                                   | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                | 1                                                                                                                       | 1       | 1       | 1       | 1       | 2                            |
| Target 4: Water Consumption |                                                                                                                                                 |                                                                                                                                                                                                                                                                                            |                                                                                                                         |         |         |         |         |                              |
| 4.1                         | Does the university adopt a proper policy to reduce the water consumption? (yes/no)                                                             | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                | 4                                                                                                                       | 5       | 4       | 4       | 4       | 2                            |

|                                                     |                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                   | Class A                                                                                                                 | Class B | Class C | Class D | Class E | Class A                      |
|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|---------|---------|---------|---------|------------------------------|
| Indicator                                           |                                                                                                                                                                                                                          | Measure                                                                                                                                                                                                                                                                                                           | (The points are according to the first iteration of the program of the dummy university data for climate class A and B) |         |         |         |         | The fised indicators weights |
| 4.2                                                 | Water consumed per capita: total consumption of water, divided by the number of FTE students ( Include all initiatives within the institution about water conservation programs)                                         | <input type="checkbox"/> > 40 (Liter per capita per day)<br><input type="checkbox"/> 39 - 29 (Liter per capita per day)<br><input type="checkbox"/> 28 - 18 (Liter per capita per day)<br><input type="checkbox"/> 17 - 7 (Liter per capita per day)<br><input type="checkbox"/> < 6.9 (Liter per capita per day) | 8                                                                                                                       | 8       | 8       | 8       | 8       | 2                            |
| 4.3                                                 | Does the university adopt greywater sustainability activities (Include all activities)                                                                                                                                   | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                       | 4                                                                                                                       | 5       | 4       | 4       | 4       | 5                            |
| Target 5: Transportation                            |                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                   |                                                                                                                         |         |         |         |         |                              |
| 5.1                                                 | Transportation policy: is there a policy to reduce the impact of transport on the pollution? (yes/no)                                                                                                                    | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                       | 6                                                                                                                       | 6       | 6       | 6       | 6       | 2                            |
| 5.2                                                 | Ecological transport of employees: percentage of employees who use an ecological means of transport, such as public transportation, biking, or walking to reach the campus and travel inside the campus                  | <input type="checkbox"/> < 1%<br><input type="checkbox"/> 1 - 25%<br><input type="checkbox"/> > 25 - 50%<br><input type="checkbox"/> > 50 - 75%<br><input type="checkbox"/> > 75%                                                                                                                                 | 4                                                                                                                       | 4       | 4       | 4       | 4       | 2                            |
| 5.3                                                 | Ecological transport of students: percentage of students who use an ecological means of transport, such as public transportation, biking, or walking to reach the campus and travel inside the campus                    | <input type="checkbox"/> < 1%<br><input type="checkbox"/> 1 - 25%<br><input type="checkbox"/> > 25 - 50%<br><input type="checkbox"/> > 50 - 75%<br><input type="checkbox"/> > 75%                                                                                                                                 | 4                                                                                                                       | 4       | 4       | 4       | 4       | 6                            |
| Target 6: Education to Environmental Sustainability |                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                   |                                                                                                                         |         |         |         |         |                              |
| 6.1                                                 | Does the university implement special measures in order to educate the students towards and become aware of environmental sustainability issues? (yes/no)                                                                | <input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                       | 1                                                                                                                       | 2       | 1       | 1       | 1       | 4                            |
| 6.2                                                 | Events on environmental sustainability: number of scholarly or public events organized by the university aimed at increasing the awareness of environmental sustainability issues, divided by the number of FTE students | <input type="checkbox"/> >= 1<br><input type="checkbox"/> < 1 - 0.5<br><input type="checkbox"/> < 0.5 - 0.125<br><input type="checkbox"/> < 0.125 - 0.045<br><input type="checkbox"/> < 0.045                                                                                                                     | 3                                                                                                                       | 4       | 3       | 3       | 3       | 8                            |
| 6.3                                                 | Research projects on environmental sustainability: number of research projects on environmental sustainability issues carried out in the university, divided by the number of FTE students                               | <input type="checkbox"/> >= 1<br><input type="checkbox"/> < 1 - 0.5<br><input type="checkbox"/> < 0.5 - 0.125<br><input type="checkbox"/> < 0.125 - 0.045<br><input type="checkbox"/> < 0.045                                                                                                                     | 3                                                                                                                       | 4       | 3       | 3       | 3       | 3                            |
| 6.4                                                 | Research funds: percentage of the total research funds devoted to the research projects on environmental sustainability issues                                                                                           | <input type="checkbox"/> <= 1%<br><input type="checkbox"/> > 1 - 5%<br><input type="checkbox"/> > 5 - 10%<br><input type="checkbox"/> > 10 - 20%<br><input type="checkbox"/> > 20%                                                                                                                                | 3                                                                                                                       | 4       | 3       | 3       | 3       | 5                            |

|                        |                                                                                                      |  | Class A                                                                                                                 | Class B | Class C | Class D | Class E | Class A                      |   |
|------------------------|------------------------------------------------------------------------------------------------------|--|-------------------------------------------------------------------------------------------------------------------------|---------|---------|---------|---------|------------------------------|---|
|                        |                                                                                                      |  | (The points are according to the first iteration of the program of the dummy university data for climate class A and B) |         |         |         |         | The fised indicators weights |   |
| Indicator              | Measure                                                                                              |  |                                                                                                                         |         |         |         |         |                              |   |
| Target 7: Biodiversity |                                                                                                      |  |                                                                                                                         |         |         |         |         |                              |   |
| 7.1                    | The measures followed in protecting Biodiversity around or in university campus                      |  | Documentation of the evidence is required                                                                               | 2       | 2       | 2       | 2       | 2                            | 6 |
| 7.2                    | The Contribution to any Biodiversity initiatives or programs on the national or international levels |  | Documentation of the evidence is required                                                                               | 2       | 2       | 2       | 2       | 2                            | 6 |
| 7.3                    | Publish Biodiversity report                                                                          |  | Documentation of the evidence is required                                                                               | 2       | 2       | 2       | 2       | 2                            | 5 |
| 7.4                    | Publish any research paper on biodiversity in an accredited journal                                  |  | Documentation of the evidence is required                                                                               | 2       | 2       | 2       | 2       | 2                            | 7 |

**Table 15 Comparison of Multi-Criteria Goal Programming and Fixed Weight Methods for University Evaluation**

| <i>Class</i> | Multicriteria Goal Programming Results |       |    | Fixed weight Results |    |
|--------------|----------------------------------------|-------|----|----------------------|----|
|              |                                        |       |    |                      |    |
| A            | University 1                           | 54.77 | 33 | 64.74                | 33 |
| A            | University 2                           | 38.20 | 42 | 51.37                | 41 |
| A            | University 3                           | 67.46 | 19 | 77.64                | 17 |
| A            | University 4                           | 69.58 | 16 | 81.76                | 14 |
| A            | University 5                           | 36.72 | 45 | 52.24                | 40 |
| A            | University 6                           | 79.14 | 3  | 99.15                | 1  |
| A            | University 7                           | 50.75 | 35 | 70.08                | 28 |
| A            | University 8                           | 77.93 | 5  | 94.41                | 6  |
| A            | University 9                           | 72.19 | 11 | 85.18                | 10 |
| A            | University 10                          | 60.52 | 25 | 70.73                | 24 |
| B            | University 11                          | 42.79 | 39 | 43.80                | 48 |
| B            | University 12                          | 20.10 | 50 | 25.21                | 50 |
| B            | University 13                          | 54.38 | 34 | 55.18                | 38 |
| B            | University 14                          | 57.09 | 29 | 58.81                | 37 |
| B            | University 15                          | 23.63 | 49 | 31.62                | 49 |
| B            | University 16                          | 67.15 | 20 | 74.09                | 21 |
| B            | University 17                          | 36.94 | 44 | 48.32                | 46 |
| B            | University 18                          | 71.16 | 13 | 76.06                | 20 |
| B            | University 19                          | 61.86 | 24 | 65.15                | 31 |
| B            | University 20                          | 57.24 | 28 | 70.60                | 25 |
| C            | University 21                          | 55.26 | 32 | 65.33                | 30 |
| C            | University 22                          | 37.69 | 43 | 50.39                | 43 |
| C            | University 23                          | 68.01 | 18 | 77.84                | 16 |
| C            | University 24                          | 70.95 | 14 | 81.86                | 13 |
| C            | University 25                          | 36.12 | 46 | 50.54                | 42 |
| C            | University 26                          | 77.51 | 6  | 95.23                | 5  |
| C            | University 27                          | 49.88 | 37 | 68.46                | 29 |
| C            | University 28                          | 78.75 | 4  | 95.61                | 4  |
| C            | University 29                          | 71.85 | 12 | 84.65                | 12 |
| C            | University 30                          | 60.32 | 26 | 70.45                | 27 |
| D            | University 31                          | 50.59 | 36 | 58.92                | 36 |
| D            | University 32                          | 33.90 | 48 | 45.61                | 47 |
| D            | University 33                          | 63.26 | 23 | 72.50                | 23 |
| D            | University 34                          | 65.90 | 22 | 76.85                | 18 |
| D            | University 35                          | 34.73 | 47 | 49.03                | 45 |
| D            | University 36                          | 74.35 | 10 | 91.07                | 8  |
| D            | University 37                          | 46.83 | 38 | 64.47                | 35 |
| D            | University 38                          | 76.88 | 8  | 93.58                | 7  |
| D            | University 39                          | 68.51 | 17 | 80.37                | 15 |
| D            | University 40                          | 55.65 | 30 | 64.70                | 34 |

| <i>Class</i> | <b>Multicriteria Goal Programming Results</b> |       |    | <b>Fixed weight Results</b> |    |
|--------------|-----------------------------------------------|-------|----|-----------------------------|----|
| E            | University 42                                 | 41.20 | 41 | 49.86                       | 44 |
| E            | University 43                                 | 70.50 | 15 | 76.51                       | 19 |
| E            | University 44                                 | 75.99 | 9  | 84.70                       | 11 |
| E            | University 45                                 | 42.33 | 40 | 54.20                       | 39 |
| E            | University 46                                 | 82.37 | 2  | 96.21                       | 3  |
| E            | University 47                                 | 55.30 | 31 | 70.57                       | 26 |
| E            | University 48                                 | 84.91 | 1  | 98.61                       | 2  |
| E            | University 49                                 | 77.26 | 7  | 86.57                       | 9  |
| E            | University 50                                 | 66.14 | 21 | 72.82                       | 22 |

## 4.5 Climate Classification Systems

Climate classification is a way to group regions' climates using different attributes. There are different climate classifications like the Aridity index, Berg climate classification, KG climate classification, and Lauer climate classification. The KG climate classification is the most popular because it was the first quantitative classification of world climates. It was first published by Wladimir Köppen in 1884 and modified later by Köppen and Rudolf Geiger. (Kottek et al., 2006). It classifies the world's regions based on their precipitation and temperature levels into five groups: A, B, C, D, and E.

The KG climate classification is applied to study the relationship of thermal zones of the Earth in different ecosystems because climate impacts the nature of life in a region. An overview of these studies shows it has significant impacts (Chmielewski et al., 2011). The KG climate classification is also used to assess the climate changes in different countries where these changes result in changing their climate zones. Algeria, for example, is a country that ranges from relatively wet to very dry (desert-like). However, the country's wet region's climate is changing. Studies analysed the climate zone changes in the period from 1951 to 2098 and concluded that the rate of expansion of desert climate will increase in the future, mainly from 2045 to 2098 (Zeroual et al., 2019).

The KG system divides the world into five climate zones based on criteria, usually temperature, which allows for different vegetation growth. KG map used different colors and shades to represent the world's different climate zones while most of the zones are organised based on the temperature of a region, Zone B focuses on

the aridity of a region. The zones are as follows: Zone A: Tropical or equatorial zone (represented by blue colors on most maps); zone B: Arid zone (represented by red, pink, and orange colors on most maps); zone C: Warm/mild temperate zone (represented by green colors on most maps); zone D: Continental zone (represented by purple, violet, and light blue colors on most maps); zone E: Polar zone (represented by gray colors on most maps).

Each zone is further subdivided based on temperature or dryness. For example, Zone A has three subdivisions: Zone Af has no dry season, Zone Am has a short dry season, and Zone Aw has a winter dry season. Zone B is divided into categories related to regions such as hot, arid deserts (Zone BWh); cold, arid deserts (Zone BWk); hot, arid steppes (Zone BSh); and cold, arid steppes (Zone BSk). Climate zones C and D are broken into categories based on when the dry seasons occur in the zones and the coldness of the summer or the warmth of the winter. Zone E climates are separated into tundra regions (Zone ET) or snow and ice regions (Zone EF). Some modern revisions to the system include a sixth region, known as Zone H. This represents a highland climate located at mountainous elevations.

Scientists and climatologists still use Köppen's classification maps to this day. Although he published his first map in the early 1900s, Köppen continued to update it until his death in 1940. Subsequent climatologists, including Rudolf Geiger, updated versions of this map, which often included Geiger's name. In our writing, herein, a recent revision to this map was published in 2018 (Kottek et al., 2006a) under the title Köppen Climate Classification System. The KG system uses colors and shades to classify the world into five climate zones based on criteria such as temperature, which allows for different vegetation growth.

The final list of indicators from the previous chapters' work Table 13 will appear to the user along with the specific weight after selecting the country from a world map categorized based on the KG classification system. Generally, in this phase, the author studied the KG classification system and the possibility of using it as a base for categorizing world countries. The results show that the author could use the KG system to classify world countries. The author used the main classes for the country classification to be identified at the beginning of the ranking procedure. Then based on the main class, the ML program will run to customize the weights of the indicators setting process. The significance of this phase is that it generates a new path in environmental sustainability higher education institutions ranking process. The

indicator weights differ from one HEI to another depending on the class of the country of residence. The limitation of this part is the usage of the main classes of the KG classification. In further studies, it is highly recommended to classify the HEI based on subclass of the KG classification system and to classify the district, not only the country of origin.

#### **4.6 The Online Website of the New ESHEIRS**

A simple and essential website was developed to demonstrate the methodology after systematically analyzing and designing the user requirements. The study collected data from the five stages and other data collection methods mentioned earlier and built an essential online website. The online website link is <http://envranking.somee.com/>. For the map design, HTML5/Javascript was used; and for the development stage java server pages was used. For hosting the website, Hosted Windows Virtual Server was used with 2.5GHz CPU, 2GB RAM, and 60GB SSD. Web hosting by Somee.com as a support of the hosting process.

When following the link, a World map is shown where it is possible to select the country of residence of the respective HEI, and the customised set of indicators will be displayed accordingly. Later, the reader, starts entering each indicator's requirement to submit their evidence for the ranking system. A snapshot of the website page is shown in Figure 9, followed by Figure 10 which shows a snapshot of the online website home page of the proposed ranking system after selecting the Kingdom of Bahrain as country of residence of the HEI.

Figure 11 shows a snapshot of the online website home page of the proposed ranking system after selecting one of the targets. Figure 12 shows a snapshot of the online website home page of the proposed ranking system after entering the data of the indicators of the first target.

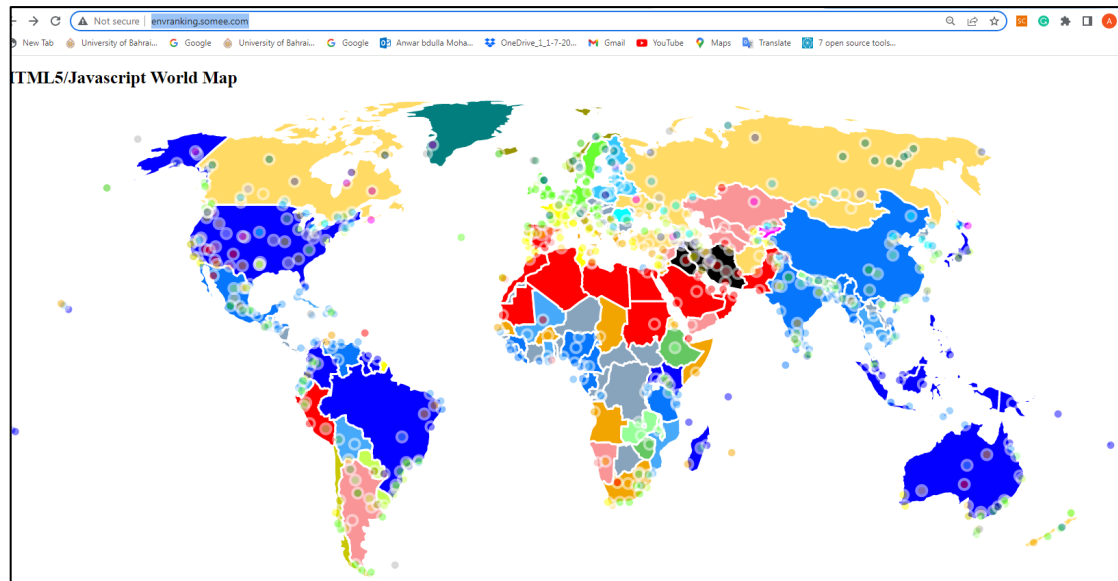


**Figure 9** A snapshot of the online website home page of the proposed ranking system

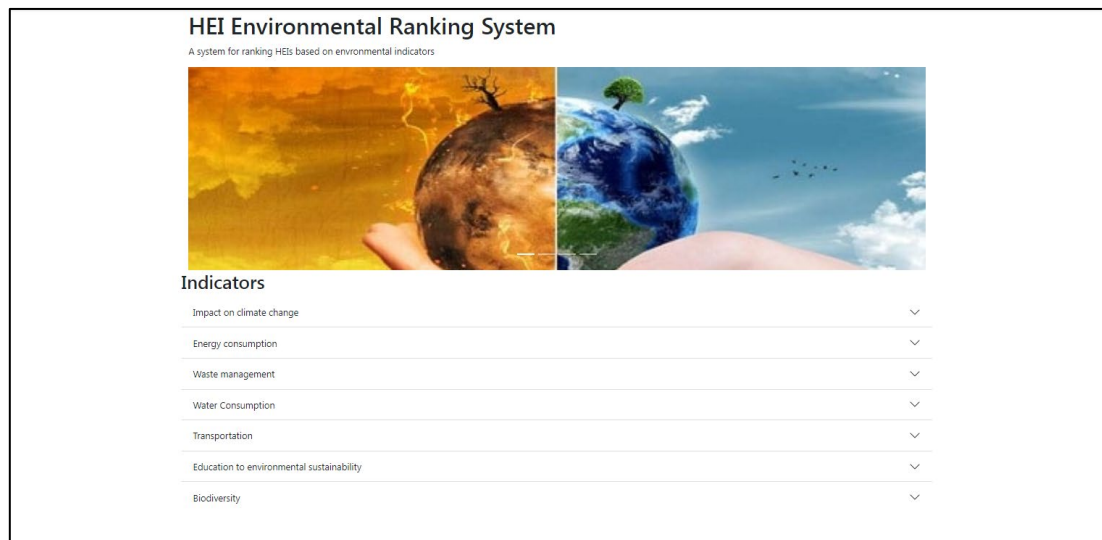


**Figure 10** A snapshot of the online website home page of the proposed ranking system after selecting the Kingdom of Bahrain as country of residence of the HEI.

**HEI Environmental Ranking System**  
A system for ranking HEIs based on environmental indicators



**Indicators**

Impact on climate change

| #   | Description                                                                                    | Input  |
|-----|------------------------------------------------------------------------------------------------|--------|
| 1.1 | Carbon policy: is a proper carbon policy adopted? (yes/no)                                     | Yes No |
| 1.2 | Energy certifications: has the university obtained one or more energy certifications? (yes/no) | Yes No |
| 1.3 | Greenhouse emissions: are the CO2 emissions measured? (yes/no)                                 | Yes No |
| 1.4 | Greenhouse emissions per capita: total CO2 emissions divided by the number of FTE students     |        |

Energy consumption

Waste management

**Figure 11** A snapshot of the online website home page of the proposed ranking system after selecting one of the targets

**HEI Environmental Ranking System**  
A system for ranking HEIs based on environmental indicators



**Indicators**

Impact on climate change

| #   | Description                                                                                    | Input        |
|-----|------------------------------------------------------------------------------------------------|--------------|
| 1.1 | Carbon policy: is a proper carbon policy adopted? (yes/no)                                     | Yes No       |
| 1.2 | Energy certifications: has the university obtained one or more energy certifications? (yes/no) | Yes No       |
| 1.3 | Greenhouse emissions: are the CO2 emissions measured? (yes/no)                                 | Yes No       |
| 1.4 | Greenhouse emissions per capita: total CO2 emissions divided by the number of FTE students     | Data entered |

Energy consumption

Waste management

Water Consumption

**Figure 12** A snapshot of the online website home page of the proposed ranking system after entering the data of the indicators of the first target

Developing an environmental sustainability ranking system is crucial to promoting a more sustainable future. A well-designed and user-friendly website is essential for showcasing the ranking system and making it accessible to a broader audience. The website can feature interactive data visualizations, detailed methodology descriptions, and examples of how the rankings can be used to promote sustainability. An effective branding strategy can help create a recognizable and trusted brand for the ranking system, increasing its visibility and credibility. A methodology brochure is also an essential tool for demonstrating the development of the ranking system, as it describes the methods used to collect and analyze data. The brochure should include information on the selection of indicators, data sources, and weighting schemes, as well as a description of the validation and verification procedures used to ensure the accuracy and reliability of the rankings. By developing a website, branding strategy, and methodology brochure, the development of an environmental sustainability ranking system and promote a more sustainable future could be demonstrated. The following pages include the first version of the brochure (See Appendix G).

#### **4.7 Real-life Implementation of a Proposed Multicriteria Ranking System for Higher Education Institutions**

The proposed system presents a new approach to ranking HEIs that takes into account the environmental group of the country in which each university operates as one of the optimization objectives. By employing a multi-objective optimization approach, the proposed system is adaptive to the university submission.

The system is a dynamic system that propose indicators weights annually and can be used either as a standalone tool or as a supporting tool to generate the weights for each indicator used in the ranking process. In the standalone version, the weights for each indicator are generated based on the collective input from all participating universities. In contrast, the supporting tool version provides recommendations for the weights of the indicators, which are then used to generate the final weights separately. A two stages plan was proposed for the ranking system implementation as a standalone tool. The first year of the proposed system will involve a two-stage process for generating the weights of the indicators. In the first stage, simulated data based on available environmental open data will be used to provide a preliminary set of weights

that can be used for initial ranking assessments. In the second stage, actual university data will be collected through the first-year submissions and used to generate the final set of weights for the indicators. Figure 13 envisioned the inaugural edition of the proposed ranking system.

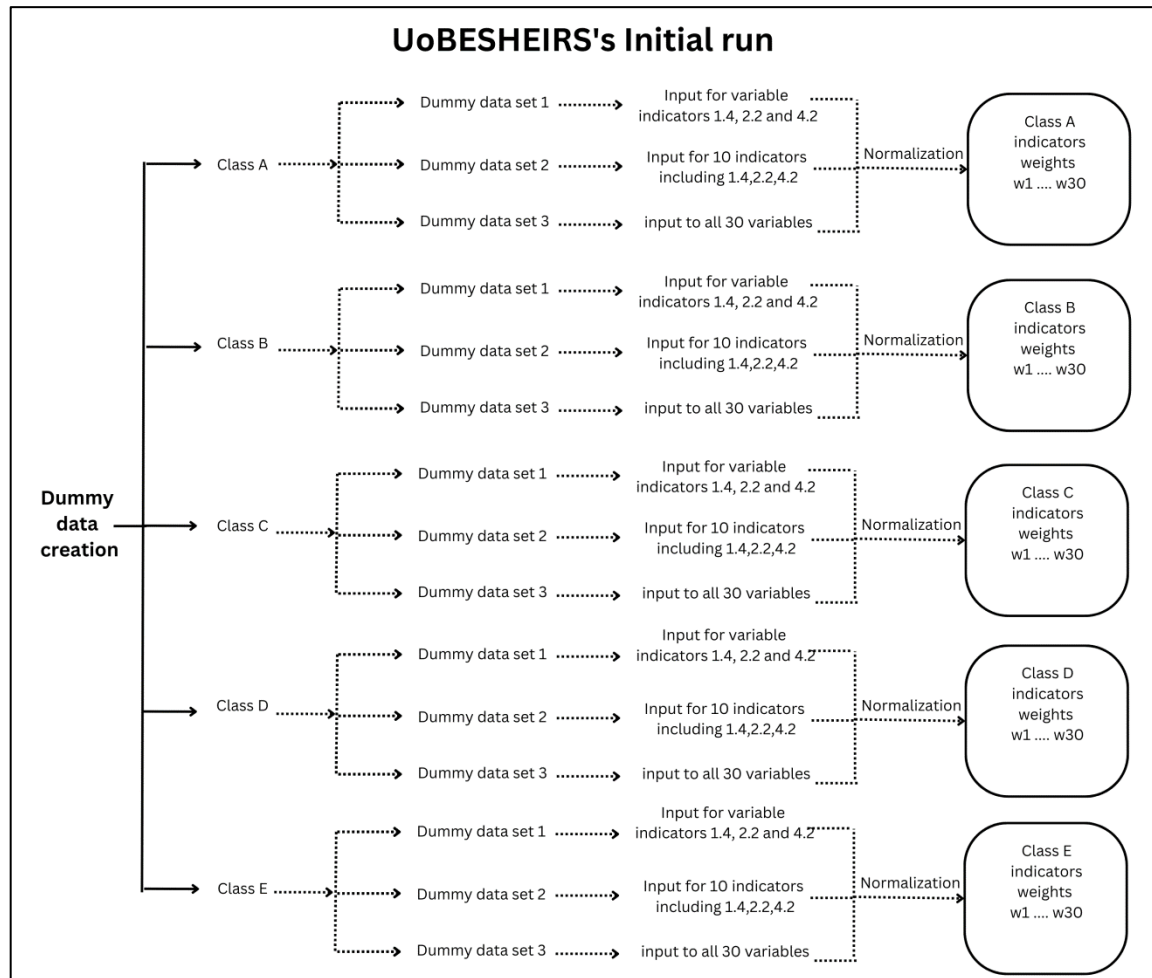


**Figure 13 UoBESHEIRS inaugural Implementation**

The system can be either a standalone ranking system or be adopted or utilized by an existing ranking system. Before the adaptation process, the weights of the indicators are calculated for the standalone ranking system. For the weight setting, the system assumes that all indicators of the five climate classes use the same weights except those related to energy and water scarcity.

The system assumes the exact size of renewable energy and waste management process for all HEIs. Therefore, all indicator weights will be fixed except for three

variable indicator weights. The three variable indicators' weights will depend on the climate class and a computer program that normalizes the values based on the multicriteria goal programming model for ranking universities. The computer program outputs different weights for the same variable indicator depending on the climate class. Here are some descriptions of the three indicators which could be considered as variable indicators:

**1.4 Greenhouse emissions per capita:** total CO<sub>2</sub> emissions divided by the number of FTE students is a measure of the carbon dioxide emissions produced per full-time equivalent (FTE) student at a university. It is calculated by dividing the total CO<sub>2</sub> emissions a university produces by the number of FTE students enrolled.

**2.2 Energy consumed per capita:** total number of Kw/h per FTE student. This indicator refers to the total energy consumed per person in a university community, particularly by students, faculty, and staff. This indicator is calculated by dividing the total energy consumption in kilowatt-hours (Kw/h) by the number of full-time equivalent (FTE) students in the university. It is a measure of the university's energy efficiency and sustainability efforts, as it reflects the amount of energy required to support the university's daily operations.

**4.2 Water consumed per capita:** total consumption of water, divided by the number of FTE students (Include all initiatives within the institution about water conservation programs). This indicator refers to the total water consumed per person in a university community, particularly by students, faculty, and staff. This indicator is calculated by dividing the total water consumption by the number of full-time equivalent (FTE) students in the university. It includes all initiatives within the institution about water conservation programs, reflecting the university's efforts to reduce water consumption and promote more sustainable water usage practices.

The use of simulated data in the first stage is intended to provide a baseline for the weights of the indicators, which then will be refined and improved in subsequent years based on actual data. This two-stage approach will also allow for any necessary adjustments to be made to the ranking methodology and indicator weights in the early

stages of implementation, based on feedback and evaluation of the initial results. Figure 14 shows the next year implementation of the proposed system.

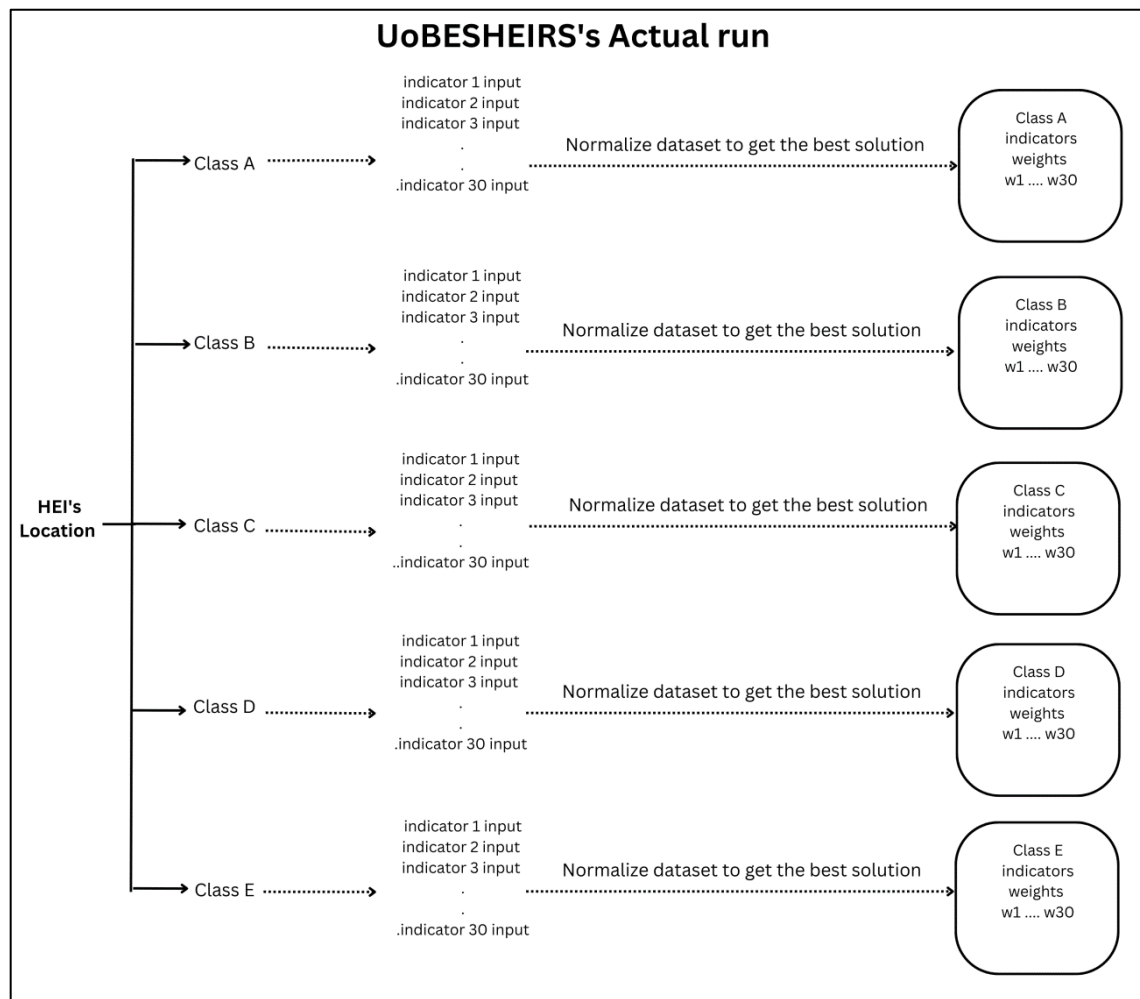


**Figure 14 UoBESHEIRS actual run**

Furthermore, the system could be embedded and integrated into an existing ranking system. The integration of a supporting module into existing ranking systems has the potential to enhance their accuracy and relevance. This module can be seamlessly integrated into the pre-existing indicator categories and the weights of these categories can be adjusted based on the submission data provided by universities as in Figure 15. However, it is important to note that this approach requires human interaction with the system, specifically the manual adjustment of weights to align with the agenda of the ranking system.

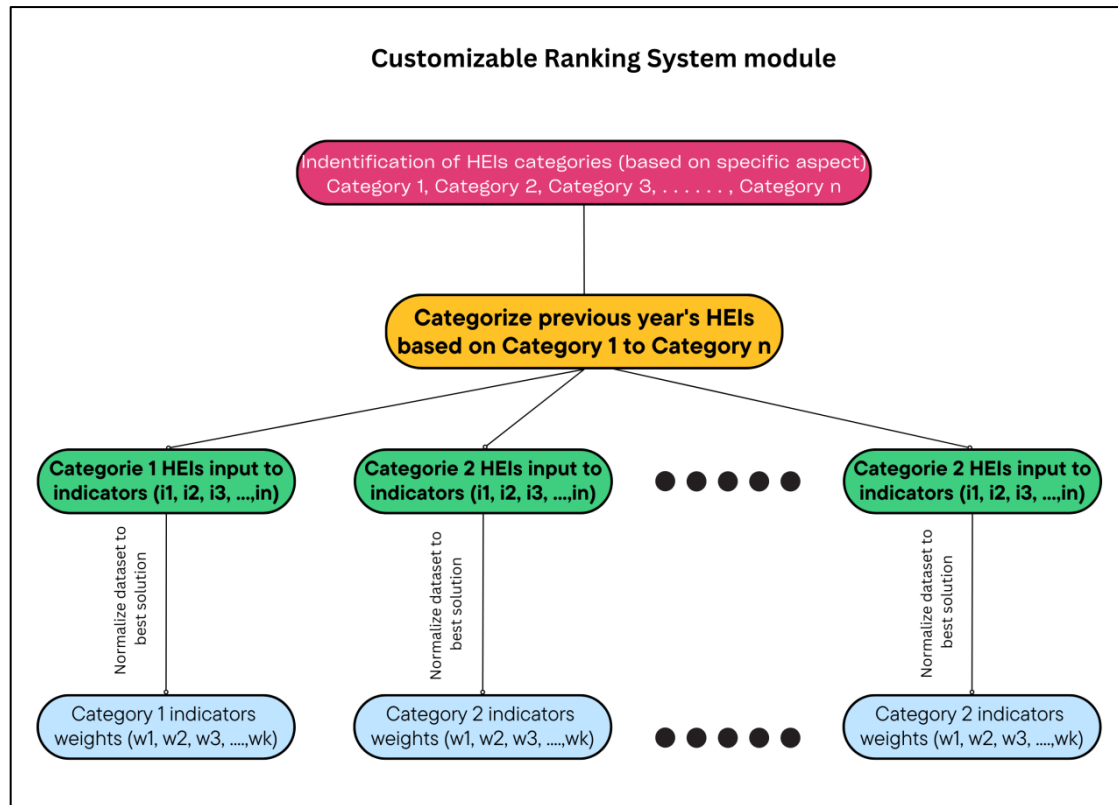


**Figure 15 Customizable ranking system module**

Overall, the proposed ranking system represents an objective and comprehensive approach to ranking HEIs that takes into account the unique environmental factors and constraints that may impact university performance. The proposed two-stage approach to generating indicator weights ensures that the ranking system is based on both simulated and actual university data, which will be refined and improved over time to provide an accurate and reliable ranking of HEIs.

Figure 16 compares top university rank from different climate classes using UobESHEIRS rank vs. Fixed weight rank. The five universities in the figure are the universities at the top. All got a rank of one for each class. University 6 from class A got the top rank and ranked one—the same for University 8 from class B. Figure 16 compares the rank result of the proposed system and the fixed weight ranking methodology. The result is that the top university of class A scores higher using the fixed weight other than UobESHEIRS. The top of class B reduced its rank when using a fixed weights method and improved its ranking with UoBESHEIRS. Class C top universities got the same in both methods and top rank in both. The top university of

class D scores better with fixed weights. Actually, for both classes B and E, the top universities of UoBESHEIRS reduced their score when being assessed with a fixed weight method.

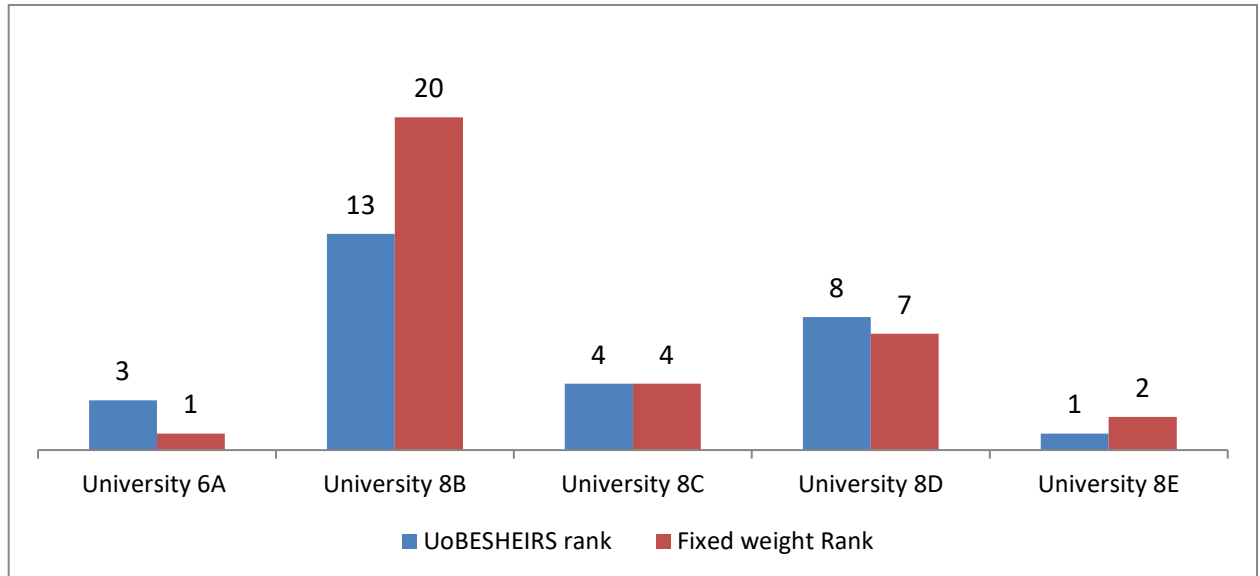


**Figure 16 Comparison of Top University rank from different climate classes using UobESHEIRS rank vs. Fixed weight rank**

# Chapter 5

## Discussion

The study presents a review of various Environmental Sustainability Higher Education Institution Ranking Systems (ESHEIRSSs) and an automated system to map indicators to Sustainable Development Goals (SDGs). The study concludes that assessing the sustainability of universities, especially environmental sustainability, is essential, as there are only 14 systems evaluating environmental sustainability. ESHEIRSSs were found to have moderate to high transparency and moderate consumer friendliness. The automated mapping system had several advantages, such as reducing human bias, being efficient, objective, and ensuring consistency. The proposed technique achieved high accuracy, but the precision was relatively low due to the large number of possible indicators mapping options. In the evaluation of a university's performance, outcome indicators should be primarily considered, while other types of indicators are often used as proxies. Some indicators are considered as input or activity indicators, while others are leading indicators that provide a comprehensive view of the university's "environmental balance."

The study suggests that HEIRS need to include more indicators to evaluate the sustainability of universities, and further research is required to assess the current ESHEIRSSs and identify best practices. The proposed automated system can be useful for decision-making purposes, but it needs improvement to increase precision. The study highlights the importance of assessing sustainability in higher education institutions and the need to use outcome indicators for accurate and comprehensive sustainability assessment.

The study has proposed a ranking system for evaluating the sustainability performance of universities. The proposed system includes a set of indicators that encompass environmental and social aspects, as well as biodiversity, and are normalized based on national averages. The study also utilizes the multicriteria goal programming technique to assign weights to the indicators in a systematic and

objective manner, accounting for climate variations. The results indicate that the proposed ranking system is effective in accounting for climate variations and provides a more accurate representation of university performance compared to other ranking systems that do not consider such factors. The results also suggest that universities in Group B and Group E have a competitive advantage over other groups due to their specific climate characteristics. However, the recommendation here is to conducting further data analysis and statistical comparisons of the proposed ranking system with other existing systems, as well as case studies that demonstrate how climate variations affect sustainability outcomes.

Three ESHEIRS are compared and ranked in terms of their compatibility with the BPs indication in the assessment of the ESHEIRS using BPs. Where 30 UK institutions were evaluated by (Vlasceanu et al., 2015) and ranked based on how well they fit with BPs. Both studies use a methodology that is comparable, yet they evaluate HEIs differently.

García and Guijarro (2021) provided a model for indicator weights customisation based on a mathematical model without the interference of human contact in relation to the application of multicriteria goal programming model for ranking colleges. The same model was applied, created, and adjusted to achieve the goals. Setting minimum and maximum values for the indicators summation allowed for customization. Three indicators were added to the model as a further addition, whereas García and Guijarro (2021) employed a fixed set of indicators.

According to the review conducted in this thesis and based on the analysis and recommendation presented in Cardin (2017) which includes a critical analysis of the weaknesses of the UIGM and suggested a new set of indicators to assess the sustainability HEIs. Although The author acknowledged that the UIGM indicators are transparent and open, he identified some limitations that need to be addressed.

The first weakness of the UIGM relates to the environmental indicators, which may not be context neutral. The author argued that it is unfair to compare universities

located in areas with different water scarcity issues using a single measure. Furthermore, HEIs located in historic cities or city centers may face constraints in implementing actions to reduce their environmental impact. The author also highlighted that the environmental impact could vary significantly based on the climate zone and population density. As a result, the author proposed that normalization should be carried out based on climate zones, but the challenge remains in assigning different weights to proposed actions.

The second weakness of the UIGM is the absence of indicators related to the social dimension of sustainability. The author highlighted that engaging the community in the university institution is crucial, and social impact and cohesion indicators are required to measure the effect of HEIs on the community, even at the economic level. The author argued that the economic situation and cultural context of a country have an impact on the achievable results of HEIs, and there is a need for indicators that reflect these differences.

The third weakness of the UIGM is the reliability of data. The author argued that rankings often require institutions to provide or build data without verifying its accuracy, leading to unfair competition among institutions. The author suggested that accompanying the ranking with a process of assurance could solve this problem.

In conclusion, Cardin (2017) proposed a new set of indicators to address the weaknesses of the UIGM. The author acknowledged the importance of the UIGM in drawing attention to the commitment of HEIs to sustainability and proposing indicators to increase awareness of this subject. However, the author argued that building upon this milestone is essential to create a more accurate scheme that allows monitoring of the actions and progress of HEIs in this framework.

By considering all indicators proposed by Cardin (2017) assessment and added the findings of our experiments especially the impact of climate elements and conducted focus group discussions to evaluate these indicators and identify more indicators to be included in the proposed ranking system.

Additionally, one of the options that were explored is the inclusion of biodiversity indicators in the proposed ranking system. (Allam & Naser, n.d.) mentioned that the establishment of the Directorate of Biodiversity at the Supreme

Council for Environment in 2012 is considered a major step forward in strengthening the institutional capacity of biodiversity protection in Kingdom of Bahrain.

Biodiversity, a critical component of a sustainable world, offers numerous services and benefits, such as food and water supply, pollination, nutrient cycling, and ecosystem resilience and adaptation to climate change. Incorporating biodiversity as an indicator in Environmental sustainability university assessment tools is necessary to enable universities to manage their land and resources better, assess their progress in meeting biodiversity targets, and identify potential improvement areas. Universities have a crucial role in supporting biodiversity, including researching the causes of biodiversity loss, developing strategies and policies to protect it, raising awareness about its importance, equipping students with the knowledge and skills to preserve it, and providing resources, funding, and expertise to local conservation initiatives.

It is strongly believed that the proposed ranking system should include indicators that capture universities' performance in the biodiversity aspect. Universities must contribute to addressing biodiversity by ensuring that their activities and operations do not harm the natural world. By incorporating biodiversity indicators in the ranking system, universities will be encouraged to prioritize and implement conservation measures, leading to a more sustainable future. Proposed indicators could include the number of threatened and endangered species on campus, the amount of green space dedicated to wildlife habitat, and the percentage of the university's land set aside for conservation. Such indicators will enable universities to track their progress and promote accountability, thereby contributing to the broader goal of preserving biodiversity.

As a result, a total of 30 indicators have been selected as listed in Table 13. However, the main goal of the research in this thesis is to avoid the implementation of a one-size-fits-all approach utilized by current ranking systems. Instead, the aim is to assign weights to the indicators that consider the climate elements. This is due to the fact that it would be inequitable to assign the same weight to the CO<sub>2</sub> footprint for universities within countries that have high AAT and countries have low AAT. This is because universities operating in the former group, in comparison to those in the latter

group, are required to utilize more electrical power for heating/air cooling because of the climate. So, there is a need to classify the universities according to the climate elements and to assign weights to the indicators according to the universities data in each class. To address this issue, a system using multi-objective goal programming has been developed. This system assigns varying weights to each indicator based on university data in each environmental group. The KG climate classification system was adopted which is a widely used system for classifying the world's climates based on the annual and monthly averages of temperature and precipitation. It was developed by the German climatologist Wladimir Köppen and modified by his student Rudolf Geiger in the early 20<sup>th</sup> century.

Here comes the development of a new ranking system called “UoBESHEIRS”. The concept underpinning UoBESHEIRS indicator identification process pertains to the development of a set of quantifiable sustainability indicators that, akin to the UIGM indicators, are intended to be integrated into a worldwide ranking system. Moreover, these indicators are designed to evaluate all three dimensions of sustainability, namely the environment, social considerations, and the interaction with the local community. The pliability of the suggested indicator system renders it facile to integrate within a multidimensional ranking system such as the U-Multirank.

Performance indicators can be classified into different typologies, namely: scenario indicators, input indicators, activity indicators, output indicators, and outcome indicators (Mio, 2013). When utilized for university institutions, scenario indicators are intended to portray the reference context, whereas input indicators assess the diverse resources employed by the university for its activities. Activity indicators measure the magnitude of various activities, while output indicators quantify the results generated by the activities conducted. Ultimately, outcome indicators articulate the influence on stakeholders caused by the actions undertaken by the university.

In the evaluation of a university's performance, outcome indicators should be primarily considered as they represent the desired results. However, in practice, it may be challenging to compute these indicators, and other types of indicators are often used as proxies. This is especially true for sustainability issues, where defining a quantitative measure is difficult. In this study, I have distinguished between different types of environmental indicators. Some indicators are considered as input or activity

indicators, while others are leading indicators that provide a comprehensive view of the university's "environmental balance."

Moreover, for social sustainability, I have focused on indicators related to social services, integration, human rights, gender integration, policies towards international students, and university human resources. The study has also examined indicators related to the HEI's impact on its local community. I take into account the environmental and social context of the university to properly consider sustainability issues. For this reason, many of the sustainability indicators proposed in this study are normalized based on the average values registered in the country.

For instance, the country's environmental policies impact the management of waste and water in a university, and the prevalence and characteristics of disabilities may also vary across countries. Moreover, the interpretation of social phenomena can differ depending on the country. Hence, it is crucial to compare university outcomes with national averages. To achieve this, some indicators are computed as a ratio of the observed university value to the average national value. Essentially, this ratio serves as a proxy to assess how well a university performs relative to its national context, providing a rewarding mechanism to encourage universities to adopt effective practices that surpass the effectiveness of their national systems. Other indicators aim to measure the efforts undertaken or the results obtained concerning the university size. In these cases, the size is measured, depending on the circumstances, by the number of full-time equivalents students, the number of full-time equivalents employees (academic and administrative staff), or the total amount of expenditures, research funds, etc. Of course, all the data will be related to the reference period, usually a year.

Before delving into further discussion regarding the proposed ranking system and the allocation of weights to the indicators, it is essential to summarize the key points that have been covered in this study. These points are as follows:

- 1- Through a comprehensive review process, a set of potential indicators have been set that can be used in the proposed ranking system.
- 2- To ensure sustainability assessment, recommendations have been included for integrating sustainability aspects, based on relevant literature and our own experimentation.
- 3- To encompass biodiversity aspects, indicators have been included that are related to this area.

- 4- The weight of each indicator in the ranking system must consider the relevant climate elements. To achieve this, the KG climate classification system was adopted for categorizing countries.
- 5- To assign weights to the indicators in a systematic and objective manner, the multi-criteria goal programming approach was utilized.

Now, comes the presentation of the selected indicators for the proposed ranking system. The indicators are distributed under seven targets. The first target relates to the impact on climate change, the target is to measure and reduce the impact of universities on climate change. This can be achieved by adopting a proper carbon policy, obtaining energy certifications, implementing a greenhouse gas efficient inventory, and monitoring greenhouse emissions per capita. Carbon policy refers to a set of rules and regulations that a university has implemented to reduce its carbon emissions. Universities need to adopt a proper carbon policy to ensure they do their part in mitigating climate change. Energy certifications are a way to measure a university's energy efficiency. Obtaining one or more energy certifications can demonstrate a university's commitment to reducing its carbon footprint and mitigating the impact of climate change. Greenhouse gas efficient inventory measures the number of CO<sub>2</sub> emissions a university produces. By implementing a greenhouse gas efficient inventory, universities can identify areas where they can reduce their carbon emissions and make changes to become more energy-efficient. Greenhouse emissions per capita measure the total CO<sub>2</sub> emissions a university produces divided by the number of full-time equivalent (FTE) students. Monitoring greenhouse emissions per capita can help universities identify areas to improve their energy efficiency and reduce their carbon footprint.

The second target is related to sustainable management of buildings by reducing energy consumption through using renewable energy, such as heat gain for campus building(s), and purchasing electricity from a green energy supplier. Sustainable management of buildings refers to managing buildings to decrease their environmental impact and promote sustainability. By reducing energy consumption in buildings, universities can decrease their carbon footprint and mitigate the impact of climate change. Heat gain for campus building(s) (BTUs/hour) refers to the heat a building gains from the outside environment. By using renewable energy to manage heat gain in campus buildings, universities can reduce their reliance on fossil fuels

and contribute to efforts to combat climate change. This can be measured in BTUs (British Thermal Units) per hour. Purchasing electricity from a green energy supplier refers to buying electricity from a supplier that generates electricity from renewable causes, such as wind or solar power. By purchasing electricity from a green energy supplier, universities can reduce their carbon footprint and support the growth of renewable energy. This can be measured by the percentage of electricity purchased from green energy suppliers.

The third target is related to effective waste management by reducing waste production, increasing recycling rates, properly treating toxic waste, and reducing plastic and paper consumption. Waste production per capita refers to the total weight of waste produced by a university divided by the number of full-time equivalent (FTE) students. Measuring waste production per capita can help universities identify areas where they can reduce waste and promote sustainable waste management practices. Unrecycled waste refers to the per capita unrecycled waste produced in the university, divided by the per capita unrecycled waste recorded in the country. Measuring unrecycled waste can help universities identify areas to improve their waste management practices. Internal waste recycling refers to the percentage of internal waste recycled in the total produced. Universities can improve their waste management practices by increasing the percentage of waste that is recycled internally. External waste recycling refers to the percentage of externally and internally recycled through the proper separate collection of the total waste produced. Universities can improve their waste management practices by increasing the percentage of waste recycled externally. Recycling of toxic waste refers to the percentage of toxic waste adequately treated on the overall toxic waste produced. Properly treating toxic waste is crucial for protecting the environment and public health. Sewage disposal refers to the percentage of sewage that is adequately treated. Proper treatment of sewage is crucial for protecting the environment and public health. Plastic consumption refers to whether the university implements a fair policy to reduce plastic consumption. Universities can reduce their environmental impact by reducing their consumption of plastic. Paper consumption refers to whether the university implements a fair policy to reduce paper consumption. Universities can reduce their environmental impact by reducing their consumption of paper.

The fourth target is to reduce water consumption and promote sustainable water management practices. Does the university adopt a fair policy to reduce water

consumption? Universities can adopt policies to reduce water consumption, such as promoting water conservation practices, implementing water-efficient technologies, and reducing water waste. On the other hand, water consumed per capita refers to the total consumption of water by a university divided by the number of full-time equivalent (FTE) students. Measuring water consumption per capita can help universities identify areas to reduce water usage and promote sustainable water management practices. This indicator should also include all initiatives within the institution about water conservation programs. Does the university adopt greywater sustainability activities? Greywater refers to wastewater from washing machines, showers, and sinks that can be reused for non-potable purposes. Universities can adopt greywater sustainability activities, such as treating greywater for reuse in irrigation and toilet flushing, to reduce their water consumption and promote sustainable water management practices.

The fifth target is to incorporate sustainability into transportation decision-making and reduce transportation's impact on the environment. Transportation policy refers to whether there is a policy in place to reduce the impact of transportation on pollution. Universities can adopt policies to reduce transportation-related pollution, such as promoting low-emission vehicles, reducing single-occupancy vehicle trips, and encouraging public transportation. Ecological transport refers to the percentage of employees who use an ecological means of transport, such as public transportation, biking, or walking, to reach the campus and travel inside the campus. Universities can encourage using ecological transport among employees by providing motivations such as bike racks, public transportation subsidies, and carpooling programs. Ecological transport refers to the percentage of students who use an ecological means of transport, such as public transportation, biking, or walking, to reach the campus and travel inside the campus. Universities can encourage using ecological transport among students by providing incentives such as bike-sharing programs, public transportation subsidies, and pedestrian-friendly campus designs.

The sixth target is to incorporate environmental sustainability into education at different levels and to promote awareness of sustainability issues among students and staff. Does the university implement special measures to educate the students about and become aware of environmental sustainability issues? Universities can implement special measures to educate students about environmental sustainability issues, such as integrating sustainability into the curriculum, offering sustainability-focused

courses or programs, and providing sustainability-related extracurricular activities. Events on environmental sustainability refer to the number of scholarly or public events organized by the university to increase awareness of environmental sustainability issues, over the number of full-time equivalent (FTE) students. Events can include lectures, workshops, and conferences focused on environmental sustainability and can help to raise awareness and knowledge about sustainability issues. Research projects on environmental sustainability refer to the number of research projects on environmental sustainability issues carried out in the university, divided by the number of FTE students. Research projects on environmental sustainability can help promote understanding and knowledge of sustainability issues and lead to the development of new solutions and technologies to address sustainability challenges. Research funds refer to the percentage of total research funds devoted to research projects on environmental sustainability issues. By allocating research funds towards sustainability-related projects, universities can promote sustainability research and innovation and contribute to developing solutions to sustainability challenges.

The seventh target is protecting and promoting Biodiversity around or within the university campus and contributing to national and international biodiversity initiatives. The measures followed in protecting Biodiversity around or on the University campus refer to the measures taken by the university to protect and promote Biodiversity around or within the campus, such as preserving natural areas, promoting native plants and wildlife, and minimizing negative impacts on Biodiversity from campus development and operations. The Contribution to any Biodiversity initiatives or programs on the national or international levels refers to the university's Contribution to national and international biodiversity initiatives and programs, such as supporting conservation efforts, participating in research collaborations, and sharing information and expertise on biodiversity issues. Publish Biodiversity report refers to the publication of a biodiversity report by the university, which can provide information on the state of Biodiversity around or within the campus and the university's efforts to protect and promote Biodiversity. Publish any research paper on Biodiversity in an accredited journal refers to the publication of research papers on Biodiversity in accredited journals by university researchers, which can contribute to the understanding of biodiversity issues and inform conservation efforts.

In order to test the efficacy of the proposed system and the application of multicriteria goal programming for assigning weights to indicators, I conducted simulations using data from 50 universities evenly distributed across 5 climate groups according to the KG classification system. This data was generated using publicly available information about university performance in the UIGM ranking system, as well as country-wise performance for the proposed indicators.

To assign weights to the indicators, I employed the multicriteria goal programming technique described in Chapter 3, utilizing Algorithms 1, 2, and 3. A new application was developed based on these algorithms and run on simulated data for the 50 universities. The application generated weights for each indicator based on the universities' data for that indicator, as well as the object value (optimal required value). For example, a target of zero CO<sub>2</sub> emissions was set, indicating the desired outcome. The system then sought to find the best combinations of indicator weights that minimized the total deviation of the optimal required values.

The resulting weights for each climate group by the multicriteria goal programming technique were displayed in Table 13. It is important to note that the multicriteria goal programming technique tends to favor solutions that take a greedy approach. As a result, the indicator with the least deviation value was assigned the maximum weight, leaving the other indicators with the minimum possible weight of 1. However, to avoid such extreme values, the algorithm was modified to force minimum and maximum weights for each indicator.

The findings of the study have important implications for policymakers, university administrators, and ranking system developers. Policymakers and university administrators need to focus on sustainability assessment, especially environmental sustainability, in their institutions. Ranking system developers should include more indicators to evaluate sustainability and use outcome indicators for a comprehensive view of the institution's sustainability. Moreover, developers should improve the transparency and consumer friendliness of their ranking systems to increase their effectiveness. The proposed ranking system could provide a valuable tool for universities to assess their sustainability performance and identify areas for improvement. The system could also serve as a rewarding mechanism to encourage

universities to adopt effective practices that surpass the effectiveness of their national systems. Additionally, the inclusion of biodiversity aspects in the ranking system could encourage universities to contribute to the preservation of biodiversity.

Biodiversity is essential for sustaining life on earth, as it offers many services and benefits, such as food and water supply, pollination, and nutrient cycling. Biodiversity also improves ecosystems' resilience and helps them adapt to climate change. By emphasizing biodiversity in the global campaign, it is hoped that people will understand the importance of protecting and conserving this vital resource and take steps toward creating a healthier, more sustainable planet.

Biodiversity is the variability of life on earth and comprises species diversity, ecosystems, and genetic variation within species. Biodiversity can be measured in various ways, including species richness (the number of species present in an area) and species abundance (the relative abundance of different species in an area). Other measures of biodiversity include species evenness (the relative abundance of different species in an area) and species diversity (the variety of species in an area).

Adding biodiversity indicators to the Environmental sustainability university assessment tools is beneficial in several ways. First, it can provide universities with a better understanding of the conservation status of their ecosystems, enabling them to make informed decisions about how best to manage their land and resources. Second, it can help universities assess their progress in meeting biodiversity targets. Finally, it can help universities identify potential improvement areas so that they can focus their efforts on the most critical issues.

Universities have an essential role to play in supporting biodiversity. They can research the causes of biodiversity loss and develop strategies and policies to protect biodiversity. Through their teaching and research, universities can help raise awareness of the importance of preserving biodiversity and equip students with the knowledge and skills needed to protect it. Universities can also serve as a platform to bring together stakeholders to discuss and develop collaborative strategies to protect biodiversity. Additionally, universities can support local conservation initiatives by providing resources, funding, and expertise.

In regards to the limitations. First, the proposed automated mapping system needs improvement to increase its precision. Second, the study's scope is limited to ESHEIRSSs, and further research is required to evaluate other ranking systems. Third, the study is limited to environmental and social sustainability, and other dimensions of sustainability, such as economic sustainability, were not considered. Fourth, the lack of open data related to the selected indicators for some countries. This forced us to use simulated data based on general country level data, which may not accurately represent the specific conditions of each country. Fifth, the multicriteria goal programming technique tends to favor solutions that take a greedy approach, which may result in extreme weights for certain indicators. However, the study has addressed this limitation by modifying the algorithm to force minimum and maximum weights for each indicator.

In conclusion, this study highlights the importance of sustainability assessment in higher education institutions, especially environmental sustainability. The study suggests that ranking system developers need to include more indicators and use outcome indicators for a comprehensive view of sustainability. Policymakers and university administrators need to focus on sustainability assessment to improve their institutions' sustainability. The proposed automated mapping system can be useful for decision-making purposes, but it needs improvement to increase its precision.

# Chapter 6

## Conclusions and Recommendations

Incorporating environmental sustainability in higher education is crucial, particularly regarding the development of an environmental sustainability performance index. In conclusion, the importance of ranking systems for measuring universities' performance has been widely acknowledged. However, with the recent announcement of the United Nations SDGs and the increasing global concern regarding climate change, there is a growing need for ranking systems to include more indicators to measure the environmental sustainability of universities and raise awareness about SDGs and climate issues. Our research, which employed a combination of BP analysis, literature review, and multicriteria goal programming, found that the existing ranking systems have limitations in measuring universities' performance regarding environmental sustainability. Therefore, a ranking system was proposed that aims to address these limitations and assign variable weights for the indicators to avoid a one-size-fits-all approach. Our proposed ranking system utilized machine learning and artificial intelligence techniques to identify environmental sustainability indicators and assigned weights for the indicators based on simulated data for universities in different climate groups. The results showed that the climate elements have a strong impact on university performance, and our proposed system resolved the limitation of the negative impact of the AAT on university scores. The proposed ranking system provides a more comprehensive and accurate assessment of universities' environmental sustainability performance, which is essential for promoting sustainability and achieving SDGs.

Extending the research in this thesis is highly recommended in the following directions:

- Conduct further research to evaluate and compare the proposed ranking system with other existing systems, and perform case studies that demonstrate how climate variations affect sustainability outcomes.

- Develop a comprehensive ranking system that considers all dimensions of sustainability, including economic sustainability, and evaluate the feasibility and usefulness of such a system.

- Develop more indicators to evaluate the sustainability of universities and include these indicators in existing ranking systems to provide a more accurate representation of sustainability performance.

- Improve the precision of the proposed automated mapping system by exploring new techniques and tools for mapping indicators to Sustainable Development Goals (SDGs).

- Encourage universities to contribute to the preservation of biodiversity by including biodiversity aspects in sustainability assessments and ranking systems.

- Increase transparency and consumer-friendliness of ranking systems to increase their effectiveness and usefulness for decision-making purposes.

- Develop and share open data related to the selected indicators for each country to ensure that the data used in ranking systems accurately represents the specific conditions of each country.

- Develop and implement sustainable practices in universities and use the ranking system as a rewarding mechanism to encourage universities to adopt effective practices that surpass the effectiveness of their national systems.

- Increase awareness and education around sustainability, especially environmental sustainability, in higher education institutions to encourage sustainability-focused behaviors among students, faculty, and staff.

- Encourage policymakers and university administrators to focus on sustainability assessment to improve their institutions' sustainability performance and contribute to a more sustainable future.

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# Appendices

**Appendix A:** Ranking Systems Overview

**Appendix B:** Journal Paper 1

**Appendix C:** Conference Paper 1

**Appendix D:** Conference Paper 2

**Appendix E:** Journal Paper 2 (In process)

**Appendix F:** Journal Paper 3 (In process)

**Appendix G:** UoB ESHEIRS Methodology 2023 (Sample)

**Appendix H:** UoB ESHEIRS\_Questionnaire\_2023\_V1 (SAMPLE)

**Appendix I:** FindIndicatorWeight code

**Appendix J:** PythonCode First run

**Appendix K:** PythonCode Second run

## **Appendix A: Ranking Systems Overview**

| <b>No.</b> | <b>College and University ranking system</b>     | <b>Regional/ National/ global</b> | <b>Green University ranking (yes,/No,)</b> | <b>Number of Targets</b> | <b>Elaborations</b>                                                                                                                             | <b>Number of Universities contributed for 2020 or 2021</b> | <b>Focus</b>                       |
|------------|--------------------------------------------------|-----------------------------------|--------------------------------------------|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------|
| <b>1</b>   | QS World University Rankings                     | global                            | No                                         | 6                        | Academic peer review, Faculty/Student ratio, Citations per faculty, Employer reputation, International student ratio, International staff ratio | more than 1000                                             | Research, Education, and Services. |
| <b>2</b>   | Times Higher Education World University Rankings | global                            | No                                         | 13                       | Teaching, Research, Citation, industry income, international outlook                                                                            | 1400                                                       | Research, Education, and Services. |
| <b>3</b>   | Academic Ranking of World Universities (ARWU)    | global                            | No                                         | 3                        | Journals, Awards, Conferences                                                                                                                   | 1000                                                       | Research, Education, and Services. |
| <b>4</b>   | Center for World University Rankings CWUR        | global                            | No                                         | 4                        | Quality of Education, Alumni Employment, Quality of Faculty, Research Performance                                                               | 2000                                                       | Research, Education, and Services. |
| <b>5</b>   | Leiden Ranking                                   | global                            | No                                         | 4                        | Scientific impact, collaboration, open access, genre                                                                                            | over 1000                                                  | Research, Education, and Services. |

| <b>No.</b> | <b>College and University ranking system</b> | <b>Regional/ National/ global</b> | <b>Green University ranking (yes,/No,)</b> | <b>Number of Targets</b>                            | <b>Elaborations</b>                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>Number of Universities contributed for 2020 or 2021</b> | <b>Focus</b>                       |
|------------|----------------------------------------------|-----------------------------------|--------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------|
| <b>6</b>   | Eduniversal                                  | global                            | No                                         | Two groups of targets. qualitative and quantitative | The Eduniversal System allows for an horizontal comparison within 9 geographical zones, which is different from the vertical comparison generally established by others ranking agency. Thus, the Eduniversal Ranking System doesn't compare schools from one country to another, but ranks the best schools within each country, which allows a better inclusion of the diversity of the higher education world and the specificities of each geographical areas | 1000                                                       | Research, Education, and Services. |
| <b>7</b>   | G-factor                                     | global                            | No                                         | 1                                                   | G-factor ranks university and college web presence by counting the number of links only from other university websites, using Google search engine data. G-factor is an indicator of the popularity or importance of each university's website from the combined perspectives of other institutions. It                                                                                                                                                           | 20                                                         | Research, Education, and Services. |

| No. | College and University ranking system | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                                                                                        | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|---------------------------------------|----------------------------|-------------------------------------|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
|     |                                       |                            |                                     |                   | claims to be an objective peer review of a university through its website—in social network theory terminology, G-factor measures the centrality of each university's website in the network of university websites |                                                     |                                    |
| 8   | Global University Ranking by RatER    | global                     | No                                  | 7                 | academic performance, research performance, faculty expertise, resource availability, socially significant activities of graduates, international activities, and international opinion                             | 400                                                 | Research, Education, and Services. |
| 9   | HEEACT—Ranking of Scientific Papers   | global                     | No                                  | 11                | 11 years articles, Current articles, 11 years citations, Current citations, Average citations, H-index, Highly cited papers, and High Impact journal articles                                                       | not mentioned                                       | Research, Education, and Services. |
| 10  | Human Resources & Labor Review        | global                     | No                                  | 2                 | Human Resources & Labor Review Index (HRI and LRI)                                                                                                                                                                  | 300                                                 | Research, Education, and Services. |
| 11  | High Impact Universities: Research    | global                     | No                                  | 1                 | Research Performance Index( 10-year g-index and h-index)                                                                                                                                                            | 500                                                 | Research, Education, and Services. |

| No.               | College and University ranking system           | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                                                                                                                                                                                                           | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-------------------|-------------------------------------------------|----------------------------|-------------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
| Performance Index |                                                 |                            |                                     |                   |                                                                                                                                                                                                                                                                                                                                        |                                                     |                                    |
| 12                | Nature Index (magazine)                         | global                     | No                                  | 1                 | Research Performance Index( 10-year g-index and h-index)                                                                                                                                                                                                                                                                               | not mentioned                                       | Research, Education, and Services. |
| 13                | Newsweek (magazine)                             | global                     | No                                  | Not mentioned     | usinf data from other ranking systems                                                                                                                                                                                                                                                                                                  | 100                                                 | Research, Education, and Services. |
| 14                | Professional Ranking of World Universities      | global                     | No                                  | 1                 | number of Chief Executive Officers                                                                                                                                                                                                                                                                                                     | 20                                                  | Research, Education, and Services. |
| 15                | Reuters World's Top 100 Innovative Universities | global                     | No                                  | 2                 | number of published articles in scholarly journals as indexed in the Thomson Reuters Web of Science Core Collection database frequency of patent applications granted, number of filed patents, frequency of those patents being cited, as well as how many of their papers were cited by patents or co-authored by an industry author | 100                                                 | Research, Education, and Services. |
| 16                | Round University Ranking                        | global                     | No                                  | 4 main (20 sub)   | teaching, research, international diversity, financial sustainability                                                                                                                                                                                                                                                                  | 829                                                 | Research, Education, and Services. |
| 17                | SCImago Institutions Rankings                   | global                     | No                                  | 3 main ( 17 sub)  | Innovation factor , Research factor, Social factor                                                                                                                                                                                                                                                                                     | 459                                                 | Research, Education, and Services. |

| No. | College and University ranking system | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|---------------------------------------|----------------------------|-------------------------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
| 18  | U-Multirank                           | global                     | No                                  | 5 with many sub   | <p>general, Teaching &amp; Learning, Research, International Orientation, Regional Engagement, Knowledge Transfer,</p> <p>U-Multirank does not produce a combined, weighted score across these different areas of performance and then use these scores to produce a numbered league table of the world's "top" 100 universities. The underlying principle is that there is no theoretical or empirical justification for such composite scores. Empirical studies have shown that the weighting schemes of existing global rankings are not robust: small changes in the weights assigned to the underlying measures (the indicator scores) will considerably change the composite scores and hence the league table positions of individual universities. Therefore, the U-Multirank</p> | 1759                                                | Research, Education, and Services. |

| No. | College and University ranking system           | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                          | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|-------------------------------------------------|----------------------------|-------------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
|     |                                                 |                            |                                     |                   | methodology looks at the scores of universities on individual indicators and places these in five performance groups (“very good” through to “weak”). |                                                     |                                    |
| 19  | University Ranking by Academic Performance URAP | global                     | No                                  | 6                 | Number of articles, Citations, total documants, Article Impact Total (AIT), Citation Impact Total (CIT), International Collaboration                  | 2000                                                | Research, Education, and Services. |

| <b>No.</b> | <b>College and University ranking system</b>                 | <b>Regional/ National/ global</b> | <b>Green University ranking (yes,/No,)</b> | <b>Number of Targets</b> | <b>Elaborations</b>                                                                                                                                                                | <b>Number of Universities contributed for 2020 or 2021</b> | <b>Focus</b>                       |
|------------|--------------------------------------------------------------|-----------------------------------|--------------------------------------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------|
| <b>20</b>  | U.S. News & World Report's Best Global Universities Rankings | global                            | No                                         | 3                        | global research reputation, publications and number of highly cited papers                                                                                                         | 750                                                        | Research, Education, and Services. |
| <b>21</b>  | Webometrics                                                  | global                            | No                                         | 1                        | offers information about more than 12,000 universities according to their web presence (an assessment of the scholarly contents, visibility and impact of universities on the web) | 12000                                                      | Research, Education, and Services. |
| <b>22</b>  | Wuhan University                                             | global                            | No                                         | 2                        | journal article publication counts and citation frequencies                                                                                                                        | not mentioned                                              | Research, Education, and Services. |
| <b>23</b>  | QS's Asian University Rankings                               | Regional                          | No                                         | 13                       |                                                                                                                                                                                    | 350                                                        | Research, Education, and Services. |
| <b>24</b>  | THE Asia University Rankings                                 | Regional                          | No                                         | 13                       |                                                                                                                                                                                    | 489                                                        | Research, Education, and Services. |

| No. | College and University ranking system  | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|----------------------------------------|----------------------------|-------------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
| 25  | BCUR, by Shanghai Jiao Tong University | National                   | No                                  | 9                 | Among these 9 indicators, there are 2 used for the dimension on teaching and learning, including average score of incoming freshmen in national college entrance exam and employment rate of bachelor degree recipients for measuring the quality of incoming students and education outcome respectively. There are 4 indicators for research, e.g. number of papers in Scopus is for evaluating the scale of research, Field Weighted Citation Impact for the quality of research, World Top 1% Most Cited Paper for the top research products and Most Cited Researchers in China for the top scholars. There are 2 indicators in the dimension of social service: research income from industry is used for measuring universities' technology service and income from technology transfer for the outcome of technology transfer. | 1243                                                | Research, Education, and Services. |

| No. | College and University ranking system                                                    | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                         | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|------------------------------------------------------------------------------------------|----------------------------|-------------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
|     |                                                                                          |                            |                                     |                   | The last indicator is International Students as a Percentage of Total Students, which measures internationalization. |                                                     |                                    |
| 26  | Wu Shulian, published in the name of the Chinese Academy of Management Science (payment) | National                   | No                                  | rank by subject   | by subject                                                                                                           | top 100                                             | Research, Education, and Services. |
| 27  | Netbig, the higher                                                                       | National                   | No                                  | 7                 | optional indicators                                                                                                  | 61                                                  | Research, Education, and           |

| No. | College and University ranking system                                                 | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets                                                                   | Elaborations                                                                                                                                                                                                    | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|---------------------------------------------------------------------------------------|----------------------------|-------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
|     | education internet information company                                                |                            |                                     |                                                                                     |                                                                                                                                                                                                                 |                                                     | Services.                          |
| 28  | CUAA, by Airuishen (a company) in the name of Chinese Universities Alumni Association | National                   | No                                  | 1 indicator for the billionaire university, and 6 indicator for the general ranking | the amount of billionaire a university or college have, including its alumni and faculty. General ranking indicators: 1) Government Recognition, 2) Research, 3) Faculty, 4) Program, 5) Student, 6) Reputation | 10                                                  | Research, Education, and Services. |
| 29  | National Institutional Ranking Framework (NIRF)                                       | National                   | No                                  | 5 (for the overall ranking), others by department                                   | Teaching, Learning & Resources (TLR), Research and Professional Practice (RP), Graduation Outcomes (GO), Outreach and Inclusivity (OI), Peer Perception                                                         | 101                                                 | Research, Education, and Services. |
| 30  | Brand rankings of Japanese universities                                               | National                   | No                                  | 49                                                                                  |                                                                                                                                                                                                                 | 10 or 20 university by region                       | Research, Education, and Services. |
| 31  | Truly Strong Universities                                                             | National                   | No                                  | 11                                                                                  | The "TSU" ranking is designed to assess a university's strength as an organization                                                                                                                              | 181                                                 | Research, Education, and Services. |
| 32  | Japan's Top 30 University Rankings in Natural Sciences                                | National                   | No                                  | 4                                                                                   | research funding (Kaken only), citations of research publications, entrance exam difficulty, and a                                                                                                              | 30                                                  | Research, Education, and Services. |

| No. | College and University ranking system                                         | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                   | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|-------------------------------------------------------------------------------|----------------------------|-------------------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
|     | and Technology                                                                |                            |                                     |                   | reputation survey.                                                                                                                             |                                                     |                                    |
| 33  | Pakistan's Higher Education Commission Ranking                                | National                   | No                                  | not mentioned     |                                                                                                                                                | 73                                                  | Research, Education, and Services. |
| 34  | Professional Regulation Commission and Commission on Higher Education Ranking | National                   | No                                  | 3                 | based on accreditations, academic designations and the average passing rates in board tests                                                    | not mentioned                                       | Research, Education, and Services. |
| 35  | Korean Council for University Education                                       | National                   | No                                  | 5                 | Mission and Management, Education, Institutional Community, Educational Facilities and Student Support, Achievements and Social Responsibility | not mentioned                                       | Research, Education, and Services. |
| 36  | European Commission Ranking                                                   | Regional                   | No                                  | 1                 | highest scientific impact                                                                                                                      | 22                                                  | Research, Education, and Services. |

| <b>No.</b> | <b>College and University ranking system</b>               | <b>Regional/ National/ global</b> | <b>Green University ranking (yes,/No,)</b> | <b>Number of Targets</b>     | <b>Elaborations</b>                                                                                                                                                      | <b>Number of Universities contributed for 2020 or 2021</b> | <b>Focus</b>                       |
|------------|------------------------------------------------------------|-----------------------------------|--------------------------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------|
| <b>37</b>  | CHE University Ranking                                     | National                          | No                                         | exclusively subject specific | Top Group, Middle Group or Bottom Group. The use of league positions bear                                                                                                | 280                                                        | Research, Education, and Services. |
| <b>38</b>  | The Bulgarian University Ranking System                    | National                          | No                                         | not mentiond                 | such as teaching and learning conditions, scientific research, career development opportunities, prestige, and material resources.                                       | not mentioned                                              | Research, Education, and Services. |
| <b>39</b>  | CEPOS Ranking                                              | National                          | No                                         | not mentiond                 | Highly political association                                                                                                                                             | not mentioned                                              | Research, Education, and Services. |
| <b>40</b>  | The Sunday Times ranking                                   | National                          | No                                         | not mentioned                | secondary school examination scores, graduation rates, staff-student ratio, research efficiency, accommodation, nontraditional students, athletics and sports facilities | 20                                                         | Research, Education, and Services. |
| <b>41</b>  | La Repubblica and CENSIS ranking                           | National                          | No                                         | website in Italian Language  | website in Italian Language                                                                                                                                              | website in Italian Language                                | Research, Education, and Services. |
| <b>42</b>  | ranking of Macedonian Higher Education Institutions (HEIs) | National                          | No                                         | 3                            | Teaching and Learning, Research, Social Service                                                                                                                          | 19                                                         | Research, Education, and Services. |

| No. | College and University ranking system                             | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                               | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|-------------------------------------------------------------------|----------------------------|-------------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
| 43  | Perspektywy Ranking                                               | National                   | No                                  | 6                 | PRESTIGE, ALUMNI SITUATION ON THE JOB MARKET , ACADEMIC POTENTIAL , SCIENTIFIC EFFICIENCY, DIDACTIC POTENTIAL, INNOVATION, | 21                                                  | Research, Education, and Services. |
| 44  | Ad Astra association of Romanian scientists Ranking               | National                   | No                                  | Romanian language | Romanian language                                                                                                          | 49                                                  | Research, Education, and Services. |
| 45  | RIA Novosti / Forbes                                              | National                   | No                                  | 5                 | research, teaching standards, public opinion and social and international activity                                         | 476                                                 | Research, Education, and Services. |
| 46  | Confederation of Swedish Enterprise (Svenskt Näringsliv)          | National                   | No                                  | 4                 | entry salary, career development, internationalization, and degree of academic-business collaboration                      |                                                     | Research, Education, and Services. |
| 47  | Ukraine's Ministry of Education and Science University Evaluation | National                   | No                                  | 1                 | students satisfaction                                                                                                      | 200                                                 | Research, Education, and Services. |

| <b>No.</b> | <b>College and University ranking system</b> | <b>Regional/ National/ global</b> | <b>Green University ranking (yes,/No,)</b> | <b>Number of Targets</b> | <b>Elaborations</b>                                                                                                                                                                                                                       | <b>Number of Universities contributed for 2020 or 2021</b> | <b>Focus</b>                       |
|------------|----------------------------------------------|-----------------------------------|--------------------------------------------|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------|
| <b>48</b>  | The Complete University Guide                | National                          | No                                         | 10                       | Entry standards, Students satisfaction, research quality, research intensity, graduate prospects, academic services spend, facilities spend, good honors, degree completion, student-staff ratio                                          | 130                                                        | Research, Education, and Services. |
| <b>49</b>  | Guardian University Guide                    | National                          | No                                         | 10                       | graduation score out of 100, satisfied with the course, satisfied with the teaching, satisfied with the feedback, student to staff ratio, spend per student, average entry tariff, value added score, career after 6 months, continuation | 121                                                        | Research, Education, and Services. |
| <b>50</b>  | Research Excellence Framework                | National                          | No                                         | 3                        | Quality profile of institutions %, GPA(0 to 4), research power                                                                                                                                                                            | 1911                                                       | Research, Education, and Services. |
| <b>51</b>  | Teaching Excellence Framework (TEF)          | National                          | No                                         | 4                        | Student satisfaction, Continuation rates, Employment rates, Academic support                                                                                                                                                              | 150                                                        | Research, Education, and Services. |
| <b>52</b>  | Maclean's ranking                            | North America                     | No                                         | 2                        | reputation, student satisfaction                                                                                                                                                                                                          | 82                                                         | Research, Education, and Services. |
| <b>53</b>  | Estudio Comparativo de Universidades         | North America                     | No                                         |                          | No English translation                                                                                                                                                                                                                    |                                                            | Research, Education, and Services. |

| No.              | College and University ranking system                    | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                                                                                               | Number of Universities contributed for 2020 or 2021 | Focus                              |
|------------------|----------------------------------------------------------|----------------------------|-------------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
| Mexicanas (ECUM) |                                                          |                            |                                     |                   |                                                                                                                                                                                                                            |                                                     |                                    |
| 54               | The Daily Beast's Guide to the Best Colleges             | United States              | No                                  | 9                 | future earnings, affordability, and graduation rate weighted most heavily. The other criteria include academics, diversity, athletics, nightlife, activities, and campus quality (things like food, dorms, and crime rate) | 200                                                 | Research, Education, and Services. |
| 55               | The "Objective" College rankings                         | United States              | No                                  | 29                | based solely on objective, measurable data, such as student test scores and the like.                                                                                                                                      | 50                                                  | Research, Education, and Services. |
| 56               | Revealed preference rankings                             | United States              | No                                  |                   |                                                                                                                                                                                                                            | 105                                                 | Research, Education, and Services. |
| 57               | Social Mobility Index (SMI) rankings                     | United States              | No                                  | 8                 | economic mobility, Tuition, % Low Income, % Grad Rate, Median Early Career Salary, Avg Debt, Endowment (in M), % Freshman Pell, % Pell to rich 1/2                                                                         | 1458                                                | Research, Education, and Services. |
| 58               | U.S. News & World Report college and university rankings | United States              | No                                  | 15                | Outcomes, Graduation and retention rates, Graduation rate performance, Social mobility, Pell Grant graduation rates, Pell Grant graduation rate performance, Faculty Resources, Class size,                                | not mentioned                                       | Research, Education, and Services. |

| No. | College and University ranking system            | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                                                                                                                                                | Number of Universities contributed for 2020 or 2021 | Focus                              |
|-----|--------------------------------------------------|----------------------------|-------------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------|
|     |                                                  |                            |                                     |                   | faculty salary, proportion of full-time faculty with the highest degree in their fields (3%), student-faculty ratio (1%) and the proportion of faculty who are full time (1%)                                                                                               |                                                     |                                    |
| 59  | United States National Research Council Rankings | United States              | No                                  | 8                 | R-Ranking(faculty ratings), S-Ranking(faculty survey), Publications per faculty , Citations per publication, % Faculty with grants, % Students in academic positions, Awards per faculty, Average GRE scores, Number of PhD's awarded, Number of student support activities | not mentioned                                       | Research, Education, and Services. |
| 60  | Niche College Rankings                           | United States              | No                                  |                   | they provide best of any category required                                                                                                                                                                                                                                  |                                                     | Research, Education, and Services. |
| 61  | The Princeton Review,                            | United States              | No                                  | not mentioned     | ranking by category                                                                                                                                                                                                                                                         | 385                                                 | Research, Education, and Services. |

| <b>No.</b> | <b>College and University ranking system</b>                         | <b>Regional/ National/ global</b> | <b>Green University ranking (yes,/No,)</b> | <b>Number of Targets</b>      | <b>Elaborations</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Number of Universities contributed for 2020 or 2021</b> | <b>Focus</b>                       |
|------------|----------------------------------------------------------------------|-----------------------------------|--------------------------------------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------|
| <b>62</b>  | NACDA Directors' Cup                                                 | United States                     | No                                         | championships related ranking | an award given annually by the National Association of Collegiate Directors of Athletics to the colleges and universities in the United States with the most success in collegiate athletics. Points for the NACDA Directors' Cup are based on order of finish in various championships sponsored by the National Collegiate Athletic Association (NCAA) and the National Association of Intercollegiate Athletics (NAIA) or, in the case of Division I Football, media-based polls | Top ten                                                    | Research, Education, and Services. |
| <b>63</b>  | National Law Journal's Go-To Law School Rankings                     | United States                     | No                                         | 1                             | doctor graduates into associate positions at the largest 100 law firms in the country                                                                                                                                                                                                                                                                                                                                                                                               | 50                                                         | Research, Education, and Services. |
| <b>64</b>  | The Good Universities Guide and Excellence in Research for Australia | Oceania                           | No                                         | 14                            | by category                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                            | Research, Education, and Services. |

| No. | College and University ranking system                                       | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations                                                                                                                                                                                                                                                                                                    | Number of Universities contributed for 2020 or 2021 | Focus                                |
|-----|-----------------------------------------------------------------------------|----------------------------|-------------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|--------------------------------------|
| 65  | QS University Rankings: Latin America                                       | Oceania                    | No                                  | 8                 | INTERNATIONAL RESEARCH NETWORK, WEB IMPACT, FACULTY STAFF WITH PHD, PAPERS PER FACULTY, CITATIONS PER PAPER, FACULTY STUDENT, EMPLOYER REPUTATION, ACADEMIC REPUTATION                                                                                                                                          | 400                                                 | Research, Education, and Services.   |
| 66  | the National Commission for University Evaluation and Accreditation ranking | Oceania                    | No                                  | 3                 | their web presence and popularity in terms of estimated traffic, trust/authority and quality link popularity.<br>The uniRank University Ranking™ is not an academic ranking and, therefore, should not be adopted as the main criteria for selecting a higher education organization where to enroll and study. | not mentioned                                       | Research, Education, and Services.   |
| 67  | National Wildlife Federations State of the Campus Environment               |                            | Yes                                 | 3                 | management systems, curricula, and operations                                                                                                                                                                                                                                                                   | not mentioned                                       | Research, Education, and Environment |
| 68  | Sustainability Assessment                                                   | National                   | Yes                                 |                   |                                                                                                                                                                                                                                                                                                                 |                                                     | Research, Education, and Environment |

| No. | College and University ranking system                              | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations | Number of Universities contributed for 2020 or 2021 | Focus                                |
|-----|--------------------------------------------------------------------|----------------------------|-------------------------------------|-------------------|--------------|-----------------------------------------------------|--------------------------------------|
|     | Questionnaire                                                      |                            |                                     |                   |              |                                                     |                                      |
| 69  | AISHE - Auditing instrument for sustainability in higher education |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 70  | Higher Education 21s Sustainability Indicators                     |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 71  | Environmental Workbook and Report                                  |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 72  | Greening Campuses                                                  |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 73  | Campus Ecology                                                     |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 74  | Environmental Performance survey                                   |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 75  | Indicators Snapshot/Guide                                          |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 76  | Grey Pinstripes with Green Ties                                    |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 77  | EMS Self-assessment                                                |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 78  | UNI-Metrics                                                        |                            | Yes                                 |                   |              |                                                     | Research, Education, and             |

| <b>No.</b> | <b>College and University ranking system</b>                                           | <b>Regional/ National/ global</b> | <b>Green University ranking (yes,/No,)</b> | <b>Number of Targets</b> | <b>Elaborations</b> | <b>Number of Universities contributed for 2020 or 2021</b> | <b>Focus</b>                         |
|------------|----------------------------------------------------------------------------------------|-----------------------------------|--------------------------------------------|--------------------------|---------------------|------------------------------------------------------------|--------------------------------------|
|            |                                                                                        |                                   |                                            |                          |                     |                                                            | Environment                          |
| <b>79</b>  | GRI Global report initiative                                                           | National                          | Yes                                        |                          |                     |                                                            | Research, Education, and Environment |
| <b>80</b>  | GASU - Graphical Assessment of Sustainability in Universities                          |                                   | Yes                                        |                          |                     |                                                            | Research, Education, and Environment |
| <b>81</b>  | GREENSHIP (developed by GBCI and NGO)                                                  | National                          | Yes                                        |                          |                     |                                                            | Research, Education, and Environment |
| <b>82</b>  | STARS by AASHE (Association for the Progression of Sustainability in Higher Education) | National                          | Yes                                        |                          |                     |                                                            | Research, Education, and Environment |
| <b>83</b>  | The College Sustainability report card (GREEN REPORT CARD)                             | National                          | Yes                                        |                          |                     |                                                            | Research, Education, and Environment |
| <b>84</b>  | Green Metric                                                                           |                                   | Yes                                        |                          |                     |                                                            | Research, Education, and Environment |
| <b>85</b>  | People & Planets                                                                       | National                          | Yes                                        |                          |                     |                                                            | Research, Education, and Environment |
| <b>86</b>  | International ISCN                                                                     | Global                            | Yes                                        |                          |                     |                                                            | Research, Education, and             |

| No. | College and University ranking system            | Regional/ National/ global | Green University ranking (yes,/No,) | Number of Targets | Elaborations | Number of Universities contributed for 2020 or 2021 | Focus                                |
|-----|--------------------------------------------------|----------------------------|-------------------------------------|-------------------|--------------|-----------------------------------------------------|--------------------------------------|
|     |                                                  |                            |                                     |                   |              |                                                     | Environment                          |
| 87  | CAMPUS SCORE                                     | National                   | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 88  | Times Higher Education University Impact Ranking | Global                     | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 89  | Green Metric                                     | Global                     | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 90  | ISCN                                             |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |
| 91  | QS stars                                         |                            | Yes                                 |                   |              |                                                     | Research, Education, and Environment |

## Appendix B: Journal Paper 1

### Evaluation of Environmental Sustainability Higher in Education Ranking Systems: Towards a Flat Intraranking System

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#### Abstract

This paper reviews different ranking criteria for universities practicing environmental sustainability – named here as “Environmental Sustainability Higher Education ranking systems (ESHERS)”. The purpose is to evaluate the degree of such criteria in supporting the higher education institutions (HEIs) in achieving environmentally sustainable development goals (SDGs). In this paper, the potential metrics for ranking systems are identified to promote environmentally sustainable development practices within HEIs and support their home countries in achieving SDGs. Three ESHERS - known in focusing on teaching & research, environment and social scope are evaluated and scored according to their compliance with the Berlin Principles (BPs), where the later are used to propose a new framework for an intra- ranking system that contribute to more effective practice in Environment and Education, i.e. developing University of Bahrain Environmental Sustainability Higher Education ranking system ( UoBESHERS).

**Keywords:** University Ranking, Sustainable Development, Environment, Higher Education, SDGs.

#### Introduction

Ranking systems are widespread in the field of higher education. In general, these systems adopt a one-size-fits-all approach and support the perspectives of some stakeholders better than others. New ranking systems are introduced by various bodies annually at either the national or global levels and joined by higher education institutions (HEIs). Some ranking systems, such as those developed by Quacquarelli Symonds (QS), Times Higher Education (THE), and Shanghai Jiao Tong University, focus on the quality of teaching and research, whereas other ranking schemes, like the University of Indonesia GreenMetric (UI GreenMetric) ranking, focus on environmental aspects of HEIs (Table 1). THE's University Impact Rankings 2019 also focuses on sustainable development and was built based on the United Nations' Sustainable Development Goals (UN SDGs), which cover the triple bottom-line (TBL) elements of economy, environment, and society as part of the 2030 Agenda for Sustainable Development.

Received: 07/06/2021  
Revised: 23/08/2021  
Accepted: 03/09/2021



# Automated Mapping of Environmental Higher Education Ranking Systems Indicators to SDGs Indicators using Natural Language Processing and Document Similarity

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**Abstract**—To evaluate the ESHERSs and determine their efficiency to measure environmental sustainability, we tackle this problem as a classification assignment. This study benchmark three ESHERSs: UI GreenMetric, Times Higher Education Impact ranking, and STARS (Sustainability Tracking, Assessment Rating System) by AASHE (the association for the advancement of sustainability in higher education). Next, we recruited a group of experts who mapped the ESHERS indicators to the SDGs indicators. Then, we use NLP techniques to classify (map) the ESHERS indicators to the SDGs indicators. Since most of the ESHERS indicators and the SDGs indicators are in the form of short text, we use the query expansion technique to make the NLP techniques more effective. Each ESHERS indicator and its expanded text represents a document. And, each SDG indicator and its expanded text represents a document. We took the expanded text from the description of the ESHERS indicators and the description of SDG indicators, forming the corpus for our study. Then, we used document similarity to find the similarity between every pair of the corpus documents. We used different similarity measures to see the similarity between the forms. Then, we used a voting system to map the ESHERSs indicators to the SDGs indicators. The proposed system was able to automatically map the underlying ranking systems indicators to the UN SDGs with 99% accuracy compared to the experts mapping.

**Index Terms**—Natural Language Processing (NLP), Document Similarity, Environmental Sustainability, Higher Education ranking, SDGs.

## I. INTRODUCTION

ESHERSs have become an essential topic in the academic world. Each ESHER comes with a different methodology to rank HEIs. Most of ESHERSs base their evaluation on several criteria and indicators. [1] uses a narrative review to highlight the number of inconsistencies in the methodologies applied to rank HEIs. They found that several flaws in the rankings

caused inconsistencies in university placings in different rankings. They propose integrating criteria and indicators for better ranking exercises. SDGs shape the sustainable development of Higher education. Many HEIs were responsible for providing the next generation with sustainability knowledge by embedding the SDGs in their policy, curriculum, and practice through several initiatives. [2] suggests that the advancement of Higher education for sustainable development in practice, policy, and curriculum depends on the knowledge of the differences, goals, and shared aims across local Higher education for sustainable development agendas. This method will hopefully provide HEIs with a way to succeed in the alignment with SDGs.

Before proposing our ESHERS with a set of indicators, we find it essential to benchmark three popular ESHERSs with ESDGs. This work aims to find the missing parts from each ESHERS compared to ESDGs targets and Indicators. First, we benchmark each ESHERS with all ESDGs targets and indicators using the cosine technique of the document similarity.

Datamining the practice of examining large pre-existing databases to generate new information. Data mining is a combination of three sciences: statistics, machine learning, and artificial intelligence. Data mining tasks are either: predictive, which include classification and prediction. Or descriptive, which include summarization and clustering. Predictive classification is a process of categorizing a given set of data into classes; It can be performed on both structured or unstructured data. Classification has several algorithms: Nearest Neighbor, Support Vector Machines, Decision Trees, Boosted Trees, Random Forest, Neural Networks, Linear Classifiers including (Logistic Regression, Naive Bayes Classifier), NLP Natural



Conference paper  
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# Temperature-dependency of Environmental Higher Education Ranking Systems

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**Abstract**— Many higher education stakeholders criticize the existing Environmental Higher Education Ranking Systems for not taking environmental factors which a given university operates in into consideration in processing the university portfolio and to group universities based on environmental factors similarities. This study intended to evaluate one of these environmental factors the Average Annual Temperature [AAT] and its impact on the ranking of universities. We studied the relationship between the AAT and two Environmental sustainability Higher education ranking systems [ESHERS] which are the University of Indonesia Greenmetric [UGM] and Times Higher Education University Impact ranking [THEUIR]. We aim to find to what extent should UGM and THEUIR methodologies consider the countries average annual temperature in evaluating the progress of the universities. We collected data of the overall university scores of 2020 ranking for the two ESHERS along with the AAT values for countries host these universities from the Listfirst website We used the linear regression technique to figure out any relationships between AAT and university ranking scores. The initial results show the AAT of a country doesn't have any impact on a university ranking operates in that country. The residual plot shows that many residuals are left without explanation by the model and the fit figure shows that there is no linear pattern in the dependent variable.

**Index Terms**— Temperature, Environmental Sustainability, Higher Education, ranking, SDGs.

## I. INTRODUCTION

The process of Higher Education Assessment has been explored and implemented by many organizations, Government entities, private educational institutions and much more. Higher Education Assessment lies between two main categories in terms of indicators classification. Group (A) that focuses on the progress towards Research, Education and Services like, QS World University Ranking, Times Higher Education Ranking to name a few. Group (B) that focuses on Research, Education and

Environment like, UGM, THEUIR, Green Report Card and more. The latter mainly considers water, energy, climate change, waste, transportation, education and research in their assessments. But the question is: Do they consider customizing their methodology, calculations and equations based on the AAT of the country of the specific university? Here are some previous studies concerning climate change and education.

(Amani-Beni et al., 2019) Study shows a strong negative correlation between green space ration and the land surface temperature. Majid Amani et al (2019) suggest that the land surface temperature decreases by 0.4 °C for every 10% increase in the green space ratio. The land surface temperature is also affected by the distance between the surface and the green space or waterbodies. As the distance decreases by one kilometer, the land surface temperature decreases by 0.15 °C. Thus, it is important to not only increase the green space but to plan for its distribution in an urban land to enhance the cooling effect.

Additionally, (Hossain, 2010) suggested that the structure of a city has direct effect on its microclimate. To maintain a sustainable environment, then the pattern, orientation, shape, and density are all important factors in planning the structure of a city and organizing its streets, green space, and buildings. The effect of the morphological character of a city, which affects its microclimate, also affects its electrical energy consumption. Thus, planning a city's structure is very significant to reduce the energy consumption.

An in-depth analysis was done by (Shareef & Altan, 2021) to study the major factors in neighborhood sustainable design; using specialized computer software packages; it has become clear that improvement can be implemented to enhance environmental sustainability



## Appendix E: Journal Paper 2 (In process)

### SYSTEMATIC REVIEW OF DEVELOPING ENVIRONMENTAL SUSTAINABILITY PERFORMANCE INDEX FOR HIGHER EDUCATION INSTITUTIONS

#### Abstract

Despite implementing and subscribing to the 2030 Programme and its Sustainable Development Goals (SDGs), public sector organisations, notably higher education institutions (HEIs), have faced increased quantities of accountability. HEIs are supposed to guide diverse stakeholders on this topic and execute this agenda and the SDGs at respective organizations. Even though such organisations' functions have been acknowledged, the disciplines and concerns HEIs must handle along the journey to sustainability and sustainable development (SD) remain unknown. A comprehensive assessment of the sustainability performance index HEIs was carried out to determine the essential ideas and primary study subjects that reflect sustainability and SD in HEIs and guide future investigation. In addition, the review enhances our understanding of sustainability and SD in the framework of higher education institutions.

**Keywords:** sustainable development, sustainable, higher education institutions; sustainability performance index

#### 1. Introduction

In higher education, there is a significant prevalence of ranking systems. In practice, these systems employ an approach meant to meet all circumstances and encourage the points of view of various stakeholder groups more effectively than those of the rest of the group. Periodically, current rating systems are developed by various agencies on both the national and international stages, and higher education institutions (HEIs) begin participating in these rankings. A few rankings, like those established by Quacquarelli Symonds (QS), Times Higher Education (THE), and Shanghai Jiao Tong University (SJTU), place importance on the excellence of education and research. On the contrary, many ranking schemes, including the University of Indonesia GreenMetric (UI GreenMetric) ranking, emphasise the environmental

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Systematic Review  
paper.pdf

## Appendix F: Journal Paper 3 (In Process)

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### Applying Koppen–Geiger Classification to the Multicriteria Goal Programming Model for Ranking Universities

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#### Abstract:

Higher Education Institutions' (HEIs) performance is essential in knowledge transfer, research contribution, learning, and sustainable development. HEIs ranking systems assess the progress based on a predefined set of targets and indicators. Targets and indicators differ from one ranking system to another. There are two ranking systems groups; the first focuses on research, education, and services, while the second focuses on sustainability, research, and education. The second group has a subgroup called Environmental Sustainability of Higher Education Institutions Ranking Systems [ESHEIRSs]. ESHEIRSs assess the progress towards environmental sustainability, specifically aside from research, education, and services. Current ESHEIRSs do not consider climate parameters of the country of residence of the assessed university in their methodology. They use one method that fits all universities regardless of the climate parameters of the country of residence. In this research we aim to study the possibility of designing an ESHEIRS with a customizable methodology that changes either the list of its indicators or the weight for each indicator based on the climate class of the country of the HEI. The proposed environmental ranking system uses the Kuppen-Gieger climate classification system in categorizing world countries and set a list of targets and indicators for each environment group. The setting of the new ESHEIRS indicators is based on a published work with the customization and addition of new targets. The customization in our model is initially changing: the number of indicators and the indicator evaluation method based on the country's climate class. We apply the multicriteria goal programming model for ranking universities in setting the weights for the customizable set of indicators.

**Keywords:** climate classification, Goal programming, ranking, Koppen–Geiger, University, multicriteria model

**Reference** to this paper should be made as follows: Author. (XXXX) 'Title', *Int. J. xxxxxxxxxxxx*, xxxxxxxxxxxx.

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## 1 Introduction

Ranking systems became a standard feature in the higher education field. These systems generally adopt a one size fits all approach and support the perspectives of some stakeholders better than others. Every year, different bodies introduce new ranking systems on national or global levels, and more institutions participate in these ranking systems. For instance, the Arab Ranking for Universities was issued in 2022 and will gather universities' participation in December 2022. They will start ranking Arab region universities and will cover worldwide universities at a later stage. Another system started functioning in 2019; Times Higher Education (THE) introduced its inaugural impact ranking system, "University Impact Rankings 2019", and Quacquarelli Symonds (QS) announced that 60 new institutions joined its ranking table in 2019. In 2022, QS will feature 1300 universities from around the world; in 2022, this year's university rankings are their most significant number of participants ever. The QS, THE, and Shanghai ranking systems claim that they focus on the quality of teaching and research. Other ranking schemes like (the UGM) University of Indonesia GreenMetric ranking focus on environmental aspects of higher education institutions. (THEUR) The "University Impact Rankings 2019" focuses on



Applying Koppen  
Geiger Classification

## Appendix G: UoB ESHEIRS Methodology 2023 Version 1



# UoB ESHEIRS Methodology 2023 Version 1



UoBESHEIRS  
Methodology.pdf

## Appendix H: UoB ESHEIRS\_Questionnaire\_2023\_V1

| University of Bahrain Higher Education Institutions Ranking System |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                     |                 |                 |                        |                  |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|-----------------|-----------------|------------------------|------------------|
| Indicator                                                          | Measure                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Points (Tropical A) | Points (Arid B) | Points (Warm C) | Points (Continental D) | Points (Polar E) |
| <b>Impact on climate change</b>                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                     |                 |                 |                        |                  |
| 1.1                                                                | Carbon policy: is a proper carbon policy adopted? (yes/no)<br><input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                                                                      | 2                   | 7               | 5               | 2                      | 2                |
| 1.2                                                                | Energy certifications: has the university obtained one or more energy certifications? (yes/no)<br><input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                                  | 5                   | 3               | 4               | 2                      | 3                |
| 1.3                                                                | Greenhouse gases efficient inventory: are the CO2 emissions measured? (yes/no)<br><input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                                                  | 2                   | 2               | 2               | 2                      | 2                |
| 1.4                                                                | Greenhouse emissions per capita: total CO2 emissions divided by the number of FTE students<br><input type="checkbox"/> $\geq 2.05$ metric tons<br><input type="checkbox"/> $< 2.05 - 1.11$ metric tons<br><input type="checkbox"/> $< 1.11 - 0.42$ metric tons<br><input type="checkbox"/> $< 0.42 - 0.10$ metric ton<br><input type="checkbox"/> $< 0.10$ metric ton                                                                                                                                          | 2                   | 4               | 5               | 3                      | 2                |
| <b>Energy consumption</b>                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                     |                 |                 |                        |                  |
| 2.1                                                                | Sustainable management of buildings: percentage of buildings (measured in cubic meters) managed in an energy sustainable way on the overall extension of the university buildings not subject to legal restrictions<br><input type="checkbox"/> $< 1\%$<br><input type="checkbox"/> $1 - 25\%$<br><input type="checkbox"/> $> 25 - 50\%$<br><input type="checkbox"/> $> 50 - 75\%$<br><input type="checkbox"/> $> 75\%$                                                                                        | 3                   | 4               | 3               | 2                      | 3                |
| 2.2                                                                | Energy consumed per capita: total number of Kwh per FTE student<br><input type="checkbox"/> $\geq 2424$ kWh<br><input type="checkbox"/> $< 2424 - 1535$ kWh<br><input type="checkbox"/> $< 1535 - 633$ kWh<br><input type="checkbox"/> $< 633 - 279$ kWh<br><input type="checkbox"/> $< 279$ kWh                                                                                                                                                                                                               | 2                   | 3               | 3               | 3                      | 2                |
| 2.3                                                                | Renewable energy: Heat gain for campus building(s), (BTUs/hour)<br>Heat gain $q = 1.10 \times cfm \times (t_o - t_i)$<br>Where,<br>$q$ = sensible heat gain from the outside air in Btu/h<br>$cfm$ = flow rate of outside air entering the building<br>$t_o$ = outside air temperature in °F<br>$t_i$ = inside air temperature in °F                                                                                                                                                                           | 2                   | 3               | 3               | 3                      | 3                |
| 2.4                                                                | Are you purchasing electricity from green energy supplier (yes/no)<br>if Yes provide a copy of the contract agreement and the name of the energy supplier.                                                                                                                                                                                                                                                                                                                                                     | 1                   | 2               | 2               | 3                      | 2                |
| <b>Waste management</b>                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                     |                 |                 |                        |                  |
| 3.1                                                                | Waste production per capita: total weight of the waste produced, divided by the number of FTE students<br><input type="checkbox"/> $> 0.0926$ (kg/person/day)<br><input type="checkbox"/> $0.0700 - 0.0926$ (kg/person/day)<br><input type="checkbox"/> $0.0400 - 0.0699$ (kg/person/day)<br><input type="checkbox"/> $0.0003 - 0.0399$ (kg/person/day)<br><input type="checkbox"/> $< 0.0003$ (kg/person/day)                                                                                                 | 2                   | 3               | 3               | 2                      | 3                |
| 3.2                                                                | Unrecycled waste: per capita unrecycled waste produced in the university, divided by the per capita unrecycled waste recorded in the country<br><input type="checkbox"/> $< 1\%$<br><input type="checkbox"/> $1 - 25\%$<br><input type="checkbox"/> $> 25 - 50\%$<br><input type="checkbox"/> $> 50 - 75\%$<br><input type="checkbox"/> $> 75\%$                                                                                                                                                               | 2                   | 3               | 3               | 3                      | 4                |
| 3.3                                                                | Internal waste recycle: percentage of waste recycled internally on the total waste produced<br><input type="checkbox"/> Not managed<br><input type="checkbox"/> Partial ( $1 - 25\%$ treated)<br><input type="checkbox"/> Partial ( $> 25 - 50\%$ treated)<br><input type="checkbox"/> Partial ( $> 50 - 75\%$ treated)<br><input type="checkbox"/> Extensive ( $> 75\%$ treated)                                                                                                                              | 3                   | 3               | 3               | 2                      | 2                |
| 3.4                                                                | External waste recycle: percentage of waste recycled externally and internally through a proper separate collection on the total waste produced<br><input type="checkbox"/> Not managed<br><input type="checkbox"/> Partial ( $1 - 25\%$ treated)<br><input type="checkbox"/> Partial ( $> 25 - 50\%$ treated)<br><input type="checkbox"/> Partial ( $> 50 - 75\%$ treated)<br><input type="checkbox"/> Extensive ( $> 75\%$ treated)                                                                          | 2                   | 2               | 2               | 2                      | 2                |
| 3.5                                                                | Recycle of toxic waste: percentage of toxic waste which is properly treated on the overall toxic waste produced<br><input type="checkbox"/> Not managed<br><input type="checkbox"/> Partial ( $1 - 25\%$ treated)<br><input type="checkbox"/> Partial ( $> 25 - 75\%$ treated)<br><input type="checkbox"/> Extensive ( $> 75\%$ treated)<br><input type="checkbox"/> 100% No toxic waste is produced                                                                                                           | 1                   | 3               | 1               | 3                      | 4                |
| 3.6                                                                | Sewage disposal: percentage of sewage which is properly treated<br><input type="checkbox"/> Not managed<br><input type="checkbox"/> Partial ( $1 - 25\%$ treated)<br><input type="checkbox"/> Partial ( $> 25 - 75\%$ treated)<br><input type="checkbox"/> Extensive ( $> 75\%$ treated)<br><input type="checkbox"/> 100% No toxic waste is produced                                                                                                                                                           | 4                   | 4               | 3               | 2                      | 2                |
| 3.7                                                                | Plastic consumption: does the university implement a proper policy to reduce the consumption of plastic? (yes/no)<br><input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                               | 2                   | 2               | 2               | 2                      | 2                |
| 3.8                                                                | Paper consumption: does the university implement a proper policy to reduce the consumption of paper? (yes/no)<br><input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                   | 2                   | 2               | 2               | 3                      | 3                |
| <b>Water consumption</b>                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                     |                 |                 |                        |                  |
| 4.1                                                                | Does the university adopt a proper policy to reduce the water consumption? (yes/no)<br><input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                                             | 2                   | 2               | 2               | 2                      | 2                |
| 4.2                                                                | Water consumed per capita: total consumption of water, divided by the number of FTE students (Include all initiatives within the institution about water conservation programs)<br><input type="checkbox"/> $> 40$ (Liter per capita per day)<br><input type="checkbox"/> $39 - 29$ (Liter per capita per day)<br><input type="checkbox"/> $28 - 18$ (Liter per capita per day)<br><input type="checkbox"/> $17 - 7$ (Liter per capita per day)<br><input type="checkbox"/> $< 6.9$ (Liter per capita per day) | 2                   | 4               | 4               | 3                      | 2                |
| 4.3                                                                | Does the university adopt greywater sustainability activities (Include all activities)<br><input type="checkbox"/> Yes<br><input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                                          | 5                   | 4               | 4               | 4                      | 2                |



| No. | Required Information (evidence is required for all items)                                                                                                                 |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | University Name                                                                                                                                                           |
| 2   | Date of Establishment                                                                                                                                                     |
| 3   | Address                                                                                                                                                                   |
| 4   | URL of the official website                                                                                                                                               |
| 5   | HEI's President Contact Information                                                                                                                                       |
| 6   | Environmental Sustainability Coordinator contact information                                                                                                              |
| 7   | Partnerships on Environmental Sustainability                                                                                                                              |
| 8   | Networks (Local, Regional, International)                                                                                                                                 |
| 9   | Partnerships (Government, Community, Education, Business, etc.)                                                                                                           |
| 10  | Public access to open spaces                                                                                                                                              |
| 11  | Open green spaces' details: Open Space Name, Total Area (m <sup>2</sup> ), Duration (hours per week)                                                                      |
| 12  | Community services' details: Community Name, Number of Participants, Duration                                                                                             |
| 13  | Type of higher education institution (Comprehensive, Specialized higher education institution)                                                                            |
| 14  | Climate (Tropical wet, Tropical wet and dry, Semi-arid, Arid, Mediterranean, Humid subtropical, Marine west coast / Oceanic Climate, Humid continental, Subarctic)        |
| 15  | Number of campus sites                                                                                                                                                    |
| 16  | Campus setting (Rural, Suburban, Urban, City center, High rise building area)                                                                                             |
| 17  | Total campus area (m <sup>2</sup> )                                                                                                                                       |
| 18  | Total campus ground floor area of buildings (m <sup>2</sup> )                                                                                                             |
| 19  | Total campus buildings area (m <sup>2</sup> )                                                                                                                             |
| 20  | Total number of regular students (part time and full time)                                                                                                                |
| 21  | Total number of online students (part time and full time)                                                                                                                 |
| 22  | Total number of academic and administrative staff                                                                                                                         |
| 23  | Estimated annual total population                                                                                                                                         |
| 24  | Total university budget (in US Dollars)                                                                                                                                   |
| 25  | University budget for sustainability effort (in US Dollars)                                                                                                               |
| 26  | Total carbon footprint (CO <sub>2</sub> emission in the last 12 months, in metric tons)                                                                                   |
| 27  | Electricity usage per year (in kilowatt hours)                                                                                                                            |
| 28  | Number of cars actively used and managed by university                                                                                                                    |
| 29  | Number of cars entering the university daily                                                                                                                              |
| 30  | Number of motorcycles entering the university daily                                                                                                                       |
| 31  | Number of shuttles operated in the university                                                                                                                             |
| 32  | Average number of passengers of each shuttle                                                                                                                              |
| 33  | Total trips of each shuttle services each day                                                                                                                             |
| 34  | Average number of Zero Emission Vehicles (e.g. bicycles, cano, snowboard, electric car, etc.) on campus per day                                                           |
| 35  | Total campus' smart building area (m <sup>2</sup> )                                                                                                                       |
| 36  | Renewable energy sources and its capacity (in kilowatt hour)(Bio diesel, Clean biomass, Solar power, Geothermal, Wind power, Hydropower, Combine Heat and Power, or None) |
| 37  | Total ground parking area (m <sup>2</sup> )                                                                                                                               |
| 38  | Number of courses/subjects related to sustainability offered                                                                                                              |
| 39  | Total number of courses/subjects offered                                                                                                                                  |
| 40  | Total research funds dedicated to sustainability research (in US Dollars)                                                                                                 |
| 41  | Total research funds (in US Dollars)                                                                                                                                      |
| 42  | Sustainability website address (URL) if available                                                                                                                         |
| 43  | Approximate daily travel distance of a vehicle inside your campus only (in Kilometers)                                                                                    |



UoB  
ESHEIRS\_Questionnaire

## Appendix I: FindIndicatorWeight code

```
import numpy as np

# Read universities array from file
universities = np.loadtxt('universities.csv', delimiter=',')

# Read Optimal_target array from file
Optimal_target = np.loadtxt('Optimal_target.csv', delimiter=',')

# Read Alpha array from file
Alpha = np.loadtxt('Alpha.csv', delimiter=',', dtype=bool)

# Compute deviation for each column in universities
deviation = np.zeros(universities.shape[1])
for j in range(universities.shape[1]):
    col = universities[:, j]
    if Alpha[j]:
        deviation[j] = np.sum(np.where(col < Optimal_target,
Optimal_target - col, 0))
    else:
        deviation[j] = np.sum(np.where(col > Optimal_target, col -
Optimal_target, 0))

# Read integer array from file
solutions = np.loadtxt('Solutions.csv', delimiter=',', dtype=int)
```

## Appendix J: PythonCode First run

```
import itertools

# Define the number of variables and the target sum
n = 3 # number of indicators
target_sum = 20
min_weight = 2
max_weight = 14
# Generate all possible values for the variables
values = range(min_weight, max_weight)

# Generate all possible combinations of the values
combinations = itertools.product(values, repeat=n)

# Filter the combinations to keep only those that sum up to
the target sum
valid_combinations = filter(lambda x: sum(x) == target_sum,
combinations)

# Write the valid combinations to a file
with open("solutions.csv", "w") as f:
    for combination in valid_combinations:
        f.write(",".join(map(str, combination)) + "\n")
```

## Appendix K: PythonCode second run

```
import itertools

# Define the number of variables and the target sum
n = 3 # number of indicators
target_sum = 20
min_weight=4
max_weight=11
# Generate all possible values for the variables
values = range(min_weight, max_weight)

# Generate all possible combinations of the values
combinations = itertools.product(values, repeat=n)

# Filter the combinations to keep only those that sum up to
the target sum
valid_combinations = filter(lambda x: sum(x) == target_sum,
combinations)

# Write the valid combinations to a file
with open("valid_combinations_V3_20.txt", "w") as f:
    for combination in valid_combinations:
        f.write(",".join(map(str, combination)) + "\n")
```

## Appendix L: Dummy Data

| Climate Class | Indicators |      |      |      |        |      |      |      |      |      |      |      |      |      |
|---------------|------------|------|------|------|--------|------|------|------|------|------|------|------|------|------|
|               | 1.1        | 1.2  | 1.3  | 2.1  | 2.3    | 2.4  | 3.1  | 3.2  | 3.3  | 3.4  | 3.5  | 3.6  | 3.7  | 3.8  |
| Tropical A    | 1.00       | 1.00 | 1.00 | 0.01 | 15.00  | 1.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.40 | 400.00 | 0.00 | 0.00 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.50 | 300.00 | 1.00 | 0.00 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.56 | 234.00 | 1.00 | 0.00 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.43 | 123.00 | 0.00 | 0.01 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.67 | 54.00  | 1.00 | 0.01 | 0.67 | 0.67 | 0.67 | 1.00 | 1.00 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.80 | 67.00  | 0.00 | 0.01 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.73 | 98.00  | 1.00 | 0.01 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.60 | 106.00 | 1.00 | 0.01 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.10 | 370.00 | 1.00 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 1.00 | 1.00 |
| Arid B        | 1.00       | 1.00 | 1.00 | 0.01 | 15.00  | 1.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.40 | 400.00 | 0.00 | 0.00 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.50 | 300.00 | 1.00 | 0.00 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.56 | 234.00 | 1.00 | 0.00 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.43 | 123.00 | 0.00 | 0.01 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.67 | 54.00  | 1.00 | 0.01 | 0.67 | 0.67 | 0.67 | 1.00 | 1.00 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.80 | 67.00  | 0.00 | 0.01 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.73 | 98.00  | 1.00 | 0.01 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.60 | 106.00 | 1.00 | 0.01 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.10 | 370.00 | 1.00 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 1.00 | 1.00 |
| Warm C        | 1.00       | 1.00 | 1.00 | 0.01 | 15.00  | 1.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.40 | 400.00 | 0.00 | 0.00 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.50 | 300.00 | 1.00 | 0.00 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.56 | 234.00 | 1.00 | 0.00 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.43 | 123.00 | 0.00 | 0.01 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.67 | 54.00  | 1.00 | 0.01 | 0.67 | 0.67 | 0.67 | 1.00 | 1.00 | 1.00 | 1.00 |
|               | 0.00       | 0.00 | 0.00 | 0.80 | 67.00  | 0.00 | 0.01 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.00 | 0.00 |
|               | 1.00       | 1.00 | 1.00 | 0.73 | 98.00  | 1.00 | 0.01 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.60 | 106.00 | 1.00 | 0.01 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.10 | 370.00 | 1.00 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 1.00 | 1.00 |
|               | 1.00       | 1.00 | 1.00 | 0.01 | 15.00  | 1.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 1.00 | 1.00 |



Dummy Data.pdf

## ملخص البحث

تقدم هذه الأطروحة مؤشرا جديدا للأداء البيئي لمؤسسات التعليم العالي، يسمى ESHEIRS ، فأنظمة تصنيف مؤسسات التعليم العالي للاستدامة البيئية تهدف إلى تقييم تقدم الجامعات نحو الاستدامة البيئية. ويدرس هذا العمل، بشكل نقدي، أنظمة التقييم الحالية، ويسلط الضوء على قيودها في تقييم الجامعات بناء على أهداف ومؤشرات محددة مسبقا وفقا لمبادئ برلين. ومع ذلك، فإن أنظمة التصنيف هذه تتبنى نهجا موحدا لا يأخذ في الاعتبار العوامل المتعلقة بالمناخ الخاصة بالبلد الذي تقع فيه الجامعة. وعلى هذا النحو، يعتمدون على منهجية عالمية قد لا تكون مناسبة لجميع الجامعات. إن UoBESHEIRS هو نظام ديناميكي، يستفيد من تقنيات الذكاء الاصطناعي والتعلم الآلي لاقتراح أوزان مختلفة لكل مؤشر سنويا، بناء على بيانات الجامعات من العام السابق بالإضافة إلى الأهداف المدرجة بشكل شائع مثل تأثير تغير المناخ، واستهلاك الطاقة، وإدارة النفايات، واستهلاك المياه، والنقل، والتعليم حول الاستدامة البيئية حيث يقدم UoBESHEIRS التنوع البيولوجي كهدف متميز. كما بحث هذا العمل في تأثير العناصر المناخية على أداء الجامعات، وأكتشف وجود علاقة كبيرة بين متوسط درجة الحرارة السنوية وأداء الجامعات في التصنيف.

يأخذ UoBESHEIRS في الاعتبار العوامل المناخية الخاصة بالبلد الذي تقع فيه الجامعة، ويضع أوزان المؤشرات بناء على بيانات الجامعة للعام السابق، وبذلك يضمن هذا النهج تقييما عادلا وغير متحيز لتقدم مؤسسات التعليم العالي من حيث الاستدامة البيئية والتعليم والبحث والخدمات. ويمكن أن يعمل هذا النظام المقترح في هذا العمل كنظام تصنيف مستقل أو يمكن دمجه في نظام تصنيف آخر، وبالإمكان الاعتماد على مجالات اهتمام مختلفة في احتساب أوزان المؤشرات (لا تقتصر حصريا على الاستدامة البيئية)، كما أنه يقدم نهجا شاملا وآليا لتقييم أداء مؤسسات التعليم العالي.

## الكلمات الرئيسية

الاستدامة البيئية، مؤشر أداء مؤسسات التعليم العالي ، نظام التصنيف ، عوامل المناخ ، التعلم الآلي ، برمجة الأهداف.

جامعة البحرين

برنامج البيئة والتنمية  
المستدامة



كلية العلوم

## تطوير نظام تصنيف لأداء الاستدامة البيئية لمؤسسات التعليم العالي

أطروحة مقدمة إكمالاً لمتطلبات الدكتوراه في البيئة والتنمية المستدامة

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يونيو 2023