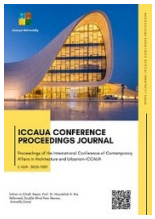

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Empowering Urban Sustainability Through Higher Education: A Strategic Framework for Student-Driven Initiatives at Istanbul Gelisim University

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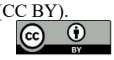

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Abstract

University campuses serve as critical infrastructures within specific regions, playing a pivotal role in the development of surrounding communities by fostering knowledge dissemination and contributing to the establishment of knowledge clusters. This study explores the impact of Istanbul Gelisim University's sustainability initiatives, focusing on student engagement, strategic planning, collaboration, and innovation as key drivers of urban sustainability. Using structured questionnaires, the research gathers quantitative data on students' perceptions and identifies barriers, opportunities, and strategies for enhancing sustainability efforts on campus. It proposes an integrated framework combining current practices with innovative, actionable steps to guide sustainable campus development. Emphasising alignment with the UN Sustainable Development Goals (SDGs), the study highlights the university's role in minimising environmental impact and promoting inclusive stakeholder participation. Key recommendations include forming a sustainability committee, launching awareness campaigns, conducting energy audits, and initiating waste reduction programs. Long-term goals suggest investing in renewable energy, incorporating sustainability into infrastructure planning, and supporting sustainability-focused research. This approach positions Gelisim University as a model for sustainability in higher education, demonstrating how education, collaboration, and practical initiatives can address urban sustainability challenges and empower students to contribute meaningfully to a sustainable future.

Keywords: Urban Sustainability; Higher Education; Student Engagement; Sustainable Development Goals (SDGs); Sustainability Initiatives.

1. Introduction

Universities are increasingly recognised as critical regional infrastructures that extend their impact beyond education and research, influencing socio-economic development, urban innovation, and environmental sustainability (Alshuwaikhat & Abubakar, 2008; Biberhofer & Rammel, 2017; Amen 2024). As hubs of knowledge creation and dissemination, universities shape local and regional economies, contribute to urban resilience, and foster societal transformation, positioning themselves as strategic actors in advancing sustainable development goals (SDGs) (Cortese, 2003). Sustainability in higher education involves a wide range of initiatives that integrate environmental stewardship, social responsibility, and economic resilience into campus operations, academic programs, and institutional culture (Leal Filho et al., 2015; Wright, 2002). University campuses, which engage in diverse activities requiring significant energy, water, and resource consumption, have increasingly recognised sustainability as a critical management priority (Lozano et al., 2013). Achieving campus sustainability requires adopting practices that minimise environmental impact, promote social equity, and ensure long-term economic viability (Cortese, 2003). This comprehensive approach reflects a commitment to meeting current needs without compromising the ability of future generations to meet theirs (Brundtland Report, 1987).

The integration of sustainable practices within universities is essential for several reasons. First, as centres of learning and innovation, universities are responsible for leading by example, fostering sustainable values among students, faculty, staff, and the wider community (Tilbury, 2011). Embedding sustainability across academic and operational frameworks nurtures environmentally literate graduates capable of addressing complex global challenges (Barth & Rieckmann, 2012). Second, sustainable operations enhance institutional efficiency, reduce

operational costs, and mitigate risks associated with resource scarcity (Shriberg, 2002). Third, universities have a significant influence on surrounding ecosystems and communities; through sustainable campus development and outreach initiatives, they can promote biodiversity, public health, and improved quality of life (Noonan, 2014). Lastly, embracing sustainability strengthens a university's reputation, helping attract talented students, faculty, and strategic partners who prioritise environmental and social responsibility (Velazquez et al., 2006).

University campuses play a pivotal role in knowledge dissemination and urban sustainability by serving as living laboratories for innovative practices, environmental stewardship, and stakeholder engagement (Leal Filho et al., 2015). Through sustainability-oriented education, research, and community outreach, campuses are positioned to not only minimise their environmental footprint but also to promote a culture of sustainability among students, staff, and surrounding communities. The integration of sustainability principles into campus operations, from energy management and waste reduction to green building initiatives, demonstrates a commitment to addressing global challenges such as climate change, resource depletion, and social inequities (Wright, 2002).

In line with this global movement, Istanbul Gelisim University (IGU) has embarked on significant sustainability initiatives aimed at reinforcing its role as a proactive agent of change within Istanbul and beyond. IGU's efforts are centred on strategic sustainability planning, fostering student engagement in environmental activities, enhancing collaboration with various stakeholders, and promoting innovation in sustainable practices. The university has initiated programs that align with the United Nations Sustainable Development Goals (UN SDGs), particularly focusing on quality education (Goal 4), sustainable cities and communities (Goal 11), and climate action (Goal 13), thereby strengthening its commitment to environmental responsibility and inclusive growth (IGU Sustainability Report, 2023).

This research aims to explore the impact of IGU's sustainability initiatives on student engagement and campus development, examining the barriers, opportunities, and strategies for enhancing these efforts. The study's main objective is to propose an integrated framework combining existing practices with innovative, actionable steps to guide sustainable campus development. It seeks to highlight how strategic planning, collaboration, and innovation can transform university campuses into catalysts for broader urban sustainability. Ultimately, the research provides insights that can contribute to policymaking, strategic planning in higher education, and the advancement of sustainable development both within and beyond the campus environment.

2.0 Sustainability in Higher Education Institutions (HEIs)

Sustainability in higher education institutions (HEIs) has evolved into a critical priority over the past few decades, driven by the need to prepare future leaders capable of addressing complex environmental, social, and economic challenges (Leal Filho et al., 2015). Universities act not only as knowledge hubs but also as operational models of sustainability, embedding sustainable practices into campus management, curricula, research, and community outreach (Cortese, 2003; Wright, 2002). Various frameworks, such as the Talloires Declaration and the Sustainability Tracking, Assessment & Rating System (STARS), have been developed to assist HEIs in evaluating and reporting their sustainability performance (Shriberg, 2002; AASHE, 2020). The integration of sustainability is considered essential for fostering ecological literacy, reducing institutional environmental impacts, and fulfilling universities' social responsibilities (Lozano et al., 2013).

Universities contribute significantly to regional development by serving as anchors for knowledge-based clusters and innovation ecosystems (Etzkowitz & Leydesdorff, 2000). Through partnerships with industry, government, and civil society, universities stimulate economic activity, encourage entrepreneurial ventures, and support sustainable community development (Benneworth & Hospers, 2007). Knowledge clusters facilitated by universities also promote social cohesion and capacity building, providing resources and expertise necessary for addressing local sustainability challenges (Perry & May, 2010). The presence of sustainability-focused initiatives within these clusters enhances regional resilience and fosters the transition towards greener economies (Uyarra, 2010). Figure 1 shows the main components and the scoring system of the STARS (Sustainability Tracking, Assessment & Rating System) framework on a campus basis, which includes the relationship between SDGs, STARS, and universities, according to Zhu et al. (2020). The STARS framework, initiated by the Association for the Advancement of Sustainability in Higher Education (AASHE), provides an open-access self-assessment tool for colleges and universities to measure, track, and improve their sustainability (AASHE, 2017). So this is STARS-far; just a measuring device, but also a yardstick for the green building and development in higher educational institutions. This is a platform through which universities all over the world can share their green campus status. As of 2019, the number of colleges and universities that have adopted STARS has increased to 659 globally, using it to assess and promote their green campus initiatives (AASHE, 2019a).

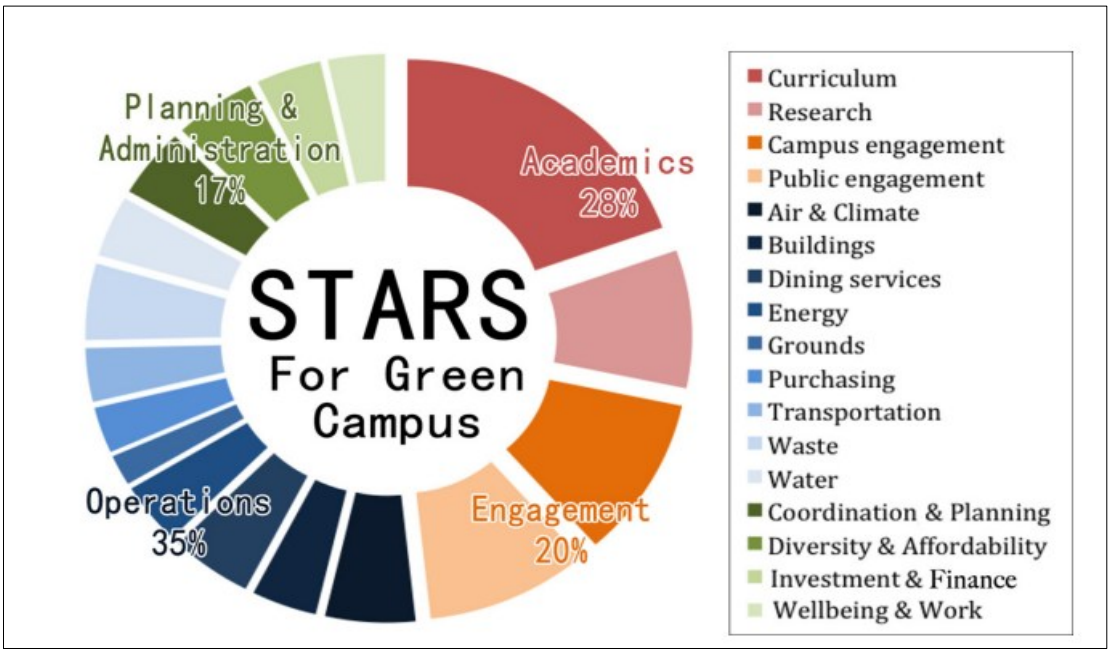

Figure 1: The relationship among SDGs, STARS and universities. Source: Zhu et. al., (2020).

2.1 Alignment of Campus Sustainability Efforts with UN Sustainable Development Goals (SDGs)

The 2030 Agenda for Sustainable Development, particularly through the United Nations Sustainable Development Goals (SDGs), has significantly influenced HEIs to realign their sustainability strategies (SDSN Australia/Pacific, 2017). Universities are increasingly adopting comprehensive approaches that integrate the 17 SDGs across teaching, research, operations, and community engagement (Leal Filho et al., 2018). Initiatives such as reducing carbon emissions, promoting gender equality, ensuring quality education, and advancing innovation align directly with specific SDGs (Ferrer-Balas et al., 2008). Institutions such as the University of British Columbia and the University of Gothenburg have pioneered SDG integration, demonstrating how universities can serve as living laboratories for sustainable innovation (Findler et al., 2019). Figure 2 provides a visual representation of the Sustainable Development Goals (SDGs), encompassing diverse subjects and assisting nations and businesses in comprehensively assessing the impacts of their activities. These 17 objectives serve as a roadmap for guiding human progress in the future, emphasising the importance of current efforts and strategies to achieve them (Zhu et al., 2020).

Globally, best practices in campus sustainability include initiatives like zero-waste programs, renewable energy adoption, sustainable transportation systems, green building certifications (e.g., LEED, BREEAM), and sustainability-centred curricula (Velazquez et al., 2006; Sonetti et al., 2019). Universities such as Arizona State University and the University of Cambridge have led ambitious projects aimed at carbon neutrality and environmental stewardship. However, despite these advances, numerous barriers persist. Key challenges include limited funding, lack of administrative support, fragmented efforts across departments, and difficulties in measuring and reporting sustainability outcomes (Lozano, 2006; Stephens & Graham, 2010). Cultural resistance to change and competing institutional priorities often hinder the depth and breadth of sustainability integration (Evans et al., 2015). Addressing these barriers requires strong leadership commitment, stakeholder engagement, interdisciplinary collaboration, and continuous monitoring and assessment of progress (Beringer, 2007).

Figure 2: Contents of 17 SDGs. Adapted from: Zhu et al. (2020).

2.2 Study's Conceptual Framework and Theoretical Underpinning

This study endeavours to conceptualise a broader engagement of Sustainability Transition Theory and the Triple Helix Model of Innovation, which would offer good interpretative frameworks that may empower understanding of how higher education institutions can catalyse systemic changes towards urban sustainability. The aspect of Sustainability Transition Theories again provides a multi-dimensional view to grasp the very complexities and long-term transformations in embedding practices of sustainability in socio-technical systems such as universities. In this, it argues that transformation happens through the interaction of technological innovations, policy frameworks, cultural norms, and societal values (Markard, Raven, & Truffer, 2012). The theory under Istanbul Gelisim University points to the fact that the institution is not just a place where students learn, but one of the living laboratories for the development of sustainability. As such, by providing opportunities for student-led initiatives, increasing energy and resource efficiency in operations, as well as developing pro-environment behaviours, the institution is seen to be a microcosm of broader transitions towards urban sustainability.

Moreover, in line with this development, the Triple Helix Model, which explains the dynamics of interaction between the university, industry, and government towards fostering innovation-led sustainability, offers a pathway. Being particularly relevant to Istanbul Gelisim University's efforts to involve external stakeholders in the co-development of sustainable solutions, the university could partner with municipal authorities, industry practitioners, and civil society to funnel the impact of campus-based student sustainability action projects beyond the campus and regional development strategies, particularly along the lines of the United Nations Sustainable Development Goals (SDGs), namely SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). These frameworks together stress the possibilities of higher education institutions as transformation agents, apart from empowering students, promoting innovation, and creating cooperation among various sectors of society towards building greener urban futures.

The conceptual framework of the study (Figure 3) is designed to understand sustainability in higher education campuses about institutional practices, global goals for sustainability, and stakeholder engagement. Focused on Istanbul Gelisim University, the framework studies sustainability initiatives like energy conservation, waste and water management, and green infrastructure as key elements of environmental stewardship. It further aligns these efforts with the United Nations Sustainable Development Goals (SDGs) that ensure global relevance, particularly concerning SDGs 4, 7, 11, 12, 13, 16, and 17. A key dimension of the framework includes stakeholder and public participation, stressing the importance of students, faculty, alumni, and community partners in the advancement of sustainable practices through teaching, research, and campus-wide initiatives. Quantitative measurement and analysis provide the basis for this study, enabling sustainability performance and engagement to be assessed through an evidence-based lens. The integrated nature of this study thus provides for a broad understanding of how strategic planning, collaboration, and innovation in the higher education sector contribute to urban and environmental sustainability in the long term.

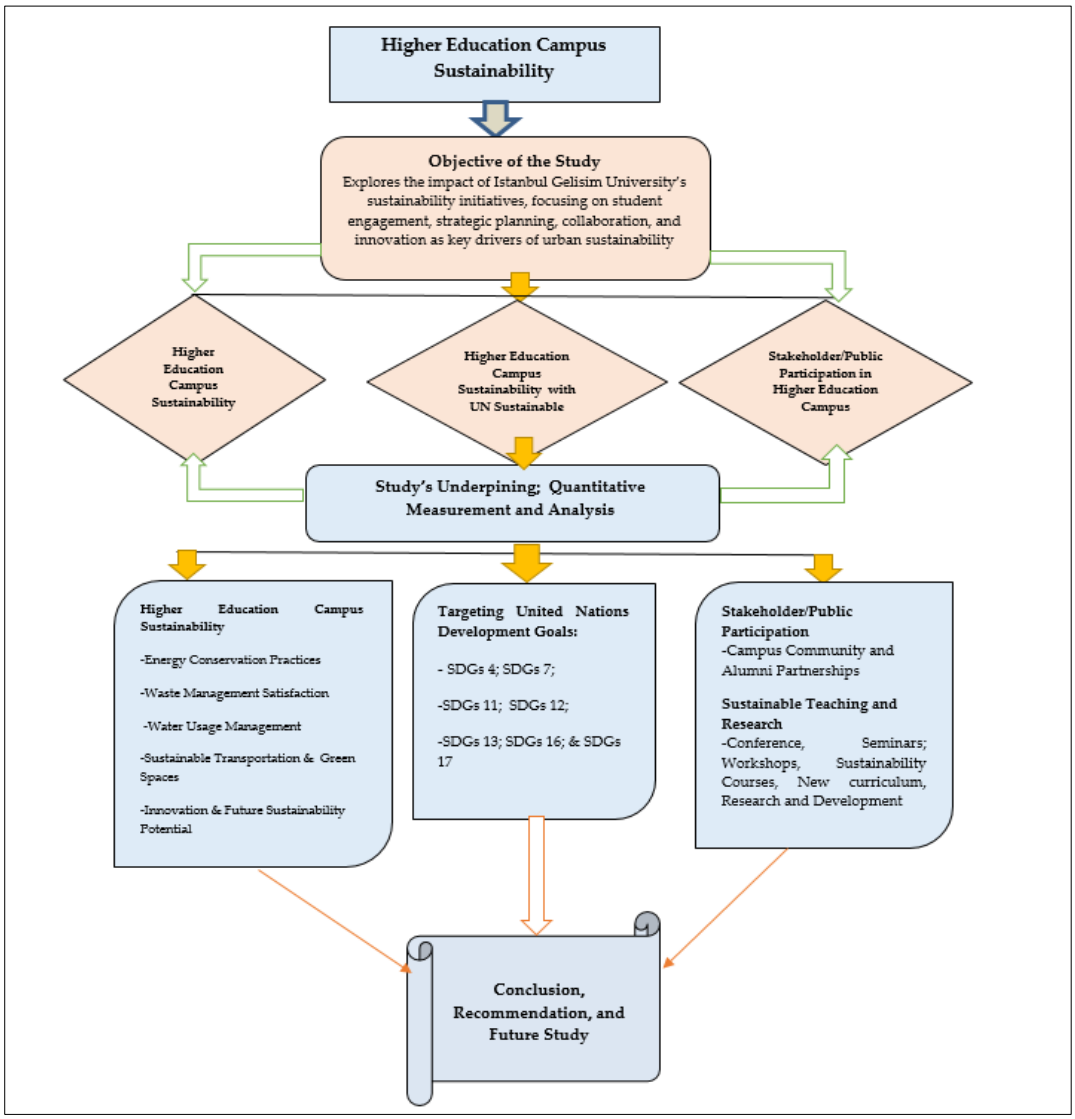

Figure 3: Study's Framework.

3. Material and Methods

3.1 Case Study: Istanbul Gelisim University, Istanbul, Turkey

Istanbul Gelisim University (IGU), established in 2008, is a dynamic and fast-growing higher education institution located in Istanbul, Turkey (Figure 4 a, b & c). With a mission to offer world-class education and foster global competencies, IGU has rapidly positioned itself as a forward-thinking university, deeply committed to sustainability, innovation, and community development. The university's location in Istanbul, a vibrant metropolis at the crossroads of Europe and Asia, offers unique opportunities for influencing regional development through education, research, and public engagement. In alignment with global sustainable development trends, particularly the United Nations Sustainable Development Goals (SDGs), Istanbul Gelisim University has launched a series of sustainability initiatives across its academic, infrastructural, and administrative activities. The university promotes green campus practices, including energy efficiency programs, waste reduction efforts, water conservation systems, and eco-friendly building designs.

IGU integrates sustainability into its academic programs, encouraging interdisciplinary research on environmental challenges, renewable energy, and urban development. It also organises sustainability-focused seminars, workshops, and community outreach projects, promoting awareness and active engagement among students, staff, and external stakeholders. Student participation is a cornerstone of IGU's sustainability strategy. The university has initiated programs encouraging students to lead environmental campaigns, participate in sustainability competitions, and contribute to campus greening projects. Innovation hubs and entrepreneurship centres further foster an environment where students can propose and implement projects that align with sustainable practices. IGU's leadership emphasises strategic planning that embeds sustainability into long-term campus development. Collaborations with international organisations, other universities, and local authorities strengthen IGU's sustainability efforts. Partnerships focus on knowledge-sharing, joint research projects, and policy advocacy for sustainable urban and educational environments.

Despite notable progress, IGU, like many institutions, faces challenges such as limited funding for large-scale green projects, balancing traditional academic priorities with sustainability goals, and integrating sustainable practices uniformly across all departments. However, these challenges also offer opportunities for continuous improvement, innovation, and the strengthening of a sustainability-driven campus culture. Through its sustainability programs,

Istanbul Gelisim University has significantly contributed to raising environmental awareness within its community. Future directions include further investment in renewable energy, implementing smart technologies for campus management, expanding sustainability research funding, and enhancing global partnerships to position IGU as a leading model for sustainable higher education in Turkey and beyond.
In summary, Istanbul Gelisim University demonstrates how a relatively young institution can play a vital role in promoting sustainability within higher education. By integrating sustainable development into education, infrastructure, governance, and community engagement, IGU showcases a comprehensive approach to preparing future leaders capable of addressing the environmental challenges of the 21st century.

Figure 4 (a,b & c**):** Istanbul Gelisim University, Istanbul, Turkey.

3.2 Data collection, Measurement and Analysis

The research methodology involved conducting of literature review to search for the concepts of a sustainable campus. Table 1 shows this study's quantitative measurements based on the past studies. This study's quantitative data involves surveys to provide a comprehensive understanding of the challenges and opportunities for sustainability implementation in Istanbul Gelisim University. Examining the evaluation frameworks for sustainable campuses is crucial for fostering development, as the global community's collaborative efforts have enriched the concept of sustainable campuses. As nations increasingly participate in creating sustainable campuses, it is imperative to consistently enhance and refine assessment criteria to effectively tackle emerging challenges in construction (Abubakar et al., 2017; Zhu et al., 2022). In a recent development, Horan and O'Regan (2021) devised a set of sustainability indicators to streamline the assessment of sustainability progress in Higher Education Institutions (HEIs) and enable more meaningful international rankings. The framework encompasses various key performance indicators (KPIs), such as education, governance, greenhouse gas emissions, on-site energy, research, solid waste, travel, and water. These indicators were evaluated in light of data availability to gauge their effectiveness in measuring sustainability outcomes.

Surveys were administered to the academic community within the campus under study, aiming to obtain qualitative insights into the community's dedication to reducing electricity usage and improving energy efficiency, level of engagement in sustainability activities, and their perspectives on the challenges and opportunities for sustainability implementation in universities. The survey contents involve assessing the level of stakeholders' engagement, drawing inspiration. Additionally, it is crucial to consider the community's comprehension of sustainability issues and their viewpoints on implemented or planned measures, as highlighted by Firdaus et al. (2021). The analysis identifies trends and patterns in the results, including the community's preferences and priorities regarding sustainability and energy efficiency, as discussed by Amini & Bienstock (2021) and Leal Filho et al. (2019). It is essential to ascertain whether the implemented measures align with the Higher Education institutions' (HEIs)

expectations and needs, and to pinpoint areas requiring further attention to fulfil those needs, as noted by Faghihi et al. (2015) and Zhao et al. (2021). Assessing user willingness through surveys is an effective approach to ensuring the sustainability of university campuses and actively engaging the university community in energy-saving and efficiency endeavours, etc (Dade, 2013; & Adenle et. al., 2021; from Moullin et al., 2020).

To collect quantitative data on perceptions, attitudes, and behaviours related to sustainability, a structured questionnaire was administered to key university stakeholders, including students, faculty members, administrative staff, and technical personnel. The survey employed a purposive sampling method to ensure representation across various university demographics and roles. The instrument was developed based on established literature and reviewed for content validity, reliability, and alignment with the research objectives. Distribution was conducted via an online platform, allowing for broader reach and ease of response.

The data analysis involves SPSS version 23, statistical techniques to analyse survey data and derive insights that contribute to the advancement of knowledge and practice in sustainable development. In seeking alternative organisational strategies to manage energy consumption and enhance environmental consciousness among the university community, concerning energy efficiency and sustainable development. Descriptive statistics, such as means, frequencies, and percentages, are used to summarise the survey responses and provide an overview of stakeholders' perceptions and attitudes towards sustainability. Additionally, advanced statistical methods, such as factor analysis, were utilised to identify underlying dimensions of sustainability implementation.

Table 1. Quantitative Approach.

Objectives	Measurement	Rating
Objective: To comprehensively examine and document the existing sustainability practices implemented within the Istanbul Gelisim University.	**Quantitative Study Approach** This involves conducting thorough research surveys with key stakeholders to gain insights into the current initiatives, policies, and actions undertaken by the university towards sustainability in various aspects such as energy conservation, waste management, water usage, transportation, and beyond. The questionnaires were adapted using a 5-point Likert scale.	

4. Results

4.1 Demographic results

A total number of 223 surveys were completed, retrieved, and subjected to a rigorous data screening process for completeness and consistency, which were adequate data quality for subsequent analysis. The gender (Figure 5) imbalance is above 50% as there are more females (53.8%) compared to males (46.2%) among the respondents, thereby implying fairly near in gender representation but also signifying the higher engagement or response of women concerning environmental matters. Such a theory, acted upon in study by Zelezny et al. (2000), has decided that women show more appropriate support for pro-environment behaviour. Therefore, in terms of gender, the strategies would create more drive for participation in campus sustainability initiatives.Majorly, single respondents accounted for 58.4% while most respondents fell within the age bracket of 22-25 years (32.9%), with significant proportions also observed in the brackets of 18-21 years (20.3%) and 26-30 years (23.4%) as shown in Figures 6 and 7. Such a demographic depicts a youthful population typical within university environments and consistent with studies by Leal Filho et al. (2019), who remarked that university students form critical stakeholders in achieving sustainability goals owing to their openness towards environmental education and innovations. It is thus preferable that sustainability campaigns take different forms that suit the target audience, for instance, by using digital platforms, peer-based initiatives, or experiential learning models.

As regards institutional attaché, (Figure 8) undergraduate students count for almost half of the respondents (49.3%), postgraduate students are represented, followed by academic staff at 22% and 14.3%. The student body, thus, dominates, implying that they constitute a critical part of sustainability programming and a deliberate effort to create open and welcoming engagement opportunities (Velazquez et al., 2005). The noticeably lower representation of administrative and technical staff suggests that there exists an even wider gap in cross-sectional sustainability participation, which needs inclusion and orientation programs directed at strengthening such awareness among different levels of staff.

Figure 9 indicates the length of association with the university, which showed that 42.7% had been associated for 2-3 years, 26.6% for 4 and 6 years. This very wide range shows that most of the respondents have enough exposure to the policies of the university as well as to its infrastructure to provide meaningful insight into the practice of sustainability. Engaging long-term institutions, as Lozano suggested, is essential to creating a culture of sustainability in our academic institutions and can work in good alliances to continue empowering the present efforts.

The highest representation of the faculty was relatively balanced between Engineering and Architecture (23.8%) and Economics, Administrative and Social Sciences (20.6%), as shown in Figure 10. Since these disciplines would help put in place interdisciplinary sustainability solutions, such are the views of Adomssent et al. (2007) who argue that sustainability requires concerted interventions across many disciplines in higher education. There are many other examples, for example, those contributing from engineering and architecture may develop green building designs, while economics may look into sustainability policy or cost efficiencies.

The mode of transport pattern shows that most respondents, about 51.7%, use public transport, 26.6% walk, and just 15.4% take private vehicles for travel, as depicted in Figure 11. These data are commendable because of sustainable mobility, and indeed, echo the findings of Filho et al. (2017), which states that universities promoting public and non-motorised transport greatly contribute to reducing their carbon footprint. However, the considerable percentage of low bicycle and scooter adoption (6.3) indicates the need for better infrastructure and security provisions, and also incentives to use alternative modes of transport.

Overall, the data illustrate that there is generally a young, student-heavy population to some degree heterogeneously distributed across faculties, which seems to adopt a sustainable commuting habit. These findings highlight the specific need for targeted, inclusive, and interdisciplinary strategies that engage and cultivate the sustainability paradigm within higher education institutions. It is most important that students are inducted early and periodically, along with the involvement of staff and faculty, as this can greatly affect meaningful long-term change within the institution.

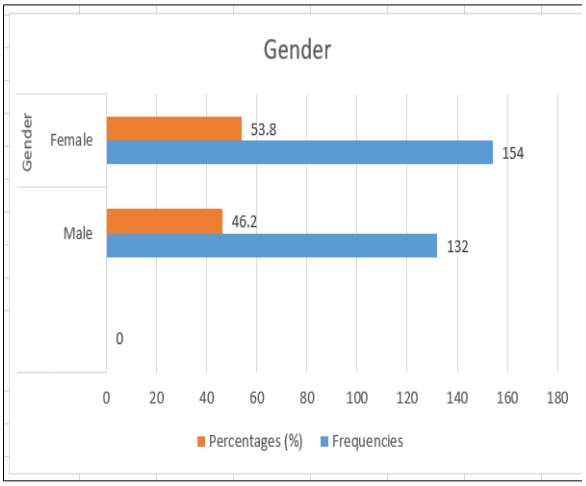

Figure 5: Gender distribution.

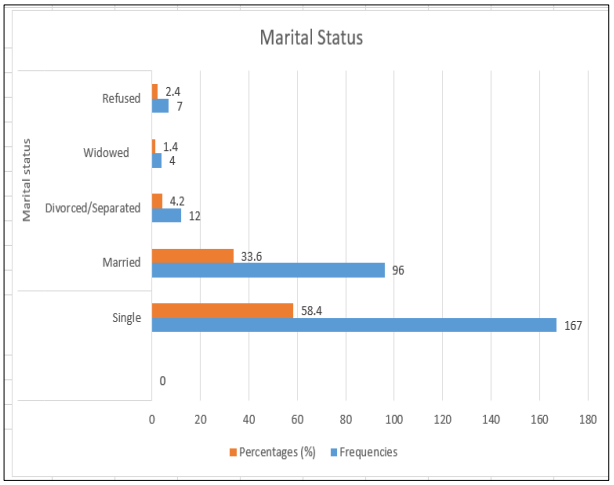

Figure 6: Marital status.

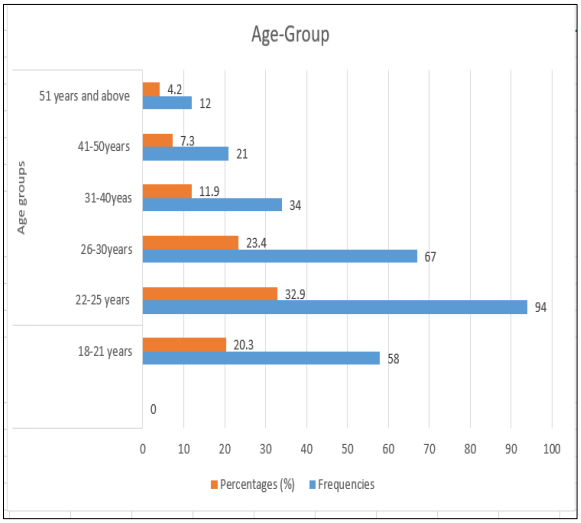

Figure 7: Age distribution.

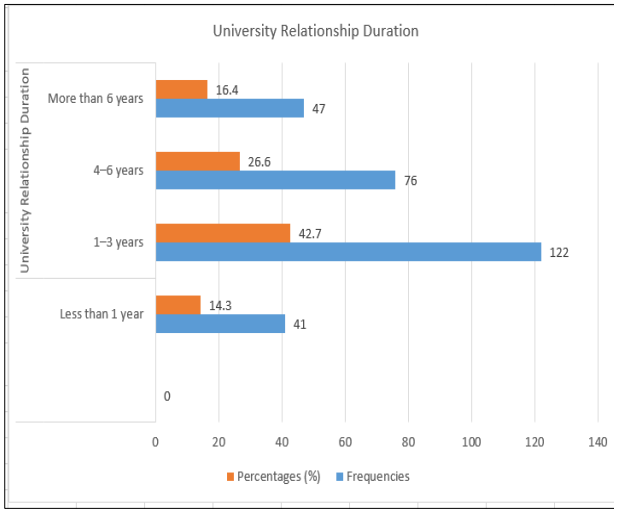

Figure 8: Respondents' University's Relationship Duration.

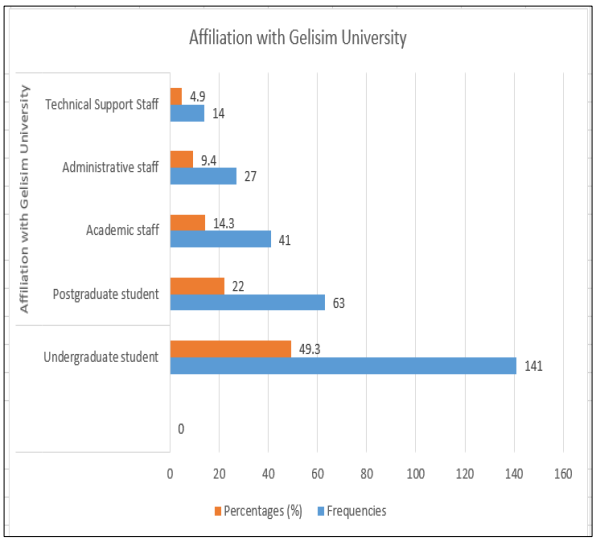

Figure 9: Respondents' Affiliations with the University.

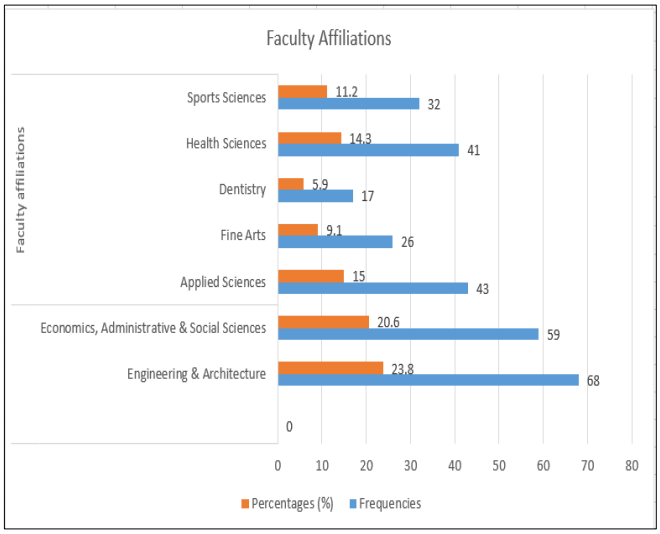

Figure 10: Faculty Affiliations.

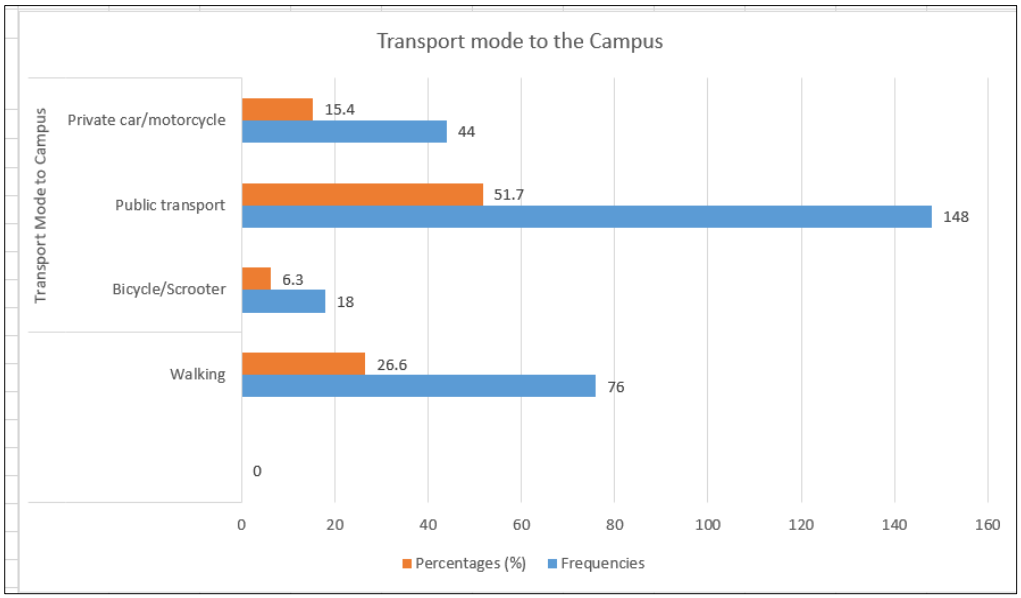

Figure 11: Transport mode to the Campus.

4.2 Results of the Factor Analysis

The data for this analysis were collected from 286 respondents, who rated some questions on a scale of 1 to 5, where 1 indicates strongly disagree/low satisfaction and 5 represents strongly agree/high satisfaction. These responses were set against a backdrop of 20 variables made up of questions Q11-Q30 (Table 4) that probed into the respondents' perceptions and or behaviours about sustainability practices. An exploratory factor analysis (EFA) using Principal Component Analysis (PCA) with Varimax rotation was conducted to examine the underlying structure of the 30 survey items measuring dimensions of sustainability engagement. The Kaiser-Meyer-Olkin (KMO) measure verified sampling adequacy (KMO = 0.845), and Bartlett's Test of Sphericity was significant ($\chi^2(435) = 3221.84$, $p < 0.001$), indicating that the data were suitable for factor analysis. The implication is that data with this kind of value is very well prepared for factor analysis since higher KMO values indicate the sample as being sufficiently representative (greater than 0.6). Another test that was conducted was Bartlett's Test of Sphericity, and this test paid off very well with a significant test result at a p-value less than. 001. Thus, this result further proved that the correlation matrix was not an identity matrix, which means that enough association existed amongst the different variables that would justify the factor analysis. These two tests above confirm that the data could be analysed further with factor analysis.

The extraction of factors was done using Principal Component Analysis (PCA). PCA is applied extensively for dimensionality reduction and for uncovering hidden structures in the data by extracting the most significant factors. Varimax rotation was utilised to facilitate the interpretation of these factors. Varimax is an orthogonal rotation method that maximises the variance of squared loadings of a factor across variables, thus making it easier to interpret the factors by ensuring each factor is as distinct from the others as possible.

After factor extraction and rotation, eigenvalues were assessed, and per the "Eigenvalue > 1" rule, six factors were retained. This rule is commonly employed for determining how many meaningful factors should be retained, as factors with eigenvalues lower than one account for less variance than a single variable. An analysis of the Scree Plot was conducted to help support determining how many factors were best. A definite "elbow" was observed after

the sixth factor, with a major decline in the rate of explained variance commencing beyond the sixth factor. This break corroborated that six dimensions best represent the data, thus supporting the decision to maintain six factors in the analysis, as shown in Table 5. The factor analysis validates six coherent dimensions of sustainability engagement on campus, each of which corresponds meaningfully to the domains of engagement, planning, collaboration, and implementation challenges. With high KMO and significant Bartlett's test results, the data are not only statistically valid but also rich in insights for institutional reforms and targeted programming.

Table 4. Extractions from the questionnaires.

Factors	Corresponding Questions
F1-Awareness and Participation	Q11–Q13
F2-Energy Conservation Perceptions	Q14–Q16
F3-Waste Management Satisfaction	Q17–Q19
F4-Water Conservation Efforts	Q20–Q21
F5-Transportation and Green Spaces	Q22–Q23
F6-Future Sustainability Potential	Q24–Q28
F7-Collaboration and Communication	Q29–Q30

Table 5. Rotated Component Matrix.

Item	Factor 1 (Energy Conservation Practices)	Factor 2 (Waste Management Satisfaction)	Factor 3 (Water Usage Management)	Factor 4 (Sustainable Transportation & Green Spaces)	Factor 5 (Innovation & Future Sustainability Potential)	Factor 6 (Stakeholder Engagement and Communication)
Q14	**0.81**					
Q15	**0.78**					
Q16	**0.77**					
Q17		**0.84**				
Q18		**0.80**				
Q19		**0.76**				
Q20			**0.82**			
Q21			**0.80**			
Q22				**0.86**		
Q23				**0.82**		
Q27					**0.81**	
Q28					**0.78**	
Q24					**0.74**	
Q25					**0.73**	
Q29						**0.85**
Q30						**0.83**
Q11–13, Q26	Mixed loading (some loaded on Engagement and Innovation)					

The analysis yielded six prime dimensions of sustainability, which were arrived at through factor analysis as shown in Figure 12. The dimensions encapsulate areas of sustainability perceived or acted on by the respondents, thus providing a full picture of the respondents' attitudes and behaviours towards sustainability practices. The analysis of variance (ANOVA) results presented in Table 6 provide insights into the differences among the identified clusters across six key sustainability-related factors at Istanbul Gelisim University. The six-component as indicated by factor analysis results, is one with eigenvalues larger than 1, indicating that it accounts for a large percentage of the variance in the data. Six factors with eigenvalues greater than 1 were extracted, collectively explaining 63.84% of the total variance. The rotated component matrix revealed clear factor loadings, with each item loading significantly on one factor. The rule of eigenvalues greater than 1 explains more variance than a single variable can explain and is conventionally used in factor analysis to retain only those components that take on meaning, thus representing the principal underlying dimensions.

The six components conjointly account for nearly 64 per cent of the variance in the data. The factors that have been uncovered appear to be very useful in that they account for a considerable proportion of the variation in responding

to sustainability practices. The other 36 per cent may well be explained by other unmeasured factors or random noise; nevertheless, the 64 per cent offered by these six components points toward a very good representation of the underlying structure of the data. This result affirms the validity of the six dimensions as meaningful constructs for engaging sustainability with the respondents. The analysis of variance (ANOVA) results presented in Table 4 provide insights into the differences among the identified clusters across six key sustainability-related factors at Istanbul Gelisim University.

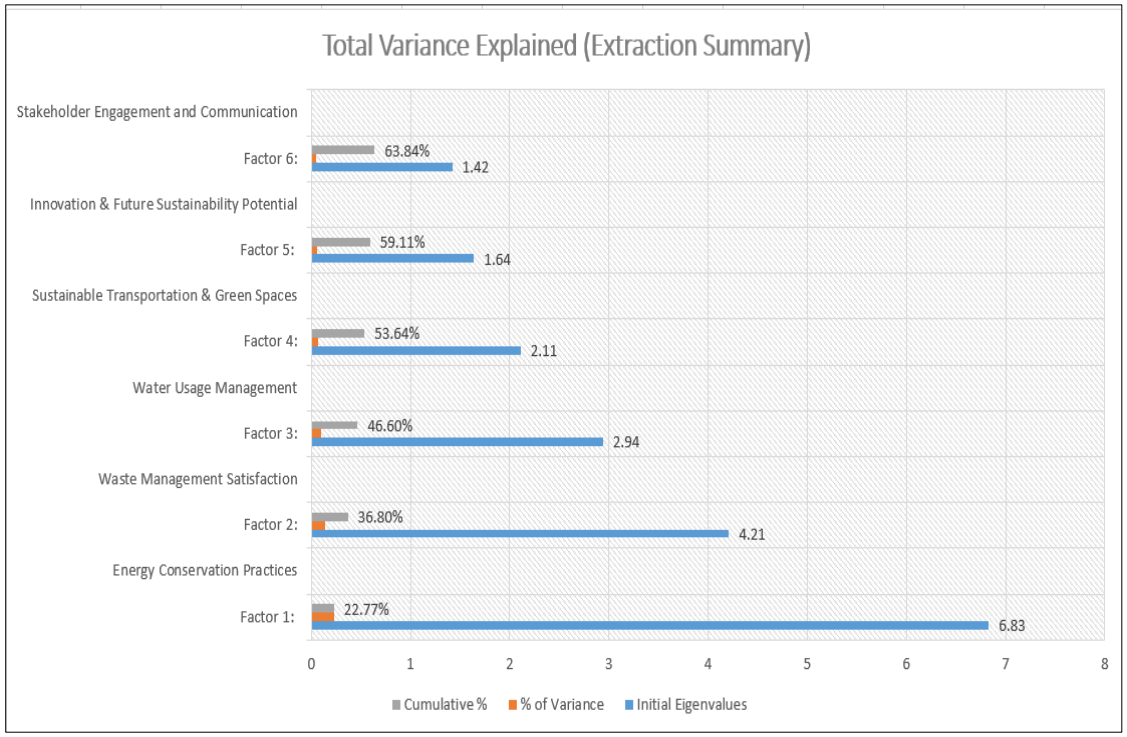

Figure 12: Total Variance Explained.

Table 6: ANOVA Test Results.

Factor	F-value	p-value
FAC_1: Energy Conservation Practices	42.58	**0.000****
FAC_2: Waste Management Satisfaction	35.21	**0.000****
FAC_3: Water Usage Management	28.14	0.412
FAC_4: Sustainable Transportation & Green Spaces	19.67	0.335
FAC_5: Innovation & Future Sustainability Potential	25.88	**0.002****
FAC6_6: Stakeholder Engagement and Communication	18.44	**0.000****

Note: p-values less than 0.05 are considered statistically significant and are indicated with **"**"**

The results revealed statistically significant differences in Energy Conservation Practices (FAC_1) with an F-value of 42.58 and a p-value of 0.000. This indicates that the level of engagement with energy-saving behaviours significantly varies among the student clusters, reflecting a strong differentiation in how energy efficiency is perceived and practised on campus. Similarly, Waste Management Satisfaction (FAC_2) showed a significant difference ($F = 35.21$, $p = 0.000$), suggesting that students' satisfaction with current waste management practices differs meaningfully across the groups. This underscores the need for targeted interventions to enhance recycling programs, reduce waste, and raise awareness about proper waste disposal techniques. In contrast, the factors Water Usage Management (FAC_3) and Sustainable Transportation & Green Spaces (FAC_4) did not demonstrate statistically significant differences among the clusters, with p-values of 0.412 and 0.335, respectively. This suggests a general homogeneity in perceptions and experiences regarding water conservation efforts and green mobility options on campus, pointing to areas that may require more innovation or visible initiatives to generate varied engagement levels.

On the other hand, Innovation & Future Sustainability Potential (FAC_5) showed a significant difference ($F = 25.88$, $p = 0.002$), indicating that the student clusters differ in their attitudes towards innovation and perceived capacity of the university to evolve sustainably. This highlights the importance of fostering a culture of creative thinking,

research, and forward-looking strategies to address environmental challenges. Lastly, Stakeholder Engagement and Communication (FAC_6) also recorded a statistically significant difference ($F = 18.44$, $p = 0.000$), emphasising varying levels of perceived inclusion and communication among the university's key stakeholders. This result suggests that while some groups feel actively involved in sustainability discussions and decisions, others may feel disconnected or underrepresented.

Overall, the ANOVA results reveal that while certain sustainability dimensions (such as energy conservation, waste management, innovation, and engagement) demonstrate clear variation among student groups, other areas, like water use and green space, may require more strategic planning and investment to yield impactful engagement outcomes. These findings offer valuable direction for designing inclusive and effective sustainability initiatives that resonate across the diverse student body.

5. Discussions

The study's results reveal vital facets of student engagement and university dynamics in campus sustainability at Istanbul Gelisim University that correspond with several strands of the existing literature. The analysis reinforces that while certain aspects of sustainability are well-received and actively engaged with, others remain underdeveloped or poorly communicated. Bridging these gaps requires a multifaceted strategy involving education, innovation, collaborative governance, and inclusive student participation to overcome barriers and leverage opportunities for transformative sustainability on campus.

5. 1. Student Engagement in Sustainability Initiatives

The significant statistical difference across cluster means in Energy Conservation Practices, Waste Management Satisfaction, and Stakeholder Engagement and Communication indicates different levels of awareness and participation by students. This finding corroborates the earlier research studies of Velazquez et al. (2006) and Agyeman, Bullard, & Evans (2003) that highlight that active student participation is imperative to achieve sustainability objectives in higher education institutions. Disparities indicate that if certain clusters are working towards sustainability initiatives, others may have poor levels of awareness or, worse yet, accessibility to such initiatives; hence, an urgent requirement exists for affirmative and targeted outreach strategies.

5. 2. Strategic Planning for Sustainable Campus Development

This aspect of Innovation & Future Sustainability Potential within the analysis reflects the perception students have of a university being well prepared to embed sustainability in its long-term planning strategies. Thus, a forward-looking and systematically planned strategy for sustainability is relevant in institutional transformation (Lozano et al., 2013). The differences between cluster responses suggest that there are students who can see institutional efforts on the one hand, but believe that there is or there has been a gap between strategy and practice on the other side. It thus calls for greater visibility and transparency in the treatment of sustainability planning.

5.3. Role of Collaboration and Innovation in Encouraging Campus Sustainability

With innovation and emotional engagement being recognised as statistically significant, they do seem to match with the Triple Helix Model university integrating synergistic roles with industry and government to promote innovation to achieve sustainability (Etzkowitz & Leydesdorff, 2000). Cross-sectoral partnership is not only, as Leal et al. (2018) argue, necessary to increase innovation but also for broadening university capacities to provide solutions for sustainability within its context. All the findings show that interdisciplinary collaboration is highly relevant and should not only constitute research but also be included in the curriculum and policy debate.

5.4. Barriers and Opportunities for Enhancing Sustainability on Campus

Interestingly, the lack of significant variation in Water Usage Management and Sustainable Transportation & Green Spaces suggests that these areas may be suffering from little visibility, limited innovation, and/or some infrastructural constraints. This agrees with the conclusions of Shriberg (2002) and Stephens et al. (2008), who identified institutional inertia, resource limitations, and lack of stakeholder involvement as common barriers facing the campus sustainability process. The implication is that there exist opportunities for the university to scale up its intervention programs concerning water conservation and green mobility through awareness campaigns, infrastructure upgrades, and participatory planning mechanisms.

5.5. Integrated Framework for Sustainable Campus Development

This study focused on the integrated framework that combines existing sustainability practices at Istanbul Gelisim University with innovative, actionable strategies aligned with the United Nations Sustainable Development Goals (SDGs). The proposed framework (Figure 13) is structured around four core pillars:

- Institutional Commitment and Governance (SDG 16 & SDG 17): Establish a dedicated *Sustainability Committee* composed of faculty, students, and administrative staff to guide policy, monitor progress, and ensure cross-sectoral collaboration. This promotes transparency, participatory decision-making, and institutional accountability.
- Curriculum and Research Integration (SDG 4, SDG 9 & SDG 13): Embed sustainability into academic programs and support interdisciplinary, sustainability-focused research. Incentivise faculty-student projects that address local and global environmental challenges, enhancing student engagement and innovation.

- Campus Operations and Infrastructure (SDG 7, SDG 11 & SDG 12): Implement green building standards, conduct periodic *energy and waste audits*, and invest in renewable energy solutions. Promote sustainable transportation, green spaces, and smart water usage systems to reduce the campus's ecological footprint.
- Awareness, Engagement, and Partnerships (SDG 11 & SDG 17): Launch awareness campaigns and sustainability workshops to educate the campus community. Strengthen partnerships with industries, municipalities, and NGOs to co-develop sustainability solutions and amplify outreach efforts.

By aligning university actions with the SDGs, this framework not only enhances environmental responsibility on campus but also empowers students and staff to contribute to broader urban and global sustainability efforts.

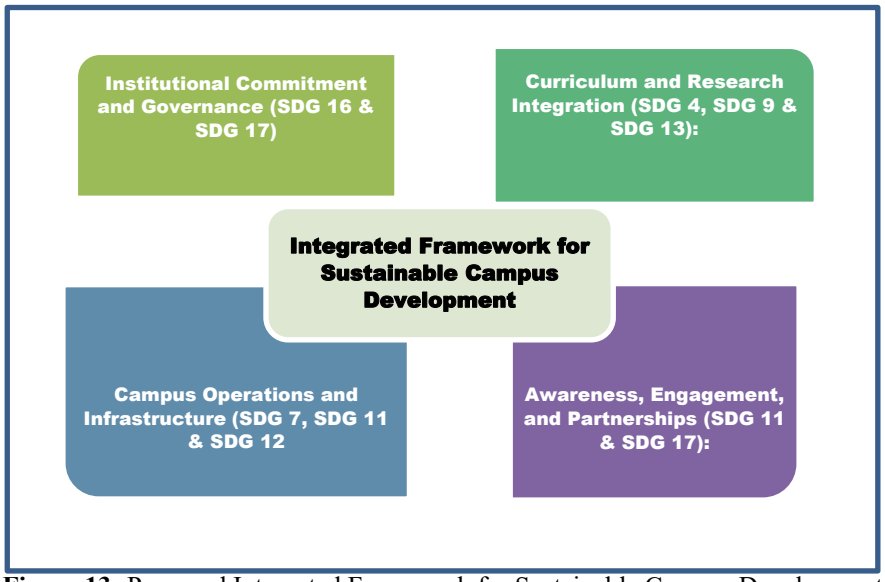

Figure 13: Proposed Integrated Framework for Sustainable Campus Development.

5. Conclusions

The university catalyses environmental responsibility and is a platform for inclusive stakeholder participation. Results indicate students and staff express varying degrees of engagement, suggesting the need for targeted interventions that promote deeper involvement across the board. By embedding sustainability into its governance and curricula, the university can minimise its ecological footprint while empowering students, faculty, administrators, and external partners to participate in co-creating sustainable futures. The participatory approach ensures diverse perspectives are integrated into planning and implementation, promoting equity and social responsibility. By embracing this integrated, data-driven approach, Istanbul Gelisim University positions itself as a model for sustainability in higher education. The synergy of education, collaboration, and strategic action empowers students and faculty to address local and global sustainability challenges. Ultimately, this framework not only enhances campus life but also contributes meaningfully to broader urban sustainability efforts, helping shape a generation of environmentally conscious leaders and changemakers.

This integrated scheme is intended for developing a sustainable campus at Istanbul Gelisim University, wherein the existing practices and innovative, concrete measures are blended with those defined in the United Nations Sustainable Development Goals (SDGs), through four pillars interrelated to institutional development towards stewardship and social responsibility in environmental issues. Institutional Commitment and Governance (SDG 16 & SDG 17) emphasises the establishment of a Sustainability Committee. Haven-to-be representatives from the faculties, students, and administrative personnel, this Committee creates policy formulation and progress monitoring on sustainability issues while at the same time ensuring transparent, participatory governance. This structure permits institutional accountability while allowing for various sectors to collaborate in what should be long-range success. Curricula and Research Integration (SDG 4, SDG 9 and SDG 13) aims to establish sustainability within academic programs, as well as to facilitate interdisciplinary study within sustainability. This will best engage students, energise innovation, and contribute directly to problem-solving when the university stimulates faculty-student collaborations on addressing environmental issues at local and global dimensions.

Campus Operations and Infrastructure (SDG 7, SDG 11 & SDG 12) works to introduce sustainable operational practices within the campus. They involve the adoption of green building standards, energy and waste auditing periodically, investments in renewable energy sources and eco-friendly means of transport, as well as smart source systems for water. These activities goal towards a remarkable reduction of the ecological footprint of the university. Awareness, Engagement and Partnerships (SDG 11 & 17) advocate for public sustainability awareness campaigns, workshops, and active engagement of the university community. Their framework also encourages strategic partnerships with industries and municipalities, and NGOs to create innovative solutions and scale the university's impact in sustainability beyond its borders. By aligning all initiatives with the SDGs, this integrated framework not only strengthens Istanbul Gelisim University's environmental leadership but also empowers students, faculty, and partners to play active roles in addressing pressing urban and global sustainability challenges.

5. 1. Recommendations and Future Study

To operationalise the framework, the following key recommendations are proposed:

- Form a Sustainability Committee, comprising faculty, staff, and students, to oversee sustainability policies and monitor progress.
- Launch Campus-Wide Awareness Campaigns using digital platforms, events, and exhibitions to promote sustainable habits and practices.
- Conduct Regular Energy and Resource Audits to assess current usage patterns, identify inefficiencies, and implement corrective measures.
- Implement a Waste Reduction Strategy, including recycling programs, composting organic waste, and reducing single-use plastics across campus.

These actions are not only cost-effective but also capable of producing measurable outcomes in the short term. To ensure lasting impact, the university should commit to ambitious long-term goals, including:

- Investing in Renewable Energy Technologies (e.g., solar panels and geothermal systems) to transition toward a low-carbon energy system.
- Integrating Sustainability into All Infrastructure Planning from new buildings to landscape design, ensuring eco-efficient and climate-resilient development.
- Supporting Interdisciplinary Sustainability Research by funding faculty and student projects that explore innovative solutions to pressing environmental and urban issues.

University leadership should give priority to sustainability in their strategies for institutional integration and cross-unit collaboration, as well as resource allocation for green infrastructure and student initiatives. Urban planners can partner with universities to co-create scalable sustainability models, promote green innovation, and develop data-informed urban development with environmental and societal goals. Future research includes providing longitudinal insights into students' sustainability initiatives, evaluating the effectiveness of sustainability metrics, and assessing stakeholder views. The framework must also undergo constant updates and changes since it becomes outdated in terms of technology, global environmental policy, as well as the changing reality of local socio-economics.

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Conflict of Interests

The Author(s) declare(s) that there is no conflict of interest.

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