Article

Establishing the Relative Importance of Specific Sustainability Themes That Influence Women's Choice of Engineering as a Career Using the Analytical Hierarchy Process

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Abstract: Understanding the importance of salient factors associated with sustainability challenges that engineers are known to solve in influencing women's choice of engineering is particularly important in this present world where a combination of these sustainability issues, the underrepresentation of women and the need for more engineers remain a challenge to the profession. However, little is known about the degree of importance of more detailed themes within the social, environmental and economic sustainability pillars in such career decisions. Consequently, the aim of this paper is to understand the relative importance of specific sustainability-themed factors influencing women's choice of engineering, using the Analytical Hierarchy Process (AHP). An AHP structurally designed online survey was used to gather and analyze data from a sample of 414 UK and Nigeria respondents. The results showed that of all the ten sustainability-themed factors examined in this study, *water quality/quantity, climate change, waste management, biodiversity, and material consumption/energy use,* had a greater influence on the respondents' choice of engineering relative to other factors. The data revealed specific rather than general sustainability themes that appeal to women's choice of engineering. This could offer valuable insight from a recruitment strategy perspective to help engineering stakeholders to focus their attention and recruitment efforts on the most salient areas of influence.

1. Introduction and Background

Addressing the demand for more engineers has been identified as one of the important tasks for the engineering profession. This task includes the need to develop a diverse pool of individuals who possess the required skills, knowledge and interests to tackle complex global sustainability challenges [1–3]. The Institution of Engineering and Technology (IET) [4] report cautions that this skill shortage problem poses a potential threat to the future of the industry and the sustainability agenda. This is amplified by the slow and persistent low representation of women in engineering. For instance, the Higher Education Statistics (HESA) [5] reported in 2019/20 that women represented only 19% of HE student enrolments in engineering and technology in the UK. Likewise, at the professional level, although approximately 70% of women were working professionals in the UK in 2020 [6], only 10.4% of engineering professionals were women [7]. Additionally, the Women in Science and Engineering (WISE) [7] data show that while the proportion of women engineering professionals increased from 8% to 10.4% in 2016 and 2020, respectively, the general percentage split for this period has remained low and static since 2018.

As a way of addressing this twin problem of underrepresentation of women and shortage of engineers in the profession, an emerging body of evidence suggests that the relevance of engineering in solving societal problems should be emphasized [8–10]. Some of the aforementioned studies claim that women rather than men are more interested in topics that relate to helping people and society. For instance, findings from Godwin [11] showed that beliefs about the positive impact of engineering on the world were more predictive of women's choice of engineering than their physics and math identities, whereas the reverse was the case for men. Therefore, researchers argue that identifying the connection between engineering and such themes is not only key to making the profession attractive to underrepresented students but could also influence the decision of more women to choose a career in engineering [12–14].

However, although these themes of interest to women are synonymous with the sustainability concept, no study has been conceptualized using the three pillars of sustainability (social, economic and environment, also known as the "three P's", namely people, planet and profit) to classify the themes and assess their importance in the decision of women to choose engineering. Stopper, et al. [15] suggest that these three themes provide an integrated model for sustainability to be achieved. Nevertheless, related works have only focused on studying the influence of generic sustainability topics such as the prospect of contributing to helping people, societal impact, protecting the environment, and changing the world, on women's attraction to the profession [12,13,16]. That approach provides narrow insights to only the social and environmental sustainability aspects. Hence, the specific sustainability-themed influential factors across all three aspects that inform women's choice of engineering remain unknown.

Alternatively, Sánchez-Carracedo et al. [2] suggest that clarifying the link between diverse and specific sustainability areas such as renewable energies or electronic waste and engineering could expand and inspire the interests of engineering students, including their commitment to other diverse critical challenges of sustainability. This becomes critical as the current and emerging complex challenges in the world such as climate change, deforestation, poverty, hunger and loss of biodiversity have led to calls for engineering educators in particular to produce more individuals who are knowledgeable and skilled in providing sustainable solutions to these complex problems [2,3]. Hence, this indicates the relevance of identifying more heterogeneous engineering associated sustainability themes that can influence women's choice of engineering as this is likely to attract more women and thus broaden the talent pool of engineers. It could also attract a more diverse pool of individuals who are interested in solving the numerous sustainability challenges across the three aspects [10,17].

Likewise, although most previous research efforts have utilized this general approach to the research topic, a significant proportion has been conducted in the United States [13,16,18,19]. Although women underrepresentation in engineering and the complex SD challenges remain a global problem across both developed and developing nations, these previous studies' findings are mostly limited to context-specific factors such as the prevailing sustainability challenges in the United States. This justifies the reason for conducting this study in the UK and Nigeria, where no such research has been conducted to date. This would contribute rich insights into the research problem from both developed and developing nations' perspectives. While both contexts related to women underrepresentation in engineering and the complex sustainability challenges may differ slightly, lessons learnt might advance culture-appropriate solutions for attracting women to engineering in both countries.

Furthermore, research into specific sustainability themes relative to the others, which are most important in women's decisions to engage in engineering, is currently lacking. In making such a decision, there are always competing multi-criteria or factors to consider, as evident in the numerous sustainability themes and challenges associated with engineers' role in addressing these issues [2,3]. Hence, this situation reflects the relevance of developing research that will provide insights into specific sustainability-themed influential factors that appeal mostly to women's choice of engineering.

As a result, this paper focuses on two separate but interrelated aims. First, the primary aim is to empirically apply a specific multi-criteria decision-making (MCDM) method, the Analytical Hierarchy Process (AHP), in a survey study to better understand the relative importance of sustainability-themed factors influencing women's choice of engineering. The survey study comprised female engineering undergraduate and graduate students and professionals in Nigeria and the UK. As a secondary aim, this paper will also report the efficacy and suitability of the AHP approach in the context of this current study.

2. Related Work and Conceptual Framework

This section details the conceptual foundation of this study. First, the literature surrounding women's choice of engineering career influenced by sustainability themes is reviewed. Next, the relationship between the key concepts of the study is discussed and depicted in a conceptual framework.

2.1. Sustainability Themes and Women's Choice of Engineering as a Career

Engineering's role in developing solutions to meet the rising needs of humanity and society calls for more engineers with the required skills, knowledge and interests [1,3]. Thus, some studies have examined how students' interests in addressing these societal needs might explain their choice of engineering [13,14,18]. Likewise, others suggest that general sustainability topics related to the societal relevance of engineering could make the discipline attractive to women [8–10,12]. However, it has been observed that these topics reflect only social sustainability themes such as helping people, a better world, social impact, societal wellbeing, social responsibility and communal goals. For instance, some studies claim that women are more interested in socially conscious engineering work than men [14,20]. Similarly, in a related study, Klotz et al. [16] pointed to more specific social sustainability topics that influence women's choice of engineering, such as poverty and distribution of resources and opportunities for women and minorities. The authors found that women's interest in these themes were significantly higher than men.

In contrast, few studies have examined the influence of environmental sustainability themes on women's choice of engineering, with even fewer focusing on economic themes [13,16,21]. In one prominent study on the subject, Klotz et al. [16], who analyzed their survey data using descriptive statistics and correlational analysis, showed some significant gender differences within their engineering student population. The results indicated that women were less likely than men to be motivated by economic themes such as energy demand and supply in their choice of engineering. In this study, however, the sustainability themes that women reported as their motivation to engage in engineering were rather mostly social themes such as poverty and disease. In a different study, female students showed more commitment to climate change than their male counterparts and expressed a desire to address these issues in addition to environmental degradation in their future careers as engineers [13].

These contradictory findings in Klotz et al. [16] and Shealy et al. [13] might derive from the different sustainability themes that both studies' participants were exposed to and were familiar with, as defined by the two countries' prevailing sustainability challenges [22–25]. Likewise, these findings indicate the misunderstanding of the overlap among the three pillars of sustainability, where an environmental sustainability theme such as water pollution may be viewed as a social or economic theme, depending on the context of the study [26]. Similarly, this interrelatedness of the three pillars of sustainability is seen in Brubaker et al. [27], who defined societal impact as "measurable effects on environmental, social and economic issues facing human wellbeing and/or planet" (p.3). Although more studies outlined several social sustainability topics that influence women's choice of engineering, it is not clear whether a reference to these topics such as women's interest in the societal relevance of engineering or the desire to change the world should be regarded or classified under any of the three sustainability themes.

Therefore, these studies have mostly been limited to identifying general socially relevant themes of helping people and societal impact as appealing to women's interest in engineering. One exception was Klotz et al. [16], who examined some specific outcome expectations related to sustainability themes. However, the authors focused only on social and environmental themes, reflecting only two of the three pillars of sustainability, an approach that did not consider the comprehensive elements of the three pillars. This approach of incorporating a generic and random list of sustainability topics, without detailing their related diverse characteristics, fails to clarify the link between specific sustainability themes and women's choice of engineering. It also does not reflect the diverse and specific challenges that engineers are meant to solve as identified by the United Nations (UN) formulated SDGs [28] and Mote et al. [29]. Consequently, it is important to examine the influence of all three aspects of sustainability, including economic themes, on women's choice of engineering.

Another limitation of previous studies is that the majority utilized quantitative approaches such as Likert survey scales to study the important sustainability factors that influence the choice of engineering [13,16]. Such an approach would only result in the respondents listing the topic that influenced their career choice. However, in practice, certain sustainability-themed factors will exert more influence on the respondents' choice relative to the other factors. As suggested by Taylor's [30] seminal study on the implications of cognitive strain for decision-making effectiveness, understanding the relative importance of factors is critical owing to the fact that individuals lack the cognitive ability to consider all possible elements in a complex decision.

Hence, in this study, where the problem considers various themes that cut across the three sustainability aspects, an understanding of their relative importance in women's choice of engineering is pertinent.

2.2. Conceptualizing the Three Sustainability Pillars within the Research on Women's Attraction to Engineering Influenced by Sustainability Themes

Corbin and Strauss [31] defined concepts as the "products of analysis" (p.2). Thus, a conceptual framework is an integrated way of logically structuring the concepts and clarifying the relationships between them [32]. Moreover, previous related empirical studies on the influence of specific sustainability topics that cut across the three sustainability pillars on women's choice of engineering are somewhat scarce. Hence, the lack of empirical research in this area and previous studies' general approach to studying this phenomenon necessitate the importance of clarifying the concepts within the research problem [33]. To provide such clarity, it becomes necessary to develop a conceptual framework that underpins this study.

In developing the conceptual framework for this research, the UN formulated SDGs and indicators [28], including Mote et al.'s [29] engineering grand challenges and RAE [34] report on engineering's contributions to solving the world's problems, provided a basis for the selection of the concepts, including their definitions and how they are linked to the three pillars of sustainability. The definition of the concepts central to this research is shown in Table S1.

These concepts, which are defined in this study as the key challenges engineers should solve, also reflect the broad sustainability themes that previous studies, especially Klotz et al. [16], identified as influential in women's decision to choose engineering. For instance, as illustrated in Figure 1, women sustainability-themed interest in helping people and societal impact as a motivation to engage in engineering is linked to the social sustainability theme, which is then intrinsically linked to four sub-themes such as healthcare, equity, housing conditions and population problems. These sub-themes are defined as the SDGs that seek to help people and impact society, which forms part of the sustainability challenges engineers are meant to solve.
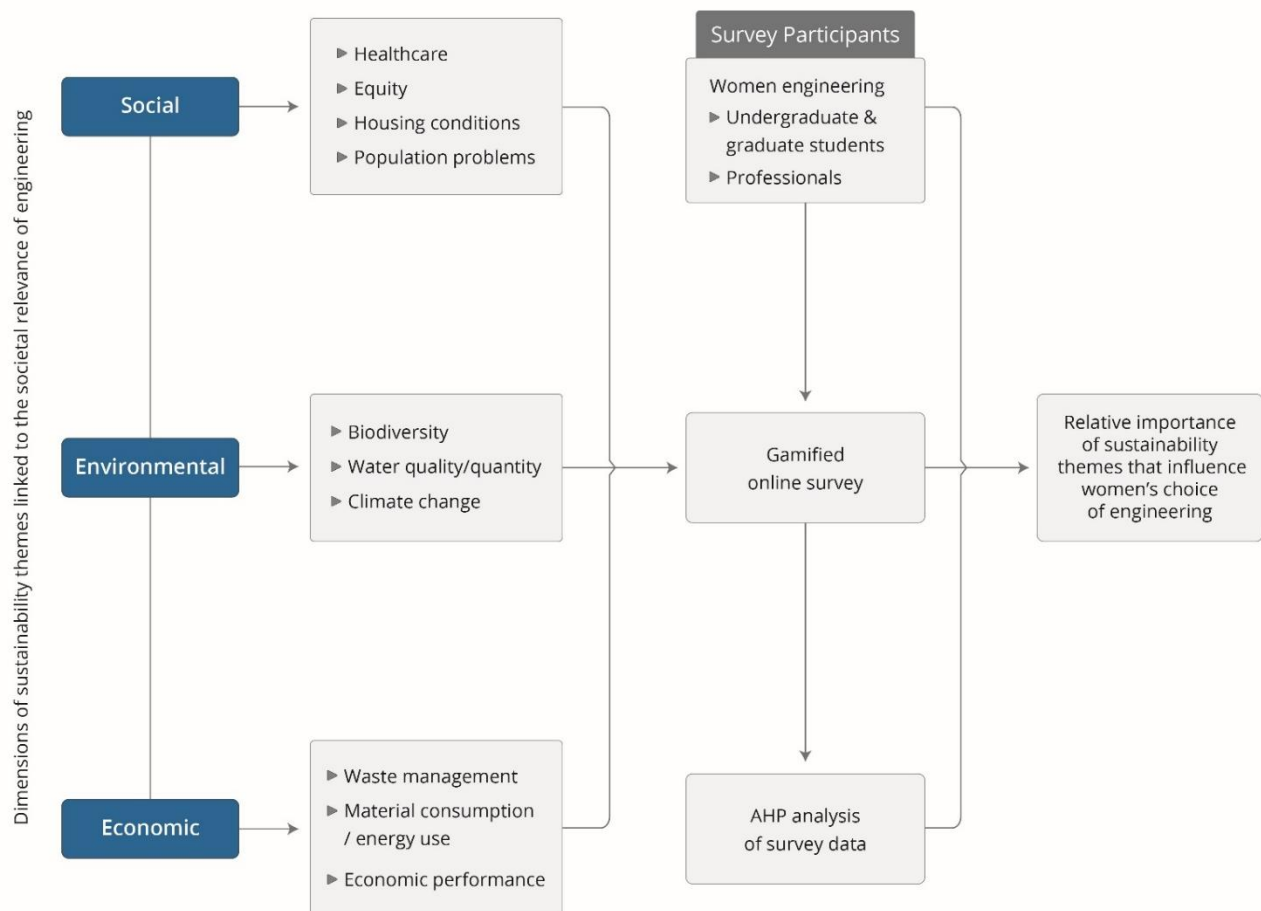
Figure 1. Conceptual framework for studying women's choice of engineering influenced by SD themes [28].

Additionally, women's motivational factor of protecting the environment is linked to the environmental sustainability theme and subsequently to three sub-themes: biodiversity, water quality/quantity and climate change. Similar to the first main theme, these second sub-themes are defined as the SDGs that seek to achieve environmental protection and are part of the sustainability challenges engineers are meant to solve. It is important to note, however, that the influence of the economic sustainability themes has not been examined in previous studies. Instead, they were hypothesized in this study based on the interrelatedness and nested nature of the three pillars of sustainability as posited by Dalampira and Nastis [26] and UNDP [35]. Therefore, the economic themes and challenges that engineers are meant to solve, which were incorporated in this study to examine their influence on women's choice of engineering, include waste management, material consumption/ energy use and economic performance.

Hence, the conceptual framework, as shown in Figure 1, presents the significant factors for studying women's choice of engineering influenced by SD themes based on findings obtained from previous studies. It reflects the primary aim of this study, which is to understand the relative importance of sustainability-themed factors influencing women's choice of engineering using the AHP approach (see Section 1). As shown in the framework (Figure 1), the relationships between the thirteen themes and women's choice of engineering were examined by applying the AHP to analyze the survey data. More specifically, the study sought to examine which of the themes mostly appeal to female engineers and engineering students' choice of engineering.

3. Methodology

In this section, the mechanics of the AHP and its significance in the context of this study is first presented. Next, the AHP procedure is presented in four phases, namely, AHP criteria identification, Sampling strategy, Data collection and Data analysis.

3.1. AHP and Its Significance in the Study

Multi-criteria decision-making (MCDM) involves addressing complex decisions relating to multiple goals or objectives of conflicting nature using decision support tools and methodologies [36]. As an MCDM method, AHP involves making preference decisions by choosing alternatives against conflicting attributes [37]. Developed by Thomas Saaty in the 1970s, the underlying philosophy of the AHP is based on its relevance as a framework for structuring decision problems in a hierarchy and quantifying the various factors of the problem by assessing their relative importance across the hierarchy [38]. The AHP is used in this study to quantitatively assess the relative importance of a combination of specific sustainability themes that influence women's decision to engage in engineering. Based on AHP theory, the general structure comprising factors (criteria and sub-criteria) that might influence a decision were identified from the literature. Subsequently, these were analyzed through pairwise comparison (criteria vs criteria; sub-criteria vs sub-criteria) to determine the most significant factors relative to the others in the decision problem [39]. Figure 2 illustrates the AHP hierarchy structure with the goal (G), representing the focus of the problem, at the top of the hierarchy on level 1; the criteria (C1, C2, C3), which contributes to the goal, on level 2; and the sub-criteria (SC) on level 3.
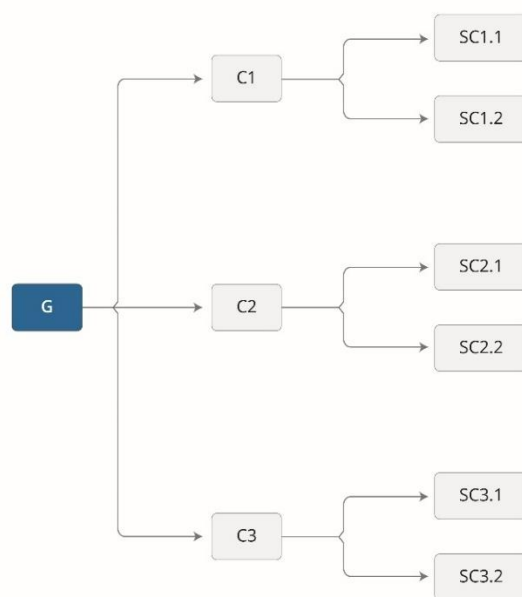

Figure 2. Simple AHP three-level decision hierarchy.

The main rule of this type of hierarchical layout states that all factors on any particular level should be related to a corresponding factor at the higher level in order to be able to determine or assess their relative importance at that particular level [38]. As shown in Figure 2, the relative importance of 'C1, C2, and C3' is assessed by conducting pairwise comparisons of all the criteria with respect to the 'goal' and the sub-criteria- 'SC1.1 and SC1.2' with respect to C1 on the upper level. SC2.1, SC2.2, SC3.1 and SC3.2 are also assessed with respect to C2 and C3, respectively.

When conducting pairwise comparisons, Saaty [38] suggests that the AHP fundamental scale is utilized to answer the basic question: how many times is one factor more dominant, important or preferred than the other with respect to a certain criterion? In making these comparisons, the decision-maker assigns suggested numbers from the AHP

scale from 1/9 to 9, as an expression of the degree of importance/preference attached to the factor being compared. A participant's choice of scale 1 implies that the two factors (criteria or sub-criteria) being compared are equally important. On the other hand, a choice of 9 is an indication that one criterion (i) is extremely important compared to the other (j), while 1/9 implies that criterion (j) is less important compared to the other (i). However, for aggregating group participants' judgements, the preference numbers assigned by each individual are averaged to determine the weighted average for each criterion.

A typical pairwise comparison operation is conducted in a matrix of 'n × n'. For instance, the relative importance of the criteria on level 2 as shown in Figure 2 with respect to the goal on level 1 is expressed in a (n × n) matrix, where the element ajk represents the ratio of wj/wk and the reciprocal matrix is expressed as:

$$ajk = 1/akj \text{ and } ajj = 1, \text{ for all } j \text{ and } k \tag{1}$$

Likewise, a typical pairwise matrix has been noted to contain a certain number of comparisons expressed as:

$$\frac{n(n-1)}{2} \tag{2}$$

(where n is the number of criteria being compared).

Therefore, only 3 comparisons are required for the 3 criterions in Figure 2. The typical comparisons to be conducted on the criteria on level 2 with respect to the goal on level 1, is shown in Matrix A (Table 1).

Table 1. Pairwise comparison matrix A.

	C_1	C_2	C_3
C_1	C_1/C_1	C_1/C_2	C_1/C_3
C_2	C_2/C_1	C_2/C_2	C_2/C_3
C_3	C_3/C_1	C_{13}/C_2	C_3/C_3

AHP has been applied in various decision-making contexts. These include selecting the factors and alternatives for technology transfer adoption for profitability [40], selecting software for engineering education [41], and determining the relative importance of factors influencing students' school and university choices [42,43]. However, AHP research on the factors influencing the choice of an engineering career is scarce. This study recognizes the deficiency in this area and utilizes the opportunity to contribute to the engineering field. Through this theoretical and analytical approach, insights into the salient and specific sustainability-themed factors that influence women's choice of engineering can be identified. Consequently, these insights have implications for engineering stakeholders who can incorporate them into their recruitment strategies to attract more girls to the profession. AHP procedures are presented in the following methodology section.

3.2. AHP Problem Definition/Criteria and Sub-Criteria Identification

The study's primary aim to empirically apply AHP in a survey study to better understand the relative importance of sustainability-themed factors influencing women's choice of engineering, partly defined the criteria and sub-criteria of this AHP problem. However, to identify the most relevant of such factors influencing women's career decisions, a two-stage process was employed. First, a literature review was conducted (see Section 2.1). Next, a conceptual framework for studying women's choice of engineering influenced by sustainability themes was developed (see Section 2.2). For both stages of AHP factor (Criteria and sub-criteria) identification, the works of Klotz et al. [16], UN [28] and Mote et al. [29] proved useful. The former work, which identified broad sustainability themes that are influential in women's decision to choose engineering, was combined with the SDGs, sustainability indicators and grand challenges generated from the latter works. These themes were utilized in developing the conceptual framework of this study. They

were categorized according to the three pillars of sustainability themes and sub-themes and defined as the challenges engineers are meant to solve. Thus, the framework (see Figure 1) illustrates how the relationship between the sustainability-related themes and women's choice and attraction to engineering in Nigeria and the UK is studied in this research.

Furthermore, the concepts in this framework were incorporated into the development of the study's AHP hierarchy model (see Figure 3). This provided the basis for identifying their relative importance in the decision of the participants to choose engineering as a career. As mentioned in Section 3.1, this AHP model is a typical part of this method. Several iteration processes were conducted for the purpose of validity and factor reduction of the model contents. Following this, the final structure of the AHP model was developed. As illustrated in Figure 3, the model is divided into 3 levels: goal, criteria, and sub-criteria, with the goal representing level 1, criteria level 2, and sub-criteria level 3 in the hierarchy.
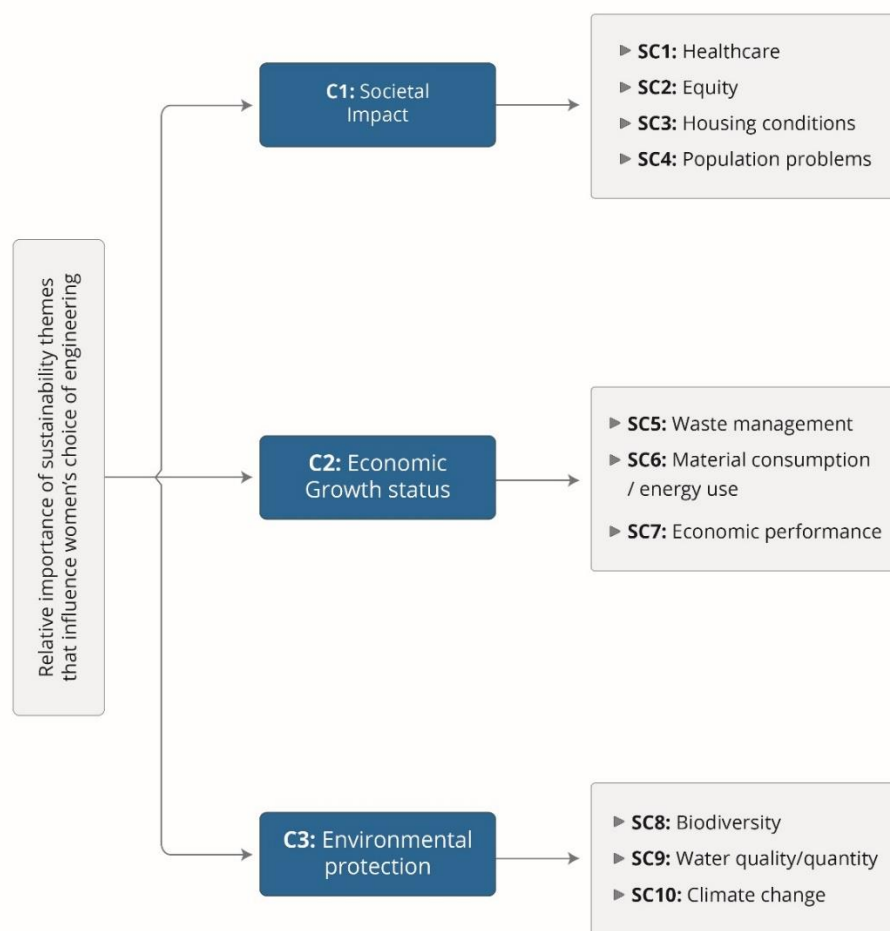

Figure 3. Study's AHP hierarchy model.

First, the goal on level 1 is the focus of the problem, which is to determine the participants' preferences of sustainability themes that influence their decision to choose engineering, hence representing the aim of the survey. Next, the criteria on level 2 are the elements that contribute to the goal. These are the three pillars of sustainability themes, which were assessed to determine their relative importance in the decision of the female participants to engage in engineering. Finally, the sub-criteria on level 3 represents tangible sustainability-related challenges that cut across the three pillars, including the grand engineering challenges and 17 SDGs. These sub-themes can potentially provide better insight into the diverse aspects of sustainability-related themes that could attract an increase in female participation, as well as highlight the different opportunities and possibilities that a career in engineering can bring to prospective participants.

In addition to the selection benchmark, the selection of sub-criteria was based on their relevance to engineering, representing sustainability challenges that engineers should address [29,44] and their synonymity with sustainability issues faced by all regions and countries in the world [28]. Unlike the criteria (the three pillars of sustainability themes), which may be constrained to a limited number, there is no defined limit on the number of sub-criteria (sub-sustainability themes) to be included in the AHP model. This implies a potential for more sub-criteria inclusion in the model, which might differ depending on the goal of the decision-maker. This study's AHP model hierarchy, shown in Figure 4, comprises 3 criteria and 10 sub-criteria. The survey then incorporated all the factors (goals, criteria, and sub-criteria) in the hierarchy model. Consequently, the survey data were used to determine the relative importance among the themes across each level of the AHP hierarchy model.
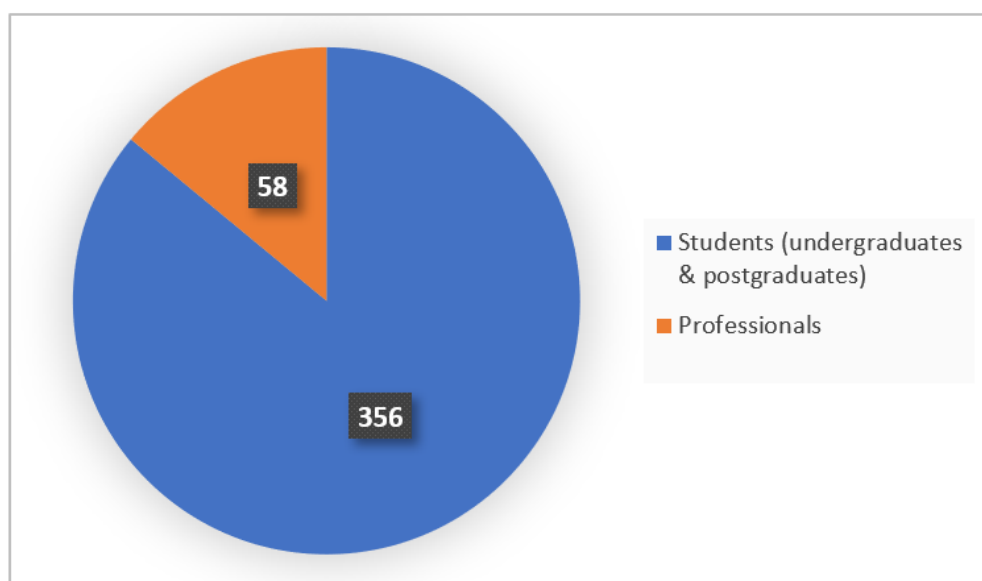

Figure 4. Respondents' group distribution.

3.3. Sampling Strategy

In this quantitative study, a convenience stratified sampling, which is a non-probability sampling technique was used to select the respondents. This means that respondents in this study from different strata (the female engineering undergraduates, graduates and professionals) were selected based on their status as female engineers and students and their willingness and availability to participate in the study. Men were excluded in this sample as the primary aim of the study is to understand the salient factors that influence the career choice of women, who are largely underrepresented in the discipline. Hence, this sampling strategy allowed for the relevant group associated with the study's goals to be selected [45]. Regarding the required sample size for a quantitative study, there seems to be a lack of consensus on a suitable method to select the appropriate number of respondents that would be representative of a study's target population [46–48]. Despite this disagreement, some studies have utilized different approaches for their research [13,47,49]. One widely accepted sample size strategy is the National Education Association [NEA] sampling formula [50], a technique suitable for use in quantitative research and utilized in this study. The NEA formula, as shown in Equation (3), was utilized by Krejcie and Morgan [50] to develop a standard table as a technique for determining the sample size of a given population. This table, as shown in Table S2, can be applied to any defined population from 10 to 1 million.

$$S = X^2 \, NP(1 - P) \div d^2 \, (N - 1) + X^2 \, P(1 - P) \tag{3}$$

where:

S = required sample size
X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level
N = the population size
P = the population proportion (assumed to be 0.50, to provide the maximum sample size)
D = the desired margin of error expressed as a proportion (0.05)

Utilizing this sampling technique, the sample size was calculated and estimated to ensure that the sample is relatively a reflection of the study's population and thus accommodate the challenges associated with adopting the convenience sampling strategy. One of the required variables that make up this formula is the population size (N). Due to the difficulty of obtaining the exact population size of females in engineering in Nigeria and the UK for the 2019–2020 academic year when the study was conducted, the population (N) and sample size (S) were estimated using two approaches:

1. The latest published data of the UK and Nigeria engineering professionals and students' enrolment to engineering courses:

N (from the latest published data) ≈ The number of women engineers and enrolments of females (UG and PG) to engineering courses in both polytechnics and universities in Nigeria [51–53].

The number of women engineering students and professionals (UG, PG and Prof.) published in the UK-2017/2018 data [54].

N ≈ 7019 + 86,488 ≈ 93,507
S from Table S2 ≈ 382 – 384

The Nigerian data were derived as follows: The 2018 data recorded 523 female engineering UG and PG students in the year 2016, while the 2015 data recorded 1709 in the year 2013 and 4787 female professionals [52]. Hence, the total estimated number was 7019. The UK published data for 2017/2018 showed an estimate of female engineering students comprising 23,650 UG students, 5050 PG students and 57,788 female professionals. The total estimated number was 86,488.

2. The survey's targeted population, reached by publishing the survey online and email invitation to universities, engineering associations/organizations across Nigeria and the UK, was 463. Out of this number, 414 completed the survey.

Both approaches showed that the research sample size of 414 was adequate and acceptable as the number of respondents as it exceeded the estimated sample size provided by the Krejcie and Morgan's [50] technique, thus making the data usable for the study [46]. In total, 414 respondents (356 female engineering UG (319) and PG (37) students and 58 engineering professionals), drawn from Nigerian and UK Universities and organizations, completed the survey questions during 2019/2020 academic year. Their background information is presented in Table 2, while Figure 4 illustrates the distribution chart of both groups of respondents from the UK and Nigeria. The students' group represented in Table 2 and Figure 4 comprised of female engineering undergraduates and graduate students across petroleum, environmental, biomedical, civil, electrical/electronics, agricultural, water resources, metallurgical, mechanical, gas, chemical and computer engineering programs. The Professional group is comprised of female engineers from organizations, universities and professional associations. The ethical approval to conduct the study, as granted by the University of Portsmouth's Faculty of Technology ethics committee, is presented in Figure S1.

3.4. Data Collection

Regarding the data collection method adopted in this study, an online survey comprising three sections was used to gather quantitative data for this paper. One advantage of this questionnaire method is that it allows data to be obtained from a larger population; hence the findings can be more generalized [55,56]. Questionnaires have been chosen due to their usefulness in engaging the opinions of groups of participants on certain subjects, making it one of the frequently used methods in education research and related studies [13,16,19].

Table 2. Survey respondents' background information.

Name of Universities	Type of University	Number of Respondents
Nigeria:		
University of Port Harcourt	Federal Government	45
University of Abuja	Federal Government	118
Ahmadu Bello University	Federal Government	82
University of Ilorin	Federal Government	9
Kwara State Polytechnic	State Government	8
Federal University of Technology Akure	Federal Government	4
University of Benin	Federal Government	1
Federal university of petroleum resources Delta state	Federal Government	1
Kwara state Ministry of water resources	State Government	2
Segun Labiran and Associates	Private organisation	1
Goshi Heritage Limited	Private organisation	1
Rivers State University of Science and Technology	State Government	1
University of Lagos	Federal Government	1
Association of Professional Women Engineers of Nigeria (APWEN)	Association	10
UK:		
University of Portsmouth	Public	25
University of the West of Scotland	Public	2
Glasgow Caledonian University	Public	14
Aston University	Public	3
University of Warwick	Public	4
UK and IE Engineering Education Research Network	Association	1
TU Dublin	Public	4
Others (anonymous)	Both Nigeria and UK	77
Total		414

The questionnaire, which was structured and designed using the conceptual framework (see Section 2.2) and AHP hierarchy model (Figure 3), comprised three main sections, A–C. Sections A and C forms the core aspect of this study.

Section A contains column and/or dropdown box sections to collate the respondent's background information whilst retaining anonymity: their universities, schools, organizations and career levels such as undergraduate and postgraduate students and professionals.

Section C represents the fundamental section of the questionnaire, as the questions are the most direct measure of the combination of sustainability themes that can appeal mostly to the decision of the participants to engage in engineering. Hence, they correspond to the study's aim. It has 4 questions that measured the constructs as indicated in the conceptual framework (see Section 2.2). The traditional Analytical Hierarchy Process [AHP] scales of 1–9 were strategically integrated within the questions to generate a better understanding of the degree of importance placed by the different groups of female respondents on the selected sustainability themes [57].

The first questions asked the participants to identify the order of importance in which the three aspects of sustainability themes would influence them to choose or remain in engineering as represented on level 2 of the AHP hierarchy model (see Section 3.2).

The response options were societal impact/helping people, economic status/growth and environmental protection (Figure 3).

They were followed by three other questions representing level 3 of the AHP model (see Figure 3). These questions measured the level of importance that the participants place on sub-sustainability themes, which represent challenges/themes that cut across the three aspects of sustainability and the SDGs. These themes are climate change, water quality/quantity, healthcare, housing conditions, equity, population problems, waste management, and economic performance. These response options were selected following the literature review as recommended by Dörnyei [56] and Mackey and Gass [58]. The authors agree that it can both save time and help in navigating potential pitfalls and difficulties of writing new items, as previously used items have gone through testing and piloting and have been proven to yield statistically valid and reliable data. In addition, the items were selected based on their relevance to the engineering discipline and its role in addressing sustainability, and as such, they would be useful in identifying the combination of sustainability-themed factors that can appeal mostly to women's engagement in engineering.

3.5. AHP Data Analysis

Owing to the nature of a web-based survey design, it is impossible to have all decision-makers (DM), that is, respondents, in one place to obtain their scores for each criterion. Therefore, this required a suitable method to represent all the DMs' opinions. Related works have mostly preferred the use of the average mean to represent the entire DM's opinion or judgement of the criteria [59,60]. The mean of a data set is the average of all the data values. It has been observed that since the questionnaire respondent assigns weights to the criteria individually, it is necessary to calculate the average of the weights assigned to the criteria by the DMs before deriving the criteria weights [61,62]. This helped in assessing the relative importance of the criteria. These criteria weighted average can be expressed as:

$$\sum W_i \times X_i / N \tag{4}$$

(where W_i is the weight assigned to ith option, X_i is the number of respondents who selected the ith option; N is the total number of respondents, and i is the integer).

The average mean was calculated from the values given by the DMs on a scale of 1–9 to represent the given weighting for each criterion by the DMs. Typical of AHP analysis, pairwise comparisons of the criteria and sub-criteria across the AHP model were conducted, followed by a consistency test to ensure that the respondents' judgements were consistent and logical [38]. The following steps and formulas were utilized:

3.5.1. Criteria Weighting Calculation

- Sum the values in each column of the pairwise comparison matrix.

$$C_{ij} = \sum_{i=1}^{n} C_{ij} \tag{5}$$

where C is the criterion value, i and j are integers representing the row and column, respectively.

- Divide each element in the pairwise comparison matrix by its column total to obtain the normalized values

$$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}} \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix} \tag{6}$$

- Calculate the average of the elements in each row of the matrix (sum each row of normalized matrix/no. of criteria) to obtain the criteria weighting/priority vector)

$$W_{ij} = \frac{\sum_{j=1}^{n} X_{ij}}{n} \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix} \tag{7}$$

3.5.2. Consistency Ratio Estimation

After performing the pairwise comparisons, the procedure for conducting the consistency test was applied. Inconsistencies in the pairwise comparisons based on the judgement of the participants are a possibility with decision analysis problems. The AHP took these inconsistencies into consideration and, as such, applied a consistency check to ensure that the priorities or criteria weights were accurate [53]. This is important, as weights only make sense if determined from consistent or near consistent matrices [54,55]. The steps for calculating the consistency ratio were as follows:

- Calculate the consistency vector for each criterion using Equation (8). This was performed by calculating the weighted sum vector, then multiplying the criteria weights by the values in the pairwise comparison matrix, summing the acquired values over the rows and dividing the weighted sum vector by the criteria weights)

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} \times \begin{bmatrix} W_1 \\ W_2 \\ W_3 \end{bmatrix} \begin{bmatrix} [C_{11}W_1 + C_{12}W_2 + C_{13}W_3]\frac{1}{W_1} \\ [C_{21}W_1 + C_{22}W_2 + C_{23}W_3]\frac{1}{W_2} \\ [C_{31}W_1 + C_{32}W_2 + C_{33}W_3]\frac{1}{W_3} \end{bmatrix} = \begin{bmatrix} Cv_1 \\ Cv_2 \\ Cv_3 \end{bmatrix} \tag{8}$$

- Calculate the eigenvalue (sum of the consistency vectors divided by the number of the consistency vectors using Equation (9).

$$\lambda = \frac{\sum_{i=1}^{n} Cv_{ij}}{n} \tag{9}$$

- Calculate the Consistency Index (CI) using Equation (10). It shows the relationship between CI and the maximum principal eigenvalue (λ_{max}) of an n × n pairwise comparison matrix.

$$CI = \frac{\lambda_{max}-n}{n-1} \tag{10}$$

where λ_{max} = maximum eigenvalue

It has been observed that a matrix is perfectly consistent if the eigenvalue (λ_{max}) is equal to the number of compared items (n), otherwise it is inconsistent if more than (n) [53,54]. Likewise, the consistency of the matrix can also be checked by confirming if the Consistency Index (CI) is equal to zero (0).

- Calculate the Consistency ratio (CR)

This consistency test was conducted on all pairwise comparison matrices in the AHP hierarchy. A consistency index (CI) is compared to a random index (RI). The ratio between the consistency index (CI) and the random index (RI) is the CR. This relationship is expressed in Equation (11).

$$CR = \frac{CI}{RI} \tag{11}$$

The RI is the expected value of the CI, where the pairwise comparisons were conducted randomly from a set of numbers. Although other random indices have been developed by some researchers [56,57], this study applied those of Saaty [58], where the RI depended on the number of criterions (n) represented in Table 3. Hence, it is expected that if the participants made consistent and logical pairwise comparisons with no mistakes, the CI should be smaller than the RI. Alternatively, a typical consistency test accepts a matrix to be consistent if the CI is less than 10% of the RI [55,59].

Table 3. Random Indices developed by Saaty [58].

RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49
N	1	2	3	4	5	6	7	8	9	10

The CR rule states that a reliable AHP result can only be generated if the CR is less than or equal to 10% [60]. This means that:

- if CR is $\leq$10%; valid result ➔ comparisons are consistent
- if CR is >10%; invalid result ➔ comparisons are inconsistent

When invalid results are generated, the process is revisited until a 10% CR or less is reached [53]. The criteria and the sub-criteria pairwise comparisons results were used to calculate the priority vectors at the global level. This was performed by multiplying the local weight at the sub-criteria level by the local weight at the criteria level [63]. For instance, if a theme with a sub-criteria score of 0.3526 is housed within a criteria category holding a 0.3490 score, multiplying 0.3526 × 0.3490 generates a global weight or priority of 0.1231. Given that the sum of all global weights will equal 1, this can imply that this theme holds approximately 12% influence on the decision at hand. Finally, the relative importance rank of the factors, highlighting the dominance of one factor over the other, was derived by dividing the global weights.

4. Results

The study results are presented according to the criteria level weight and rank, sub-criteria level weight and rank, and finally, global level weight and rank. This is followed by a discussion of their interpretations and implications.

4.1. Criteria Level Weights and Rank

The first set of pairwise comparisons was conducted for the themes on levels 1 (the goal) and 2 (the criteria) of the AHP hierarchy. All participants gave their judgement for each criterion using the AHP scale of 1–9. To calculate criteria weights, the total values and the average mean values (AMVs) were aggregated, representing the collective decision of the participants regarding the values given for each criterion.

At the "Criteria" level, the results displayed in Table 4 reveal that the *Environmental* criteria (C3) contributed most to the goal with a criteria weight of 0.3490, closely followed by the *Social* criteria (C1) with 0.3443, whereas the *Economic* criteria (C2) contributed the least to the goal with a criteria weight of 0.3067. The criteria weights with respect to the goal are also displayed in Figure 5. These criteria weights signify the relative importance amongst the three sustainability-themed criteria, social impact, economic status and environmental protection, with respect to influencing females' choice in engineering, which is the goal of the problem.

Table 4. Criteria weighting in Matrix representation (Matrix A).

PV	C1	C2	C3	Total	Criteria Weights/Priority Vectors
C1	0.3443	0.3443	0.3443	1.0329	0.3443
C2	0.3067	0.3067	0.3067	0.9200	0.3067
C3	0.3490	0.3490	0.3490	1.0471	0.3490
λmax = 3.00, CI = 0.00, RI = 0.58, CR = 0.00 < 10% (acceptable)					1.0000

Note: Matrix A represents the result of the pairwise comparison and weights of the three criteria on hierarchy level 2.
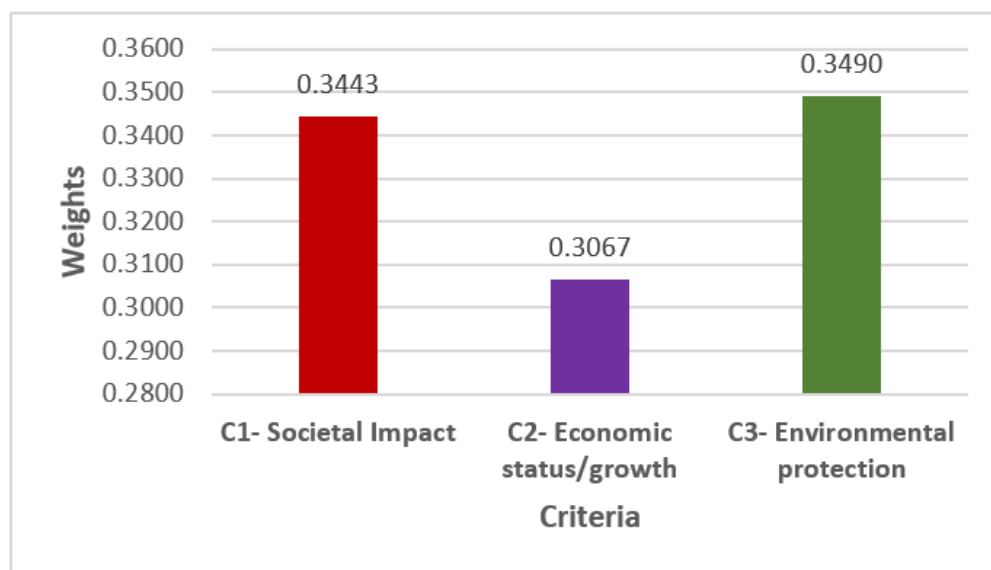
Figure 5. Graphical representation of criteria weights.

Calculating the Consistency Ratio for Matrix A

To determine the consistency of the participants' decisions as represented in the matrix displaying the criteria weighting (Table 4), the principal or maximal eigenvalue (λ_{max}) was evaluated first using Equations (8) and (9). The consistency index (CI) was then calculated to measure the degree of consistency using Equation (10). Then the CR was calculated by comparing the resulting CI with the appropriate random index (RI) as previously expressed in Equation (11). Table 3 shows the RI for only 3–10 'n' values. For matrix A (Table 2), the RI is 0.58 for any 3 criteria, as derived from Saaty's randomly filled matrices. Hence, the CR for matrix A = 0.00/0.58 = 0.00.

The AHP provided different ways to determine the consistency of human judgements. One of the AHP consistency rules states that a matrix is considered consistent when λ_{max} is equal to the number of comparisons. In this case, the number of pairwise criteria compared was equal to three. In addition, if CI is equal to '0', a matrix is consistent. An additional consistency rule considers a matrix to be consistent if CR is ≤10% (0.1). For matrix A, it was determined that $\lambda_{max} = 3$ and CI = 0, confirming the consistency of the participant's judgements. The analysis showed that this matrix was consistent as CR was ≤10% (0.1). Table 5 summarizes the results of the consistency ratio analysis.

Table 5. Consistency Ratio Estimation/Analysis for matrix A.

Criteria	Principal Eigen Value (PEV)
C1- Societal Impact	1.00
C2- Economic growth/status	1.00
C3- Environmental protection	1.00
Total (λ_{max})	3.00
CI ($\frac{\lambda_{max-n}}{n-1}$)	0.00
RI (for any 3 criteria)	0.58
CR ($\frac{CI}{RI}$)	0.00

4.2. Sub-Criteria Level Weights and Rank

Within each of the criteria level factors, pairwise comparisons at the criteria level generated local results for each item. Specifically, the results in Figure 6 show that with

respect to C1 *(Societal Impact)*, the survey participants assigned the highest weight of importance to SC1 (*health care*—0.2848), whereas the least weight of importance was assigned to SC2 (*equity*—0.2328). Meanwhile, SC3 (*housing conditions*—0.2426) and SC4 (*population problems*—0.2397) had a higher degree of importance than SC2 (*equity*). The order of importance/preference for all SC under C1 (*Societal Impact*) is depicted as follows: SC1 > SC3 > SC4 > SC2.
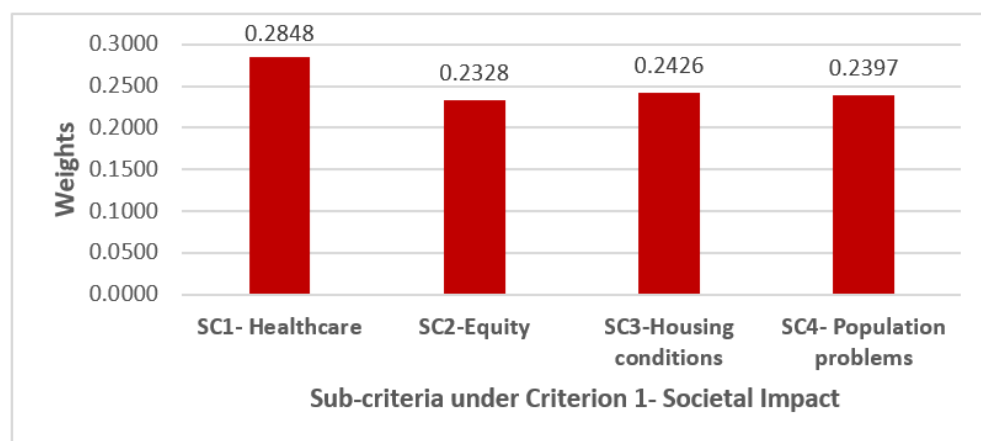

Figure 6. Graphical representation of sub-criteria weights with respect to criterion 1 (Societal impact).

The *Economic growth* (C2) category revealed that the participants assigned the highest weight of importance to *Waste management*—3445 (SC5), followed by *Material consumption/energy use*—0.3445 (SC6), whereas *Economic performance*—0.3183 (SC7) was assigned the least importance within the category (see Figure 7). Finally, as indicated in Figure 8 under the *Environmental protection* category, *Water quality/quantity*—0.3526 (SC9) sub-theme showed the biggest influence on the participants' choice of engineering, followed by *Climate change*—0.3489 (SC10), and Biodiversity—0.2985 (SC8) with the least influence within the category.
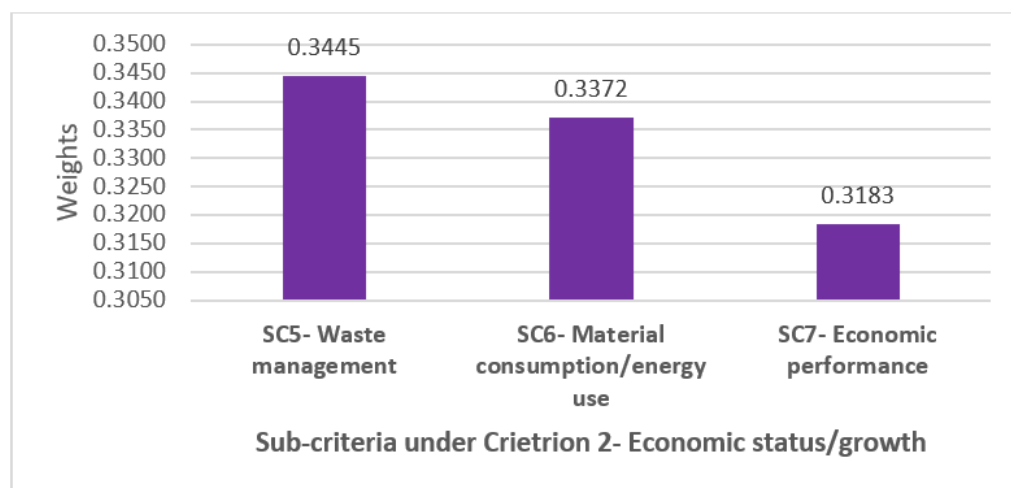

Figure 7. Graphical representation of sub-criteria weights with respect to criterion 2 (Economic growth/status).
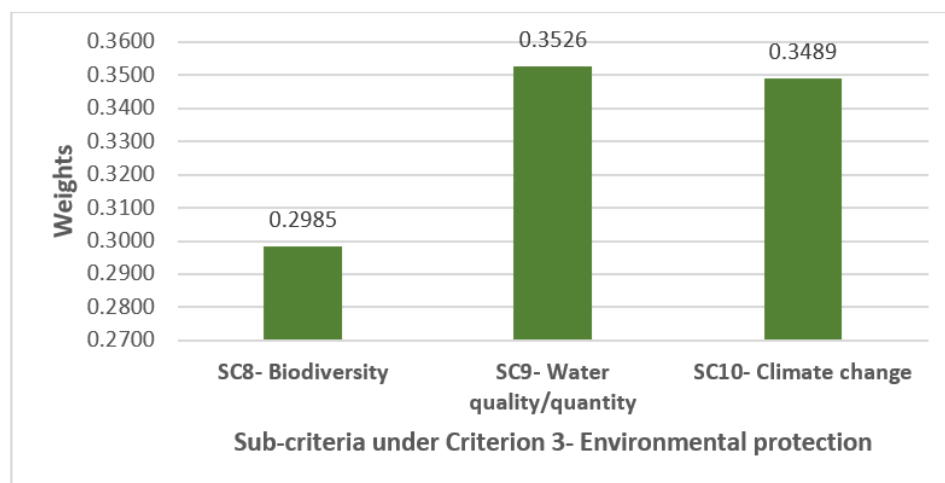
Figure 8. Graphical representation of sub-criteria weights with respect to criterion 3 (Environmental protection).

Calculating the Consistency Ratio for All Sub-Criteria under C1, C2, and C3

The CR calculations were also conducted for all sub-criteria under the three criteria, C1, C2 and C3, using Equations (8)–(11). The results also revealed that all three matrices generated $\lambda_{max} = 3$, CI = 0, and CR $\leq$ 10% (0.1), indicating the consistency of the participants' judgements on the relative importance of all the sub-criteria on level 3 and the criteria on level 2 of the AHP hierarchy.

4.3. Global Weights and Rank

The global (overall) weights of each influencing sub-criteria factor were calculated by multiplying the local weight at the sub-criteria level by the local weight at the criteria level. Consequently, the global (overall) level rank, which showed the relative influence of the sustainability-themed factors on women's choice and attraction to engineering, was derived by dividing the global weights. This global weights and rankings were derived at the combined group level (both students and professional groups) and the individual groups. Table 6 illustrates the results of the global weights and ranking, including the previously generated criteria and sub-criteria weights at the combined group level.

Table 6. Group level Aggregation of final score- Hierarchy level 2 (criteria) and 3 (sub-criteria) total weights.

Criteria	Criteria Level Weight	Criteria Level Rank	Sub-Criteria	Sub-Criteria Level Weight	Sub-Criteria Level Rank	Global Level Weight	Global Level Rank
C1-Societal Impact	0.3443	2nd	SC1-Healthcare	0.2848	1st	0.0981	6th
			SC2-Equity	0.2328	4th	0.0802	10th
			SC3-Housing conditions	0.2426	2nd	0.0835	8th
			SC4-Population problems	0.2397	3rd	0.0825	9th
C2-Economic status/ growth	0.3067	3rd	SC5-Waste management	0.3445	1st	0.1057	3rd
			SC6-Material consumption/energy use	0.3372	2nd	0.1034	5th
			SC7-Economic performance	0.3183	3rd	0.0976	7th
C3-Environmental protection	0.3490	1st	SC8-Biodiversity	0.2985	3rd	0.1042	4th
			SC9-Water quality/quantity	0.3526	1st	0.1231	1st
			SC10-Climate change	0.3489	2nd	0.1218	2nd

4.3.1. Group Level Global Weights and Ranking

The combined group-level results showed that the two most prominent sustainability-themed factors influencing women's choice of engineering were *Environmental* sub-themes.

While the first most prominent theme, *Water quality/quantity*, was just 1.01 times as important as the second most prominent theme (*Climate change*), both themes influenced almost one-quarter of the weighting (0.1231 + 01218 = 0.2431) thus of the women's choice and engagement in engineering.

Surprisingly, although the *Economic* theme was ranked third relative to the other two criteria, it was also a significant influence as two of the three *Economic* sub-themes were listed in the top 5 influential themes as depicted in Figure 9. Here, *Waste management* and *Material consumption/energy use* (with a global weight of 0.1057 and 0.1034, respectively) were ranked as the third and fifth most influential sustainability-themed factors with regards to the participants' choice of engineering. Relatively, these sub-themes were marginally more influential than *Biodiversity* (1.01 times) and *Healthcare* (1.05 times), which were the fourth- and sixth-ranked influential factors, under the *Environmental* and *Social* criteria, respectively. Likewise, apart from *Economic Performance* (under *Economic* Criteria), which was the seventh-ranked influential theme, the *Social* criteria sub-themes were ranked as the least influential factors as follows: *Housing conditions* (8th, 0.0835), *Population problems* (9th, 0.0825) and *Equity* (10th, 0.0802).
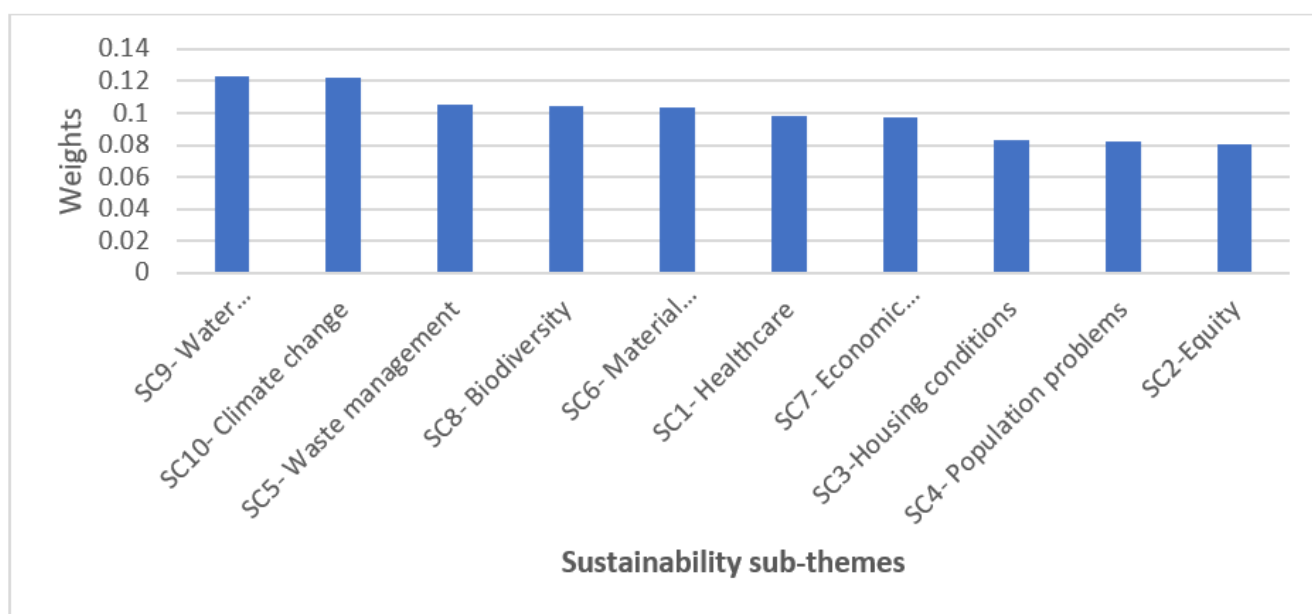

Figure 9. Combined group level sustainability-themed influential factors for engineering career choice.

4.3.2. Individual Group Level Global Weights and Ranking- Difference between Students and Professionals Ranking of SD-Themed Influential Career Choice Factors

At the individual group level, the results revealed that each group indicated their preference for environmental sub-themes as their motivation to engage in engineering (see Tables S3 and S4). However, slight differences were observed. For instance, as indicated in Figure 10, the first most prominent theme for the students' group was *climate change* followed by *water quality/quantity*, whereas the professionals' group indicated their first preference for *water quality/quantity* followed by *climate change* (Figure 11). Despite this slight difference, each group's preference for the top five sustainability themes that influence their choice of engineering comprised environmental followed by economic subthemes. The top five influential factors for the students' group engineering career choice comprised *climate change* (0.1222), *water quality/quantity* (0.1214), *waste management* (0.1052), *material consumption/energy use* (0.1037)) *and biodiversity* (0.1022). On the other hand, the ranking for the professional group comprised *water quality/quantity* (0.1334), (*climate change* (0.1192), *biodiversity* (0.1105), *waste management* (0.1078), *and material consumption/energy use* (0.1014). It was observed from this result that the professional group indicated more preference for

environmental themes, as evident in the emergence of such themes in the first three top themes. Additionally, each group indicated the least preference for social themes such as *Housing conditions*, *Population problems* and *Equity*.
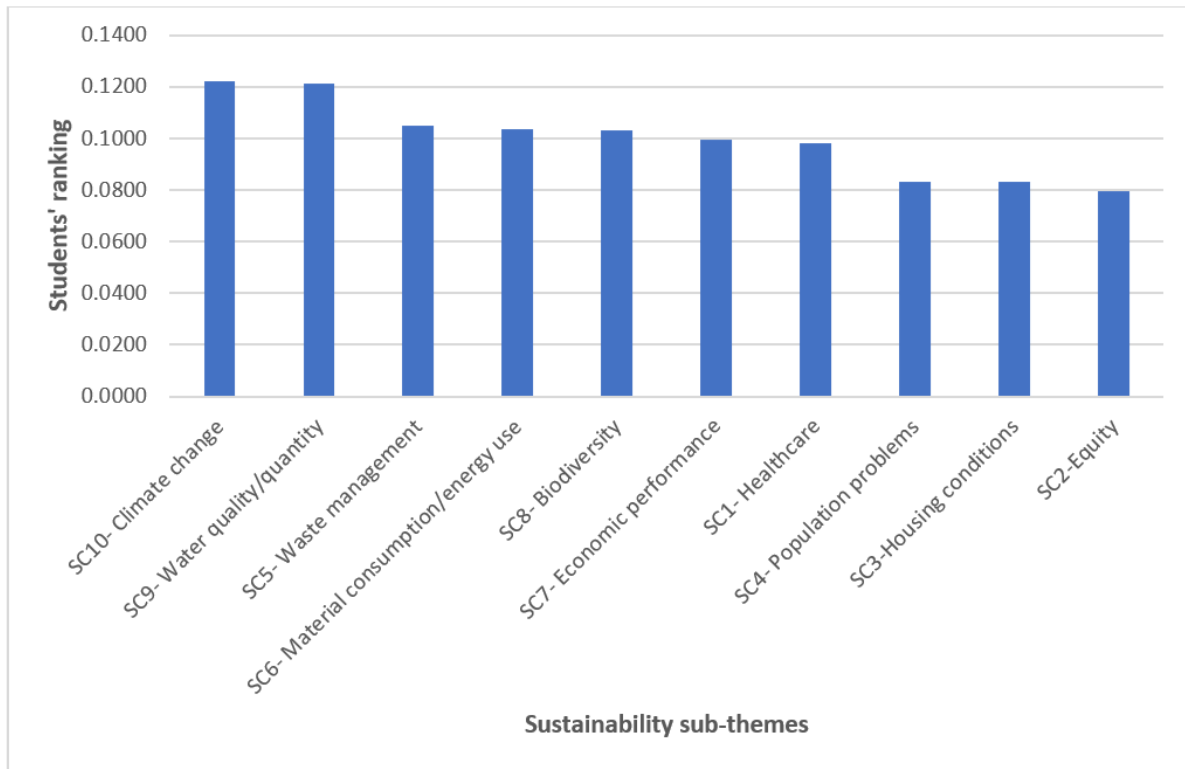

Figure 10. Students group Sustainability-themed influential factors for engineering career choice.
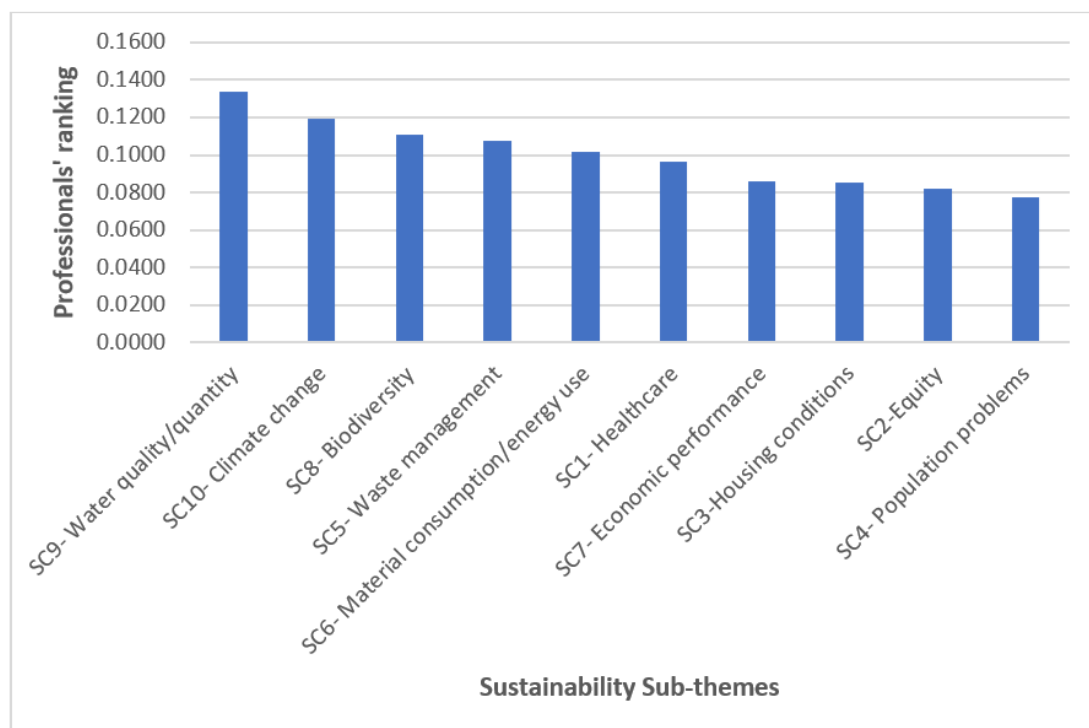

Figure 11. Professionals group Sustainability-themed influential factors for engineering career choice.

5. Discussion

AHP theory supports a decision-making problem such as the one addressed in this study, which involved various factors such as criteria and sub-criteria, to be structured in a hierarchy to quantify the various factors by assessing their relative importance across the hierarchy [38]. Hence, the application of this method in this study has demonstrated its capability and suitability in better understanding the relative importance of sustainability-themed factors influencing women's choice of engineering.

The AHP implementation and its findings in this study differ from those of previous studies that examined the importance of various factors using Likert scale questionnaires [13,16]. This theoretically required the criteria to be assessed in isolation, and each could be assigned a score of 4 (fairly important) or 5 (very important). In contrast, the AHP generated the relative scale of importance through pairwise comparisons. For example, *water quality/quantity* was 1.01 times as important as the second most prominent theme (*climate change*), while both themes influenced almost one-quarter of the women's choice and engagement in engineering. Furthermore, the application of the AHP in this study contributed to determining the consistency of the data. The consistency tests results revealed that although the judgements given by the survey participants were based on subjective perceptions, the outcome of their decision proved to be consistent and logical, as depicted by the consistent matrices.

Additionally, the relative importance of specific sustainability themes that influence the study participants' (female engineering undergraduate and graduate students and professionals) choice of engineering as a career, which was the primary aim of the study, was determined from the AHP analysis. First, the results showed that among the three criteria, the *Environmental* (0.3490) *and Social* themes (0.3443) were deemed to be the most important criteria relative to the Economic theme (0.3067) in the participants' choice of engineering. Although there is a marginal difference in the weights assigned to all three themes, mostly between the top two most preferred themes, namely, Social and Environmental, this finding is consistent with studies that refer to the social and environmental themes as the motivation for females to engage in engineering without reference or insight into the impact of the economic sustainability themes [8,9,13,16]. Additionally, although the *Economic* sustainability theme was not reflected in literature as one of the influential factors for women's choice of engineering, the marginal difference among the three criteria weights seem to prove otherwise. Hence, this study's findings may suggest that the participants perceive all three sustainability themes as interrelated in their career choice. This interpretation is broadly supported by Ashraf and Alanezi [1] and Wilson et al. [64] and also reflected by the final global weight ranking.

Next, the results from the relative importance of the sub-criteria themes showed the most influential sub-sustainability themes (within each of the three-criterion groups) in the participants' career choices. It was not possible to compare these results with previous studies due to a lack of research that utilized this detailed approach to examine the influence of various sustainability themes on women's career choices. However, our research yielded some surprising findings. For instance, the participants attributed more detailed sustainability themes such as *water quality/quantity* (SC9), *climate change* (SC10), *healthcare* (SC1), *housing conditions* (SC3), *waste management* (SC5), and *material consumption and production/energy use* (SC6), to their motivation to engage in engineering. This finding, therefore, puts into question the notion of highlighting the broad societal relevance of engineering to attract women to engineering [9,12,18]. It rather supports the suggestion that clarifying the link between diverse sustainability topics and engineering can lead to expanding and inspiring the interests of engineering students, especially females, who are likely to disassociate from the discipline, where there is a lack of understanding of such link [2,5,7].

Finally, the global weights and ranking provided insightful results and clearer explanations of both the criteria and sub-criteria level weights results at the combined group and individual group levels. Of all the ten factors (sub-criteria) examined in this study at

the combined group level, it is clear that five (*water quality/quantity* (0.1231), *climate change* (0.1218), *waste management* (0.1057), *biodiversity* (0.1042), *and material consumption/energy use* (0.1034)) provided the most influence on the participants' choice of engineering. While the emergence of the environmental sub-themes in the top five influential factors (Table 4) is in line with previous studies [8,9,13,16], it was rather surprising to see the economic sub-themes emerge in this top list and as the second most influential sub-factors in the participants' career choice. This suggests the significance of this research's novel approach of detailing and characterizing the three pillars into specific sub-themes in identifying the various aspects of engineering associated with such themes that can appeal to women's interest. Likewise, at the individual group level, the results of the top five influential sustainability-themed factors comprised environmental and economic themes with marginally different weights. Although this finding is similar to the preferred themes derived at the group level, there are slight differences. For instance, the professional group indicated more preference for environmental themes than economic themes. The students' group, on the other hand, preferred a mix of both environmental and economic themes. This finding from the professional group may imply that their preference for mostly environmental themes may be attributed to the fact that they are already directly involved and engaged on the job or the field and, as such, can possibly relate to the impact of their decisions on the environment. However, further study is required to ascertain the reasons for the individual groups' preference.

The marginal difference in the criteria weights may imply that the participants perceived the themes as interrelated. This finding reflects that of Dalampira and Nastis's [26], the study of the relationship between the United Nations SDGs, which showed the interrelatedness amongst the three sustainability aspects. For instance, the study revealed that SDG #3 (good health), #11 (Sustainable cities), #12 (responsible consumption and production tended to overlap between environmental and Economic themes, while SDG #8 (Economic growth) overlapped between economic and social themes. On the other hand, SDG #6 (Clean water), #3 (good health), #13 (climate action), and #7 (affordable and clean energy) interrelate with environmental and societal themes.

The fact that this marginal difference was observed mainly between the *environmental* (0.3490) and social themes (0.3443) could potentially imply that the participants perceived both themes as more interrelated and similar. This is evident in their selection of mainly *environmental* themes and sub-themes as most influential in their career choice and social themes as the least preferred themes at both the group and individual group level (see Tables S3 and S4). This finding agrees with that of Wilson et al. [64], who suggest that a significant number of students that participated in their study held narrow views of sustainability being restricted to ecological or environmental impacts. This may imply that the participant's perception of the sustainability themes that most influence their career choice could reflect the themes that they are familiar with.

Additionally, the participants' selection of *economic* themes as the second most influential factor after *environmental* themes could relate to the fact that the inclusion of economic themes associated with engineers' sustainability role broadened their perspectives of its potential impact on the economy. This finding challenges the idea that women's motivation to engage in engineering is mostly driven by altruistic values, the desire to help people and protect the environment, as suggested by Diekman et al. [8], Silbey [9], and Shealy et al. [13]. Furthermore, the marginal difference between the sub-factor's weights, especially *biodiversity* and *material consumption/energy use* (*both environmental* and *economic* themes, respectively) could stem from both the UK and Nigeria's focus on addressing their individual prevailing sustainability challenges. For instance, the current unique challenge for Nigeria is energy generation and distribution [22,23,65], whereas the UK's current focus is energy transitions to net-zero and biodiversity [24,25,66,67]. Hence, the participants from both countries likely assigned similar importance to the sustainability themes that their countries are focused on addressing.

The achievement of the study aims using AHP, as evident in these findings, offer valuable insights that could serve as a strategy tool for engineering stakeholders interested in diversifying the population of individuals they recruit into their institutions.

Study Limitations

Despite the importance and novelty of this study, there are limitations that should be considered. First, the sustainability-themed factors examined in this study were selected based on their association with the role of engineering in addressing sustainability challenges and helping people. This is an important gap to be addressed as it has been argued that since themes related to helping people attract women, more of such themes should be examined to gain greater insights into diverse ways through which engineers help people and hence broaden the pathways of attracting women to engineering [16]. Additionally, findings from the study showed that students who hope to address other sustainability issues such as poverty and disease are less likely to indicate an interest in an engineering career.

Hence, this work only considered the sustainability themes across the three pillars that are directly related to the challenges, which engineers are known to solve, as suggested by Mote et al. [29]. However, it is recommended that further work could consider examining other themes across the 17 SDGs based on their context or focus. Moreover, the AHP approach adopted in this paper provides the possibility for further research into more sustainability themes that align with the goal of the study (see Section 3.2).

Next, the fact that the scope of this study is limited to two countries, the UK and Nigeria, means that its findings are only currently generalizable to both countries and possibly other countries with similar contexts. It is recommended that further work in different contexts could choose to focus on context-specific factors such as the prevailing SD challenges and engineering gender inequality problem in their region country.

6. Conclusions

This study utilized AHP to better understand the relative importance of sustainability-themed factors influencing women's choice of engineering, and to test its suitability in the study's context. The findings reveal that the sustainability-themed motivational factors for women to engage in engineering cut across all three pillars of sustainability. These included the top five environmental and economic related sub-themes such as, *water quality/quantity*, *climate change*, *waste management*, *biodiversity and material consumption/energy use.* While distinctions will exist among women engineers in different countries, these findings provide practical implications for engineering stakeholders such as Higher Education Institutions (HEIs) to utilize. First, although these top five influential factors reveal the priority areas for attracting women to engineering, the marginal difference in the weights of these themes imply that HEIs such as universities and departments of engineering can also focus on any combination of the themes that are relevant to their organization.

However, this selection should include each of the three social, environmental and economic sustainability sub-themes in the mix. For instance, during open days, HEIs could choose to highlight the role of engineering in addressing any combination of the influential themes such as the environmental sub-theme (climate change, ranked second), the economic sub-theme (material consumption/energy use, ranked fifth position) and social sub-theme (healthcare, ranked sixth) as a valuable strategy to recruit and attract women to engineering.

Additionally, stakeholders such as universities that organize school outreach programs could focus on highlighting any of the most influential themes that align with the prevailing sustainability challenge specific to their country. For instance, since energy transitions to net-zero and biodiversity and energy generation and distribution constitute some of the foremost sustainability challenges receiving increased attention in the UK and Nigeria, respectively, these engineering stakeholders in both countries can choose to focus on highlighting the connection between engineering and any of such influential themes.

Hence, these results imply that the utilization of this study's outcome should be based on a strategy to focus on any of the influential factors, especially the top 6 which cuts across the three main themes but subject to the users' missions, corporate responsibilities and prevailing sustainability challenges in the country of application. This approach is likely to appeal to young people who are interested in contributing to addressing such issues but undecided about their future career choice. Although they may be aware of the impact of these sustainability challenges, they may not understand the role and relevance of engineering in addressing these. Therefore, this presents an opportunity for HEIs, especially engineering education institutions, to showcase the link between engineering and these priority areas of influence. The significance of this implication is evident in recent times, where more girls are showing more interest in pursuing careers such as healthcare, with renowned relevance and contributions to addressing current global challenges caused by the COVID19 pandemic [68].

The findings also demonstrated the appropriateness and applicability of the AHP approach in this study, as revealed by the relative importance of the decision factors and consistency of the results. Hence, by achieving the study aims, valuable insights into various specific rather than generic sustainability themes that appeal to women's choice of engineering were provided. These insights could be useful from a recruitment strategy perspective to help engineering stakeholders focus their attention and recruitment efforts on the most salient areas of influence. They could also broaden the options and pathways for making the profession attractive to women (and other underrepresented groups) [10].

However, this study is not without limitations. First, since there is no uniform approach to generating the criteria and sub-criteria factors [69], it is possible that the selected factors were not inclusive of all the sustainability themes that influence women's engineering career choice, as they mainly comprised of sustainability themes that are directly related to the challenges, which engineers are known to solve. Further work could focus on other themes across the 17 SDGs based on their research goal. Next, the study focused on sampled participants from two countries, the UK and Nigeria. Hence, unique and prevailing challenges in other countries may produce different participants' responses, thus outputs. Therefore, the study findings are currently generalizable to both countries and possibly other countries with similar contexts.

Finally, owing to marginal differences between criteria and sub-criteria weights, it is recommended that future studies confirm the robustness of this study's AHP decision outcome through sensitivity analysis to observe any change in the preferences as a result of the criteria weight variation. A follow-up study is also needed to provide insights into how these three pillars of sustainability themes influence women's choice and engagement in engineering. This type of understanding, which will require a qualitative approach, can offer valuable insights into the reasons for the different groups' sustainability-themed preferences.

Despite the highlighted limitations and possible distinctions that may exist in other contexts, the possibility of the inclusion of additional decision variables or factors in the developed AHP structure apart from the ones examined in this study indicates that the approach is scalable and adaptable to suit other research's goal and context. For instance, future work can adopt a similar approach as utilized in this study to examine differences in the influential factors that drive students' participation across various engineering disciplines. Similar studies can also be conducted across other disciplines.

References

1. Ashraf, M.W.; Alanezi, F. Incorporation of Sustainability Concepts into the Engineering Core Program by Adopting a Micro Curriculum Approach: A Case Study in Saudi Arabia. *Sustainability* **2020**, *12*, 2901. [CrossRef]
2. Sánchez-Carracedo, F.; Moreno-Pino, F.M.; Sureda, B.; Antúnez, M.; Gutiérrez, I. A Methodology to Analyze the Presence of Sustainability in Engineering Curricula. Case of Study: Ten Spanish Engineering Degree Curricula. *Sustainability* **2019**, *11*, 4553. [CrossRef]
3. Wilson, D. Exploring the Intersection between Engineering and Sustainability Education. *Sustainability* **2019**, *11*, 3134. [CrossRef]
4. IET. IET Skills for Net Zero and a Green Recovery 2020 Survey. Available online: https://www.theiet.org/media/press-releases/press-releases-2021/2-february-2021-93-of-industry-without-skills-to-meet-2050-climate-targets/ (accessed on 5 October 2021).
5. HESA. HE Student Enrolments by Subject of Study 2019/20. Available online: https://www.hesa.ac.uk/data-and-analysis/students/table-46#notes (accessed on 5 October 2021).
6. Devine, B.F. *Women and the Economy*; House Commons Library: London, UK, 2021; Volume 26.
7. WISE. Updated Workforce Statistics to September 2020. Available online: https://www.wisecampaign.org.uk/statistics/updated-workforce-statistics-to-september-2020/ (accessed on 5 October 2021).
8. Diekman, A.B.; Steinberg, M.; Brown, E.R.; Belanger, A.L.; Clark, E.K. A Goal Congruity Model of Role Entry, Engagement, and Exit: Understanding Communal Goal Processes in STEM Gender Gaps. *Personal. Soc. Psychol. Rev.* **2017**, *21*, 142–175. [CrossRef]
9. Silbey, S. Why Do So Many Women Who Study Engineering Leave the Field? Available online: https://hbr.org/2016/08/why-do-so-many-women-who-study-engineering-leave-the-field (accessed on 5 October 2021).
10. Litchfield, K.; Javernick-Will, A. "I Am an Engineer AND": A Mixed Methods Study of Socially Engaged Engineers. *J. Eng. Educ.* **2015**, *104*, 393–416. [CrossRef]
11. Godwin, A.F. Understanding Female Engineering Enrollment: Explaining Choice with Critical Engineering Agency. Ph.D. Thesis, Clemson University, Clemson, SC, USA, 2014.
12. Bielefeldt, A.R. Does Engineering Attract or Repel Female Students Who Passionately Want to Help People? In Proceedings of the 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana, 15 June 2014; pp. 1–14.
13. Shealy, T.; Valdes-Vasquez, R.; Klotz, L.; Potvin, G.; Godwin, A.; Cribbs, J.; Hazari, Z. Career Outcome Expectations Related to Sustainability among Students Intending to Major in Civil Engineering. *J. Prof. Issues Eng. Educ. Pract.* **2016**, *142*, 1–9. [CrossRef]
14. Stout, J.G.; Grunberg, V.A.; Ito, T.A. Gender Roles and Stereotypes about Science Careers Help Explain Women and Men's Science Pursuits. *Sex Roles* **2016**, *75*, 490–499. [CrossRef]
15. Stopper, M.; Kossik, A.; Gastermann, B. Development of a Sustainability Model for Manufacturing SMEs Based on the Innovative Doughnut Economics Framework. In Proceedings of the International MultiConference of Engineers and Computer Scientists 2016, Hong Kong, China, 16–18 March 2016; Volume II, p. 9.
16. Klotz, L.; Potvin, G.; Godwin, A.; Cribbs, J.; Hazari, Z.; Barclay, N. Sustainability as a Route to Broadening Participation in Engineering. *J. Eng. Educ.* **2014**, *103*, 137–153. [CrossRef]
17. Sandekian, R.; Amadei, B.; Bielefeldt, A.; Summers, R.S. Engineering for Poverty Reduction: Challenges and Opportunities. In Proceedings of the 5th Latin American and Caribbean Conference for Engineering and Technology, Tampico, Mexico, 29 May–1 June 2007; Volume 8.
18. Boucher, K.L.; Fuesting, M.A.; Diekman, A.B.; Murphy, M.C. Can I Work with and Help Others in This Field? How Communal Goals Influence Interest and Participation in STEM Fields. *Front. Psychol.* **2017**, *8*, 901. [CrossRef] [PubMed]
19. Canney, N.E.; Bielefeldt, A.R. Differences in Engineering Students' Views of Social Responsibility between Disciplines. *J. Prof. Issues Eng. Educ. Pract.* **2015**, *141*, 04015004. [CrossRef]
20. Diekman, A.B.; Weisgram, E.S.; Belanger, A.L. New Routes to Recruiting and Retaining Women in STEM: Policy Implications of a Communal Goal Congruity Perspective: Communal Processes in STEM. *Soc. Issues Policy Rev.* **2015**, *9*, 52–88. [CrossRef]

21. Cerinsek, G.; Hribar, T.; Glodez, N.; Dolinsek, S. Which Are My Future Career Priorities and What Influenced My Choice of Studying Science, Technology, Engineering or Mathematics? Some Insights on Educational Choice—Case of Slovenia. *Int. J. Sci. Educ.* **2013**, *35*, 2999–3025. [CrossRef]

22. Monyei, C.G.; Adewumi, A.O.; Obolo, M.O.; Sajou, B. Nigeria's Energy Poverty: Insights and Implications for Smart Policies and Framework towards a Smart Nigeria Electricity Network. *Renew. Sustain. Energy Rev.* **2018**, *81*, 1582–1601. [CrossRef]

23. Oyedepo, S.O.; Babalola, O.P.; Nwanya, S.C.; Kilanko, O.; Leramo, R.O.; Aworinde, A.K.; Adekeye, T.; Oyebanji, J.A.; Abidakun, A.O.; Agberegha, O.L. Towards a Sustainable Electricity Supply in Nigeria: The Role of Decentralized Renewable Energy System. *Eur. J. Sustain. Dev. Res.* **2018**, *2*. [CrossRef]

24. Freeman, R.; Ekins, P. Decarbonising Energy and the Energy Transition. Available online: https://www.ucl.ac.uk/bartlett/news/2021/apr/decarbonising-energy-and-energy-transition (accessed on 8 October 2021).

25. GOV.UK. UK Convenes Key Ministers to Unlock Investment for Energy Transition Ahead of COP26. Available online: https://www.gov.uk/government/news/uk-convenes-key-ministers-to-unlock-investment-for-energy-transition-ahead-of-cop26 (accessed on 8 October 2021).

26. Dalampira, E.-S.; Nastis, S.A. Mapping Sustainable Development Goals: A Network Analysis Framework. *Sustain. Dev.* **2020**, *28*, 46–55. [CrossRef]

27. Brubaker, E.R.; Schar, M.; Sheppard, S. Impact-Driven Engineering Students: Contributing Behavioral Correlates. In Proceedings of the American Society for Engineering Education Annual Conference, Columbus, OH, USA, 24 June 2017.

28. DESA Indicators of Sustainable Development: Framework and Methodologies. Available online: https://www.un.org/esa/sustdev/csd/csd9_indi_bp3.pdf (accessed on 6 October 2021).

29. Mote, C.D.; Dowling, D.A.; Zhou, J. The Power of an Idea: The International Impacts of the Grand Challenges for Engineering. *Engineering* **2016**, *2*, 4–7. [CrossRef]

30. Taylor, R.N. Psychological Determinants of Bounded Rationality: Implications for Decision-Making Strategies. *Decis. Sci.* **1975**, *6*, 409–429. [CrossRef]

31. Corbin, J.M.; Strauss, A.L. Analyzing Data for Concepts. In *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*; Sage Publications, Inc: Thousand Oaks, CA, USA, 2012; pp. 159–194. ISBN 978-1-4129-0643-2.

32. Osanloo, A.; Grant, C. Understanding, Selecting, and Integrating a Theoretical Framework in Dissertation Research: Creating the Blueprint for Your "House". *Adm. Issues J. Connect. Educ. Pract. Res.* **2016**, *4*, 7. [CrossRef]

33. Luse, A.; Mennecke, B.; Townsend, A. Selecting a Research Topic: A Framework for Doctoral Students. *Int. J. Dr. Stud.* **2012**, *7*, 143–152. [CrossRef]

34. RAE. *Engineering a Better World-Achieving the United Nations Sustainable Development Goals*; Royal Academy of Engineering: London, UK, 2016; pp. 1–44.

35. Human Development Report. Available online: http://hdr.undp.org/sites/default/files/reports/258/hdr_1997_en_complete_nostats.pdf (accessed on 6 October 2021).

36. Kahraman, C.; Onar, S.C.; Oztaysi, B. Fuzzy Multicriteria Decision-Making: A Literature Review. *Int. J. Comput. Intell. Syst.* **2015**, *8*, 637–666. [CrossRef]

37. Hwang, C.-L.; Yoon, K. Methods for Multiple Attribute Decision Making. In *Multiple Attribute Decision Making: Methods and Applications A State-of-the-Art Survey*; Hwang, C.-L., Yoon, K., Eds.; Lecture Notes in Economics and Mathematical Systems; Springer: Berlin/Heidelberg, Germany, 1981; pp. 58–191. ISBN 978-3-642-48318-9.

38. Saaty, T.L. Decision Making with the Analytic Hierarchy Process. *Int. J. Serv. Sci.* **2008**, *1*, 83–98. [CrossRef]

39. Ishizaka, A.; Lusti, M. How to Derive Priorities in AHP: A Comparative Study. *Cent. Eur. J. Oper. Res.* **2006**, *14*, 387–400. [CrossRef]

40. Lee, S.; Kim, W.; Kim, Y.M.; Oh, K.J. Using AHP to Determine Intangible Priority Factors for Technology Transfer Adoption. *Expert Syst. Appl.* **2012**, *39*, 6388–6395. [CrossRef]

41. Dorado, R.; Gómez-Moreno, A.; Torres-Jiménez, E.; López-Alba, E. An AHP Application to Select Software for Engineering Education. *Comput. Appl. Eng. Educ.* **2014**, *22*, 200–208. [CrossRef]

42. Frangos, C.C.; Fragkos, K.C.; Sotiropoulos, I.; Manolopoulos, I.; Gkika, E. Student Preferences of Teachers and Course Importance Using the Analytic Hierarchy Process Model. In Proceedings of the World Congress on Engineering 2014, London, UK, 2 July 2014; Volume II, p. 5.

43. Chard, C.R.; Potwarka, L.R. Exploring the Relative Importance of Factors That Influence Student-Athletes' School-Choice Decisions: A Case Study of One Canadian University. *J. Intercoll. Sport* **2017**, *10*, 22–43. [CrossRef]

44. UNESCO. Engineering: Issues, Challenges and Opportunities for Development. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000189753 (accessed on 6 October 2021).

45. Mike, B. Convenience Sampling. In *Encyclopedia of Survey Research Methods*; SAGE Publications: Thousand Oaks, CA, USA, 2011; p. 149. ISBN 978-1-4522-6147-8.

46. Jogulu, U.D.; Pansiri, J. Mixed Methods: A Research Design for Management Doctoral Dissertations. *Manag. Res. Rev.* **2011**, *34*, 687–701. [CrossRef]

47. Phuong, N.H. Engineering Education for Sustainable Development in Vietnamese Universities: Building Culturally Appropriate Strategies for Transforming the Engineering Curriculum towards Sustainable Development. Ph.D. Thesis, University of Gloucestershire, Cheltenham, UK, 2013.

48.　Qureshi, M.E.; Harrison, S.R. Application of the Analytic Hierarchy Process to Riparian Revegetation Policy Options. *Small-Scale For. Econ. Manag. Policy* **2003**, *2*, 441. [CrossRef]

49.　Sivapalan, S. Engineering Education for Sustainable Development (EESD) for Undergraduate Engineering Programmes in Malaysia: A Stakeholder Defined Framework. Ph.D. Thesis, University of Nottingham, Nottingham, UK, 2015.

50.　Krejcie, R.V.; Morgan, D.W. Determining Sample Size for Research Activities. *Educ. Psychol. Meas.* **1970**, *30*, 607–610. [CrossRef]

51.　Imasogie, B.I.; Oyatogun, G.M.; Taiwo, K.A. Enhancing Gender Balance in Engineering Education and Practice. In Proceedings of the 2018 World Engineering Education Forum—Global Engineering Deans Council (WEEF-GEDC), Albuquerque, NM, USA, 12–16 November 2018; pp. 1–8.

52.　NSE. Membership. Available online: https://www.nse.org.ng/ (accessed on 12 July 2021).

53.　Okorafor, A.O.; Kakiri, W.; Okorafor, E.C. Women Participation in Science, Technology, Engineering and Mathematics in Nigeria: Challenges and Way Forward. *NAM Inst. Empower. Women NIEW J.* **2015**, *7*, 99–112.

54.　HESA. Percentages of Women in STEM Statistics. Available online: https://www.stemwomen.co.uk/blog/2021/01/women-in-stem-percentages-of-women-in-stem-statistics (accessed on 19 October 2021).

55.　Cirocki, A. Conducting Research in the EFL Classroom. *Mod. Engl. Teach.* **2013**, *22*, 76–81.

56.　Dörnyei, Z. *Research Methods in Applied Linguistics*; Oxford University Press: Oxford, UK, 2007; ISBN 978-0-19-442258-1.

57.　Saaty, R.W. The Analytic Hierarchy Process—What It Is and How It Is Used. *Math. Model.* **1987**, *9*, 161–176. [CrossRef]

58.　Mackey, A.; Gass, S.M. *Second Language: Methodology and Design*; Lawrence Erlbaum Associates: London, UK, 2005.

59.　Al-Harbi, K.M.A.-S. Application of the AHP in Project Management. *Int. J. Proj. Manag.* **2001**, *19*, 19–27. [CrossRef]

60.　Ozturk, D.; Batuk, F. Implementation of Gis-Based Multicriteria Decision Analysis with VB in ArcGIS. *Int. J. Inf. Technol. Decis. Mak. IJITDM* **2011**, *10*, 1023–1042. [CrossRef]

61.　Perera, N.A.; Sutrisna, M.; Yiu, T.W. Decision-Making Model for Selecting the Optimum Method of Delay Analysis in Construction Projects. *J. Manag. Eng.* **2016**, *32*, 04016009. [CrossRef]

62.　Perera, N.; Sutrisna, M. The Use of Analytic Hierarchy Process (AHP) in the Analysis of Delay Claims in Construction Projects in the UAE. *Built Hum. Environ. Rev.* **2010**, *3*, 29–47.

63.　Albayrak, E.; Erensal, Y.C. Using Analytic Hierarchy Process (AHP) to Improve Human Performance: An Application of Multiple Criteria Decision Making Problem. *J. Intell. Manuf.* **2004**, *15*, 491–503. [CrossRef]

64.　Wilson, D.; Roberts, R.; Allendoerfer, C.; Kim, M.J. A Sustainability Toolbox for Engineers: Exploring How Students Are Likely to Engage in Sustainability Education. In Proceedings of the 2015 ASEE Annual Conference & Exposition, Seattle, WA, USA, 14–17 June 2015; pp. 26.118.1–26.118.21.

65.　Festus, M.O.; Ogoegbunam, O.B. Energy Crisis and Its Effects on National Development: The Need for Environmental Education in Nigeria. *Br. J. Educ.* **2015**, *3*, 21–37.

66.　Holland, R.A.; Scott, K.; Agnolucci, P.; Rapti, C.; Eigenbrod, F.; Taylor, G. The Influence of the Global Electric Power System on Terrestrial Biodiversity. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 26078–26084. [CrossRef]

67.　Kilburn, C.; Anton, M. Energy Transition—Net Zero through Integration in the UK. Available online: https://www.wfw.com/articles/energy-transition-net-zero-through-integration-in-the-uk/ (accessed on 8 October 2021).

68.　Engineering UK. *Our Careers, Our Future STEM Careers Provision and Young People*; Engineering UK: London, UK, 2020.

69.　Lee, S.; Walsh, P. SWOT and AHP Hybrid Model for Sport Marketing Outsourcing Using a Case of Intercollegiate Sport. *Sport Manag. Rev.* **2011**, *14*, 361–369. [CrossRef]