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Development of Mathematical Empirical Equation for Eco-score in Green Audit

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***Abstract*: The pursuit of sustainability in contemporary industries has spurred the adoption of green auditing practices to assess environmental performance. Central to this endeavour is the development of robust metrics capable of quantifying ecological impacts across various operational domains. This study proposes the formulation of a mathematical empirical equation termed the 'Eco-Score' to evaluate the environmental footprint of processes within the context of green audits. Drawing upon established principles of environmental science and mathematical modelling, the Eco-Score equation integrates key parameters such as energy consumption, resource utilization, emissions, and waste generation. Through a systematic analysis of these variables, the equation aims to provide a comprehensive assessment of the ecological efficiency of industrial operations. The development of the Eco-Score equation involves rigorous empirical data collection and statistical analysis to calibrate coefficients and validate the model's accuracy. Furthermore, the equation's versatility enables its adaptation to diverse industrial sectors, facilitating standardized environmental performance evaluation across industries. By offering a quantitative framework for green audits, the Eco-Score equation contributes to enhancing environmental management practices and fostering sustainability initiatives within organizations. Its implementation holds promise for promoting responsible resource utilization, minimizing environmental impacts, and driving continuous improvement in ecological performance.**

***Keywords*: Eco-Score, Green Audit, Sustainability, Environmental Performance, Mathematical Modelling.**

I. INTRODUCTION

Green Audit is a method of systematically identifying, quantifying, recording, reporting, and analysing environmental diversity components in various enterprises. Its goal is to examine environmental practices both inside and outside of the concerned sites that have an impact on the environment. In today's world, where environmental concerns are at the forefront of global discourse, the need for effective tools to measure and evaluate environmental impacts is paramount. Green auditing, a systematic examination of an organization's environmental performance, has emerged as a critical practice for businesses and institutions striving to minimize their ecological footprint. Central to green auditing is the concept of an Eco Score, a quantitative measure that assesses the environmental performance of a system or process. The development of a mathematical empirical equation for calculating the Eco Score is crucial for providing organizations with a comprehensive and standardized method for evaluating their environmental impact. Such an equation takes into account various factors including resource consumption, waste generation, emissions, and other pertinent environmental indicators. This paper aims to outline the process of developing a mathematical empirical equation for the Eco Score in green auditing. It will discuss the theoretical foundations, methodology, and considerations involved in formulating such an equation. Additionally, it will explore the practical implications and potential applications of the Eco Score equation in assessing and improving environmental sustainability across different sectors. By establishing a robust mathematical framework for calculating the Eco Score, organizations will be better equipped to quantify their environmental performance, identify areas for improvement, and implement targeted strategies for sustainability. Ultimately, the development of an empirical equation for the Eco Score represents a significant advancement in the field of green auditing, facilitating more informed decision-making and contributing to the collective effort towards a greener and more sustainable future.

Scope of the Work

The goal of the project "Development of Mathematical Empirical Equation for Eco-Score in Green Audit" is to develop a formula for determining an Eco-Score, an estimate that evaluates how processes or goods affect the environment. This entails specifying the environmental parameters to be taken into account, deciding on the data gathering and analysis methods, and detailing the practical applications of the equation in places like consumer information labels and sustainability assessments. In order to guarantee the equation's applicability and dependability in green auditing procedures, the scope additionally discusses the limits and challenges associated with creating it.

II. LITERATURE REVIEW

A Green Audit of the Institution: A Step Towards Environmental Sustainability by Cherkupally Rama Rajul, Munagala Alivelu, Gurram Lingareddy, V. Karunakar and Samaleti Priyanka, Biological Forum – An International Journal, 20 June 2023.

Green auditing of the institution is crucial in order to assess the environmental performance of educational institutions and to consider potential options for turning the educational campus into an eco-campus. The MKR Government Degree College, Devarakonda, has undergone a green audit to evaluate its environmental impact. The main focus of this green audit is on the consumption of energy in terms of electricity and fossil fuels, soil and water quality, vegetation, waste management procedures, and the campus carbon footprint. To learn more about the resources on campus and their consumption, a questionnaire survey was first carried out. Water and soil samples were taken from various sites on the college campus and analyzed for their characteristics. The gathered information was sorted, tallied, and examined to give a report on the environment with recommendations. It is observed that drinking water sources need to be routinely treated and monitored to eliminate possible threats to both human and animal health. This study might be expanded in future research by including various institutes. Only information that is freely accessible is used in this investigation. To learn more about green audits, future studies may include other methodologies like those used by environmentalists and certified green auditors. Identify the environmental media that will be under audit, such as waste, water, and air. Make plans to raise environmental consciousness. Prepare strategies and procedures for handling crises.

Green Campus Audit Procedures and Implementation to Educational Institutions and Industries by S. Rajalakshmi, B. Mythili Gnanamangai, D. Vinoth Kumar, V. Sri Santhya, M. Priya, R. Mary Josephine, Ashutosh Kumar Srivastava, R. Sudhakaran and M. A. Deepa, Nature Environment and Pollution Technology An International Quarterly Scientific Journal, volume 21, Issue 04, April 2022.

Nature provides a free lunch, but only if we control our appetites. As we are in the twentyfirst century, modernization and industrialization are the two important outputs that have made human life more luxurious and comfortable. Today, people are getting more familiar with global issues like global warming, the greenhouse effect, ozone depletion, climate change, etc. Now, it is considered a final call by Mother Earth to walk on the path of sustainable development. The time has come to wake up, unite and combat together for a sustainable environment. The green audit is an important key not only for sustainable development and also for a clean environment, at industries level, it detects some environmental problems. The pollution problems are uprooted by equipping the industries with several maintenance measures. The audit is essential to provide indication management about the performance of the equipment and system of an environmental organization or institute. As a result, the best methods that are practicable can be applied to preserve water, air, soil plants, and animal life from adverse effects. Higher educational Institutes want to implement the green audit, also referred to as a green audit. One should understand the process of green auditing. It is a cyclic and continuous process. Still, there is a scope for further action, when academic institutes or organizations take part in restoring the environment. The economic development and rapid urbanization at the global, regional and local have led to ecological and environmental crises. In this background, for all the institutes it becomes essential to adopt the system of campus to be green for further development which will lead to sustainable development. NAAC, the National Assessment and Accreditation Council, New Delhi, has made it essential that all higher educational institutions should submit an annual Green Audit Report.

Green Audit & Green Campus: Need of the Hour by Bhojak N, Bhandari H.S, Uma Rathore Bhandari H.S, Uma Rathore., Jatolia S.N, Raja Ram and Verma Jatolia S.N., Raja Ram and Verma S.K, International Journal of Current Advanced Research, Volume 10, Issue 07(A), July 2021.

Green auditing is one of the most important area not only important for industrial organization but for academic institutions too. The aspects, principle and procedure for Green audit is essential to be understood and applied at institutional level, it will be helpful for students learning perspective as well as from environmental monitoring point of view. The present paper describes a general procedure and methodology which can be applied by t campus in order to turn the campus Green. NAAC accreditation is mandatory for all the higher learning institutes, particularly state universities. Green Audit is assigned to the Criteria 7 of NAAC, National Assessment and Accreditation Council. The general procedure described in the paper for Green auditing can be applied to conduct at any institution.

Indian Green Building Council (IGBC) Green Campus Rating System and Certification Process

Here's a summary of the information into four key points:

1. **Green Building Certifications in India –** LEED (Leadership in Energy and Environmental Design) and GRIHA (Green Rating for Integrated Habitat Assessment)

are the two main green building certifications in India. LEED is licensed in India by the Indian Green Building Council (IGBC), which was established in 2001 by the Confederation of Indian Industry (CII). The first LEED Platinum certified building in India was the CII-Sohrabji Godrej Green Business Centre in Hyderabad.

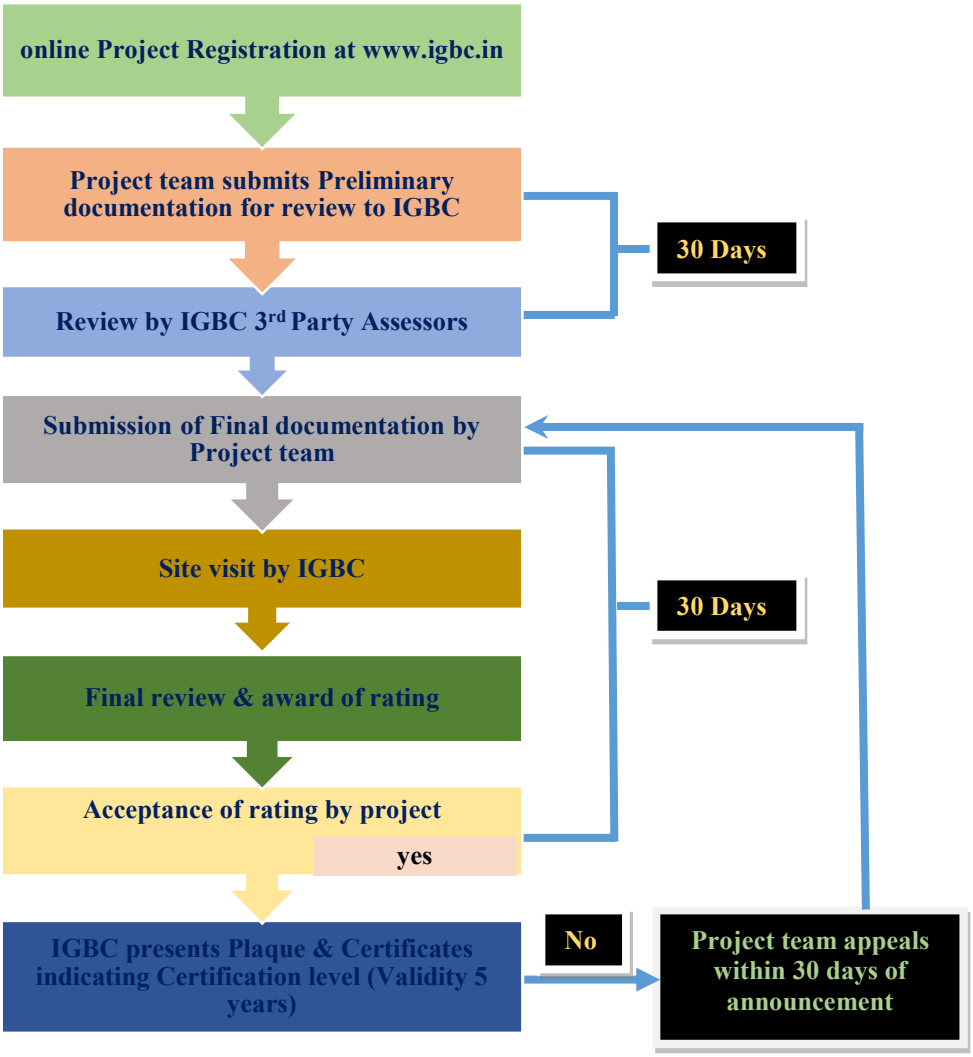
2. **Evolution and Features of IGBC –** IGBC developed the LEED India rating system in collaboration with the USGBC to adapt international standards for the Indian market. Since 2014, IGBC has been developing its own rating systems and currently offers over 20. The IGBC Green Campus rating system, which is voluntary and consensus-based, promotes environmentally friendly campuses focusing on water use, green spaces, waste management, and overall sustainability.
3. **Scope and Validity of IGBC Green Campus Rating System –** The IGBC Green Campus rating system applies to both new and existing campuses across various types of facilities, including educational institutions, hotels, and industrial parks. The certification is valid for five years, after which campuses must reapply using the latest version of the rating system to maintain or improve their rating.

TABLE 1
IGBC Green Campus Certification Levels

Certification Level	New Campus	Existing Campus	Recognition
Certified	40-49	36-44	Best Practices
Silver	50-59	45-53	Outstanding Performance
Gold	60-74	54-66	National Excellence
Platinum	75-100	67-90	Global Leadership

Green campuses that meet one of the rating levels will be awarded a mountable plaque and a certified letter of certification by IGBC.

IGBC Certification Process



III. Materials and Methods

This audit was conducted using a three-step methodology that included:

Data Collection – In the preliminary data collection phase, exhaustive data collection was performed using different tools such as observation, survey communication with responsible persons, and measurement

The following steps were taken for data collection:

1. Data about the general information was collected by observation and interview.
2. The power consumption of appliances was recorded by taking an average value in some cases

Data Study – A detailed analysis of the data obtained includes the computation of energy use and an examination of the campus's most recent electricity bill. Water usage and waste management data were also examined using the appropriate approach.

Recommendation – Based on the results of data analysis and observations, detailed recommendations are given.

Fig 1 the Seven Steps of Green Campus Program

Estimation of Eco-Score for Green Audit Parameters

As per the IGBC Green Campus Rating System, JNTUK is under Existing Campus type. So, we can estimate the eco score out of 90. The Green Campus calculator is a simple tool to estimate the total score of the institution in which it implements environmental, energy-efficient, and sustainable practices. The experts committee evaluates the 10 parameters given in the green calculator chart. However, I would like to create my own mathematical formula in my thesis to determine Green Campus's Eco Score, which yields results comparable to the IGBC Certification Process. Analyzes the energy audit, water audit, waste audit, green initiatives, carbon footprint, biodiversity audit, health audit, environmental quality and noise, oxygen footprint, and built environment—the 10 parameters associated with green audit on the green campus. A maximum of 10 points are assigned to each parameter. The Eco score ranges from 1 (very poor) to 9 (exemplary).

1. Energy Audit: An energy audit involves inspecting and analyzing energy flows for conservation in buildings. At JNTUK, with 71 classrooms/seminar halls and 601 computers, energy consumption is significant. Monthly electricity costs in 2024 ranged from Rs. 55000/- to Rs. 1450935/- totalling Rs. 6467223/- over six months. The campus employs solar energy and LED lighting, promoting energy efficiency, with potential annual savings of Rs. 500000/- from solar installations.

2. Water Audit: Water audits help institutions like JNTUK improve energy, environmental, and economic performance by reducing wastage and costs. JNTUK employs water conservation measures such as rainwater harvesting, bore well recharge, tanks, bunds, and wastewater recycling, alongside maintaining water bodies. Daily water usage for domestic purposes is 5,52,285 litre, supported by two RO water treatment facilities (2000 LPH and 3000 LPH).

3. Waste Audit: JNTUK manages solid, liquid, biomedical, e-waste, and hazardous waste through comprehensive systems, ensuring minimal environmental impact and promoting recycling. Daily solid waste generation is 2740.97 kg, liquid waste is managed via soakage pits, and hazardous chemicals are neutralized. The campus embraces a paperless office, recycles e-waste, and utilizes waste materials creatively, such as in the "Open Classroom" built from discarded items.

4. Green Initiatives: JNTUK enthusiastically celebrates national events to instill patriotism, promote harmony, and raise awareness on various social issues. The institution's motto includes sensitizing students to community conditions, the need for plantation, holistic life perspectives, and promoting student abilities through events like Plantation Day, Swachh Bharat, and Blood Donation camps. Events like Plantation drives, Swachh JNTUK, and blood donation camps are regularly organized, involving active participation from students and staff.

5. Carbon Footprint: Carbon Footprint measures the total greenhouse gas emissions, primarily carbon dioxide, caused directly or indirectly by an individual, organization, or product. At JNTUK, 950 vehicles contribute significantly to carbon emissions, with bikes emitting 1812.5 kg and cars 254.6 kg of CO_2 daily. The campus mitigates this with a carbon absorption capacity of 6317.2 kg from trees and 4791.6 kg from its area.

6. Biodiversity Audit: In 2024, JNTUK's biodiversity audit identified 1158 trees of 47 varieties, 26 bird species, 22 butterfly varieties, and 4 snake types. The campus features a natural forest with species like Lonchocarpus and Ficus Religiosa, and undertakes plantation activities during rainy seasons and national festivals, introducing medicinal and economically important plants. Biodiversity is crucial for ecosystem health, providing resilience against environmental changes and maintaining ecological balance.

7. Health Audit: The Institute prioritizes health consciousness, providing a safe, clean environment and recognizing a healthy workplace as a fundamental human right. JNTUK's health audit reveals facilities like dispensaries, doctors, and daily yoga classes, alongside a robust sports infrastructure including a modern indoor stadium, gymnasium, yoga centre, various courts, and tracks. Regular evaluations of sickness leave, first aid availability, atmospheric quality, and student achievements in sports are conducted to ensure a healthy campus.

8. Environmental Quality and Noise: JNTUK assessed environmental quality and noise pollution, noting the heavy carbon footprint of transportation modes except bicycles. Day and night noise levels were measured across 16 locations on campus, revealing average Traffic Noise Index (TNI) values of 72.79 dB during the day and 41.18 dB at night. The overall Noise Quality Index for JNTUK is 56.985 dB, indicating a moderate noise level according to the TNI Scale.

9. Oxygen Footprint: The oxygen footprint of JNTUK, reflecting the impact of daily activities, includes the annual oxygen consumption by 4091 people, amounting to 1567.70 ton per year. Trees on the campus release 3676.45 ton of oxygen annually and sequester 1414.47 tons of carbon. Thus, the campus maintains a positive oxygen footprint, contributing significantly to atmospheric oxygen production.

10. Built Environment: JNTUK spans 110 acres (445,154 m^2), with 12,600 sq. m for buildings, 351,900 m^2 for greenery, 77,400 m^2 for parking, and 3,254 m^2 for roads. The campus features 56 buildings, 71 classrooms and seminar halls, 3 parks, 1,158 trees, and a 30-acre stadium for sports and games.

Fig 2 A few photos taken while working on a project at JNTUK

Eco-Score Assessment for JNTUK

The three audit checklists (green, eco, and energy) were used to calculate the 10 criteria of the eco score. From 1 (very low) to 9 (exemplary), the eco-score is a numerical rating. The IGBC Green Campus Checklist lists JNTUK as one of the Existing Campuses. Check the environmental score, then, out of 90. To assess the eco score, use the computations and the information gathered about ten green audit parameters, including their quantities, standards, and indexes in JNTUK. The JNTUK eco-score rating for 2024 is displayed in the table below.

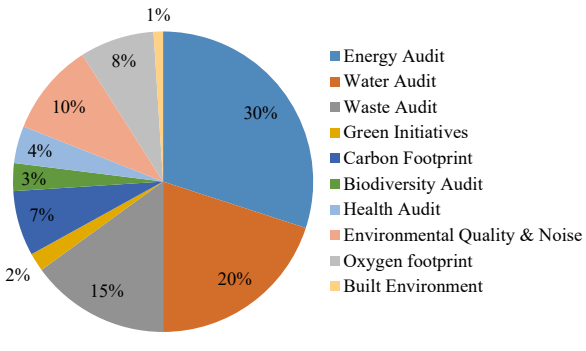
TABLE 1
Green Campus Eco-Score for JNTUK

GREEN CAMPUS Eco-Score for JNTUK			
Eco-Score on a scale of 1 for very poor to 9 for exemplary			
S. NO	**Green Audit Parameter**	**Eco-Score in 2023**	**Eco-Score in 2024**
1	Energy Audit	5	6
2	Water Audit	3	4
3	Waste Audit	4	5
4	Green Initiatives	3	4
5	Carbon Footprint	6	6
6	Biodiversity Audit	5	6
7	Health Audit	4	5
8	Environmental Quality & Noise	2	3
9	Oxygen footprint	4	5
10	Built Environment	5	6
Total Eco-Score of JNTUK		**41**	**50**
Ideal Eco-Score for the Existing Campus = 10x9 = 90			

I would like to formulate a mathematical empirical equation to determine the total eco score of JNTUK. This algorithm yields comparable outcomes and is dependent on the parameters that are given priority.

I have to assign the built environment the lowest priority and the energy audit the highest priority, based on their respective significance for the sustainable development of the environment. Ten of the categories below will receive the remaining 100% of the total priority.

Percentage Priority for Green Audit Parameters



Here, computes the sum of P (∑ P) and the number of parameters (n) that were used.

∑P = 0.3+0.2+0.15+0.02+0.07+0.03+0.04+0.1+0.08+0.01 = 1

No. of parameters taken (n) = 10

$$\text{Mathematical Empirical Equation} = \frac{\sum(P*EC)}{\sum P} *n$$

Where, P = Given Priority in percentage (%)
EC = Assessment of Eco Score
n = no. of parameters taken

By using this formula, we can calculate total eco score of JNTUK in 2023

$$\text{Mathematical Empirical Equation} = \frac{\sum(P*EC)}{\sum P} * n$$

$$= \frac{(A*4)+(B*3)+(C*5)+(D*3)+(E*6)+F*5)+(G*4)+(H*2)+(I*4)+(J*5)}{\sum P} *10$$

Here A = Priority of energy audit = 30% = 0.3
B = Priority of water audit = 20% = 0.2
C = Priority of waste audit = 15% = 0.15
D = Priority of green initiatives = 2% = 0.02
E = Priority of carbon footprint = 7% = 0.07
F = Priority of biodiversity audit = 3% = 0.03
G = Priority of health audit = 4% = 0.04
H = Priority of environmental quality & noise = 10% = 0.1
I = Priority of oxygen footprint = 8% = 0.08
J = Priority of built environment = 1% = 0.01

Now put all these values in above equation

$$\frac{(0.3*5)+(0.2*3)+(0.15*4)+(0.02*3)+(0.07*6)+0.03*5)+(0.04*4)+(0.1*2)+(0.08*4)+(0.01*5)}{1} *10$$

= (1.5+0.6+0.75+0.06+0.42+0.15+0.16+0.2+0.32+0.05) *10 = 40.6

As you can see, applying the formula value yields nearly identical results in this case. However, 0.4 was required to get the precise number. We can identify the Green Performance Index and use it to address this kind of problem.

Calculating Green Performance Index (GPI) at different ranges

For green campuses, eco value has a minimum score of 36 and a maximum value of 90. By utilizing the previous mathematical empirical equation to calculate the eco score, it obtains a numerical value that is comparable to the IGBC. It can compute the Green Performance Index (GPI) for the eco score ranges of 30–40, 40–50, 50–60, 60–70, 70–80, and 80–90 using this method. The average of the three eco-score values can be used to get the index value for each of these ranges. For example, three average eco score values (30, 35, and 40) must be found in order to compute the GPI in the range of 30 to 40 eco scores. The index for the remaining ranges may also be computed.

An empirical mathematical equation, for instance, has been used to determine the ECO SCORE range of 30 to 40. Any three values can now be measured within the selected ranges. Assume that the ultimate GPI value is equal to the sum of these numbers, which is 30, 35, and 40. For the remaining ranges, the same procedure applies, correspondingly. The procedure that was previously used to evaluate the eco score for JNTUK in 2023 can be replicated here. Determine the accuracy of the GPI number by utilizing the means and standard deviations of these ranges.

$$\text{Standard Deviation} = \sqrt{\frac{\sum(x-\bar{x})2}{n-1}}$$

Mean ($\bar{x}$) = Eco score average = Total eco score / No. of parameters (n)

Here x = Parameters eco score

TABLE 2
Calculating GPI for 30-40 Eco Score Range

S. NO	Green Audit Parameters	Given Priority (P) in percentage (%)	Assuming points for Eco-Score (EC) using scale (1 – 9) in 30–40 range			P*EC(A)	P*EC(B)	P*EC(C)
			(A)	(B)	(C)			
1	Energy Audit	30	3	5	5	0.9	1.5	1.5
2	Water Audit	20	3	3	3	0.6	0.6	0.6
3	Waste Audit	15	2	2	4	0.3	0.3	0.6
4	Green Initiatives	2	5	6	6	0.10	0.12	0.12
5	Carbon Footprint	7	3	1	4	0.21	0.07	0.28
6	Biodiversity Audit	3	1	4	4	0.03	0.12	0.12
7	Health Audit	4	1	3	4	0.04	0.12	0.16
8	Environmental Quality & Noise	10	6	5	2	0.6	0.5	0.2
9	Oxygen footprint	8	2	2	3	0.16	0.16	0.24
10	Built Environment	1	4	4	5	0.04	0.04	0.05
	Total	100%	30	35	40	2.98	3.53	3.87
Using Mathematical Empirical Equation = $\frac{\sum(P*EC)}{\sum P}$ *10						29.8	35.3	38.7
Green Performance Index in 30-40 range Eco Score						Average = 34.6		

Finding standard deviation for 30-40 range value

For value 30

Mean ($\bar{x}$) = 30/10 = 3

Standard Deviation= $\sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(3-3)2+(3-3)2+(2-3)2+(5-3)2+(3-3)2+(1-3)2+(1-3)2+(6-3)2+(2-3)2+(4-3)2}{10-1}}$

$= \sqrt{\frac{0+0+1+4+0+4+4+9+1+1}{9}}$

$= \sqrt{\frac{24}{9}} = \pm 1.632$

For value 35

Mean ($\bar{x}$) = 35/10 = 3.5

Standard Deviation= $\sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(5-3.5)2+(3-3.5)2+(2-3.5)2+(6-3.5)2+(1-3.5)2+(4-3.5)2+(3-3.5)2+(5-3.5)2+(2-3.5)2+(4-3.5)2}{10-}}$

$= \sqrt{\frac{(1.5)2+(-0.5)2+(-1.5)2+(-2.5)2+(-2.5)2+(0.5)2+(-0.5)2+(1.5)2+(-1.5)2+(0.5)2}{9}}$

$= \sqrt{\frac{2.25+0.25+\ .25+6.25+6.25+0.25+0.25+2.25+2.25+0.25}{9}}$

$= \sqrt{\frac{22.5}{9}} = \pm 1.581$

For value 40

Mean ($\bar{x}$) = 40/10 = 4

Standard Deviation = $\sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(5-4)2+(3-4)2+(4-4)2+(6-4)2+(4-4)2+(4-4)2+(4-4)2+(2-4)2+(3-4)2+(5-4)2}{10-1}}$

$= \sqrt{\frac{1+1+0+4+0+0+0+4+1+1}{9}}$

$= \sqrt{\frac{12}{9}} = \pm 1.154$

TABLE 3
Calculating GPI for 40-50 Eco Score Range

S. NO	Green Audit Parameters	Given Priority (P) in percentage (%)	Assuming points for Eco Score (EC) using scale (1 – 9) in 40–50 range			P*EC(A)	P*EC(B)	P*EC(C)
			(A)	(B)	(C)			
1	Energy Audit	30	5	3	6	1.5	0.9	1.8
2	Water Audit	20	3	5	5	0.6	1.0	1.0
3	Waste Audit	15	4	6	2	0.6	0.9	0.3
4	Green Initiatives	2	6	4	4	0.12	0.08	0.08
5	Carbon Footprint	7	4	2	7	0.28	0.14	0.49
6	Biodiversity Audit	3	4	7	3	0.12	0.21	0.09
7	Health Audit	4	4	5	7	0.16	0.20	0.28
8	Environmental Quality & Noise	10	2	6	5	0.2	0.6	0.5
9	Oxygen footprint	8	3	4	5	0.24	0.32	0.40
10	Built Environment	1	5	3	6	0.05	0.03	0.06
	Total	100%	40	45	50	3.87	4.38	5.0
Using Mathematical Empirical Equation = $\frac{\sum(P*EC)}{\sum P} * 10$						38.7	43.8	50
Green Performance Index in 40-50 range Eco Score						Average = 44.17		

Finding standard deviation for 40-50 range value

For value 40

As for 40, ascertain the mean and standard deviation within the range of 30 to 40 already. Thus, using the same number here, ±1.154.

For value 45

Mean ($\bar{x}$) = 45/10 = 4.5

Standard Deviation = $\sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(3-4.5)2+(5-4.5)2+(6-4.5)2+(4-4.5)2+(2-4.5)2+(7-4.5)2+(5-4.5)2+(6-4.5)2+(4-4.5)2+(3-4.5)2}{10-1}}$

$= \sqrt{\frac{(-1.5)2+(0.5)2+(-1.5)2+(-0.5)2+(-1.5)2+(-2.5)2+(0.5)2+(1.5)2+(-0.5)2+(-1.5)2}{9}}$

$= \sqrt{\frac{2.25+0.25+2.25+0.25+2.25+6.25+0.25+2.25+0.25+2.25}{9}}$

$= \sqrt{\frac{18.25}{9}} = \pm 1.424$

For value 50

Mean ($\bar{x}$) = 50/10 = 5

Standard Deviation $= \sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(6-5)2+(5-5)2+(2-5)2+(4-5)2+(7-5)2+(3-5)2+(7-5)2+(5-5)2+(5-5)2+(6-5)2}{10-1}}$

$= \sqrt{\frac{1+0+9+1+4+4+4+0+0+1}{9}}$

$= \sqrt{\frac{24}{9}} = \pm 1.633$

TABLE 4
Calculating GPI for 50-60 Eco Score Range

S.NO	Green Audit Parameters	Given Priority (P) in percentage (%)	Assuming points for Eco-Score (EC) using scale (1 – 9) in 50–60 range			P*EC(A)	P*EC(B)	P*EC(C)
			(A)	(B)	(C)			
1	Energy Audit	30	6	5	5	1.8	1.5	1.5
2	Water Audit	20	5	6	8	1.0	1.2	1.6
3	Waste Audit	15	2	7	6	0.3	1.05	0.9
4	Green Initiatives	2	4	4	6	0.08	0.08	0.12
5	Carbon Footprint	7	7	7	5	0.49	0.49	0.35
6	Biodiversity Audit	3	3	5	8	0.09	0.15	0.24
7	Health Audit	4	7	6	7	0.28	0.24	0.29
8	Environmental Quality & Noise	10	5	4	4	0.5	0.4	0.4
9	Oxygen footprint	8	5	6	6	0.40	0.48	0.48
10	Built Environment	1	6	5	5	0.06	0.05	0.05
	Total	100%	50	55	60	5.0	5.64	5.92
Using Mathematical Empirical Equation = $\frac{\sum(P*EC)}{\sum P} * 10$						50	56.4	59.2
Green Performance Index in 50-60 range Eco Score							Average = 55.2	

Finding standard deviation for 50-60 range value

For value 50

As for 50, ascertain the mean and standard deviation within the range of 50 to 60 already. Thus, using the same number here, ±1.633.

For value 55

Mean ($\bar{x}$) = 55/10 = 5.5

Standard Deviation $= \sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(5-5.5)2+(6-5.5)2+(7-5.5)2+(4-5.5)2+(7-5.5)2+(5-5.5)2+(6-5.5)2+(4-5.5)2+(6-5.5)2+(5-5.5)2}{10-1}}$

$= \sqrt{\frac{(-0.5)2+(0.5)2+(1.5)2+(-1.5)2+(1.5)2+(-0.5)2+(0.5)2+(-1.5)2+(0.5)2+(-0.5)2}{9}} = \sqrt{\frac{0.25+0.25+2.25+2.25+2.25+0.25+0.25+2.25+0.25+0.25}{9}}$

$= \sqrt{\frac{10.5}{9}} = \pm 1.080$

For value 60

Mean ($\bar{x}$) = 60/10 = 6

Standard Deviation $= \sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(5-6)2+(8-6)2+(6-6)2+(6-6)2+(5-6)2+(8-6)2+(7-6)2+(4-6)2+(6-6)2+(5-6)2}{10-1}}$

$= \sqrt{\frac{1+4+0+0+1+4+1+4+0+1}{9}}$

$= \sqrt{\frac{16}{9}} = \pm 1.333$

TABLE 5
Calculating GPI for 60-70 Eco Score Range

S. NO	Green Audit Parameters	Given Priority (P) in percentage (%)	Assuming points for Eco-Score (EC) using scale (1 – 9) in 60–70 range			P*EC(A)	P*EC(B)	P*EC(C)
			(A)	(B)	(C)			
1	Energy Audit	30	5	6	7	1.5	1.8	2.1
2	Water Audit	20	8	7	8	1.6	1.4	1.6
3	Waste Audit	15	6	9	8	0.9	1.35	1.2
4	Green Initiatives	2	6	6	6	0.12	0.12	0.12
5	Carbon Footprint	7	5	5	5	0.35	0.35	0.35
6	Biodiversity Audit	3	8	6	8	0.24	0.18	0.24
7	Health Audit	4	7	7	7	0.28	0.28	0.28
8	Environmental Quality & Noise	10	4	6	9	0.4	0.6	0.9
9	Oxygen footprint	8	6	7	4	0.48	0.48	0.32
10	Built Environment	1	5	6	8	0.05	0.05	0.08
	Total	100%	60	65	70	5.92	6.7	7.19
Using Mathematical Empirical Equation = $\frac{\sum(P*EC)}{\sum P} * 10$						59.2	67	71.9
Green Performance Index in 60-70 range Eco Score							Average = 66.03	

Finding standard deviation for 60-70 range value

For value 60

As for 60, ascertain the mean and standard deviation within the range of 60 to 70 already. Thus, using the same number here, ±1.333.

For value 65

Mean ($\bar{x}$) = 65/10 = 6.5

Standard Deviation $= \sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(6-6.5)2+(7-6.5)2+(9-6.5)2+(6-6.5)2+(5-6.5)2+(6-6.5)2+(7-6.5)2+(6-6.5)2+(7-6.5)2+(6-6.5)2}{10-1}}$

$= \sqrt{\frac{(-0.5)2+(0.5)2+(2.5)2+(0.5)2+(-1.5)2+(-0.5)2+(0.5)2+(-0.5)2+(0.5)2+(-0.5)2}{9}}$

$= \sqrt{\frac{0.25+0.25+6.25+0.25+2.25+0.25+0.25+\ .25+0.25+0.25}{9}}$

$= \sqrt{\frac{10.5}{9}} = \pm 1.080$

For value 70

Mean ($\bar{x}$) = 70/10 = 7

Standard Deviation $= \sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(7-7)2+(8-7)2+(8-7)2+(6-7)2+(5-7)2+(8-7)2+(7-7)2+(9-7)2+(4-7)2+(8-7)2}{10-}}$

$= \sqrt{\frac{0+1+1+1+4+1+0+4+9+1}{9}}$

$= \sqrt{\frac{22}{9}} = \pm 1.563$

TABLE 6
Calculating GPI for 70-80 Eco Score Range

S.NO	Green Audit Parameters	Given Priority (P) in percentage (%)	Assuming points for Eco-Score (EC) using scale (1 – 9) in 70–80 range			P*EC(A)	P*EC(B)	P*EC(C)
			(A)	(B)	(C)			
1	Energy Audit	30	7	8	8	2.1	2.4	2.4
2	Water Audit	20	8	6	7	1.6	1.2	1.8
3	Waste Audit	15	8	9	6	1.2	1.35	0.9
4	Green Initiatives	2	6	7	9	0.12	0.14	0.14
5	Carbon Footprint	7	5	8	8	0.35	0.56	0.56
6	Biodiversity Audit	3	8	8	8	0.24	0.24	0.24
7	Health Audit	4	7	8	9	0.28	0.32	0.36
8	Environmental Quality & Noise	10	9	6	7	0.9	0.6	0.9
9	Oxygen footprint	8	4	6	9	0.32	0.48	0.72
10	Built Environment	1	8	9	9	0.08	0.09	0.07
	Total	100%	70	75	80	7.19	7.38	8.09
Using Mathematical Empirical Equation = $\frac{\sum(P*EC)}{\sum P} * 10$						71.9	73.8	80.9
Green Performance Index in 70-80 range Eco Score							Average = 75.53	

Finding standard deviation for 70-80 range value

For value 70

As for 70, ascertain the mean and standard deviation within the range of 70 to 80 already. Thus, using the same number here, ±1.563.

For value 75

Mean ($\bar{x}$) = 75/10 = 7.5

Standard Deviation = $\sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(8-7.5)2+(6-7.5)2+(9-7.5)2+(7-7.5)2+(8-7.5)2+(8-7.5)2+(8-7.5)2+(6-7.5)2+(6-7.5)2+(9-7.5)2}{10-1}}$

$= \sqrt{\frac{(-1.5)2+(-1.5)2+(2.5)2+(-0.5)2+(0.5)2+(0.5)2+(0.5)2+(-1.5)2+(-1.5)2+(2.5)2}{9}}$

$= \sqrt{\frac{2.25+2.25+6.25+0.25+\ .25+0.25+0.25+2.25+2.25+6.25}{9}}$

$= \sqrt{\frac{22.5}{9}} = \pm 1.581$

For value 80

Mean ($\bar{x}$) = 80/10 = 8

Standard Deviation = $\sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(8-8)2+(9-8)2+(6-8)2+(7-8)2+(8-8)2+(8-8)2+(9-8)2+(9-8)2+(9-8)2+(7-8)2}{10-1}}$

$= \sqrt{\frac{0+1+4+1+0+0+1+1+1+1}{9}} = \sqrt{\frac{10}{9}} = \pm 1.054$

TABLE 7
Calculating GPI for 80-90 Eco Score Range

S.NO	Green Audit Parameters	Given Priority (P) in percentage (%)	Assuming points for Eco-Score (EC) using scale (1 – 9) in 80-90 range			P*EC(A)	P*EC(B)	P*EC(C)
			(A)	(B)	(C)			
1	Energy Audit	30	8	9	9	2.4	2.7	2.7
2	Water Audit	20	9	8	9	1.8	1.6	1.8
3	Waste Audit	15	6	9	9	0.9	1.35	1.35
4	Green Initiatives	2	7	9	9	0.14	0.18	0.18
5	Carbon Footprint	7	8	9	9	0.56	0.63	0.63
6	Biodiversity Audit	3	8	9	9	0.24	0.27	0.27
7	Health Audit	4	9	8	9	0.36	0.32	0.36
8	Environmental Quality & Noise	10	9	7	9	0.9	0.7	0.9
9	Oxygen footprint	8	9	9	9	0.72	0.72	0.72
10	Built Environment	1	7	8	9	0.07	0.08	0.09
	Total	100%	80	85	90	8.09	8.55	9
Using Mathematical Empirical Equation = $\frac{\sum(P*EC)}{\sum P} * 10$						80.9	85.5	90
Green Performance Index in 80-90 range Eco Score							Average = 85.47	

Finding standard deviation for 80-90 range value

For value 80

As for 80, ascertain the mean and standard deviation within the range of 80 to 90 already. Thus, using the same number here, ±1.054.

For value 85

Mean ($\bar{x}$) = 85/10 = 8.5

Standard Deviation = $\sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(9-8.5)2+(8-8.5)2+(9-8.5)2+(9-8.5)2+(9-8.5)2+(9-8.5)2+(8-8.5)2+(7-8.5)2+(9-8.5)2+(8-8.5)2}{10-1}}$

$= \sqrt{\frac{(0.5)2+(-0.5)2+(0.5)2+(0.5)2+(0.5)2+(0.5)2+(-0.5)2+(-1.5)2+(0.5)2+(-0.5)2}{9}}$

$= \sqrt{\frac{0.25+0.25+0.25+0.25+0.25+0.25+0.25+2.25+0.25+0.25}{9}}$

$= \sqrt{\frac{4.5}{9}} = \pm 0.707$

For value 90

Mean ($\bar{x}$) = 90/10 = 9

Standard Deviation = $\sqrt{\frac{\sum(x-\bar{x})2}{n-1}} = \sqrt{\frac{(9-9)2+(9-9)2+(9-9)2+(9-9)2+(9-9)2+(9-9)2+(9-9)2+(9-9)2+(9-9)2}{10-}} = 0$

TABLE 8
Green Performance Index (GPI)

Eco Score Ranges	Average of eco score range values by using mathematical formula	Difference with min and max values (X)	Average of X
30-40 (30, 35,40)	34.6	$\left.\begin{matrix}+4.6\\-5.4\end{matrix}\right\}0.8$	±1.2
40-50 (40, 45, 50)	44.17	$\left.\begin{matrix}+4.17\\-5.83\end{matrix}\right\}1.66$	
50-60 (50, 55,60)	55.20	$\left.\begin{matrix}+5.20\\-4.80\end{matrix}\right\}0.4$	
60-70 (60, 65, 70)	66.03	$\left.\begin{matrix}+6.03\\-3.97\end{matrix}\right\}2.06$	
70-80 (70, 75, 80)	75.53	$\left.\begin{matrix}+5.53\\-4.47\end{matrix}\right\}1.06$	
80-90 (80, 85, 90)	85.47	$\left.\begin{matrix}+5.47\\-4.53\end{matrix}\right\}0.94$	
Standard Deviation of different eco score range values			
30	±1.632	±15.822/13	±1.2
35	±1.581		
40	±1.154		
45	±1.424		
50	±1.633		
55	±1.080		
60	±1.333		
65	±1.080		
70	±1.563		
75	±1.581		
80	±1.054		
85	±0.707		
90	± 0		
Green performance Index (GPI) = ±1.2			

By using this formula, we can calculate total eco score of JNTUK in 2024

$\sum P = 0.3+0.2+0.15+0.02+0.07+0.03+0.04+0.1+0.08+0.01 = 1$

No. of parameters taken (n) = 10

Now we can put these values in above equation

$$\frac{(0.3*6)+(0.2*4)+(0.15*5)+(0.02*4)+(0.07*6)+0.03*6)+(0.04*5)+(0.1*3)+(0.08*5)+(0.01*6)}{1} *10$$

= (1.8+0.8+0.75+0.08+0.42+0.18+0.20+0.3+0.40+0.06) *10

= 49.9

Applying the mathematical formula, the total eco score will come out to be more than 0.1. Therefore, we can utilize the Green Performance Index value, or ±1.2, under these conditions. Since the resultant value falls inside the index value, as we can see, it will be relevant. Thus, we'll use 50 as the ultimate value.

The IGBC Existing Campus Certification Levels of Score indicate that JNTUK performs at the "SILVER LEVEL," or "Outstanding Performance." Therefore, there are numerous ways to raise the eco score for green campuses if you hope to eventually obtain IGBC green campus platinum accreditation for the JNTUK campus.

III. RESULTS AND DISCUSSION

Green campus eco score assessment for JNTUK in 2024

Energy Audit – Eco-score # 6

The installation of solar panels on campus reduced the electricity bill from Rs. 11,42,328.44 in 2020 to Rs. 5,39,229 in 2021, significantly lowering energy consumption. The campus is also lit with energy-efficient LEDs, and students are educated on energy conservation. Energy-saving through solar panels alone earns 8 points, while through all renewable sources, it earns 9 points.

Water Audit – Eco-score # 4

Rainwater harvesting on campus utilizes tube wells, recharge wells, pits, and trenches to conserve water and reduce runoff. With wastewater recycling and ZLD certification, the campus minimizes freshwater use, earning 8 points if design calculations and rain capacity are shown, and 9 points if a ZLD plant is present.

Waste Audit – Eco-score # 5

Regulations ensure the safe handling, processing, disposal, and management of plastic, e-waste, food, and hazardous waste, governed by the Hazardous and Other Waste (Management and Transboundary Movement) Rules, 2016, revised in 1989, 2000, 2003, and 2008. Safe collection and disposal earn 9 points, and separate bins for all waste types earn 8 points.

Green initiatives – eco-score # 4

Institutions celebrate national and international events to instill nationalism, patriotism, and commemorate great leaders, promoting harmony, peace, love, and happiness among staff, instructors, and students. Establishing green procurement policies earns 9 points.

Carbon Footprint # 6

Global warming, caused by increased Greenhouse Gas (GHG) emissions from human activities, leads to a rise in Earth's average temperature. GHG levels are measured using Global Warming Potential (GWP) and expressed as a Carbon Footprint (CF). Setting carbon reduction targets earns 9 points.

Biodiversity Audit # 6

By giving all of the plants, trees, shrubs, and climbers that are cultivated on campus common names, the general public will be able to identify the plants and learn about their traditional functions. If complete Biodiversity report is present – 9 points

Health Audit – Eco-score # 5

Improving the eco score in a health audit involves enhancing energy efficiency, water conservation, waste management, sustainable procurement, and more to reduce environmental impact while promoting health. Maintaining all these facilities adequately earns 9 points.

Environmental Quality & Noise – Eco-score # 3

Campus noise primarily comes from vehicles and DG sets, with levels in classrooms and outside the campus remaining standard. Integrating noise pollution awareness into the curriculum and using eco-friendly materials earns 9 points.

Oxygen Footprint – Eco-score # 5

The concept of an oxygen footprint is necessary to comprehend the full range of environmental impacts caused by human activities. It is a useful addition to other assessments of environmental footprints, such as carbon and water footprints, increasing the amount of green space by planting trees.

Built Environment – Eco-score # 6

At campus, the area occupied by greenery exceeds that of buildings. The National Green Building Council identifies 8 components of green buildings, including energy and water efficiency, waste reduction, and life cycle assessment.

An outstanding eco-score scale from 1, which represents extremely poor, to 9. JNTUK comes within "existing campuses," according to the IGBC Green Campus Rating System Checklist. Thus, it can be evaluated using the eco score of 90.

On the basis of the three audit checklists (energy, eco, and green), the JNTUK campus's 10 eco score categories were evaluated. The JNTUK will have a total eco score of 41 in 2023. Therefore, JNTUK obtains the "**CERTIFIED LEVEL**," which is associated with "**Best Practices**," according to the IGBC Existing Campus Certification Levels of Score.

The assessment of the total eco score of JNTUK in 2024 is 50 based on the computation and discovery of data regarding 10 parameters, such as their quantities, standards, and checklists. Thus, JNTUK obtains "**SILVER LEVEL**," which stands for "**Outstanding Performance**," according to the IGBC Existing Campus Certification Levels of Score.

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IV. CONCLUSION

This project provides a thorough methodology for evaluating environmental performance through the analysis of important sustainability variables such carbon emissions, water use, trash production, and energy use. Through careful data gathering and statistical analysis, an empirical equation is developed with the goal of improving decision-making procedures and encouraging more sustainable behaviours inside organizations. The initiative advocates for the use of renewable energy sources and better waste management techniques while also pointing out large cost-saving potential. Moreover, it shows how crucial knowledge about the environment and public health are to sustainability initiatives. The project establishes a standard for other institutions to conform to in their sustainability initiatives by developing green auditing procedures.

V. RECOMMENDATIONS

1. There aren't many solar panels on the campus. The yearly cost of the campus power rates is over 1.3 crore. After using them to save 41,000 per month and about 5 lakhs yearly, it will be advantageous to install more solar panels in order to save even more money.
2. The finest sound absorbers are plants. Several common plants were included in the experiments, including lemons, berries, roses, almond trees (Badam), neem, mango, sapodilla plants (Sapota), berry trees (Neredu), and gooseberry plants (Usiri). Nearly 10 dB of sound may be absorbed by the shrubs and plants.
3. There is only one available buggy each block on campus, hence it is recommended to have at least one

buggy every block. It's going to help cut down on carbon pollution.

4. It is advisable to carefully handle the segregation of distinct waste kinds and their transportation to waste management facilities since garbage is improperly disposed of and dumped in open areas on campus.
5. Sand buckets and fire extinguishers are only available in the campus administrative office. It is recommended that fire extinguishers and sand buckets be positioned in every campus building as a matter of safety measures.
6. use terrace farming to cool the upper stories of buildings, allowing residents to use fans or air conditioners less frequently and conserve energy.
7. On the whole campus, there is presently just one open classroom that was created with the riches from waste idea in mind. Finding a suitable location inside the campus to establish another open classroom would be a great idea.
8. Validate the equation on a regular basis using revised data and changing environmental specifications. Over time, improve its accuracy through the addition of new concepts and research findings.
9. In general, the creation of an empirical mathematical formula for the eco score in a green audit offers an empirical method for assessing and enhancing environmental performance.

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