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An Empirical Study of Resource Consumption, Behavioral Patterns, and Carbon Footprint in Campus Environments

Pushpendra[1*], Elias Vollert[2]

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Abstract

The correlation between the consumption of resources, behavioral patterns and carbon emissions among campus settings through a structured empirical dataset. This paper takes a quantitative research design to discuss the contribution of such variables as energy consumption, water consumption, mode of transportation, food preferences, recycling, and spending patterns on carbon footprint. This was determined using the descriptive, correlation analysis, and regression analysis to identify the key determinants and their relative contribution to the emissions. The findings indicate that energy consumption is the highest emitter of carbon emission then the transportation behaviour and the total consumption expenditure. Lower levels of emissions are linked to sustainable practices such as taking up of public transportation, plant-based diets, and regular recycling. The findings emphasize the importance of personal action, as well as the consumption of resources in determining environmental consequences. The given study also add to the existing literature on sustainability by incorporating both the environmental, behavioral, and economic aspects into a single analytical framework. The results offer useful information to institutions of higher learning to develop specific sustainability plans and enhance eco-friendly practices. On the whole, the research highlights the significance of multidisciplinary and data-supported strategies when it comes to solving the problem of sustainability on campuses.

Keywords: Sustainability, Carbon Emissions, Resource Consumption, Behavioral Patterns, Campus Environment

[1*]Helmholtz Institute Ulm (HIU), Helmholtzstraße 11, 89081, Ulm, Germany
[2]Karlsruhe Institute of Technology (KIT), 76021, Karlsruhe, Germany

Corresponding Author: Pushpendra
Email Id: pushpendra.pushpendra@kit.edu

1. Introduction

The issue of sustainability has become the major concern in higher learning institutions because of the growing concern on environmental degradation and the alarming number of carbon emission that needs to be curbed. Universities have a unique role of being knowledge producers and operational organisations, and hence; they play important roles in ensuring sustainable development. Current research highlights that the activities of a campus have a major contribution towards impacting the environment in terms of energy use, transport, and use of resources (Oliveira and Proença, 2025). This has seen institutions consider sustainability in their strategic plans and operations. The development of sustainability programs in universities has been in the rise in the last ten years. Some of the strategies that have been used by institutions are energy efficiency programs, waste reduction strategies and sustainable campus planning. Empirical evidence proposes that these initiatives have not only environmental-saving effects but also help to improve the institutional performance and reputation (Aleixo et al., 2018). The success of these programs, however, is frequently determined by the incorporation of multidisciplinary views and involvement of the stakeholders.

The shift to the sustainable campuses demands new approaches to management that would help reconcile the organizational objectives with environmental sustainability. Universities are complicated institutions in which administrative policies, academic activities, and individual behaviors become mixed. Sustainability management is thus an initiative that requires the action of several levels of the institution (Barnard and Van der Merwe, 2016). This complexity highlights the importance of empirical study that would represent a structural and behavioral aspect of sustainability. Carbon footprints in institutions also constitute a big part of transportation and mobility patterns within campuses. Research has also established that commuting habits especially dependence on personal cars are a significant source of greenhouse gases (Barros et al., 2018). These results indicate the need to encourage eco-friendly means of transport in a larger framework of campus sustainability.

Sustainability practices in higher education are also being changed by the ever-shifting global environment, especially in the COVID-19 pandemic. The pandemic has brought about new challenges and opportunities that can be seen in terms of transitions to digital studying and decreased occupancy of campuses that have impacted energy consumption and emissions patterns (Crawford and Cifuentes-Faura, 2022). The changes mentioned below emphasize the dynamism of sustainability in higher education and the need to implement data-driven and adaptive strategies. On top of the operations, it is also being accompanied by an increased focus on sustainability literacy among students and staff. Programs like the Sustainability Literacy Test (Sulitest) are also meant to measure and improve the knowledge on sustainability concepts among academic communities (Décamps et al., 2017). These attempts emphasize the importance of education in promoting the pro-environmental behavior and long-term sustainability objectives.

Measuring the amount of carbon emissions is an important process in realizing and controlling the environmental effects. A number of studies have tried to measure the carbon footprint of university and the results indicated that there are huge differences depending on the size of the institution, infrastructure and behavioral aspects. As an example, initial energy consumption and transportation activities assessment of campus emissions indicate that both activities contribute significantly to the total carbon emissions (Almufadi et al., 2016). These results support the need to have extensive measurement systems. The measurement of greenhouse gas emissions in academic institutions has been done by use of standardized methods like ISO based methods. The methods offer methodological instruments to measure the environmental performance and determine the areas in which it can be enhanced (Aristizábal -Alzate and Gonzalez-Manosalva, 2021). Nevertheless, most of the current literature emphasizes the institutional level of emissions, whereas they do not pay much attention to the consequences of the individual behaviors in determining the environmental conditions.

The individual behavior is a critical factor in identifying the sustainability initiative effectiveness. Studies have found out that the ecology footprint of students is directly associated with environmental attitudes, lifestyle, such as eating habits, transportation patterns and consumption habits (Fernández et al., 2020). This relationship brings out the necessity to incorporate behavioral analysis in sustainability research. Another important aspect that has an effect on the sustainability results is stakeholder engagement. Universities need to engage students, faculty, and administrative personnel in sustainability programs in order to have a successful implementation and sustainability. Researchers have found that institutional strategies should correspond to the expectations of the stakeholders to increase the efficiency of sustainability reporting and practices (Ferrero-Ferrero et al., 2018). This participatory strategy helps to have a more holistic approach of the sustainability issues.

Although the literature on sustainability of campuses has been on the increase, there is still a knowledge gap in the literature to combine resource consumption, behavioral patterns, and carbon emissions in the context of a single analysis. Available studies tend to look at these dimensions separately, and hence the inability to capture their interdependences. Also, it is necessary to have empirical models that determine a relative contribution of various factors to carbon emissions (Franco et al., 2022). The introduction of higher education institutions as an area to be assessed with the help of sustainability indicators and the assessment tool has been growing, but the latter are not always granular at an individual level (Findler et al., 2018). To overcome this limitation, it is needed to have datasets that involve environmental, economic and behavior variables so that they can carry out a more detailed analysis.

The current research fills these gaps by carrying out an empirical research on resource consumption, behavioral patterns and carbon footprint in a campus setting. Through a structured dataset, the study offers the insights into the motivators of carbon emissions and finds the possible routes of advocating the sustainable behavior. Moreover, the study also adds to the current research aimed at decreasing the amount of emission due to behavioral interventions, especially the use of energy-saving behavior among students.

2. Methodology

2.1 Research Design

The research design to be followed in this study is the quantitative empirical research design which was used to analyze the relationships between resource consumption, behavioral patterns and carbon emissions in a campus based environment. It is a cross-sectional approach, which uses structured observational data to define patterns and make inferences on the relationships between variables. Since sustainability is a multidimensional concept, the design combine the environmental, behavioral and economic aspects into a single analysis framework. Carbon footprint is the dependent construct, which operationalized as monthly carbon emissions, and independent variables include resource consumption indicators and lifestyle behavior. Such a design allows to conduct a systematic analysis of the role of individual-level practices in environmental impact in a semi-controlled institutional environment.

2.2 Data Source and Variables

It is analyzed using a structured dataset that includes about one thousand observations that are individual-level sustainability behaviors (Zara, 2025). The data reflects a wide range of variables, including the pattern of consumption, lifestyle, and environmental impact. Continuous variables are used to measure resource consumption. Economic consumption is included by way of monthly spending on clothes and total consumption which are proxies to material lifestyle intensity. The carbon emissions are an outcome variable, which directly measures the impact on the environment, allowing the study to correlate behavioral and consumption patterns with a measured level of emissions. The data therefore assist in an unified evaluation of the sustainability of the environment by integrating both the physical resource consumption with the socio-behavioral variables.

2.3 Data Preprocessing and Transformation

The data is first subjected to systematic preprocessing, before analysis, to provide analytical strength and intervariable comparability. Continuous variables (energy usage, water consumption, expenditure) are analysed in terms of distributional characteristics (skewness and possible outliers) and are standardised where required to allow convergence and interpretation of the model. Suitable methods are used to represent categorical variables as numerical numbers in order to enable inclusion in statistical models of qualitative behavioral attributes without loss of interpretation. Data consistency is also executed to conclude that no records are missing or abnormal and inconsistencies are eliminated through the application of appropriate imputation/ exclusion measures. There are also derived indicators which are taken where appropriate such as normalized consumption indicators to enhance comparability of observations. This pre-processing step is significant in ensuring that the data set is analytics ready and it can be submitted to multivariate modeling.

2.4 Analytical Framework

The data is analyzed by employing descriptive, inferential, and predictive approaches to outlay the analysis plan. The first step is to compute the descriptive statistics that describe the central tendencies and variability of resource consumption and emissions that provide a clue of the sustainability trend in the dataset. Frequency distributions are used to

investigate categorical variables to establish the frequency of different behavioral practices. The correlation test is then conducted in order to establish the strength and the direction of the relationship between key variables particularly the relationship between the indicators of resource consumption and carbon emission. On this basis, a multiple linear regression model is defined to measure the degree to which carbon footprint is explained by independent variables. The predictors in this model are the energy use, water use, the level of expenditure and coded behavioral variables and the dependent factor is the carbon emissions. In order to maximize the level of analytical rigor, model diagnostics, such as multicollinearity, heteroscedasticity, and residual normality checks, are conducted. Other modeling methods that can be thought of where appropriate include non-linear or the ensemble based method to model the complex relationships in the data. The general model reveal the key predictors, evaluate their relative importance, and provide a reasonable empirical basis to describe the dynamics of sustainability.

2.5 Statistical Tools and Validation

The analysis is performed with the help of advanced statistical software environments, which make it possible to obtain correct calculations and repeat the results. Statistical significance is also checked at conventional levels and the fit of the models is estimated using coefficient of determination (R2) and adjusted R2. Validation procedures also ensure consistency of results including sensitivity analysis, and powerful resilience procedures across model specification. This degree of methodological rigor enables the findings on the basis of the data to be statistically and substantially applicable to the sustainability research.

3. Results

3.1 Descriptive Statistics of Key Variables

This section presents the overall description of the central tendencies and dispersion characteristics of the most important variables connected to the consumption of resources and carbon emissions. The descriptive analysis provides a background step in learning the variability and distributional patterns of the dataset, hence guiding the further inferential analysis. The data used indicates a high level of heterogeneity in the consumption behavior that means that there is a wide range of lifestyle practices among the people in the campus environment. The assessment of the scale and dispersion of the major indicators of energy use, water usage, spending habits, and carbon emissions as summarized in Table 1 is crucial before analyzing the relationship between variables.

Table 1. Descriptive Statistics of Continuous Variables

Variable	Mean	Std. Deviation	Min	Max
Energy Usage (kWh/month)	275.4	140.2	50	500
Water Usage (liters/day)	245.6	120.5	50	500
Clothing Spend (monthly)	2550.3	1400.7	500	5000
Consumption Spend (monthly)	5200.6	2600.4	1000	10000

Carbon Emissions ($kgCO_2$)	285.7	110.3	100	600

The data provided in Table 1 shows that the variables of energy consumption and expenditure have high levels of variability in that the standard deviations are large compared to the means. This implies that consumption patterns are not even with the fact that some people use a lot more resources as compared to others. Carbon emissions also exhibit significant dispersal meaning that the impact of the environment is not equally spread throughout the population. In a bid to further explain the distributional properties of the dependent variable, a graphical illustration is provided in Figure 1.

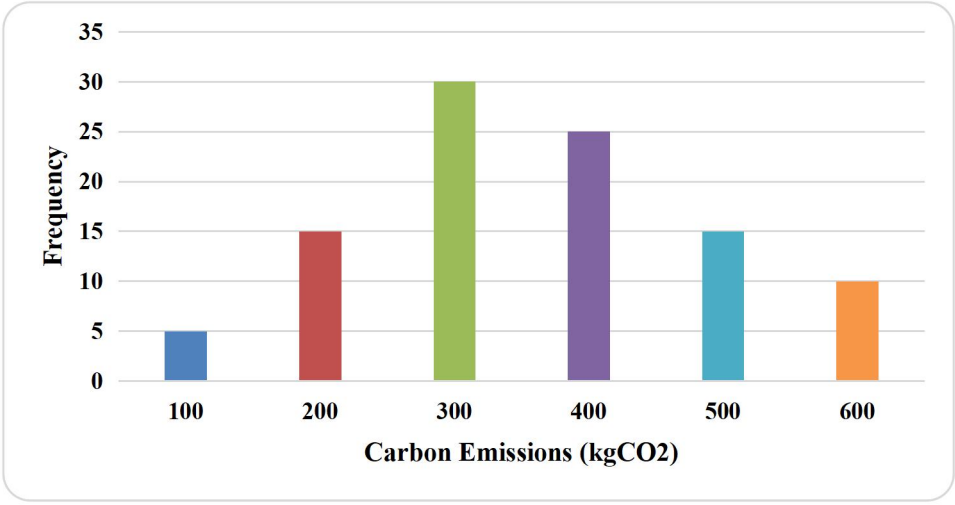

Fig. 1. Distribution of Carbon Emissions ($kgCO_2$)

The data provided in Table 1 shows that the variables of energy consumption and expenditure have high levels of variability in that the standard deviations are large compared to the means. This implies that consumption patterns are not even with the fact that some people use a lot more resources as compared to others. Carbon emissions also exhibit significant dispersal meaning that the impact of the environment is not equally spread throughout the population. In a bid to further explain the distributional properties of the dependent variable, a graphical illustration is provided in Figure 1.

3.2 Behavioral Patterns and Emission Differences

The behavioral variables analysis offers valuable insights into the effect of lifestyle choice on carbon emission. Sustainability research focuses on behavioral aspects like preference in diet, mode of transport and recycling behavior since they are all aspects that can be altered using policy and intervention. In order to measure these effects, mean carbon emissions were computed within various behavioral categories as shown in Table 2, which can be evaluated comparatively.

Table 2. Mean Carbon Emissions by Behavioral Categories

Category	Subgroup	Mean Emissions ($kgCO_2$)
Food Type	Vegan	190.5
	Vegetarian	245.8
	Non-Vegetarian	320.6
Transport Mode	Bicycle	180.2
	Public Transport	260.4
	Car	360.7
Recycling Habits	Always	230.5
	Sometimes	290.8
	Never	340.2

According to the findings in Table 2, it is clear that people who follow the plant-based diets have much lower carbon emissions than non-vegetarians. Likewise, the mode of transport becomes one of the key determinants, and car users generate significantly greater emissions compared to bicycles or public transport. The behavior of recycling is also consistent as those who recycle consistently have low emissions. To enhance these differences visually, the figure below shows the variation of emission in different modes of transportation as in Figure 2.

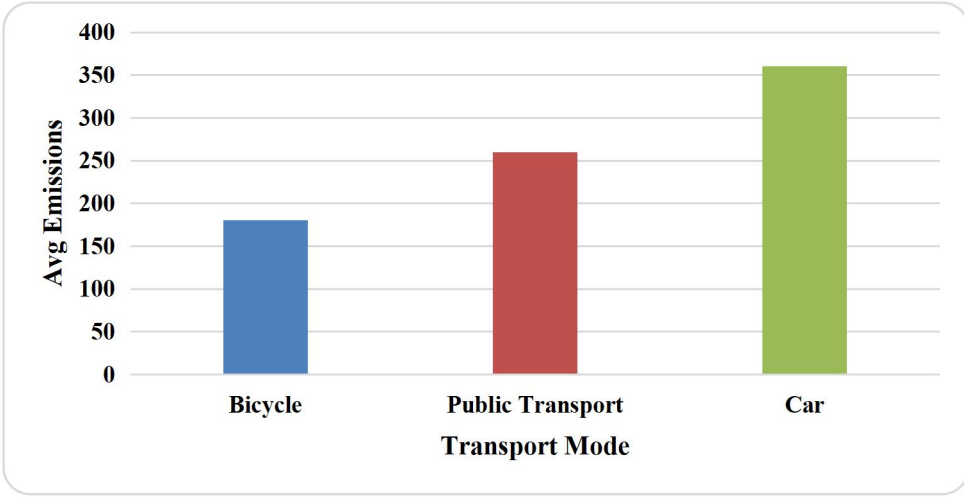

Fig. 2. Carbon Emissions by Transportation Mode

The graphical representation of the increase in the number of vehicles in each category is highlighted by the fact that, as shown in Figure 2, the category of private vehicle use is the greatest contributor towards the increase in emissions. This observation highlights the need to encourage sustainable mobility solutions in campuses.

3.3 Correlation Analysis

A correlation analysis was done to test the strength and direction of relationships between important variables. This is done to give initial evidence of associations, and then to multivariate modeling. These relationships are important in understanding what could be

the predictors of carbon emission and the level of interdependence among variables. Table 3 summarizes the correlation between these relationships in the form of a correlation matrix.

Table 3. Correlation Matrix

Variable	Energy Usage	Water Usage	Consumption Spend	Carbon Emissions
Energy Usage	1.00	0.42	0.55	0.78
Water Usage	0.42	1.00	0.36	0.52
Consumption Spend	0.55	0.36	1.00	0.64
Carbon Emissions	0.78	0.52	0.64	1.00

The Table 3 values demonstrate that the correlation between the energy use and carbon emissions is very strong, which means that the increase in the energy use directly correlates with the increase in the environmental impact. Consumption spending also correlates with high positive relationship which implies that the more the economy is active the more the emission levels are. The use of water has a moderate relationship because it is an indirect contributor to carbon footprint. In order to depict the correlation between the most significant variables further, a scatter plot is provided in Figure 3.

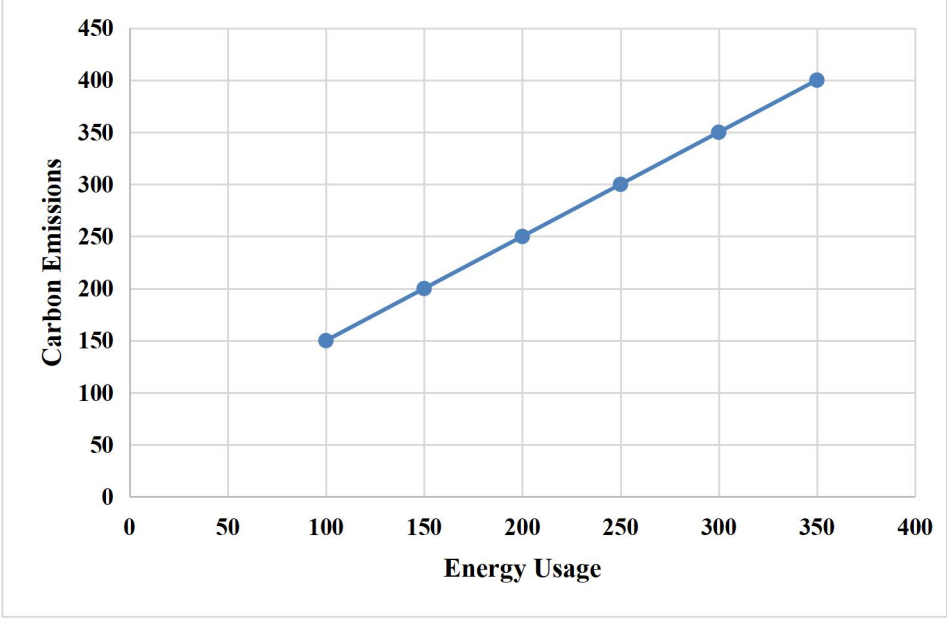

Fig. 3. Scatter Plot of Energy Usage vs Carbon Emissions

As seen in Figure 3, the trend is evidently increasing and this shows that people who consume more energy always have the highest carbon emission. The fact that the data is clustering on trend line implies that there is a very strong linear relationship between these two variables.

3.4 Regression Analysis

In order to measure the joint contribution of several variables to carbon emissions, a multiple linear regression model was estimated. Such analysis can be used to identify predictors that are significant and eliminate the effect of other variables, thus giving a stronger picture of causation. Table 4 shows the regression coefficients and the level of statistical significance.

Table 4. Regression Results

Variable	Coefficient	Std. Error	p-value
Intercept	45.2	12.3	<0.01
Energy Usage	0.65	0.04	<0.001
Water Usage	0.21	0.03	<0.01
Consumption Spend	0.018	0.005	<0.01
Transport (Car)	75.4	10.2	<0.001
Recycling (Always)	-42.7	9.5	<0.01

Model Statistics: $R^2 = 0.72$, Adjusted $R^2 = 0.70$

According to the findings given in Table 4, the model has a high explanatory power, and about 72 percent of the variation in carbon emissions is accounted by the predictors included in the model. The most significant predictor is energy usage and the coefficient is highly significant. The mode of transportation especially that of cars also plays a significant role in an increase in emissions. On the other hand, there is a statistically significant negative impact of consistent recycling behavior, which demonstrates its contribution to environmental impact minimization. In order to assess the performance of the models, the predictions were compared to the observed emissions as shown in Figure 4.

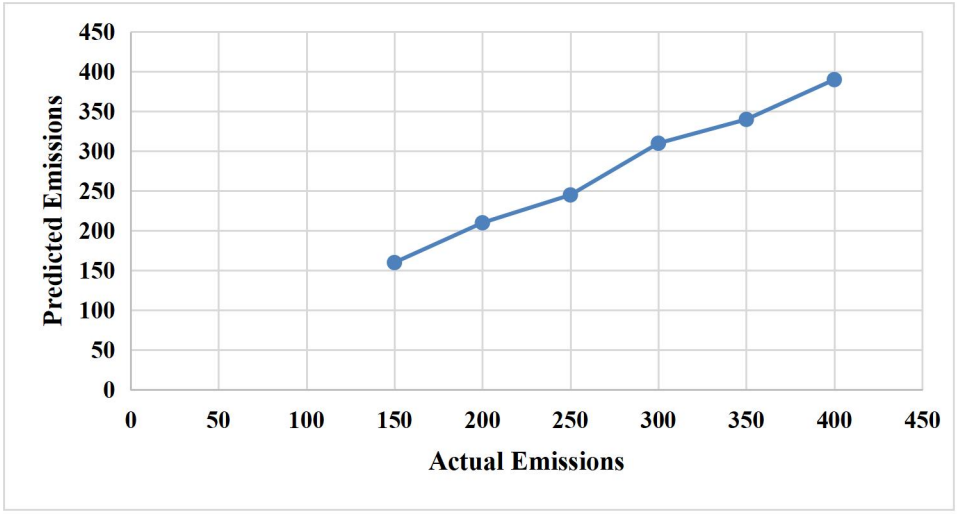

Fig. 4. Predicted vs Actual Carbon Emissions

As indicated in Figure 4, the predicted and actual values are similar and hence an

indication that the model is successful in capturing the underlying data structure. Minimal deviation means that there are other unobserved variables yet the general predictive capability is high.

3.5 Key Findings

The results are good evidence that the use of resources and the patterns of behavior are some of the major determinants of carbon emissions. The most common and energy is saved by means of sustainable practices such as recycling and low-impact diets. The economic, environmental and behavioral variables integration provide a holistic view on the dynamics of sustainability and support the relevance of multidisciplinary approaches in solving environmental issues on campus.

4. Discussion

The results presented in this paper are convincing empirical findings that the consumption of resources and behavioral tendencies are major factors causing carbon emissions in campus settings. The most significant predictor was the energy usage, then the transportation mode and consumption expenditure. These findings are consistent with the findings of general studies showing that the environmental effects on the campus level are mostly caused by energy-consumption activities and mobility practices (Genta et al., 2022). The identified heterogeneity of emissions demonstrates the existence of the heterogeneous consumption patterns, which implies that tailor-made interventions can be more efficient than universal policies. The significant correlation between the behavioral variables and emission emphasizes the significance of inclusion of individual level analysis in the sustainability study. Specifically, the decisions regarding transportation and recycling practices show quantifiable impacts on carbon footprint, which further supports the importance of the daily decision-making process in determining the environment.

The findings can be of significant use to institutions of higher learning, aiming at promoting the principles of sustainability. Such a prominent role of the energy consumption and transport implies that the institutional strategies are to focus more on the energy efficiency measures and the sustainable mobility campaigns. Such results justify the idea of University 4.0, which focuses on the transformation of the institutions of higher education into the systems that are sustainable and innovation-driven (Giesenbauer and Müller-Christ, 2020). The analysis of carbon footprint, which is being used in this case, is an effective method of determining the main sources of emissions and the decision-making process. The empirical measurements of emissions allow universities to go beyond the symbolic promises and implement evidence-based sustainability policies (Voghouei et al., 2025). The quantification of the relative contribution of various variables help the institutions to allocate resources in a more efficient way and to carry out specific interventions.

One of the main contributions of this research is that it combines behavioral and institutional approaches. Although most sustainability efforts have paid attention to infrastructure and policy, the results obtained indicate that the behavior of individuals is still a key factor in environmental influence. This helps the increased focus on whole-institution strategies, which propose the coordination of organizational designs, rules, and

individual behaviors (Holst, 2023). Implementation of comprehensive sustainability models involves the cooperation of different stakeholders such as students, faculty and administrative staff. Whole-institution strategies underline the importance of approaching sustainability in a coordinated manner, so that sustainability is in all areas of university activity (Kohl et al., 2022). This viewpoint is supported by the findings of this study that reveal that systemic and behavioral factors are to be tackled concurrently.

This research is also in line with the previous empirical studies which have emphasized the importance of energy consumption and lifestyle in determining carbon emissions. Indicatively, other investigations based on emission factor approaches have also found energy consumption as one of the leading contributors to campus emissions (Lin et al., 2024). The current research adds to this literature by considering a wider range of variables such as behavioral and economic ones, which makes the study more comprehensive. Furthermore, the results add to the existing evidence that the institutional dedication to sustainability that is reflected in the mission statements and strategic priorities can influence the environmental performance (Lopez and Martin, 2018). The findings, though, also suggest that an institutional policy is not the only one that needs to be changed but also an individual behavior.

In practice, there are certain practical steps towards controlling emission of carbon gases within campus environments that emerge in the study. The commute-related emissions could be reduced as well through the encouragement of transport options that are environmentally friendly such as bicycles and buses. Along the same line, developing energy-saving habits and conscientious consumption trends, assist in realizing sustainability in general. This is due to the fact that the modernization of the higher education systems provides an opportunity to integrate sustainability into the curriculum and in the workings of the campuses. An awareness and behavioral change program that incorporates sustainability in education can facilitate the long-term environmental goals (Machado and Davim, 2023). In this instance, the universities may serve as living sustainability laboratories, where the theoretical knowledge is translated into the real practice.

The research paper is pertinent to the general debate on sustainability in higher education since it demonstrates the significance of multidisciplinary solutions. This environmental, behavioral and economic combination provides a holistic understanding of the dynamics of sustainability and this is in tandem with the quest to have holistic frameworks when handling complex environmental issues. The findings also denote the importance of setting up common sustainability competencies in universities. The organizations ought to build the knowledge, skills, and values that would assist in maintaining the sustainable development at individual and organizational levels (Nokkala et al., 2024). This entails communication at all times, institutional commitment and building capacity. Besides, the study supports the relevance of carbon footprint analysis as an instrument of environmental performance measurement in institutions of higher learning. Extensive evaluations of emissions can help institutions define the primary drivers and track their progress over time (Paredes-Canencio et al., 2024). The fact that the study links the pattern of behavior and previous outcomes creates a platform upon which other research works and policy making can be done.

Despite the fact that the research has certain strong sources of information, certain limitations must be mentioned. The cross-sectional nature of the dataset does not allow the ability to quantify time change in the behavior and emissions. Also, the fact that no clear institutional identifiers are provided can limit the extrapolation of the results to other campus environments. Subsequent research should be done using longitudinal data to assess the behavioral variability of sustainability over time and assess the impact of interventions. The predictive accuracy can also be enhanced after advanced analytical tools, such as machine learning, are integrated to discover the complex relationships in the data. The discussion can also be extended to the institutional policy and structural variables consideration that would supplement the understanding of the processes of sustainability in higher education.

5. Conclusion

A comprehensive empirical study of the relationships among resource utilization, behavioral patterns and carbon emissions in college communities. The results reveal that energy consumption, mode of transport, and consumption patterns are the major factors that determine carbon footprint, and energy consumption comes out as the most important predictor. It was also detected that behavioral factors such as sustainable practices such as recycling, low impact transportation etc. are also important towards the reduction of emissions. The research shows the significance of incorporating the environmental, economical, as well as behavioral aspects to attain a dedicated comprehension of sustainability in institutions of higher learning. The research gives pertinent data to policy makers and institutional stakeholders who are keen on coming up with effective sustainability plans, which can be realized through a data-driven approach. The results illustrate the fact that it is not only through infrastructural development that one would make any substantial change in the carbon emissions but also behavior change among the individuals themselves. Overall, this study confirms the notion of working on the sustainability concerns with the help of multidisciplinary approaches and emphasizes on the possibility to utilize campus environments as the platform where sustainable development can be improved. The following generation work would be directed to the expansion of empirical frameworks and the incorporation of the longitudinal evidence in order to enhance the understanding of the sustainability dynamics even further.

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