Journal of Energy Research and Reviews

5(3): 71-85, 2020; Article no.JENRR.57968
ISSN: 2581-8368

Analysis of Environmental Footprint Factors on Nigerian University Campus: Multi-Criteria Analysis and System Dynamics Modelling

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Authors' contributions

This work was carried out in collaboration among all authors. Author OPA performed the following roles in the study, conceptualization, methodology, resources, software, analysis, writing- original draft preparation. Author OAJ wrote the study, reviewed and edited the study and supervised the study. Author AOA supervised the methodology. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JENRR/2020/v5i330152
Editor(s):
(1) Dr. Huan-Liang Tsai, Da-Yeh University, Taiwan.
Reviewers:
(1) Reccab Ochieng Manyala, University of Zambia, Zambia.
(2) G. Devika, Government Engineering College, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/57968

Original Research Article

Received 10 April 2020
Accepted 15 June 2020
Published 29 June 2020

ABSTRACT

Performing their role as think tank and model of the world in environmental management, universities need a more inclusive and "whole-of-university" approach to environmental issues. Accordingly, this study adopted Participatory Action Research (PAR) design to the analysis Environmental Footprint (EF) factors on university campus using Multi-criteria Analysis (MCA) and System Dynamics (SD) Model. A group of 13 informants who are environmental experts on The Federal University of Technology, Akure (FUTA), Nigeria campus were purposively selected to form an environmental assessment team for the study. Primary data were collected using environmental factors assessment form designed for the purpose after initial aggregation of contents from secondary sources. Multi-Criteria Analysis (MCA) revealed that energyprint (48.00 per cent) is the highest driver of environmental footprint followed by transportprint (30.20 per cent) and wasteprint (21.80 per cent) respectively while 'survival capability (best practices)' (40.70 per cent) was found to have the highest possibility of reducing it than any other inhibitors – legitimacy (environmental

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regulation) (34.60 per cent) and resource capability (societal practices) (24.70 per cent). To achieve a reduction in environmental footprint, scenario analyses based on Stock and Flow model of System Dynamics showed that the institution should annually combine Corporate Social Responsibility and University Rules and Regulations in proportions, 53.6 per cent and 46.4 per cent respectively. Thus, the study recommended the implementation institution-wide policy supported by awareness creation among stakeholders to foster both individual and institutional level commitments for reducing footprints.

Keywords: Environmental footprint factors; environmental management; multi-criteria analysis; participatory action research; system dynamics model; Nigerian university campus.

1. INTRODUCTION

Performing their role as think tank and model of the world require a more inclusive and "whole-of-university" approach to achieving sustainability and to rethink how higher education can address sustainability issues within the curriculum and research, and via community outreach, collaboration, and participation of the various university stakeholders [1-3]. Similarly, measuring their performance in the area of implementation of greening project initiatives is a step towards tracking progress and making improvement where possible.

Environmental response capability is an important management resource [4]. Improving environmental performance through better operational environmental management requires the knowledge of organizational demand on the ecosystems. This is referred to as environmental footprints [5]. The demand on the earth is in term of resource usage, especially the non-renewable ones, waste generation and the impact left on earth as a result of the release of harmful substances to the environment. An improved environmental performance involves the identification, measurement and management of the drivers of environmental footprints – impact across institutional operations just as inhibitors for improved environmental management and the systems and structures that can be created to improve performance need to be identified.

While driving factors increase footprints, inhibiting factors reduces it; the combining effects of the two factors determine the net condition of the system being considered in term of environmental footprints. Some activities that can be categorized as drivers are waste generation through office paper and other materials usage and the use of generating set among others. Inhibitors can be in the form of environmental regulations and waste management strategies such as 3R's (reduce, recycle and reuse). These are the decision-making areas considering their systemic connections in institutional operations.

Appreciation of the scientific uncertainties, multiple and often conflicting stakeholder goals and values, and interconnected environmental and social dynamics that characterize environmental issues couple with implementable greening project policy has led to the calls for management frameworks that facilitate deliberation among stakeholders as well as scientific analysis in support of decision-making [6]. Because of complex and tightly connected systemic issues, policymakers need an integrated approach to environmental policy and the assessment of the implementation considering the full environmental impacts of an institution's activities. Besides, the timing of the implementation of policies needs to be taken into consideration, since it may be preferable to hedge against uncertainty by combining different policies. Accordingly, integrated assessment capabilities will be needed to fill the gap between promising environmental management strategy and successful real-world implementation, and to capture the complex, dynamic interactions between 'drivers' and 'inhibitors' of environmental footprint.

The System Dynamics (SD) methodology allows for an integrated evaluation of policy options relating to a variety of issues that arise in complex social, managerial, economic, and ecological systems [7]. SD is a perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems by building formal computer simulations, to design more effective policies and organizations [8]. It aims at understanding what the main drivers for the behaviour of the system are. This implies identifying properties of real systems, such as feedback loops, nonlinearity and delays, via the selection and representation of causal relations existing within the system analyzed [9]. According to [6], system dynamics is an appropriate modelling approach for sustainability questions because of the long-term perspective and feedback dynamics inherent in such questions. By including causality and feedback loops in the analytic framework, the SD-based model will provide deeper insights than are possible with parameter-based optimization and econometric frameworks. Furthermore, the inclusion of broader social, economic and environmental outcomes in the case of environmental management decisions allows for a more comprehensive analysis of the policy implications, including unexpected side effects or bottlenecks [7]. This is where Multi-criteria Analysis (MCA) is required to achieve a logically correct and effective decision. Usually, more than one criteria may be available to arrive at the correct evaluation of a decision; with each having its pros and cons as the case may be. MCA helps to make a holistic decision using the available criteria taking into consideration the advantages of using the latter and offsetting their disadvantages. Therefore, it can be regarded as a tool for evaluating the relative importance of all criteria involved and reflect their importance in the final decision-making process [10]. It is an iterative technique for modelling and analysing multi-dimensional issues, finding the best solutions instead of optimal ones and identifying, structuring, modelling and exploring [11]. It provides an integrated measure of the value of alternatives using multiple attributes criteria that combines the relative weights of each criterion indicated by a decision-maker [12].

There are shreds of empirical evidence of the application of the tools for decision-making. These include control of socio-economic processes [13]; adding value to performance measurement [14]; mid-term planning of light-duty vehicle fleets [15]; innovations in environmental services [16]; health technology assessments [17]. Studies have expressed optimism on the outcome of decisions involving MCA and SD. [18] stated that SD and MCA help decision-makers cope with the interconnected and interrelated decisions by providing formal organizing of the reasons for which a policy is considered a solution to a problem. The synergy contributes significantly to the proper control of socio-economic systems [13]. In environmental services, [16] believe that a combinatory approach based on the two perspectives contributes to more purposeful evaluation practices and methods. The use of the approaches individually or collectively is a method for probing into dynamic complexity, making explicit trade-offs between performance criteria and assessing the impacts of initiatives to improve performance, thereby enhancing understanding and ultimately contributing to the improvement of organizational performance [14]. The availability of different indicators of environmental footprints and the need to amalgamate them into a single measure calls for the use of MCA. SD is also needed to make an appropriate projection of drivers of footprint and how inhibitors can produce their effect within a given period.

This combinatory methodology has little or no usage by scholars working on environmental management in the university system. This study proposed Multi-Criteria Analysis and System Dynamics Modellings for the analysis of environmental factors on the University campus. It is against this locale, that this study involves an analysis of factors of the environmental footprint on university campus using MCA and SD. Specifically, the study investigated the factors of the environmental footprint on the university campus; developed a system dynamics model to evaluate the environmental footprints on the university campus; and performed sensitivity analysis against scenarios to understand the policy implications of factors contributing to environmental footprints on the university campus. The study was conducted at The Federal University of Technology, Akure (FUTA). It draws managerial implications for universities and other tertiary institutions with similar characteristics. This study is beneficial for decision-making regarding combination of policies that can be used to promote reduction of impact leave on the environment from energy usage, waste generation and on-campus commuting.

2. MATERIALS AND METHODS

2.1 Research Design

The Participatory Action Research (PAR) design was used in this study. PAR is considered a subset of action research, a design which involves logical collection and analysis of data to take action and make a change by generating practical knowledge. This is aimed at developing consciousness, and mobilizing for action [19]. Participants in PAR can have different levels of involvement in generating the results of a study. Based on the [6], the study used decision-making case form of PAR for the assessment team because it seeks members' input in the areas involving model development based on their view on the impact of the factors on footprints while the simulation was undertaken by the authors.

2.2 Method of Data Collection

It is not uncommon for PAR design to involve the use of more than one method of data collection [19]. Therefore, participants' observation, and diary and personal logs and review of journals, magazines, online blogs, textbooks and FUTA publications as methods for collecting primary data. The latter are also sources of items in the environmental assessment form. The form is in the form of a semi-structured questionnaire designed for environmental factors and their indicators to elicit responses from environmental experts on the importance of each factor and indicators relative to others, in particular, and total environmental footprint in general. The special design of the form makes it possible to collect data relevant for multi-criteria analysis. The design was based on the Analytical Hierarchy Process (AHP) software (K. D. Goepel Version 11.10.2017). Table 1 presents details relating to the form. The qualitative scores are scores measured on a plus and minus (+ + + + +/- - - - -) scale. This is not a real ordinal scale, as the number of pluses or minuses reflects the size of the contribution or impact and not just the order. The study added a simple legend to the plusses and minuses describing, for example, + + + + + as a more strongly positive effect, '0' as no effect and - - - - - as a more strongly negative effect [20].

2.3 Methods of Data Analysis

Multi-Criteria Analysis (MCA) and System Dynamics (SD) modellings were used to achieve the objectives of the study. MCA was used to study the contribution of drivers and inhibitors to environmental footprint after the opinion of assessment team members have been sought. The outcome of MCA served as input to parameters for SD modelling using Vensim PLE (Student's Version).

2.3.1 Multi-criteria analysis

Multi-Criteria Analysis (MCA) is a decision-making tool developed for complex multi-criteria problems that include qualitative and/or quantitative aspects of the problem in the decision-making process [21]. It is an iterative technique for modelling and analysing multi-dimensional issues, finding the most appropriate solutions instead of optimal ones and identifying, structuring, modelling and exploring [11]. This decision tool is needed to arrive at a logically correct and effective decision. Usually, more than one criteria may be available to arrive at the correct evaluation of a decision to be taken; with each having its pros and cons as the case may be. MCA helps to make a holistic decision using the available criteria taking into consideration the advantages of using the latter and offsetting their disadvantages. It can, therefore, be seen as a tool for evaluating the relative importance of all criteria involved and reflect their importance in the final decision-making process [21]. MCA that uses Analytical Hierarchy Process (AHP) was used in this study to determine the Average Relative Weight or percentage contribution of each indicator to:

i. Driving factors which increase Total Environmental Footprints (TEFs); and
ii. Inhibiting factors which decrease Total Environmental Footprints (TEFs) at a given time based on the evaluation of assessment team members.

Table 1. Design of environmental assessment form

Input variables	Environmental factor	Indicators	Type of data	Description
Drivers	Energy Consumption	$I_1, I_2, I_3, \ldots, I_n$	Rating	Scale ranging:
	Transportation	$I_1, I_2, I_3, \ldots, I_n$		Drivers
	Waste Generation	$I_1, I_2, I_3, \ldots, I_n$		+1 (positive) to +5
Inhibitors	Legitimacy (best practices)	$I_1, I_2, I_3, \ldots, I_n$		(more strongly positive)
	Resource Capability (environmental regulation)	$I_1, I_2, I_3, \ldots, I_n$		Inhibitors - 1 (negative) to - 5
	Survival Capability (societal practices)	$I_1, I_2, I_3, \ldots, I_n$		(more strongly negative)
		I_n=Indicators for each factor		

The Average Relative Weight calculated for each indicator was combined with the (specific) score given each indicator to come up with a weighted score for each indicator. The sum of these weighted scores for the indicators provides a final weighted score for driving or inhibiting factors which serve as input for system dynamics modelling. The steps involved in MCA is beyond the scope of this paper (see [21]). However, the evaluation of these factors is in two stages. In the first stage, the weights of each criterion that make up each of the drivers and inhibitors were determined. In the second stage, the weights of each indicator that contribute to each criterion examined in stage one were also determined. The analysis was conducted using the Analytical Hierarchy Process (AHP) software (K. D. Goepel Version 11.10.2017). MCA decision-making methods like AHP do not offer analyses of decisions in a dynamic environment. Therefore, it is necessary to adopt a method to offset this limitation, and able to take into account changes and impact of medium- and long-term consequences since some decision-making problems are not static procedures [17].

2.3.2 System dynamics model

Complete system dynamics modelling of campus greening project in the areas of energy consumption, transportation and waste generation involve a large number of variables using different levels of system parameters. An effort was made to include only parameters with the likelihood of significant impact on achieving a sustainable campus environment based on a semi-structured interview that was conducted. This is necessary because it was impracticable to incorporate all the parameters. At first, the study looked at various drivers and inhibitors of environmental footprint peculiar to the campus environment to study their systemic interactions and dynamics. The study then explores the cause and effect and relationship using a system dynamics approach to the model (stock and flow). The model is represented by equations 1 and 2.

$$TEF\ (t) = \int_i^I o \int_j^J \omega_{ij} \times \frac{d\left(E_i^I - I_j^J\right)}{dt} + TEF_s(0). \qquad (1)$$

Where the initial state of the system is,

$$TEF\ (t) = E_s(0) - I_s(0) \qquad (2)$$

$TEF\ (t)$ =Total Environmental Footprint

E_i^I= amount footprints from all drivers (I)

I_j^J= the control on footprint due to inhibitors (J)

ω_{ij} = weightage determining the quantum of drivers and inhibitors present in realistic consideration.

t = time in months

2.3.3 Sensitivity analysis

To overcome the static nature of decisions associated with MCA (AHP methodology), the problem was implemented through a dynamic simulation model. The simulation generated scenarios, which analysed possible options for achieving the best solution for the system [17]. Also, since parameters of SD models are subject to uncertainty, sensitivity analysis was conducted to achieve the reliability of simulation results [22]. Sensitivity analysis was used to determine how responsive the model is to changes in the value of its parameters. In this study, a sensitivity analysis was performed for Total Environmental Footprint (TEFs) in which factors reducing its state at any given time were changed individually and in combination to see the changes in the behaviour of the system. It also helps to identify the impact of each factor. The analysis was performed on only factors, which were identified to have a significant impact on the greening project on the university campus based on the results of MCA. It was assumed that changes in TEFs will be visible within six months. Therefore, sensitivity analysis is in six months interval.

3. RESULTS AND DISCUSSION

3.1 Exploration of Factors of Environmental Footprint on the University Campus

Objective one explores factors of the environmental footprint on the university campus. The objective was achieved using MCA. This is based on the responses from the environmental assessment team.

3.1.1 Contribution of environmental factors to the environmental footprint

The normalized priority matrix (Table 2) is a useful tool to evaluate the importance of each criterion and indicator in determining the quantum of driving and inhibiting factors of environmental footprints. It is called normalized because the assessments of the team have been adjusted for likely inconsistency which [21] noted to be part of the evaluation of factors by each team member. As presented in Table 2, AHP provided weightings to show the contribution of each indicator and criterion to footprint whether on increasing (driver) or decreasing (inhibitor) basis.

It can be observed from Table 2 that in the first stage, under driving factors category, that D.1 (energyprint) has the highest weighting, and its contribution to increase in footprint was 48.0 per cent. D.2 (transportprint) and D.3 (wasteprint) individually contributed 30.20 per cent and 21.80 per cent respectively. In the second stage, the highest contributor to energy consumption was D.1.1 (lightings) (24.40 per cent) while the least was D.1.2 (office machine and electrical appliances). The highest indicator of transportprint was D.2.2 (official and utility means of commuting) (29.40 per cent) while the lowest indicator was D.2.4 (private commuting (outsiders)) (15.40 per cent). The highest contribution to wasteprint was associated with D.3.2 (paper, plastics, nylon, glasses and metal scrap) (38.8 per cent) though the lowest indicator was D.3.5 (miscellaneous products such as batteries, disposable, etc.) (11.80 per cent). This is an indication that since energy usage is paramount to every activity taking place on a university campus, major impact on the environment is likely to be very high especially if the sources of such energy are not environmental friendly. University cannot efficiently perform its functional role without an adequate supply of energy. Power outage leaves the university campus to no other option than the use of power generating plant. Individual unit and the department also have this unsustainable alternative source of electricity apart from the central supply. It is important to note that there is already a gradual move towards the use of stand-alone inverter as an alternative source of energy when there is a power outage on the campus in various departments and units. Population size and affluence are likely to expand the human impact on the environment by over one-third which means yearly increase in student enrolment is likely to lead to increased Environmental Footprint (EF) from these driving factors [23], hence, the need to put in place effective strategies for ameliorating the challenge.

The results for the first stage under inhibiting factors category showed that I.3 (survival capability (best practices)) has the highest weighting, and its contribution to achieving a given level of reduction in footprint was 40.70 per cent. I.1 (legitimacy (environmental regulation)) and I.2 (resource capability (societal practices)) individually contributed 34.60 per cent and 24.70 per cent respectively. In the second stage, the highest contributor to survival capability (best practices) was I.3.3 (using materials and new technologies that take into consideration the reduction in environmental impact) (38.70 per cent) while the least was I.3.2 (alternative sources of electricity like solar energy) (25.20 per cent). The highest indicator of legitimacy was I.1.3 (institutional incentives and best practice recognition to department/unit actively involved) (37.00 per cent) while the lowest indicator was I.1.1 (availability of stringent rules and regulations) (29.80 per cent). The highest contribution to resource capability was I.2.1 (waste minimization through recycling, reuse and reduction of waste) (38.4 per cent) while the lowest indicator was I.3.2 (corporate social responsibility) (25.80 per cent). Although rules and regulations are necessary for wide acceptance of organizational policies like greening, operational acceptance of such policies are likely to be dependent on the availability of enabling environment for their implementation. Similarly, on resource capability, even though organizations have different orientations and levels of commitment towards CSR, it should be a natural responsibility of an organization to the community from where it gets resources for its operations.

This supports the proposition of institutional theorists who believe that legitimacy is the belief that certain behaviours or practices are something everyone in the environment should engage in [24]. It means that if some actions are believed to be appropriate, it will be good if there can be a system of rules and regulations to guide such. Deliberate action is regarded as isomorphism in institutional theory, a term denoting "the process by which organizations begin to modify their organizational characteristics to conform with others to increase compatibility with environmental characteristics" [24]. Some of these factors relate to initiatives in the areas of corporate social responsibility, internal organizational policies, and top management support as identified in [25]. This supports the findings in [26] that government rule and regulation, CSR, waste management and alternative sources of electricity are the main inhibitors of EF. The latter noted that voluntary approach only cannot bring about behavioural change, but incentive measures will produce a greater positive effect on waste reduction to landfills in construction. Similarly, tree planting, developing environmental policy, creating environmental awareness programs and working with stakeholders to protect and conserve the environment are the top four preferred inhibiting factors [27].

3.1.2 Overall contributions of factors

The overall score for drivers and inhibitors are presented in Table 2 in white font. These scores were measured on a scale of 1-5. A final score of 3.02 for drivers shows that they are 'moderately positive' in their contribution to increasing environmental footprints on FUTA campus. On the other hand, a final score of 2.50 indicates that inhibitors are 'moderately negative' in their contribution to reducing environmental footprints on FUTA campus if implemented. These results seem to mean that moderate reduction in EF using the identified inhibiting factors should be adequate for moderately positive driving factors that increase EF on FUTA campus. The next subsection substantial this point. The highlighted scores in Table 2 were latter used for target setting and feedback for the evaluation of FUTA Total Environmental Footprints (TEFs) using the systems dynamic approach as presented in the next subsection.

3.2 System Dynamics Representation of FUTA Environmental Footprints

Stock and flow model of system dynamics (Fig. 1) was developed using Vensim PLE to measure the impact of each variable in the model. The effect of each variable can be studied in combination or can be studied separately by controlling the other variables depending on the situation and managerial implications that can be drawn. Each factor is defined by its corresponding weightage and per unit print. The interactions or relationships among the variables were based on those of [26]. The general stock and flow equation for measuring the environmental footprints across all the variables (drivers and inhibitors) has been presented in chapter three (equation 1 and 2).

The study used important factors based on the analysis of assessment team responses presented in Table 2 since the inclusion of the whole factors was foreseen to increase complexity. However, all drivers, that is, D.1 (energyprint), (D.2) transportprint and D.3 (wasteprint) were included in the model. They served as flows which increase EF. On the other hand, inhibitors used in the model are those with the highest scores/weightage (contribute more to the reduction of EF) except university rules and regulation and corporate social responsibilities which Sundarakani, et al. (2014) found to be important inhibitors for environmental decision making. They are I.2.1 (waste minimization through recycling, reuse and reduction of waste) and I.3.3 (using materials and new technologies that take into consideration the reduction in environmental impact). They are connectors which receive information about the stock level (EF) at a given time which they used to it. The linear feedback loops for Fig. 2 is provided in Table 3. The table consists of four feedback loops (C1–C4) involving CSR and five feedback loops (U1–U5) involving university rules and regulations. In C1 the annual environmental footprint leads to an increase in corporate responsibilities and hence reducing the footprint from transportation. This feedback is continued over time until the desired level of the annual footprint is achieved. The same scenario is for feedback loops C2–C4. In G1–G3 the annual environmental footprint leads to an increase in university rules and regulations which in turn lead to the introduction of environmentally friendly technologies and hence reducing footprint from energy usage. The same scenario is for feedback loops U2–U5.

3.3 Sensitivity Analyses

Sensitivity analysis was performed for Total Environmental Footprints (TEFs) in which University Rules and Regulations (URR) and Corporate Social Responsibility (CSR) were changed individually and collectively to observe the effect they can have on TEFs. A simplified model used to perform the sensitivity analysis is given in Fig. 2. The input data used for the analysis are provided in Table 4.

Three sets of sensitivity analyzes were conducted based on the normalized principal eigenvector (%) or relative weights of university rules and regulation (29.80 per cent) and corporate social responsibilities (25.80 per cent) to indicate by how much they can individually reduce footprints. The value used for each of these factors during the sensitivity analyses was based on their proportion in their total contribution to a reduction in footprint. University rules and regulation has a proportion of 53.6 per cent in the summative footprint reduction by these two factors while corporate social responsibility has a proportion of 46.4 per cent. Therefore, in the first set of simulations university rules and regulation was increased to 53.6 per cent annually from 0% while keeping CSR constant. In the second set, CSR was increased to 46.4 per cent annually from 0% by keeping university rules and regulations constant. In the third set, both CSR and university rules and regulations are increased by 53.6 per cent and 46.4 per cent annually respectively. The analysis was carried out by assuming both factors are zero at initial time t = 0 (the base year 2018) and all other variables constant.

Table 2. Aggregate normalized priority vectors showing the contribution of all criteria and indicators of drivers and inhibitors

		Score	Average relative weight	Final Score	
	Drivers (+)				**3.02**
D.1	**Energy Consumption**	**3.19**	**48.00%**		**1.53**
D.1.1	Lightings	3.62	24.40%	0.88	
D.1.2	Office machines and electrical appliances	3.31	15.80%	0.52	
D.1.3	Laboratory/Workshop equipment	3.15	20.10%	0.63	
D.1.4	Internet facility	2.69	19.10%	0.51	
D.1.5	Generating sets/plants (Central and individual units)	3.08	20.60%	0.63	
D.2	**Transportation**	**3.05**	**30.20%**		**0.92**
D.2.1	Using personal means of commuting	2.92	16.80%	0.49	
D.2.2	Official and utility means of commuting	3.00	29.40%	0.88	
D.2.3	Commuting using public transport (buses and cars)	3.38	16.60%	0.56	
D.2.4	Private commuting (outsiders)	2.77	15.40%	0.43	
D.2.5	Essential services commuting and on-going projects	3.17	21.80%	0.69	
D.3	**Waste Generation**	**2.60**	**21.80%**		**0.57**
D.3.1	Chemical from laboratories, workshops and teaching farms	2.00	18.30%	0.37	
D.3.2	Paper, Plastics, nylon glasses, scrap metal	2.77	38.80%	1.07	
D.3.3	Electronics and electrical materials	3.00	17.30%	0.52	
D.3.4	Construction-related materials	2.77	13.70%	0.38	
D.3.5	Miscellaneous products such as batteries, disposables, etc.	2.25	11.80%	0.27	
	Inhibitors (-)				**2.50**
I.1	**Legitimacy (environmental regulation)**	**2.36**	**34.60%**		
I.1.1	Availability of stringent rules and regulations on sustainable campus practices to reduce the impacts of drivers	2.69	29.80%	0.80	**0.82**
I.1.2	Enforcement of rules and regulations rather than guidelines	2.15	33.20%	0.72	
I.1.3	Institutional incentives and best practice recognition to dept./unit actively involved	2.27	37.00%	0.84	
I.2	**Resource Capability (societal practices)**	**2.56**	**24.70%**		**0.63**
I.2.1	Waste minimization and recycling, reuse and reduction of waste	2.38	38.40%	0.92	

I.2.2	Serving the community where the university is located through Corporate Social Responsibility (CSR) that aims towards reducing environmental impact	2.54	25.80%	0.65	
I.2.3	Improving the natural environment by creating man-made green areas landscaping and tree plantation.	2.77	35.80%	0.99	
I.3	**Survival Capability (best practices)**	**2.59**	**40.70%**		**1.05**
I.3.1	Creation of awareness on campus greening	2.58	36.10%	0.93	
I.3.2	An alternative source of electricity like solar energy considering the enormous amount of sunbeam available	3.25	25.20%	0.82	
I.3.3	Using materials and new technologies that take into consideration the reduction of environmental impact	2.17	38.70%	0.84	

Interpretation/explanation of final scores for factors	**More strongly + + + + + or - - - - -**	**Strongly + + + + or - - - -**	**More + + + or - - -**	**Moderately + + or - -**	**equally + or -**
	.80 to 1.0	.60 to .79	.40 to .59	.20 to .39	.00 to .19

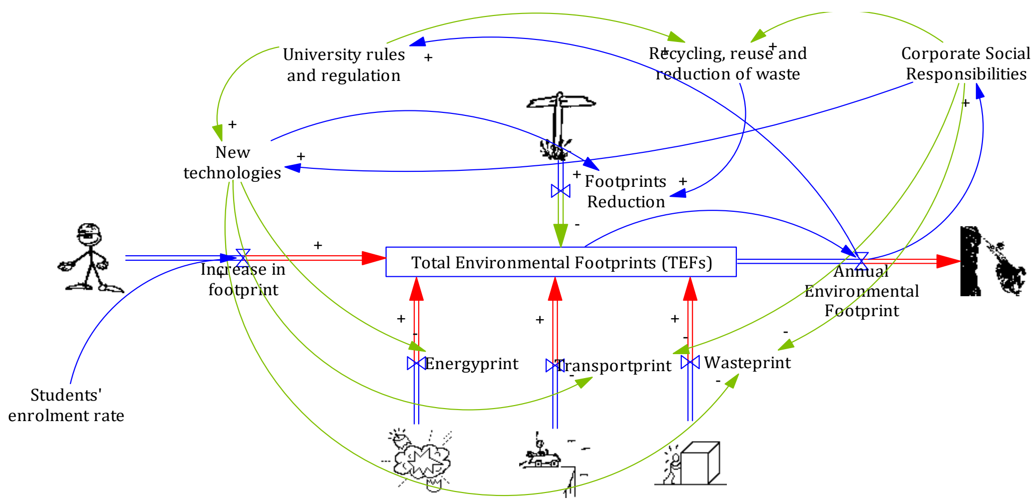

Fig. 1. System dynamics model for university
Source: Chart Developed on Vensim PLE (Student's Version)

Table 5 is the presentation of the result of the simulation run for the three scenarios. The table shows that there was a reduction in the level of TEFs in all the scenarios but fastest in scenario one, faster in scenario three and fast in scenario two within periods 2018 and 2020 as depicted by downward trends of values in the schedule and lines in Fig. 1. Therefore, scenario one appears to be the best of the three decision options whereas scenario two is the least option to be considered. However, scenario one is almost an unlikely situation. It may be impractical to take a decision where university regulation will be implemented without considering involvement in corporate social responsibilities. The same thought applies to scenario two even though it is the least considered decision. Scenario three is practical and real. Several activities can be implemented at a different level or rates to achieve a particular decision. Fig. 2 has been used to depict the scenarios graphically. [26] affirm that varying government rules and regulations and CSR together produced a similar result as found in this study. [23] reported in their study that increasing population is enough reason to seek to reduce ecological footprint driving forces through increased inefficiency in the use of resource to about 2% per year based on the tendency of population.

Table 3. Feedback loops

Feedback loops	Structure
C1	Annual Environmental Footprint → Corporate social responsibility → Transportprint → Annual Environmental Footprint
C2	Annual Environmental Footprint → Corporate social responsibility → Wasteprint → Annual Environmental Footprint
C3	Annual Environmental Footprint → Corporate social responsibility→ Recycling, reuse and reduction of waste → Footprint reduction → Annual Environmental Footprint
C4	Annual Environmental Footprint → Corporate social responsibility → Environmental friendly technologies → Footprint reduction → Annual Environmental Footprint
U1	Annual Environmental Footprint → University rules and regulation → Environmental friendly technologies → Energyprint → Annual Environmental Footprint
U2	Annual Environmental Footprint → University rules and regulation → Environmental friendly technologies → Transportprint → Annual Environmental Footprint
U3	Annual Environmental Footprint → University rules and regulation → Environmental friendly technologies → Wasteprint → Annual Environmental Footprint
U4	Annual Environmental Footprint → University rules and regulation → Recycling, reuse and reduction of waste → Footprint reduction → Annual Environmental Footprint
U5	Annual Environmental Footprint → University rules and regulation Environmental friendly technologies → Footprint reduction → Annual Environmental Footprint

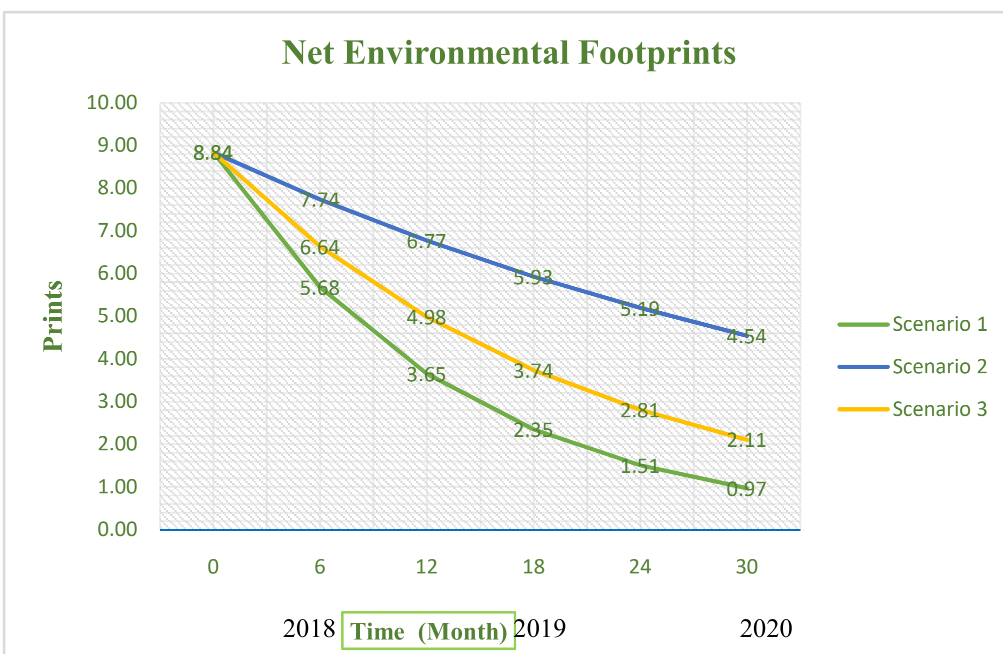

Fig. 2. Graphical representation of the three scenarios

Table 4. Input parameters

Input parameters	Values	Source
The base year for analysis	2018	-
Total Environmental Footprints (TEFs)	8.84 print*	Assessment team (2018)
University enrolment growth rate	15 per cent (approx.) annually**	Based on yearly enrolment of students
Energyprint	3.19 print	Assessment team (2018)
Transportprint	3.05 print	Assessment team (2018)
Wasteprint	2.60 print	Assessment team (2018)
**See appendix 2 for the calculation		

Table 5. Simulation results of total environmental footprints (TEFs)

Time	Month	Total Environmental Footprints (TEFs)		
Year		Scenario 1	Scenario 2	Scenario 3
		53.6 % (URR)	0 % (URR)	53.6 % (URR)
		0 % (CSR)	46.4 % (CSR)	46.4 % (CSR)
	0	8.84	8.84	8.84
2018	6	5.68	7.74	6.64
	12	3.65	6.77	4.18
2019	18	2.35	5.93	3.74
	24	1.51	5.19	2.81
2020	30	0.97	4.54	2.11

URR = University rules and regulation
CSR= Corporate Social Responsibilities
** Sensitivity analysis is in six months interval for TEFs*

4. CONCLUSION

In this study, authors have used a combinatory methodology of Multi-criteria analysis and system dynamics to investigate the factors of environmental footprint; developed a model to evaluate the environmental footprints; and perform sensitivity analysis against scenarios to understand the policy implications of factors contributing to environmental footprints on the university campus. This undertaking has also drawn some managerial inferences for environmental management in the university system. Specifically, the study used MCA to measure environmental footprints due to the multiple alternatives to finding the best solutions to environmental issues rather than just the optimal [11]. The results of the analysis revealed three main outcomes. First, the drivers of environmental footprints in the study area include energy print, transportprint and wasteprint in that order (from the highest to the least). On the other hand, survival capability (best practices), legitimacy (environmental regulation) and resource capability (societal practices) tend to reduce EF in descending that order. Secondly, effective decisions regarding the reduction of environmental footprints using alternative inhibiting factors occur when several scenarios with mixed inhibitors are considered. Thirdly, the present study shows that the mix of corporate social responsibilities and rules and regulations in proportions 53.6 per cent and 46.4 per cent respectively is have achieved the best reduction in EF on the campus. These results suggest that energy-related drivers of footprint have a major contribution to the quantum of footprints left on the environment. This is not likely to improve, with the yearly increase in students' enrolment and the on-campus activities, just as energy usage has no alternative. These factors will also increase impact from transportation and waste generation for which appropriate green practices must be encouraged to reduce footprints. Indigenous and timely environmental regulations and responsible institutional activities for the immediate communities will also be beneficial as recourse to environmental challenge. Improved sector and spatially explicit information for better mitigation policymaking and environmental education on this, at the university level, is thus advocated [28]. It is imperative for university management to seek alternatives to the current major source of electricity which is grid electricity. Such alternatives can include a stand-alone solar panel and battery inverter installation on departmental or unit basis given the natural endowment of solar energy which is already in use at minima level. Given the potential accrued benefits of environmental management, a combinatory use of MCA and SD methodology is needed to choose between different policies and regulations for implementation.

Future work should focus on extended system dynamics model of environmental footprints on a university campus can be developed from this model by including new variables and factors having a direct or indirect influence on footprints or simulating the model using other inhibitors of footprints. The cost implications of implementing the policies also have to be studied, as there will always be a trade-off between the cost involved and reducing footprints. Future studies can incorporate cost implication as one of the factors. Similar studies can be conducted in other universities or higher institutions in other countries.

ACKNOWLEDGEMENTS

Authors would like to appreciate the Directorate of Academic Planning of The Federal University of Technology for making available statistics on staff and students of the University. We also appreciate environmental experts whose wealth of experiences contributed to the success of the work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix 1: Enrolment rate from projected student enrolment in Nigerian Universities

Enrolment rate = $\frac{(3,769,461-3,277,792)}{3,769,461}$*100%

Enrolment rate = $\frac{491669}{3,769,461}$*100%

Enrolment rate = 15%

Year	Nigerian University Enrollment
*2005 (base year)	810,220
2010	1,417,080
2011	1,629,641
2012	1,874,088
2013	2,155,201
2014	2,478,482
2015	2,850,254
2016	*3,277,792*
2017	*3,769,461*

Source: [29]

Session	FUTA Enrollment
2014/2015	
2015/2016	2534
2016/2017	3000
2017/2018	3500
2018/2019	4000
	Rate = 14.3%

Appendix 2: Full List of Model's Equations

(01) Annual Environmental Footprint=
"Total Environmental Footprints (TEFs)"
Units: print

(02) Corporate Social Responsibilities=
Annual Environmental Footprint-(Annual Environmental Footprint)
Units: print

(03) Energyprints= ACTIVE INITIAL (
-New technologies,
3.19)
Units: print

(04) FINAL TIME = 2020
Units: year
The final time for the simulation.

(05) Footprints Reduction=
New technologies+"Recyclings, Reuse and Reduction of waste"
Units: print

(06) Increase in footprint=
1+Students' enrolment rate
Units: Dmnl

(07) INITIAL TIME = 2017
Units: year
The initial time for the simulation.

(08) New technologies=
-Corporate Social Responsibilities-University rules and regulation
Units: print

(09) "Recyclings, Reuse and Reduction of waste"=
-Corporate Social Responsibilities-University rules and regulation
Units: print
(10) SAVEPER =
TIME STEP
Units: year [0,?]
The frequency with which output is stored.
(11) Students' enrolment rate= 0.15
Units: Dmnl [-1,1]
(12) TIME STEP = 0.5
Units: year [0,?]
The time step for the simulation.
(13) "Total Environmental Footprints (TEFs)"= INTEG (
(Transportprints+Wasteprints+Energyprints+Footprints Reduction-Annual Environmental Footprint
)/(1+Increase in footprint),
2.95)
Units: print*year
(14) Transportprints= ACTIVE INITIAL (
-Corporate Social Responsibilities-New technologies,
3.05)
Units: print
(15) University rules and regulation=
Annual Environmental Footprint-(Annual Environmental Footprint*0.8)
Units: print
(16) Wasteprints= ACTIVE INITIAL (
-Corporate Social Responsibilities-New technologies,
2.6)
Units: print

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/57968