Ecological Footprint Analysis in Academia: A case study of Mehran University of Engineering and Technology, Pakistan

Uroosha Memon[a,*], Areej Fatemah Meghji[a], Mohsin Ali Memon[a], Owais Raza[a]

[a]*Department of Software Engineering, Mehran University of Engineering and Technology Jamshoro Sindh, 76090, Pakistan*

Abstract

Global warming is possibly one of the biggest threats of the 21st century. Carbon Footprint plays a major role in global warming. Over the last few years, it has been researched and discussed among profit, non-profit, government, and non-government organizations. Sustainability policy works as a motivation for organizational change. Currently, the overall world environment is affected by CO_2 emissions and the world needs a better sustainable strategy to address the increasing threat of these emissions. The focus of this study is to analyse the carbon footprint of Mehran University of Engineering and Technology, Sindh Pakistan and predict the CO_2 emission rate for the next five years. This study will raise the awareness about sustainability among the university. It can help out the university to focus on activities that generate CO_2 emissions. We have developed a model to analyse and predict the carbon emissions for the next five years using Python - Autoregressive Integrated Moving Average (ARIMA) methods. The observed results demonstrate that electrical consumption is the major contributor to Carbon Footprint generation.

Keywords: *Carbon footprint; Sustainability; Global warming; Carbon emissions; Ecological footprint*.

1. Introduction

Carbon Footprint (CF) is the quantity of GHG (Green House Gases) emissions that are the results of development, usage, and end of any service or product and this introduce Global Warming to our environment [1]. GHG has become a common issue around the globe for welfare of human, animal, and plant life. There are various causes and effects of global warming on the environment. These causes affect life at different scale of the earth such as locally, regionally, and globally. Climate change encompasses the change in temperature and climate of the earth in the last few decades. As climate change is driven by the primary activities done by humans, the removal of plants and burning of fossil fuel introduces global warming and raises concentration of carbon dioxide – CO_2 in the atmosphere of the Earth. The GHG emissions include carbon dioxide, methane, fluorinated gases, and nitrous oxide gases; these are heat-trapping gases which introduce global warming to the atmosphere [1].

GHG are emitted by human activities: transportation, food, chemicals usage, waste, industrial working and so on. CO_2 is the most common gas produced by humans. CF is a topical subject that induces global warming. Currently, the overall world environment is affected by CO_2 emissions and the world needs a better sustainable strategy to be followed [2, 3]. The proper use of carbon foot printing is under discussion by different organizations. Over the last few years, it has been very popular among profit, non-profit, government, and non-government organizations [4]. Internationally many universities from different countries have introduced sustainability policies as their main goal to estimate and reduce the impact of CO_2 emissions [5-9]. Globally the world is affected by CO_2 emission, and it needs mechanisms that lessen the ecological footprint. As a first step, we can lessen our personal impact on environment through our day-to-day activities. A good start can be considering how our actions will impact climate change. There are several steps that can be followed to lessen this impact on the environment. These steps include: 1) knowing about the facts; 2) exploring climate change activities of groups locally; 3) consulting local representatives and speaking about climate change; and 4) supporting and building policies about sustainability. Pakistan is on the 31st number according to the ranking by country of www.worldometers.info website. The graph of producing carbon emissions is increasing day by day ourworldindata.org. The focus of this study is to analyse the carbon footprint of MUET and predict the CO_2 emissions in coming years by considering different parameters that are used by the MUET Main campus. This study will also raise the awareness about sustainability among university. It can help out university to focus on activities that generate CO_2 emissions. An introduction of such self-assessing policies can make a university more eco-friendly and a role model to other public, private, educational, non-educational, business and industrial organization.

*Corresponding author. Tel.: N/A; fax: NA
E-mail address: urooshamemon22@gmail.com

The rest of this paper is organized as follows: A literature review has been provided in section 2, Methodology is described in section 3 that further defines data collection and forecasting method, Implementation is provided in the section 4, Results and discussions explained in section 5. Section 6 is the conclusion of the paper.

2. Literature Review

Continuous decline in the graph of climate change has made the world conscious of carbon emissions. This buzzword has been an issue all over the world. From the last few years, many universities were determined to reduce the carbon emission generated from their activities, services, and products. Different universities internationally has introduced sustainability policy as their main target to achieve [9-11]. Academics and non-academic have been working on some techniques to reduce the impact of CO_2, as it leads the environment to global warming. The most commonly used approaches and standards to measure CF were Input-out analysis (EIO), Life Cycle Analysis (LCA), Waste Reduction Model (WARM) for waste management, ISO 14064, and Green House Gas Protocol (GHGP).

The University of Mexico, Cuajimalpa campus of the Autonomous Metropolitan University (UAM) introduced the sustainability policy as their main aim in 2016. The estimation of CO_2 and to reduce its impact on the environment was assessed using the GHG Protocol (GHGP). The resources were divided into three scopes: Scope 1 deals with direct emissions, Scope 2 deals with indirect emissions, and Scope 3 deals with the other indirect emissions. The university generated approximately 3000 tons of CO_2, accounting for 4%, 24%, and 72% for Scope 1, Scope 2, and Scope 3, respectively. The results of activity-based analysis showed the major outcome 51% for the commuting activity, 24% for electricity usage, 14% for travel, and 11% for other activities. The data resources include fixed resources, mobile resources, electricity, waste, commuting, gases, and food. This study highlighted goals to develop more mitigation plans for their other campus in the future [5].

The University of Talca has been working on all five campuses to estimate the GHG Emission. The resources were modelled on three different scopes: Direct, Indirect, and Indirect emission. The emission of GHG was reported associated with Scope 1 through Scope 3. To measure the surmise on the resources that majorly affect the CO_2 emissions and suggest improvements in results. The results from scope 1 and 2 were 20.03t CO_2e, respectively 0.25t CO_2 per person per year. UT's CF in 2016, result shows that the indirect emission from scope 3 contributed 0.41t CO_2 eq each person each year. The study result identified that the main irritant is the transportation of the students and faculty [7].

The Birla Institute of Technology and Science Pilani, India (BITS Pilani) used Life Cycle Analysis (LCA). There are various emissions: direct and indirect emissions were modelled using Umberto NXT Universal software, Ecoinvent v3.0 database, and ISO 14064 Standards. The Intergovernmental Panel on Climate Change (IPCC) was used for CO_2 assessment. The overall estimation of CO_2 is estimated using three scope definitions and each one of the scope is divided into subcategories. BITS Pilani used the data of two years (2014-2015). They collected data using surveys, reading articles, and questionnaires from faculty, students, non-teaching staff, and different university authorities within the university. BITS, Pilani campus uses a bottom-up approach for the inventory data analysis. The results of the study showed 16500 t CO_2 eq of CO_2 emission. Electricity generation from scope 2 contributes 50% of emission, 48.9% contributes from scope 3 and 1.1% of diesel and petrol consumed at campus contributes from scope 1 to GHG emission. They concluded that the university facilities are the biggest contributors to the GHG emission from the campus. Travelling and computing is considered as the major contributor to CO_2 emissions. The engineering workshops are the second-largest contributors to GHG emissions [11].

The Universitas Pertamina estimated the overall CO_2 generated from some limited resources in the university. The resource scope consists of waste, electricity, and transportation. Basic and secondary data was collected from the university via surveys, direct sampling, and questionnaires. Slovene method was used to sample the data, Google Maps for distance calculation and Kementerian Perencanaan Pembangunan Nasional (2013) for fuel assessment. Calculation of waste was done by following the Waste Reduction Model (WARM) version 13. The major contributor, from the three mentioned resources, was electricity at 92.3%, followed by transportation at 6.66% and waste at 1.04%. The overall generated CO_2 within one year was 1,351.98 metric tons of CO_2 which is equal to 0.52 $MTCO_2$ /year/person. This study also mentioned some alternatives to reduce the carbon emission within the university for the future [12] .

In past some researchers have used Machine Learning techniques for CF analyses of their organization [13-15]. The goal of this study is to contribute in making the environment eco-friendly by analysing the ecological footprint of MUET and forecasting the prediction for the next five years.

3. Methodology

The overall research methodology of this paper has been outlined in Fig.1. This research used a python model to process

the collected data. The python model is used to analyse and predict the data for next five years. The real time data of MUET main campus is used to get the desired result. The real time data is comprises of 3 parameters and the parameters are paper, plastic, and electricity. The first step of the methodology is to transform the data in a structured format. Then convert it into a CF by using the emission factor of each parameter to its activity. A pre-existing formula equation (1) for carbon print is used to convert activity rate into emission factor. The CF of each parameter is used to analyse and predict the impact on the environment. The methodology demonstrates the impact rate of each parameter and impact as a whole on the environment. The structured data was in comma-separated Value (CSV) format that was used in Python Model for forecasting CF. We used ARIMA technique to forecast the CF for each parameter.

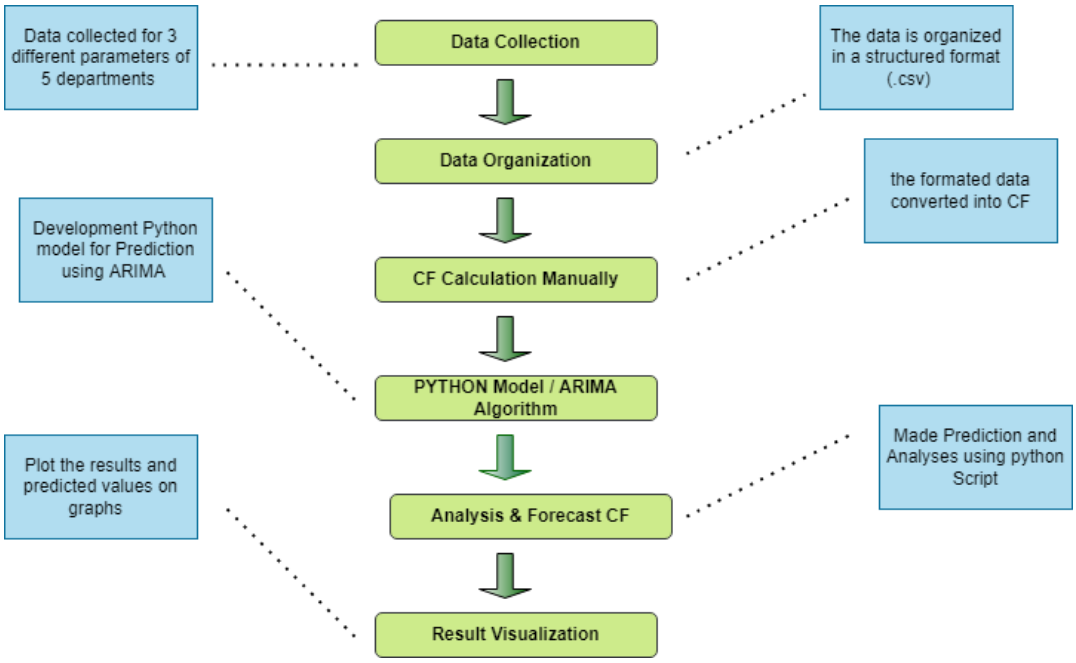

Fig. 1: Flow Chart for Research Methodology

3.1. Data Collection

The data collection process for this study is comprises of various parameter of different department for year 2017 t0 2021. The data was collected manually from the department of Faculty of Electrical Electronic & Computer Engineering (FEECE) Faculty of MUET. Collected data is comprises of various parameters such as Paper, Plastic, and Electricity. The collected data was in unstructured format for research. For this study we have structured the collected dataset and applied the CF general formula to get the overall CF and CF for each parameter by using the following equation (1).

$$Ecological\ CF = Activity\ Rate * Emission\ Factor \quad (1)$$

Equation (1) is used to calculate the overall carbon emission for each parameter. The structured data using equation is used in the analyses of CF and in the predictive model for forecasting of next five years of MUET Main Campus.

Table 1. Data Collection and Availability of Data

Data Used	Availability
Last five years of MUET	Data Collected from different Department of FEECE faculty of MUET Main Campus.
Last five-years of CF rate	Data collected from different departments of MUET where the parameter paper, plastic, and electricity is used. We calculate the CF rate by using CF equation $ECF = AR(activity) \times EF_{(parameter)}$ (2)

	Where **ECF** = Ecological CF **AR**= Activity Rate for each activity.. **EF** = Emission Factor for each Parameter.
MUET CF Forecasting Model	After application of formula, the data was then used in the python model to forecast the CF using ARIMA algorithm.
For the next five-years	Forecasted the CF of different parameters obtained by using data that was collected by using ARIMA.

3.2. Forecasting Method

Autoregressive Integrated Moving Average ARIMA, use the time series data and worked on autoregressive statically model for prediction [16] . The prediction is made on exponential smoothing and given weighted value based on past data. It is time series forecasting technique. We used ARIMA for analysis and prediction of CF of MUET Main campus for next five years. The data used in model is a real time data of 3 parameters of MUET Main Campus.

4. Implementation

We developed a model for CF prediction. The model is based on python platform. The name of the model is Analysis and Prediction for MUET CF. The model does not only perform prediction for the given data but it also perform analysis for the trained data. The script used the structured CSV data for analysis and prediction for each parameter. The structured data was of 4 parameters. Analysis and prediction is performed for each parameter individually and as a whole. The data is based on time series values. The proposed statically methodology used the time series data to analyse and predict the future rate of CF for MUET main campus. The time series data gives a better understanding of the data and better results for future prediction. ARIMA algorithm is basically use the autoregressive time series data to predict the data and analyse the results. The data of past five years for each parameter is used to analyse and prediction. From 2017 to 2021 data was gathered manually and transformed it into CSV format for further processing. The proposed methodology used the lagged values for the dynamic regression using ARIMA algorithm. These lagged values are used to apply a weight on them for forecasting. The weight put according to the recent data, as ARIMA works on auto-regression. The observed results of the analysis and forecast were then plot on the graph for better visualization and taking those results into account for further future process.

4.1. Python-Model

The python model is used to perform analysis and prediction. A Python model is developed using the python programming language. The model performs analysis and prediction, as well as training and testing the dataset. The python model is integrated in such a way that in future work we can incorporate other parameters as well to predict CF, with Python and ARIMA, the work becomes dynamic for other parameters for the future. There are different libraries that were used in this model. The libraries were required for both prediction and analysis along with ARIMA algorithm. Read_csv, Datetime, pyplot ARIMA, and Mean square error are used in the python model for processing the results. Read CSV for CSV file reading, Date time for time and date format as ARIMA worked on time series data, pyplot for plotting the results on the graphs and ARIMA for better prediction and analysis. The results were gathered for parameters individually as a whole. The results for each parameter were then gathered in a way that it is then used for comparison that which parameter is participating as a major stressor in CF generation in MUET Main Campus. The comparison shows the highest and lowest generation rate for CF for each parameter.

5. Results and Discussion

The data for past five years (2017 to 2021) were collected for MUET Main Campus, Jamshoro Sindh. The data has then been transformed into structured format for further processing. The CF for each parameter is calculated individually and as whole as well. ARIMA algorithm is used to predict the CF for each parameter. The CF is analyzed and predicted using past five year data and ARIMA algorithm. Python Model is deployed. It is aimed to forecast the CF for next five years. The results are deployed on the graphs for better comparison and vision.

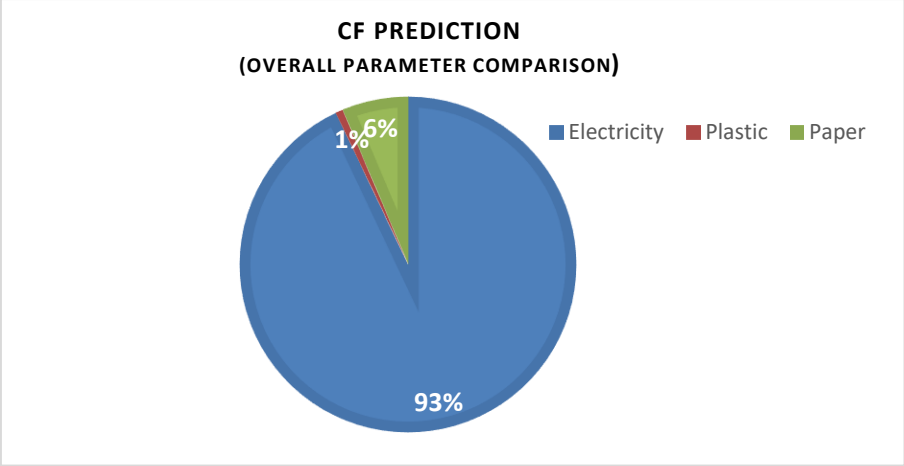

Fig. 2: Illustration of overall parameter Comparison for CF

5.1. Carbon Footprint – Major Contributor

The CF forecasting is made using ARIMA Algorithm. First of all the carbon forecasting is analysed for each parameter individually. The result is then used as whole to give a vision CF generation as a whole. There are three parameters that were used in this research that are Plastic, Paper and Electricity. The obtained results showed the highest and lowest contributor to the carbon emission for MUET, Jamshoro. The obtained results showed that electricity is the major contributor to the carbon emission with 93% among other two parameters. Paper is 2nd major contributor to the carbon emission with 6%, and finally the paper that is the last parameter considered in this research. Plastic is ranked as the lowest contributor to the carbon emission forecasting for this research.

5.2. Carbon Footprint Forecasting

The ARIMA have been explored as a time series prediction in the literature and it can compete favourably with the pre-existing techniques [17-19]. The collected past data is a time series data. Fig.3 shows the forecast for next 5 years and it comparison to the past five years. The obtained forecasted values from python model are used to predict the CF. CF data have been used to generate the graph in Fig.2. Fig3 shows that during regular time the graph for carbon emission is going high but as the COVID 19 pandemic time arrives it also affect the graph as it is showing that during 2020 to 2021 the CF is decreasing gradually and it continues to the next 2 years and then there is a gradual increase in graph.

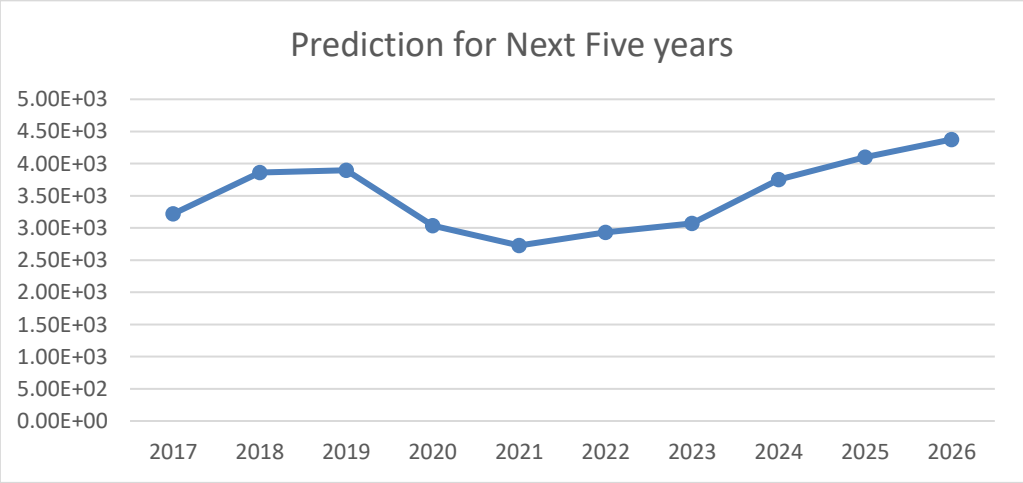

Fig. 3: Prediction Graph for CF Rate of Next Five Years

6. Conclusion

The observed confirmation about methodologies for calculation of CF in the academia reveal that there are different ways to calculate CF. Machine Learning is a well-known methodology to calculate and predict the CF. In this study focusing on MUET, Pakistan we considered 3 parameters for CF calculation and prediction for the next five years for five different departments. The CF calculation was performed for 2017-2021.
The finding of this study suggest that electricity is the main stressor to the GHG emission. Other parameters that were considered in this case study have lower impact as compared to electricity. This study suggested to lower the impact of CF Generation University should implement strategy such as 3R rule, some autonomous-systems in the building to consider less electricity usage etc. The future direction for this work is to apply the Python model on the departments individually and forecast the major contributor to GHG emission. As GHG emissions, and sustainable university are inter related terms that raise awareness about making our environment green.

Acknowledgements

The authors would like to thank the administration as well as the departmental heads of Mehran University of Engineering and Technology, Jamshoro for providing the necessary data for the conduct of this research.

References

[1] P. Cordero, "Carbon footprint estimation for a sustainable improvement of supply chains: state of the art," *Journal of Industrial Engineering and Management*, vol. 6, no. 3, pp. 805-813, 2013.
[2] N. Zhang, I. Williams, S. Kemp, and N. Smith, "Greening academia: Developing sustainable waste management at Higher Education Institutions," *Waste management*, vol. 31, no. 7, pp. 1606-1616, 2011.
[3] L. Čuček, J. J. Klemeš, and Z. Kravanja, "A review of footprint analysis tools for monitoring impacts on sustainability," *Journal of Cleaner Production*, vol. 34, pp. 9-20, 2012.
[4] B. P. Weidema, M. Thrane, P. Christensen, J. Schmidt, and S. Løkke, "Carbon footprint: a catalyst for life cycle assessment?," *Journal of industrial Ecology*, vol. 12, no. 1, pp. 3-6, 2008.
[5] R. Mendoza-Flores, R. Quintero-Ramírez, and I. Ortiz, "The carbon footprint of a public university campus in Mexico City," *Carbon Management*, vol. 10, no. 5, pp. 501-511, 2019.
[6] L. Ozawa-Meida, P. Brockway, K. Letten, J. Davies, and P. Fleming, "Measuring carbon performance in a UK University through a consumption-based carbon footprint: De Montfort University case study," *Journal of Cleaner Production*, vol. 56, pp. 185-198, 2013.
[7] P. Yañez, A. Sinha, and M. Vásquez, "Carbon footprint estimation in a university campus: evaluation and insights," *Sustainability*, vol. 12, no. 1, p. 181, 2020.
[8] N. Gómez, M.-Á. Cadarso, and F. Monsalve, "Carbon footprint of a university in a multiregional model: the case of the University of Castilla-La Mancha," *Journal of Cleaner Production*, vol. 138, pp. 119-130, 2016.
[9] S. Syafrudin, B. Zaman, M. Budihardjo, S. Yumaroh, D. Gita, and D. Lantip, "Carbon Footprint of Academic Activities: A Case Study in Diponegoro University," in *IOP Conference Series: Earth and Environmental Science*, 2020, vol. 448, no. 1: IOP Publishing, p. 012008.
[10] K. S. Sangwan, V. Bhakar, V. Arora, and P. Solanki, "Measuring carbon footprint of an Indian university using life cycle assessment," *Procedia CIRP*, vol. 69, pp. 475-480, 2018.
[11] X. Li, H. Tan, and A. Rackes, "Carbon footprint analysis of student behavior for a sustainable university campus in China," *Journal of Cleaner Production*, vol. 106, pp. 97-108, 2015.
[12] B. Ridhosari and A. Rahman, "Carbon footprint assessment at Universitas Pertamina from the scope of electricity, transportation, and waste generation: toward a green campus and promotion of environmental sustainability," *Journal of Cleaner Production*, vol. 246, p. 119172, 2020.
[13] E. GARİP and A. B. OKTAY, "CO2 Emisyonunun Makine Öğrenmesi Metotları ile Tahmin Edilmesi Forecasting CO2 Emission with Machine Learning Methods."
[14] M. V. Barros, C. M. Piekarski, and A. C. De Francisco, "Carbon footprint of electricity generation in Brazil: An analysis of the 2016–2026 period," *Energies*, vol. 11, no. 6, p. 1412, 2018.
[15] M. H. Shakil, Z. H. Munim, M. Tasnia, and S. Sarowar, "COVID-19 and the environment: A critical review and research agenda," *Science of the Total Environment*, p. 141022, 2020.

[16] T. Nyoni and C. Mutongi, "Modeling and forecasting carbon dioxide emissions in China using Autoregressive Integrated Moving Average (ARIMA) models," 2019.

[17] S. Fatima, S. S. Ali, S. S. Zia, E. Hussain, T. R. Fraz, and M. S. Khan, "Forecasting carbon dioxide emission of Asian countries using ARIMA and simple exponential smoothing models," *International Journal of Economic and Environmental Geology*, vol. 10, no. 1, pp. 64-69, 2019.

[18] A. Rahman and M. M. Hasan, "Modeling and forecasting of carbon dioxide emissions in Bangladesh using Autoregressive Integrated Moving Average (ARIMA) models," *Open Journal of Statistics*, vol. 7, no. 4, pp. 560-566, 2017.

[19] C. Zhao and C. Mao, "Forecast of intensity of carbon emission to china based on BP neural network and ARIMA combined model," *Resources and Environment in the Yangtze Basin*, vol. 21, no. 6, pp. 665-671, 2012.